“Book/Definitions”
Electrical Engineering Dictionary.
Ed. Phillip A. Laplante
Boca Raton: CRC Press LLC, 2000

Special Symbols

α-level set a crisp set of elements belonging to a fuzzy set A at least to a degree α

$$A_\alpha = \{x \in X \mid \mu_A(x) \geq \alpha\}$$

See also crisp set, fuzzy set.

Δf common symbol for bandwidth, in hertz.

$\epsilon_{\mathbf{rGaAs}}$ common symbol for gallium arsenide relative dielectric constant. $\epsilon_{\mathbf{rGaAs}} = 12.8$.

$\epsilon_{\mathbf{rSi}}$ common symbol for silicon relative dielectric constant. $\epsilon_{\mathbf{rSi}} = 11.8$.

ϵ_0 symbol for permitivity of free space. $\epsilon_0 = 8.849 \times 10^{-12}$ farad/meter.

ϵ_r common symbol for relative dielectric constant.

$\eta_{\mathbf{DC}}$ common symbol for DC to RF conversion efficiency. Expressed as a percentage.

η_a common symbol for power added efficiency. Expressed as a percentage.

η_t common symbol for total or true efficiency. Expressed as a percentage.

$\Gamma_{\mathbf{opt}}$ common symbol for source reflection coefficient for optimum noise performance.

μ_0 common symbol for permeability of free space constant. $\mu_0 = 1.257 \times 10^{-16}$ henrys/meter.

μ_r common symbol for relative permeability.

ω common symbol for radian frequency in radians/second. $\omega = 2 \cdot \pi \cdot$ frequency.

θ_+ common symbol for positive transition angle in degrees.

θ_- common symbol for negative transition angle in degrees.

$\theta_{\mathbf{cond}}$ common symbol for conduction angle in degrees.

$\theta_{\mathbf{sat}}$ common symbol for saturation angle in degrees.

θ_{CC} common symbol for FET channel-to-case thermal resistance in °C/watt.

θ_{JC} common symbol for bipolar junction-to-case thermal resistance in °C/watt.

A^* common symbol for Richardson's constant. $A^* = 8.7$ amperes · cm/°K

BV_{GD} *See* gate-to-drain breakdown voltage.

BV_{GS} *See* gate-to-source breakdown voltage.

dv/dt rate of change of voltage withstand capability without spurious turn-on of the device.

H_{ci} *See* intrinsic coercive force.

n_e common symbol for excess noise in watts.

n_sh common symbol for shot noise in watts.

n_t common symbol for thermal noise in watts.

10base2 a type of coaxial cable used to connect nodes on an Ethernet network. The 10 refers to the transfer rate used on standard Ethernet, 10 megabits per second. The base means that the network uses baseband communication rather than broadband communications, and the 2 stands for the maximum length of cable segment, 185 meters (almost 200). This type of cable is also called "thin" Ethernet, because it is a smaller diameter cable than the 10base5 cables.

10base5 a type of coaxial cable used to connect nodes on an Ethernet network. The 10 refers to the transfer rate used on standard Ethernet, 10 megabits per second. The base means that the network uses baseband communication rather than broadband communications, and the 5 stands for the maximum length of cable segment of approximately 500 meters. This type of cable is also called "thick" Ethernet, because it is a larger diameter cable than the 10base2 cables.

10baseT a type of coaxial cable used to connect nodes on an Ethernet network. The 10 refers to the transfer rate used on standard Ethernet, 10 megabits per second. The base means that the network uses baseband communication rather than broadband communications, and the T stands for twisted (wire) cable.

2-D Attasi model a 2-D model described by the equations

$$\begin{aligned} x_{i+1,j+1} &= -A_1 A_2 x_{i,j} + A_1 x_{i+1,j} \\ &\quad + A_2 x_{i,j+1} + B u_{ij} \\ y_{ij} &= C x_{ij} + D u_{ij} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers). Here $x_{ij} \in R^n$ is the local state vector, $u_{ij} \in R^m$ is the input vector, $y_{ij} \in R^p$ is the output vector, and A_1, A_2, B, C, D are real matrices. The model was introduced by Attasi in "Systemes lineaires homogenes a deux indices," *IRIA Rapport Laboria*, No. 31, Sept. 1973.

2-D Fornasini–Marchesini model a 2-D model described by the equations

$$\begin{aligned} x_{i+1,j+1} &= A_0 x_{i,j} + A_1 x_{i+1,j} \\ &\quad + A_2 x_{i,j+1} + B u_{ij} && \text{(1a)} \\ y_{ij} &= C x_{ij} + D u_{ij} && \text{(1b)} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) here $x_{ij} \in R^n$ is the local state vector, $u_{ij} \in R^m$ is the input vector, $y_{ij} \in R^p$ is the output vector A_k $(k = 0, 1, 2)$, B, C, D are real matrices. A 2-D model described by the equations

$$\begin{aligned} x_{i+1,j+1} &= A_1 x_{i+1,j} + A_2 x_{i,j+1} \\ &\quad + B_1 u_{i+1,j} + B_2 u_{i,j+1} && \text{(2)} \end{aligned}$$

$i, j \in Z_+$ and (1b) is called the second 2-D Fornasini–Marchesini model, where x_{ij}, u_{ij}, and y_{ij} are defined in the same way as for (1), A_k, B_k $(k = 0, 1, 2)$ are real matrices. The model (1) is a particular case of (2).

2-D general model a 2-D model described by the equations

$$\begin{aligned} x_{i+1,j+1} &= A_0 x_{i,j} + A_1 x_{i+1,j} \\ &\quad + A_2 x_{i,j+1} + B_0 u_{ij} \\ &\quad + B_1 u_{i+1,j} + B_2 u_{i,j+1} \\ y_{ij} &= C x_{ij} + D u_{ij} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) here $x_{ij} \in R^n$ is the local state vector, $u_{ij} \in R^m$ is the input vector, $y_{ij} \in R^p$ is the output vector and A_k, B_k $(k = 0, 1, 2)$, C, D are real matrices. In particular case for $B_1 = B_2 = 0$ we obtain the first 2-D Fornasini–Marchesini model and for $A_0 = 0$ and $B_0 = 0$ we obtain the second 2-D Fornasini–Marchesini model.

2-D polynomial matrix equation a 2-D equation of the form

$$AX + BY = C \qquad (1)$$

where $A \in R^{k \times p}[s]$, $B \in R^{k \times q}[s]$, $C \in R^{k \times m}[s]$ are given, by a solution to (1) we mean any pair $X \in R^{p\times m}[s]$, $Y \in R^{q\times m}[s]$ satisfying the equation. The equation (1) has a solution if and only if the matrices $[A, B, C]$ and $[A, B, 0]$ are column equivalent or the greatest common left divisor of A and B is a left divisor of C. The 2-D equation

$$AX + YB = C \qquad (2)$$

$A \in R^{k\times p}[s]$, $B \in R^{q\times m}[s]$, $C \in R^{k\times m}[s]$ are given, is called the bilateral 2-D polynomial matrix equation. By a solution to (2) we mean any pair $X \in R^{p\times m}[s]$, $Y \in R^{k\times q}[s]$ satisfying the equation. The equation has a solution if and only if the matrices

$$\begin{bmatrix} A & 0 \\ 0 & B \end{bmatrix} \text{ and } \begin{bmatrix} A & C \\ 0 & B \end{bmatrix}$$

are equivalent.

2-D Roesser model a 2-D model described by the equations

$$\begin{bmatrix} x^h_{i+1,j} \\ x^v_{i,j+1} \end{bmatrix} = \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} u_{ij}$$

$i, j \in Z_+$ (the set of nonnegative integers),

$$y_{ij} = C \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} + Du_{ij}$$

Here $x^h_{ij} \in R^{n_1}$ and $x^v_{ij} \in R^{n_2}$ are the horizontal and vertical local state vectors, respectively, $u_{ij} \in R^m$ is the input vector, $y_{ij} \in R^p$ is the output vector and A_1, A_2, A_3, A_4, B_1, B_2, C, D are real matrices. The model was introduced by R.P. Roesser in "A discrete state-space model for linear image processing," *IEEE Trans. Autom. Contr.*, AC-20, No. 1, 1975, pp. 1-10.

2-D shuffle algorithm an extension of the Luenberger shuffle algorithm for 1-D case. The 2-D shuffle algorithm can be used for checking the regularity condition

$$\det\left[Ez_1z_2 - A_0 - A_1z_1 - A_2z_2\right] \neq 0$$

for some $(z_1, z_2) \in C \times C$ of the singular general model (*See* singular 2-D general model). The algorithm is based on the row compression of suitable matrices.

2-D Z-transform $F(z_1, z_2)$ of a discrete 2-D function f_{ij} satisfying the condition $f_{ij} = 0$ for $i < 0$ or/and $j < 0$ is defined by

$$F(z_1, z_2) = \sum_{i=0}^{\infty} \sum_{j=0}^{\infty} f_{ij} z_1^{-i} z_2^{-j}$$

An 2-D discrete f_{ij} has the 2-D Z-transform if the sum

$$\sum_{i=0}^{\infty} \sum_{j=0}^{\infty} f_{ij} z_1^{-i} z_2^{-j}$$

exists.

2DEGFET *See* high electron mobility transistor(HEMT).

2LG *See* double phase ground fault.

3-dB bandwidth for a causal low-pass or bandpass filter with a frequency function $H(j\omega)$ the frequency at which $|H(j\omega)|_{dB}$ is less than 3 dB down from the peak value $|H(\omega_P)|$.

3-level laser a laser in which the most important transitions involve only three energy states; usually refers to a laser in which the lower level of the laser transition is separated from the ground state by much less than the thermal energy kT. *Contrast with* 4-level laser.

3-level system a quantum mechanical system whose interaction with one or more electromagnetic fields can be described by considering primarily three energy levels. For example, the cascade, vee, and lambda systems are 3-level systems.

4-level laser a laser in which the most important transitions involve only four energy states; usually refers to a laser in which the lower level of the laser transition is separated from the ground state by much more than the thermal energy kT. *Contrast with* 3-level laser.

45 Mbs DPCM for NTSC color video a codec wherein a subjectively pleasing picture is required at the receiver. This does not require transparent coding quality typical of TV signals. The output bit-rate for video matches the DS3 44.736 Megabits per second rate. The coding is done by PCM coding the NTSC composite video signal at three times the color subcarrier frequency using 8 bit per pixel. Prediction of current pixel is obtained by averaging the pixel three after current and 681 pixels before next to maintain the subcarrier phase. A leak factor is chosen before computing prediction error to main the quality of the image. For example a leak factor of $\frac{31}{32}$ the prediction decay is maintained at the center of the dynamic range.

$$X_L^- = 128 + \frac{31}{32}\left(X^- - 128\right) .$$

Finally, a clipper at the coder and decoder is employed to prevent quantization errors.

90% withstand voltage a measure of the practical lightning or switching-surge impulse withstand capability of a piece of power equipment. This voltage withstand level is two standard deviations above the BIL of the equipment.

A

a posteriori probability *See* posterior statistics.

a priori probability *See* prior statistics.

A-mode display returned ultrasound echoes displayed as amplitude versus depth into the body.

A-site in a ferroelectric material with the chemical formula ABO_3, the crystalline location of the A atom.

A/D *See* analog-to-digital converter.

AAL *See* ATM adaptation layer.

ABC *See* absorbing boundary condition.

ABCD propagation of an optical ray through a system can be described by a simple 2×2 matrix. In ray optics, the characteristic of a system is given by the corresponding ray matrix relating the ray's position from the axis and slope at the input to those at the output.

ABCD formalism analytic method using two-by-two ABCD matrices for propagating Gaussian beams and light rays in a wide variety of optical systems.

ABCD law analytic formula for transforming a Gaussian beam parameter from one reference plane to another in paraxial optics, sometimes called the Kogelnik transformation. ABCD refers to the ABCD matrix.

ABCD matrix the matrix containing ABCD parameters. *See* ABCD parameters.

ABCD parameters a convenient mathematical form that can be used to characterize two-port networks. Sometimes referred to as chain parameters. ABCD parameters are widely used to model cascaded connections of two-port microwave networks, in which case the ABCD matrix is defined for each two-port network. ABCD parameters can also be used in analytic formalisms for propagating Gaussian beams and light rays. Ray matrices and beam matrices are similar but are often regarded as distinct.

ABC parameters have a particularly useful property in circuit analysis where the composite ABCD parameters of two cascaded networks are the matrix products of the ABCD parameters of the two individual circuits. ABCD parameters are defined as

$$\begin{bmatrix} v_1 \\ i_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} v_2 \\ i_2 \end{bmatrix}$$

where v_1 and v_2 are the voltages on ports one and two, and i_1 and i_2 are the branch currents into ports one and two.

aberration an imperfection of an optical system that leads to a blurred or a distorted image.

abnormal event any external or program-generated event that makes further normal program execution impossible or undesirable, resulting in a system interrupt. Examples of abnormal events include system detection of power failure; attempt to divide by 0; attempt to execute privileged instruction without privileged status; memory parity error.

abort (1) in computer systems, to terminate the attempt to complete the transaction, usually because there is a deadlock or because completing the transaction would result in a system state that is not compatible with "correct" behavior, as defined by a consistency model, such as sequential consistency.

(2) in an accelerator, terminating the acceleration process prematurely, either by inhibiting the injection mechanism or by removing circulating beam to some sort of

dump. This is generally done to prevent injury to some personnel or damage to accelerator components.

ABR *See* available bit rate.

absolute address an address within an instruction that directly indicates a location in the program's address space. *Compare with* relative addressing.

absolute addressing an addressing mode where the address of the instruction operand in memory is a part of the instruction so that no calculation of an effective address by the CPU is necessary.

For example, in the Motorola M68000 architecture instruction ADD 5000,D1, a 16-bit word operand, stored in memory at the word address 5000, is added to the lower word in register D1. The address "5000" is an example of using the absolute addressing mode. *See also* addressing mode.

absolute encoder an optical device mounted to the shaft of a motor consisting of a disc with a pattern and light sources and detectors. The combination of light detectors receiving light depends on the position of the rotor and the pattern employed (typically the Gray code). Thus, absolute position information is obtained. The higher the resolution required, the larger the number of detectors needed. *See also* encoder.

absolute moment The pth order absolute moment μ_p of a random variable $\mathbf{X}$ is the expectation of the absolute value of $\mathbf{X}$ raised to the pth power:

$$\mu_p = E[|\mathbf{X}|]^p .$$

See also central moment, central absolute moment. *See also* expectation.

absolute pressure units to measure gas pressure in a vacuum chamber with zero being a perfect vacuum. Normally referred to as psia (pounds per square inch absolute).

absolute sensitivity denoted $\mathbf{S}(y, x)$, is simply the partial derivative of y with respect to x, i.e., $\mathbf{S}(y, x) = \partial y / \partial x$, and is used to establish the relationships between absolute changes. *See* sensitivity, sensitivity measure, relative sensitivity, semi-relative sensitivity.

absolute stability occurs when the network function $H(s)$ has only left half-plane poles.

absorber generic term used to describe material used to absorb electromagnetic energy. Generally made of polyurethane foam and impregnated with carbon (and fire-retardant salts), it is most frequently used to line the walls, floors and ceilings of anechoic chambers to reduce or eliminate reflections from these surfaces.

absorbing boundary condition (ABC) a fictitious boundary introduced in differential equation methods to truncate the computational space at a finite distance without, in principle, creating any reflections.

absorption (1) process that dissipates energy and causes a decrease in the amplitude and intensity of a propagating wave between an input and output reference plane.

(2) reduction in the number of photons of a specific wavelength or energy incident upon a material. Energy transferred to the material may result in a change in the electronic structure, or in the relative movement of atoms in the material (vibration or rotation).

(3) process by which atoms or molecules stick to a surface. If a bond is formed, it is termed chemisorption, while the normal case is physisorption. The absorption process proceeds due to, and is supported by, the fact that this is a lower energy state.

absorption coefficient (1) in a passive device, the negative ratio of the power absorbed ($p_{absorbed} = p_{in} - p_{out}$) ratioed to the power in ($p_{in} = p_{incident} - p_{reflected}$) per unit length (l), usually expressed in units of 1/wavelength or 1/meter.

(2) factor describing the fractional attenuation of light with distance traversed in a medium, generally expressed as an exponential factor, such as k in the function e^{-kx}, with units of (length)-1. Also called attenuation coefficient.

absorption cross section energy absorbed by the scattering medium, normalized to the wavenumber. It has dimensions of area.

absorption edge the optical wavelength or photon energy corresponding to the separation of valence and conduction bands in solids; at shorter wavelengths, or higher photon energies than the absorption edge, the absorption increases strongly.

absorption grating (1) a diffraction grating where alternate grating periods are opaque.

(2) an optical grating characterized by spatially periodic variation in the absorption of light. Absorption gratings are generally less efficient than phase gratings.

absorption optical fiber the amount of optical power in an optical fiber captured by defect and impurity centers in the energy bandgap of the fiber material and lost in the form of longwave infrared radiation.

AC *See* alternating current.

AC bridge one of a wide group of bridge circuits used for measurements of resistances, inductances, and capacitances, and to provide AC signal in the bridge transducers including resistors, inductors, and capacitors.

The Wheatstone bridge can be used with a sinusoidal power supply, and with an AC detector (headphones, oscilloscope), one can use essentially the same procedure for measurement of resistors as in DC applications. Only a small number of other AC bridges are used in modern electric and electronic equipment. A strong selection factor was the fact that in a standard capacitor the electrical parameter are closest to the parameters of an ideal capacitor. Hence, not only a capacitance is measured in terms of capacitance (in resistive ratio arms bridges), but the inductance as well is measured in terms of capacitance (Hay and Owen bridges).

The AC bridges with ratio arms that are tightly coupled inductances allow measurement of a very small difference between currents in these inductances, and this fact is used in very sensitive capacitance transducers.

AC circuit electrical network in which the voltage polarity and directions of current flow change continuously, and often periodically. Thus, such networks contain alternating currents as opposed to direct currents, thereby giving rise to the term.

AC coupling a method of connecting two circuits that allows displacement current to flow while preventing conductive currents. Reactive impedance devices (e.g., capacitors and inductive transformers) are used to provide continuity of alternating current flow between two circuits while simultaneously blocking the flow of direct current.

AC motor an electromechanical system that converts alternating current electrical power into mechanical power.

AC plasma display a display that employs an internal capacitive dielectric layer to limit the gas discharge current.

AC steady-state power the average power delivered by a sinusoidal source to a network, expressed as

$$P = \mid V \mid \cdot \mid I \mid \cos(\theta)$$

where $\sqrt{2} \cdot \mid V \mid$ and $\sqrt{2} \cdot \mid I \mid$ are the peak values, respectively, of the AC steady-state voltage and current at the terminals. θ represents the phase angle by which the voltage leads the current.

AC/AC converter a power electronics device in which an AC input voltage of some magnitude, frequency, and number of phases is changed to an AC output with changes to any of the previously mentioned parameters. AC/AC converters usually rectify the input source to a DC voltage and then invert the DC voltage to the desired AC voltage.

AC/DC converter *See* rectifier.

AC-DC integrated system a power system containing both AC and DC transmission lines.

ACARS aircraft communications addressing and reporting. A digital communications link using the VHF spectrum for two-way transmission of data between an aircraft and ground. It is used primarily in civil aviation applications.

ACC *See* automatic chroma control.

accelerated testing tests conducted at higher stress levels than normal operation but in a shorter period of time for the specific purpose to induce failure faster.

accelerating power the excess electric power at a synchronous machine unit which cannot be transmitted to the load because of a short circuit near its terminals. This energy gives rise to increasing rotor angle.

acceleration error the final steady difference between a parabolic setpoint and the process output in a unity feedback control system. Thus it is the asymptotic error in position that arises in a closed loop system that is commanded to move with constant acceleration. *See also* position error, velocity error.

acceleration error constant a gain K_a from which acceleration error e_a is readily determined. The acceleration error constant is a concept that is useful in the design of unity feedback control systems, since it transforms a constraint on the final acceleration error to a constraint on the gain of the open loop system. The relevant equations are $e_a = \frac{1}{K_a}$ and $K_a = lim_{s \to infty} s^2 q(s)$, where $q(s)$ is the transfer function model of the open loop system, including the controller and the process in cascade, and s is the Laplace variable. *See also* position error constant, velocity error constant.

accelerator (1) a positive electrode in a vacuum tube to accelerate emitted electrons from its cathode by coulomb force in a desired direction.

(2) a machine used to impart large kinetic energies to charged particles such as electrons, protons, and atomic nuclei. The accelerated particles are used to probe nuclear or subnuclear phenomena in industrial and medical applications.

acceptable delay the voice signal delay that results in inconvenience in the voice communication. A typically quoted value is 300 ms.

acceptance in an accelerator, it defines how "large" a beam will fit without scraping into the limiting aperture of a transport line. The acceptance is the phase-space volume within which the beam must lie to be transmitted through an optical system without losses. From an experimenters point of view acceptance is the phase-space volume intercepted by an experimenter's detector system.

acceptor (1) an impurity in a semiconductor that donates a free hole to the valence band.

(2) a dopant species that traps electrons, especially with regard to semiconductors.

access channel a channel in a communications network that is typically allocated for the purpose of setting up calls or communication sessions. Typically the users share the access channel using some multiple access algorithm such as ALOHA or CSMA.

access control a means of allowing access to an object based on the type of access sought, the accessor's privileges, and the owner's policy.

access control list a list of items associated with a file or other object; the list contains the identities of users that are permitted access to the associated file. There is information (usually in the form of a set of bits) about the types of access (such as read, write, or delete) permitted to the user.

access control matrix a tabular representation of the modes of access permitted from active entities (programs or processes) to passive entities (objects, files, or devices). A typical format associates a row with an active entity or subject and a column with an object; the modes of access permitted from that active entity to the associated passive entity are listed in the table entry.

access line a communication line that connects a user's terminal equipment to a switching node.

access mechanism a circuit board or an integrated chip that allows a given part of a computer system to access another part. This is typically performed by using a specific access protocol.

access protocol a set of rules that establishes communication among different parts. These can involve both hardware and software specifications.

access right permission to perform an operation on an object, usually specified as the type of operation that is permitted, such as read, write, or delete. Access rights can be included in access control lists, capability lists, or in an overall access control matrix.

access time the total time needed to retrieve data from memory. For a disk drive this is the sum of the time to position the read/write head over the desired track and the time until the desired data rotates under the head. (LW)

accidental rate the rate of false coincidences in the electronic counter experiment produced by products of the reactions of more than one beam particle within the time resolution of the apparatus.

accumulation (1) an increase in the majority carrier concentration of a region of semiconductor due to an externally applied electric field.

accumulator (1) a register in the CPU (processor) that stores one of the operands prior to the execution of an operation, and into which the result of the operation is stored. An accumulator serves as an implicit source and destination of many of the processor instructions. For example, register A of the Intel 8085 is an accumulator. *See also* CPU .

(2) the storage ring in which successive pulses of particles are collected to create a particle beam of reasonable intensity for colliding beams.

achievable rate region for a multiple terminal communications system, a set of rate-vectors for which there exist codes such that the probability of making a decoding error can be made arbitrarily small. *See also* capacity region, multiple access channel.

achromatic the quality of a transport line or optical system where particle momentum has no effect on its trajectory through the system. In an achromatic device or system, the output beam displacement or divergence (or both) is independent of the input beam's momentum. If a system of lenses is achromatic, all particles of the same momentum will have equal path lengths through the system.

ACI *See* adjacent channel interference.

acknowledge (1) a signal which indicates that some operation, such as a data transfer, has successfully been completed.

(2) to detect the successful completion of an operation and produce a signal indicating the success.

acoustic attenuation the degree of amplitude suppression suffered by the acoustic wave traveling along the acousto-optic medium.

acoustic laser a laser (or maser) in which the amplified field consists of soundwaves or phonons rather than electromagnetic waves; phonon laser or phaser.

acoustic memory a form of circulating memory in which information is encoded in acoustic waves, typically propagated through a trough of mercury. Now obsolete.

acoustic velocity the velocity of the acoustic signal traveling along the acousto-optic medium.

acoustic wave a propagating periodic pressure wave with amplitude representing either longitudinal or shear particle displacement within the wave medium; shear waves are prohibited in gaseous and liquid media.

acousto-optic cell a device consisting of a photo-elastic medium in which a propagating acoustic wave causes refractive-index changes, proportional to acoustic wave amplitude, that act as a phase grating for diffraction of light. *See also* Bragg cell.

acousto-optic channelized radiometer *See* acousto-optic instantaneous spectrum analyzer in Bragg mode.

acousto-optic correlator an optical system that consists of at least one acousto-optic cell, imaging optics between cells and fixed masks, and photodetectors whose outputs correspond to the correlation function of the acoustic wave signal within one cell with another signal in a second cell, or with fixed signals on a mask.

acousto-optic deflector device device where acousto-optic interaction deflects the incident beam linearly as a function of the input frequency of the RF signal driving the device.

acousto-optic device descriptor of acousto-optic cells of any design; generally describes a cell plus its transducer structure(s), and may encompass either bulk, guided-wave, or fiber-optic devices.

acousto-optic effect the interaction of light with sound waves and in particular the modification of the properties of a light wave by its interactions with an electrically controllable sound wave. *See also* Brillouin scattering.

acousto-optic frequency excisor similar to an acousto-optic spectrum analyzer where the RF temporal spectrum is spatially and selectively blocked to filter the RF signal feeding the Bragg cell.

acousto-optic instantaneous spectrum analyzer in Bragg mode device in which the temporal spectrum of a radio frequency signal is instantaneously and spatially resolved in the optical domain using a Fourier transform lens and a RF signal-fed Bragg cell.

acousto-optic modulator a device that modifies the amplitude or phase of a light wave by means of the acousto-optic effect.

acousto-optic processor an optical system that incorporates acousto-optic cells configured to perform any of a number of mathematical functions such as Fourier transform, ambiguity transforms, and other time-frequency transforms.

acousto-optic scanner a device that uses an acoustic wave in a photoelastic medium to deflect light to different angular positions based on the frequency of the acoustic wave.

acousto-optic space integrating convolver device that is the same as an acousto-optic space integrating convolver except that it implements the convolution operation.

acousto-optic space integrating correlator an acousto-optic implementation of the correlation function where two RF signals are spatially impressed on two diffracted beams from Bragg cells, and a Fourier transform lens spatially integrates these beams onto a point sensor that generates a photo current representing the correlation function.

acousto-optic spectrum analyzer an acousto-optic processor that produces at a photodetector output array the Fourier decomposition of the electrical drive signal of an acousto-optic device.

acousto-optic time integrating convolver same as the acousto-optic time integrating correlator, except implements the signal convolution operation. *See* acousto-optic time integrating correlator.

acousto-optic time integrating correlator an acousto-optic implementation of the correlation function where two RF signals are spatially impressed on two diffracted beams from Bragg cells, and a time integrating sensor generates the spatially distributed correlation results.

acousto-optic triple product processor signal processor that implements a triple integration operation using generally both space and time dimensions.

acousto-optic tunable filter (AOTF) an acousto-optic device that selects specific optical frequencies from a broadband optical beam, depending on the number and frequencies of acoustic waves generated in the device.

acousto-optics the area of study of interaction of light and sound in media, and its utilization in applications such as signal processing and filtering.

ACP *See* adjacent channel power.

acquisition (1) in digital communications systems, the process of acquiring synchronism with the received signal. There are several levels of acquisitions, and for a given communication system several of them have to be performed in the process of setting up a communication link: frequency, phase, spreading code, symbol, frame, etc.

(2) in analog communications systems, the process of initially estimating signal parameters (for example carrier frequency offset, phase offset) required in order to begin demodulation of the received signal.

(3) in vision processing, the process by which a scene (physical phenomenon) is converted into a suitable format that allows for its storage or retrieval. *See also* synchronization.

across the line starter a motor starter that applies full line voltage to the motor to start. This is also referred to as "hard starting" because it causes high starting currents. Larger motors require reduced voltage or "soft starting."

ACRR *See* adjacent channel reuse ratio.

ACSR aluminum cable, steel-reinforced. A kind of overhead electric power conductor made up of a central stranded steel cable overlaid with strands of aluminum.

ACT *See* anticomet tail.

action potential a propagating change in the conductivity and potential across a nerve cell's membrane; a nerve impulse in common parlance.

activation function in an artificial neural network, a function that maps the net output of a neuron to a smaller set of values. This set is usually $[0, 1]$. Typical functions are the sigmoid function or singularity functions like the step or ramp.

active contour a deformable template matching method that, by minimizing the energy function associated with a specific model (i.e., a specific characterization of the shape of an object), deforms the model in conformation to salient image features.

active device a device that can convert energy from a DC bias source to a signal at an RF frequency. Active devices are required in oscillators and amplifiers.

active filter (1) a filter that has an energy gain greater than one, that is, a filter that outputs more energy than it absorbs.

(2) a form of power electronic converter designed to effectively cancel harmonic currents by injecting currents that are equal and opposite to, or 180° out of phase with, the target harmonics. Active filters allow the output current to be controlled and provide stable operation against AC source impedance variations without interfering with the system impedance.

The main type of active filter is the series type in which a voltage is added in series with an existing bus voltage. The other type is the parallel type in which a current is injected into the bus and cancels the line current harmonics.

active impedance the impedance at the input of a single antenna element of an array with all the other elements of the array excited.

active layer *See* active region.

active learning a form of machine learning where the learning system is able to interact with its environment so as to affect the generation of training data.

active load a transistor connected so as to replace a function that would conventionally be performed by a passive component such as a resistor, capacitor, or inductor.

active load-pull measurement a measurement method where transfer characteristics of a device can be measured by electrically changing the load impedance seen from the device. In an active load-pull measurement, the load impedance is defined by using an output signal from the device and an injected signal from the output of the device.

active logic a digital logic that operates all of the time in the active, dissipative region of the electronic amplifiers from which it is constructed. The output of such a gate is determined primarily by the gate and not by the load.

active magnetic bearing a magnetic bearing that requires input energy for stable support during operation. Generally implemented with one or more electromagnets and controllers.

active mixer a mixer that uses three terminal devices such as FET rather than diodes as nonlinear element. One advantage of active mixers is that they can provide conversion gain.

active network an electrical network that contains some solid state devices such as bipolar junction transistors (BJTs) or metal-oxide-silicon field effect transistors (FETs) operating in their active region of the voltage vs. current characteristic. To ensure that these devices are operating in the active region, they must be supplied with proper DC biasing.

active neuron a neuron with a non-zero output. Most neurons have an activation threshold. The output of such a neuron has zero output until this threshold is reached.

active power *See* real power.

active power line conditioner a device which senses disturbances on a power line and injects compensating voltages or currents to restore the line's proper waveform.

active RC filter an electronic circuit made up of resistors, capacitors, and operational amplifiers that provide well-controlled linear frequency-dependent functions, e.g., low-, high-, and bandpass filters.

active redundancy a circuit redundancy technique that assures fault-tolerance by detecting the existence of faults and performing some action to remove the faulty hardware, e.g., by standby sparing.

active region semiconductor material doped such that electrons and/or holes are free to move when the material is biased. In the final fabricated device, the active regions are usually confined to very small portions of the wafer material.

active-high (1) a logic signal having its asserted state as the logic ONE state.

(2) a logic signal having the logic ONE state as the higher voltage of the two states.

active-low (1) a logic signal having its asserted state as the logic ZERO state.

(2) a logic signal having its logic ONE state as the lower voltage of the two states; inverted logic.

actuator (1) a transducer that converts electrical, hydraulic, or pneumatic energy to effective motion. For example in robots, actuators set the manipulator in motion through actuation of the joints. Industrial robots are equipped with motors that are typically electric, hydraulic, or pneumatic. *See also* industrial robot.

(2) in computers, a device, usually mechanical in nature, that is controlled by a computer, e.g., a printer paper mechanism or a disk drive head positioning mechanism.

ACTV *See* advanced compatible television.

acuity sharpness. The ability of the eye to discern between two small objects closely spaced, as on a display.

adaptability the capability of a system to change to suit the prevailing conditions, especially by automatic adjustment of parameters through some initialization procedure or by training.

adaptation layer control layer of a multilayer controller, situated above the direct control layer and — usually — also above the optimizing control layer, required to introduce changes into the decision mechanisms of the layer (or layers) below this adaptation layer; for example adaptation layer of the industrial controller may be responsible for adjusting the model used by the optimizing control and the decision rules used by the direct (regulation) control mechanisms.

adapter a typical term from personal computers. A circuit board containing the interface toward an additional peripheral device. For example, a graphic adapter (interface boards like EGA, VGA, CGA), a game controller, a SCSI controller, a PCMCI interface, etc.

adaptive algorithm (1) a method for adjusting the parameters of a filter to satisfy an objective (e.g., minimize a cost function).

(2) an algorithm whose properties are adjusted continuously during execution with the objective of optimizing some criterion.

adaptive antenna antenna, or array of antennas, whose performance characteristics can be adapted by some means; e.g., the pattern of an array can be changed when the phasing of each of the array elements is changed.

adaptive array an array that adapts itself to maximize the reception of a desired signal and null all interfering or jamming signals. This is achieved by finding the correct weights (input excitations) to the elements comprising the array.

adaptive coding a coding scheme that adapts itself in some fashion to its input or output.

adaptive coding of transform coefficients coding technique that is carried out by threshold sampling and exploiting masking effects by variable quantization for different blocks. High detail blocks are coded with more quantization error than low detail blocks. This is done to take into account masking and boundary distortion effects. Transform coding becomes more attractive compared with DPCM when adaptive coding is used. The main drawback of adaptive transform coding is its sensitivity to transmission bit errors due to synchronization problems at the decoder. *See also* DPCM.

adaptive control a control methodology in which control parameters are continuously and automatically adjusted in response to be measured/estimated process variables to achieve near-optimum system performance.

adaptive critic learning technique where the system learns to evaluate the actions of a system (usually a controller) so as to provide a reinforcement signal that is an estimate of the future value of the system's current action.

adaptive differential pulse code modulation (ADPCM) a modulation scheme in which only the difference between successive signal samples is encoded for transmission, and the quantization of the coding is adapted to the characteristics of the signal source.

adaptive filtering a filtering strategy in which filter coefficients or governing parameters evolve over time according to some updating strategy to optimize some criterion.

adaptive FIR filter a finite impulse response structure filter with adjustable coefficients. The adjustment is controlled by an adaptation algorithm such as the least mean square (LMS) algorithm. They are used extensively in adaptive echo cancellers and equalizers in communication systems.

adaptive fuzzy system fuzzy inference system that can be trained on a data set through the same learning techniques used for neural networks. Adaptive fuzzy systems are able to incorporate domain knowledge about the target system given from human experts in the form of fuzzy rules and numerical data in the form of input–output data sets of the system to be modeled. *See also* neural network, fuzzy inference system.

adaptive intrafield predictors a technique used for picture signal prediction based on local properties of the signal or side information if portions of local properties have not been transmitted. Intrafield methods require correlation with local information for prediction purposes.

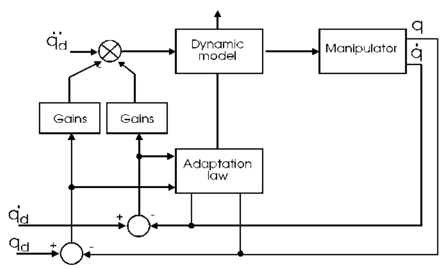
A common technique is to use a measure of the directional correlation based on local pixels that have already been transmitted. A predictor is chosen from a set to give minimum prediction error. For example, the previous line or previous pixel can be used for prediction, and the switching can then be done as follows:

$$\begin{aligned} \cap X &= \text{ predictor for element } X \\ &= \begin{cases} A & if \|B-C\| < \|A-B\| \\ C & \text{otherwise} \end{cases} \end{aligned}$$

An extension of this concept is called contour prediction where the direction of pixel A is determined by searching among E, B, C, or G.

adaptive logic network tree-structured network whose leaves are the inputs and whose root is the output. The first hidden layer consists of linear threshold units and the remaining layers are elementary logic gates, usually AND and OR gates. Each linear threshold unit is trained to fit input data in those regions of the input space where it is active (i.e., where it contributes to the overall network function).

adaptive manipulator controller a controller that uses an adaptation process which, based on observation of the manipulator position and velocity, readjusts the parameters in the nonlinear model until the errors disappear. An adaptive manipulator controller is depicted in the figure below. Such a system would learn its own dynamic properties. The adaptive manipulator control scheme



Adaptive manipulator control scheme.

presented in the figure belongs to the joint space control schemes. *See also* joint space control.

adaptive predictor a digital filter whose coefficients can be varied, according to some error minimization algorithm, such that it can predict the value of a signal say N sampling time intervals into the future. The adaptive predictor is useful in many interference cancellation applications.

adaptive resonance theory (ART) network A clustering network developed to allow the learning of new information without destroying what has already been learnt. Each cluster is represented by a prototype and learning is achieved by comparing a new input pattern with each prototype. If a prototype is found that is acceptably close to that input, the new pattern is added to that prototype's cluster and the prototype is adjusted so as to move closer to the new input. If no prototype is acceptable, the pattern becomes a new prototype around which a new cluster may develop.

adaptive vector quantization term that refers to methods for vector quantization that are designed to adaptively track changes in the input signal.

ADC *See* analog-to-digital converter.

ADCPM *See* adaptive differential pulse code modulation.

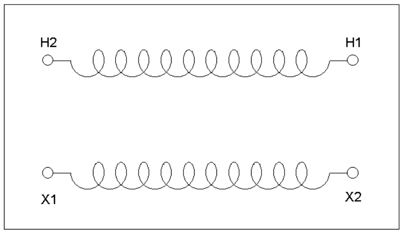
add instruction a machine instruction that causes two numeric operands to be added together. The operands may be from machine registers, memory, or from the instruction itself, and the result may be placed in a machine register or in memory.

adder a logic circuit used for adding binary numbers.

additive acousto-optic processing acousto-optic signal processing where the summation of acousto-optic modulated light waves is used to implement the signal processing operation.

additive polarity polarity designation of a transformer in which terminals of the same polarity on the low- and high-voltage coils are physically adjacent to each other on the transformer casing. With additive polarity, a short between two adjacent terminals results in the sum of the two coil voltages appearing between the remaining terminals. Additive polarity is generally used for transformers up to 500kVA and 34.5kV. Larger units use subtractive polarity. See the diagram below. *See also* subtractive polarity.

additive white Gaussian noise (AWGN) the simplest form of channel degradation in a communication system in which the source



Transformer with additive polarity.

of errors in the channel can be modeled as the addition of random noise with a Gaussian distribution and a constant (white) power spectrum. *See also* thermal noise.

address a unique identifier for the place where information is stored (as opposed to the contents actually stored there). Most storage devices may be regarded by the user as a linear array, such as bytes or words in RAM or sectors on a disk. The address is then just an ordinal number of the physical or logical position. In some disks, the address may be compound, consisting of the cylinder or track and the sector within that cylinder.

In more complex systems, the address may be a "name" that is more relevant to the user but must be translated by the underlying software or hardware.

address aliasing *See* cache aliasing.

address bus the set of wires or tracks on a backplane, printed circuit board, or integrated circuit to carry binary address signals between different parts of a computer. The number of bits of address bus (the width of the bus) determines the maximum size of memory that can be addressed. Modern microchips have 32 address lines, thus 4 gigabytes of main memory can be accessed.

address decoder logic that decodes an address.

1. A partial decoder responds to a small range of addresses and is used when recognizing particular device addresses on an I/O address bus, or when recognizing that addresses belong to a particular memory module.

2. A full decoder takes N bits and asserts one of 2^N outputs, and is used within memories (often within RAM chips themselves).

address error an exception (error interrupt) caused by a program's attempt to access unaligned words or long words on a processor that does not accommodate such requests. The address error is detected within the CPU. This contrasts with problems that arise in accessing the memory itself, where a logic circuit external to the CPU itself must detect and signal the error to cause the CPU to process the exception. Such external problems are called bus errors.

address field the portion of a program instruction word that holds an address.

address generation interlock (AGI) a mechanism to stall the pipeline for one cycle when an address used in one machine cycle is being calculated or loaded in the previous cycle. Address generation interlocks cause the CPU to be delayed for a cycle. (AGIs on the Pentium are even more important to remove, since two execution time slots are lost).

address locking a mechanism to protect a specific memory address so that it can be accessed exclusively by a single processor.

address map a table that associates a base address in main memory with an object (or page) number.

address mapping the translation of virtual address into real (i.e., physical) addresses for memory access. *See also* virtual memory.

address register a register used primarily to hold the address of a location in memory. The location can contain an operand or an executable instruction.

address size prefix a part of a machine instruction that provides information as to the length or size of the address fields in the instruction.

address space an area of memory seen or used by a program and generally managed as a continuous range of addresses. Many computers use separate address spaces for code and data; some have other address spaces for system. An address space is usually subject to protection, with references to a space checked for valid addresses and access (such as read only).

The physical address space of a computer (2^{32} bytes, and up to 2^{64} bytes) is often larger than the installed memory. Some parts of the address range (often at extreme addresses) may be reserved for input–output device addresses. *See also* byte, memory, memory mapped I/O.

address translation *See* address mapping.

addressing (1) in processors: a mechanism to refer to a device or storage location by an identifying number, character, or group of characters. That may contain a piece of data or a program step.

(2) in networks, the process of identifying a network component, for instance, the unique address of a node on a local area network.

addressing fault an error that halts the mapper when it cannot locate a referenced object in main memory.

addressing mode a form of specifying the address (location) of an operand in an instruction. Some of the addressing modes found in most processors are direct or register direct, where the operand is in a CPU register; register indirect (or simply indirect), where a CPU register contains the address of the operand in memory; immediate, where the operand is a part of the instruction. *See also* central processing unit.

addressing range numbers that define the number of memory locations addressable by the CPU. For a processor with one address space, the range is determined by the number of signal lines on the address bus of the CPU.

adequate service in terms of the blocking probability, term associated with a fixed blocking. A typically quoted value may be 2. *See also* blocking.

adiabatic a system that has no heat transfer with the environment.

adiabatic cooling a process where the temperature of a system is reduced without any heat being exchanged between the system and its surroundings. In particle beam acceleration this term is used to describe the process in the particle source storage ring where beam emittances are reduced without affecting beam energy.

adiabatic following an approximation made when some states in a quantum mechanical system respond to perturbations more quickly than the other states. In this approximation the rapidly responding states are assumed to depend only on the instantaneous values of the other states and are said to "follow" those states.

adiabatic passage a technique for the creation of a long-lived coherence in a quantum mechanical system by manipulating electromagnetic field intensities so that the system always remains in an eigenstate. In practice, this involves changing field strengths on a time scale slower than the inverse of the energy spacing between relevant eigenstates of the system. For example, consider a lambda system in which only one field is present initially and all population starts out in the uncoupled ground state. If a field is gradually turned on to couple this initial state to the excited state, the system can remain transparent by evolving in such a way that it is always mathematically equivalent to the dark state that would be produced by coherent population trapping. Adiabatic passage is often used for selective transfer of population between two long-lived states of a multistate system, especially in cases where the two-step process of absorption followed by spontaneous decay (optical pumping) would tend to populate many other states.

adjacency graph a graph in which each node represents an object, component, or feature in an image. An edge between two nodes indicates two components that are touching or connected in the image.

adjacent channel interference (ACI) the interference caused by an adjacent frequency band, e.g., in a system with frequency division duplex (FDD). Classified as either in-band or out-of-band adjacent channel interference (ACI). The in-band ACI occurs when the center frequency of interfering signal falls within the band of the desired signal. The out-of-band ACI occurs when the center frequency of interfering signal falls outside the bandwidth of the desired signal.

adjacent channel leakage power *See* adjacent channel power.

adjacent channel power (ACP) a power of distortion components generated in adjacent channel, which is caused by a nonlinearity of high-power amplifier amplifying a digitally modulated signal such as QPSK, QAM, etc. Adjacent channel power is defined as a ratio of signal power in channel and leakage power in adjacent channel.

adjacent channel reuse ratio (ACRR) the reuse ratio between radio communication cells using adjacent radio channels. *See also* reuse ratio.

adjacent channels radio channels occupying radio frequency allocations n and $n \pm 1$.

adjoint network a network with an identical structure to the original one, but with possibly different elements. As an example, for a network described by the nodal admittance matrix, its adjoint network is represented by the transposed admittance matrix of the original network. The adjoint network is a basic tool in the computer-aided sensitivity analysis of electronic and microwave circuits.

adjustable-speed drive *See* variable speed DC drive, variable speed AC drive.

admissible matrix a matrix M^- that can be obtained by fixing the free parameters of the matrix M at some particular values. M^- is said to be admissible with respect to M.

admittance the reciprocal of the impedance of an electric circuit.

admittance inverter an idealized device or set of matrix parameters that functions electrically like a quarter-wave lossless transmission line of characteristic impedance J at each frequency, thus transforming the load admittance (Y_{LOAD}) by +90 degrees and modifying the magnitude, resulting in an input admittance (Y_{in}).

$$Y_{in} = \frac{J^2}{Y_{load}}$$

admittance matrix the inverse of the impedance matrix in the method of moments.

ADP *See* ammonium dihydrogen phosphate.

ADPCM *See* adaptive differential pulse code modulation.

ADSL *See* asymmetric digital subscriber line.

adsorbent the material of an adsorber, for example, silica gel, alumina, and charcoal. Adsorbent materials are characterized by high surface to volume ratio.

adsorber (1) condensation of a gas on the solid material.

(2) material that attracts and holds (by Van der Waal forces) molecular layers of dense gases (i.e., very near condensation temperatures) on porous high surface/volume ratio materials.

ADTV *See* advanced digital television.

advanced compatible television (ACTV) an extended definition television system that can operate with existing bandwidths on existing receivers and is compatible with the NTSC broadcasting system. The ACTV system was proposed by the Advanced Television Research Consortium and was the first high definition television (HDTV) system. HDTV system was tested by the FCC July 17, 1992. The additional picture information needed to increase the picture width and to increase the resolution to the HDTV format is transmitted in an augmented channel as an alternative to simulcast transmission. *See* Advanced Television Research Consortium.

advanced digital television (ADTV) a high definition television (HDTV) digital transmission television system was proposed to the Federal Communications Commission by the Advanced Television Research Consortium. The ADTV system introduced a layered system to separately describe the digital transmission system, the video compression system, and the data packet transport system. The video compression method uses a MPEG++ standard that provides for compatibility with multimedia computing. *See* Advanced Television Research Consortium.

advanced mobile phone system (AMPS) a standard for a cellular radio communications network originally developed in the 1970s by AT&T and later adopted as an industry standard by the U.S.-based Telecommunications Industries Association (TIA). It is the first cellular standard widely deployed in North America. It is also referred to as the analog cellular system. Frequency modulation with 30 kHz channels is used.

Advanced Television Research Consortium an organization consisting of David Sarnoff Research Center, Thompson Consumer Electronics, North American Philips Corporation, NBC, and Compression Laboratories.

aeolian vibration a high-frequency mechanical vibration of electric power lines caused by wind.

aerial cable any fully-insulated electric power cable which is carried overhead upon poles, as opposed to the use of the more usual overhead bare conductors.

aerodynamic head *See* disk head.

AFC *See* automatic frequency control.

affine transform a geometric image transformation including one or more translations, rotations, scales, and shears that is represented by a 4×4 matrix allowing multiple geometric transformations in one transform step. Affine transformations are purely linear and do not include perspective or warping transformations.

AFM *See* atomic force microscope.

AFT *See* automatic fine tuning.

AFV *See* audio follow-video switcher.

AGC *See* automatic gain control or automatic generation control.

agent a computational entity that acts on behalf of other entities in an autonomous fashion.

agent-based system an application whose component are agents. *See also* agent.

aggregation an operation performed on system variables whose purpose is to collect them in a way enabling order and/or uncertainty reduction. For linear systems both continuous-time and discrete-time state aggregation is obtained by linear transformation of the original state represented by an aggregation matrix G endowed with the following properties:

$$GA = A^*G; GB = B^*; CG' = C^*;$$

where A, B, C are original system matrices (respectively state, input, and output ones) and A^*, B^*, C^* are aggregated system matrices. The aggregation is an eigenvalues-preservation approach and it provides order reduction by neglecting some of the system modes.

For uncertainties, the aggregation defines some deterministic measures for a set of uncertain variables. For stochastic model of uncertainty the aggregation may be given by mean value, higher stochastic models or other statistical characteristics, while set membership uncertainties could be aggregated by their maximal or minimal values, mass center of the set or higher inertial moments.

AGI *See* address generation interlock.

Aiken, Howard Hathaway (1900–1973) Born: Hoboken, New Jersey, U.S.A.

Aiken is best known as the inventor of the Mark I and Mark II computers. While not commercially successful, these machines were significant in the development of the modern computer. The Mark I was essentially a mechanical computer. The Mark II was an electronic computer. Unlike UNIVAC (*See* Eckert, John Presper) these machines had a stored memory. Aiken was a professor of mathematics at Harvard. He was given the assignment to develop these computers by the Navy department. Among his colleagues in this project were three IBM scientists and Grace Hopper. It was while working on the Mark I that Grace Hopper pulled the first "bug" from a computer.

air bridge a bridge made of metal strip suspended in air that can connect components on an integrated circuit in such a way as to cross over another strip. Air bridges are also used to suspend metalization in spiral inductors off of the semi-conducting substrate in a way that can lead to improved performance in some cases.

air capacitor a fixed or variable capacitor in which air is the dielectric material between the capacitor's plates.

air circuit breaker a power circuit breaker where the power contacts operate in air. Some versions employ an air blast to extend and clear the arc on contact opening, while others employ arc chutes with magnetic or thermal assists.

air core transformer two or more coils placed so that they are linked by the same flux with an air core. With an air core the flux is not confined.

air gap *See* magnetic recording air gap.

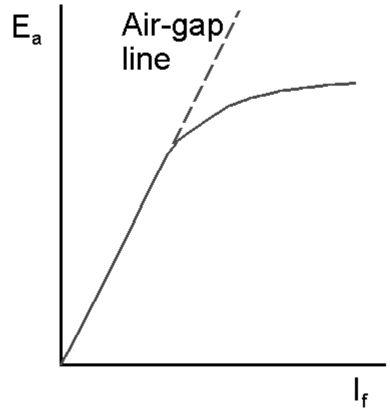
air ionization chamber a device used to monitor neutron flux.

air line a coaxial transmission line in which the volume between the inner and outer conductors are air-filled.

air terminal a lightning rod; any device which extends upward into the air from a structure for purposes of lightning protection.

air-blast circuit breaker a circuit breaker in which the arc which forms between the contacts on opening is extinguished with a blast of high-pressure air.

air-gap line the line that is obtained by continuing the linear portion of the saturation curve of a synchronous machine or a DC machine. The figure shows a plot of generated voltage vs. field current at constant machine speed. Initially, an increase in field current yields a linear increase in the generated voltage, but as the iron becomes saturated, the voltage rolls off. The air-gap line gives the



Plot of generated voltage vs. field current at constant machine speed.

voltage that would be obtained without saturation.

air-gap voltage the internal voltage of a synchronous machine that is generated by the air gap flux. Also referred to as the voltage behind leakage reactance.

airline a precision coaxial transmission line with air dielectric used in a variety of calibration techniques and measurements as an impedance standard and to establish a reference plane.

airy disk the central portion of the far-field optical diffraction pattern.

AlAs aluminum arsenide.

albedo the ratio between the total scattered intensity and the whole extracted from the incident light by scattering and absorption.

ALC *See* automatic level control.

AlGaAs symbol for aluminum gallium arsenide.

algebraic reconstruction the process of reconstructing an image **x** from a noise-corrupted and blurred image **y**. An arbitrary image is selected as the initial condition of an iterative algorithm for solving a set of linear equations. A set of linear constraints is specified. In each iteration one constraint is applied to a linear equation. The constraints are repeated in a cyclic fashion until convergence is reached. The linear constraints are vectors in a vector space with specified basis images for the type of problem to be solved.

algorithm (1) a systematic and precise, step-by-step procedure (such as a recipe, a program, or set of programs) for solving a certain kind of problem or accomplishing a task, for instance converting a particular kind of input data to a particular kind of output data, or controlling a machine tool. An algorithm can be executed by a machine.

(2) in image processing, algorithms can be either sequential, parallel, or ordered. In sequential algorithms, pixels are scanned and processed in a particular raster-scan order. As a given pixel is processed, all previously scanned pixels have updated (processed) values, while all pixels not yet scanned have old (unprocessed) values. The algorithm's result will in general depend on the order of scanning.

In a parallel algorithm, each pixel is processed independently of any changes in the others, and its new value is written in a new image, such that the algorithm's result does not depend on the order of pixel processing.

In an ordered algorithm, pixels are put in an ordered queue, where priority depends on some value attached to each pixel. At each time step, the first pixel in the queue is taken out of it and processed, leading to a possible modification of priority of pixels in the queue. By default, an algorithm is usually considered as parallel, unless stated otherwise.

algorithmic state machine (ASM) a sequential logic circuit whose design is directly specified by the algorithm for the task the machine is to accomplish.

aliasing (1) in signal processing, distortion introduced in a digital signal when it is undersampled.

In all digital systems the signals should be filtered before they are sampled to eliminate signal components with frequencies above the Nyquist frequency,

$$\omega_N = \omega_s/2 = \pi/T \ ,$$

where T is a sampling time, are eliminated. If this filtering is not done, signal components with frequencies

$$\omega > \omega_N$$

will appear as low-frequency components with the frequency

$$\omega_a = |((\omega + \omega_N) \mod \omega_s) - \omega_N|$$

The prefilters introduced before a sampler are called anti-aliasing filters (common choices are second- or fourth-order Butterworth, integral time absolute error (ITAE), or Bessel filters).

(2) in computer graphics, distortion due to the discrete nature of digital images that causes straight lines to appear jagged.

(3) in computer software, a single object having two different identities, such as names in memory space. Aliasing can make it difficult to determine whether two names (or access paths to reach an object) that appear to be different really access the identical object; a system designed to find parallelism when two accesses really reach different objects will have trouble achieving correct (functional) operation if aliasing is present.

alignment (1) the requirement that a datum (or block of data) be mapped at an address with certain characteristics, usually that the address modulo the size of the datum or block be zero. For example, the address of a naturally aligned long word is a multiple of four.

(2) the act of positioning the image of a specific point on a photomask to a specific point on the wafer to be printed.

(3) the process of determining the time or phase shift of a certain signal so that part of it may be matched with another signal. *See also* image registration.

all-digital synchronization synchronization algorithm, where the analog-to-digital conversion takes place as early as possible to assist digital implementation of the synchronizer. In most cases, an all-digital synchronization approach leads to optimal maximum likelihood algorithms.

all-optical network an optical communications network where the role of electronics is reduced to basic supervisory and control functions. All-optical devices are used exclusively between the nodes to re-configure the network which enables the greatest use of fiber bandwidth.

all-optical switch an optically addressed device whose optical transmission can be switched between two possible states by changes in the incident optical power.

all-pass system a system with unit magnitude and poles and zeroes that are complex conjugate reciprocals of each other. An all-pass system with a pole at $z = a$ and a zero at $z = \frac{1}{a^*}$ is

$$H_a p(z) = \frac{z^{-1} - a^*}{1 - az^{-1}}.$$

alley arm a crossarm meant for use in an alleyway or other confined area in which poles must be placed close to buildings. *See* crossarm.

allocate to create a block of storage of a given size in some memory, which is not to be used for any other purpose until expressly freed.

allocation the act of allocating. *See also* allocate.

allocation of authority process by which the authority (scope of competence) is allocated to various decision units; this allocation may result form the natural reasons or be a product of system partitioning.

almost sure convergence for a stochastic process, the property of the sample values converging to a random variable with probability one (for almost all sample paths).

alnico a permanent magnet material consisting mainly of aluminum, nickel, cobalt, and iron, which has a relatively low-energy product and high residual flux density. An alnico is most suitable for high-temperature applications.

ALOHA a random access, multiple access protocol, originally developed by Norman Abramson at the University of Hawaii in 1970. A given user transmits a message when the message is generated without regard for coordination with the other users sharing the channel. Messages involved in collisions are retransmitted according to some retransmission algorithm. Literally, "aloha" is a greeting in the Hawaiian native language.

alpha channel a grayscale image associated with the color channels of an image that dictates the opacity/transparency of the corresponding color channel pixels. If the color channels are multiplied by the alpha channel when stored, the image is referred to as premultiplied; otherwise, it is known as unpremultiplied.

alpha particle a subatomic particle emitted by ceramic packaging materials that causes soft errors in memory integrated circuits.

alpha particle noise this type of noise occurs exclusively in small semiconductor capacitors, when an energetic alpha particle, either from cosmic rays or from the packaging or substrate itself, traverses the capacitor, discharging it, thereby creating an error in the stored charge. Such an accumulation of errors in a digital system has the effect of creating a noise signal.

alpha-cut the set of all crisp, or nonfuzzy, elements whose membership function in A is greater than or equal to a given value, α.

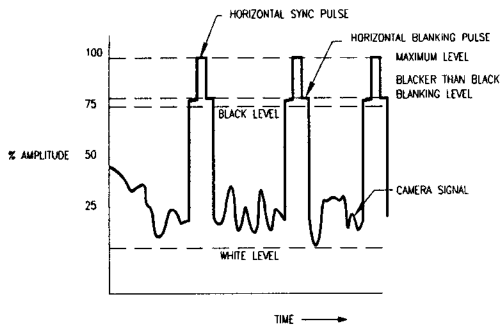
alphanumeric mode relates to alphabetic characters, digits, and other characters such as punctuation marks. Alphanumeric is a mode of operation of a graphic terminal or other input/output device. The graphics terminal should toggle between graphic and alphanumeric data.

alternate channel power a measure of the linearity of a digitally modulated system. The amount of energy from a digitally transmitted RF signal that is transferred from the intended channel to one which is two channels away. It is the ratio (in decibels) of the power measured in the alternate channel to the total transmitted power.

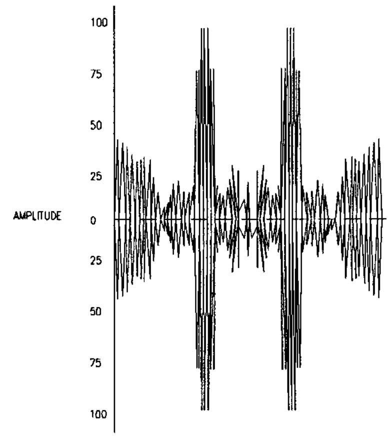
alternating current (AC) a periodic current the average value of which over a period is zero.

alternating current machine an electromechanical system that either converts alternating current electrical power into mechanical power (AC motor), or converts mechanical power into alternating current electrical power (AC generator, or alternator). Some AC machines are designed to perform either of these functions, depending on the energy source to the dynamo.

alternator-rectifier exciter a source of field current of a synchronous machine derived from the rectified output voltage of an alternator. The components of the exciter consist of the alternator and the power rectifier (including possible gate circuitry), exclusive of all input control elements. The rectifier circuits may be stationary, or rotate with the alternator, which may be driven by



COMPOSITE VIDEO SIGNAL FOR THREE SCANNED LINES



THE AMPLITUDE MODULATED CARRIER WAVE

a motor, prime mover, or by the shaft of the synchronous machine.

ALU *See* arithmetic and logic unit.

AM *See* amplitude modulation.

AM to PM conversion phase variations of an output signal, due to passing through an active device, where the phase of the output signal varies in response with the amplitude of the input signal.

AM video the amplitude modulated video carrier wave is produced by an amplitude modulated video transmitter where the amplitude of the wave form varies in step with the video signal similar to that shown in the figure.

amateur radio The practice and study of electronic communications as an avocation; most often referring to those persons possessing a license earned by examination (in the U.S., the Federal Communications Commission grants such licenses).

ambient field the background magnetic field level existing in the environment, without contribution from specific magnetic field sources.

ambient temperature the temperature of the air or liquid surrounding any electrical part or device. Usually refers to the effect of such temperature in aiding or retarding removal of heat by radiation and convection from the part or device in question.

ambiguity in artificial intelligence, the presence of more than one meaning or possibility.

Amdahl's law states that the speedup factor of a multiprocessor system is given by

$$S(n) = \frac{n}{1 + (n-1)f}$$

where there are n processors and f is the fraction of computational that must be performed sequentially (by one processor alone). The remaining part of the computation is assumed to be divided into n equal parts each executed by a separate processor but simultaneously. The speedup factor tends to $1/f$ as $n \to \infty$, which demonstrates that under the assumptions given, the maximum speedup is constrained by the serial fraction.

American National Standards Institute (ANSI) The U.S. organization that recommends standards for metrology, drawing symbology and numerous other facets for products and industries.

American standard code for information interchange (ASCII) a binary code comprised of seven digits, originally used to transmit telegraph signal information.

ammeter an instrument for measuring electric current in amperes.

ammonia maser first maser, invented by Charles H. Townes. Such a maser operates at microwave frequencies.

ammonium dihydrogen phosphate (ADP) a strong linear electro-optic material. Its chemical formula is $NH_4H_2PO_4$. *See also* potassium dihydrogen phosphate (KDP).

amorphous alloy a ferromagnetic material with very low coercive force (i.e., a narrow hysteresis loop). The material is formed as a very thin ribbon, by freezing the molting alloy before it can crystallize, thus providing a random molecular orientation.

amortisseur winding *See* damper winding.

ampacity the maximum current which can be safely carried by a conductor under specified conditions.

ampere interrupting rating the interrupting rating of a device expressed in amps (often rms symmetrical amps). *See also* MVA interrupting rating.

Ampere's Law a fundamental relationship in electromagnetic theory. In a fairly general form it is expressed by one of Maxwell's equations,

$$\nabla \times \mathbf{H}(\mathbf{r}, t) = \frac{\partial \mathbf{D}(\mathbf{r}, t)}{\partial t} + \mathbf{J}(\mathbf{r}, t)$$

where t is the time, $\mathbf{r}$ is the coordinate vector, and the other vectors are defined as $\mathbf{D}(\mathbf{r}, t)$ electric displacement; $\mathbf{H}(\mathbf{r}, t)$, magnetic field strength; $\mathbf{J}(\mathbf{r}, t)$, electric current density.

Ampere, Andre Marie (1775–1836) Born: Lyon, France

Ampere is best known for his pioneering work in the field of Electrodynamics. During his emotionally troubled life, he held several professorships: at Bourg, Lyon, and at the Ecole Polytechnic in Paris. While Ampere worked in several sciences, the work of the Danish physicist Hans Christian Oerstad on the electric deflection of a compass needle, as demonstrated to him by Dominique Arago, caused Ampere's great interest in electromagnetism. His seminal work, *Notes on the Theory of Electrodynamic Phenomena Deduced Solely from Experiment*, established the mathematical formulations for electromagnetics including what is now known as Ampere's Law. It can be said that Ampere founded the field of electromagnetics. He is honored for this by the naming of the unit of electric current as the ampere.

amperometric sensor an electrochemical sensor that determines the amount of a substance by means of an oxidation–reduction reaction involving that substance. Electrons are transferred as a part of the reaction, so that the electrical current through the sensor is related to the amount of the substance seen by the sensor.

amplidyne a special generator that acts like a DC power amplifier by using compensation coils and a short circuit across its brushes to precisely and fastly control high powers with low level control signals.

amplified spontaneous emission spontaneous emission that has been enhanced in amplitude and perhaps modified in spectrum by propagation through an amplifying medium, usually the medium in which it was first generated.

amplifier a circuit element that has a linear input-output signal relationship, with gain in voltage, current, and/or power. *See also* balanced amplifier, feedback amplifier, feedforward amplifier, laser amplifier, maser amplifier, optical amplifier, single-ended amplifier.

ASCII Code Chart

Hex	Char	Hex	Char	Hex	Char	Hex	Char
00	nul	20	sp	40	@	60	‘
01	soh	21	!	41	A	61	a
02	stx	22	"	42	B	62	a
03	etx	23	#	43	C	63	c
04	eot	24	$	44	D	64	d
05	enq	25	%	45	E	65	e
06	ack	26	&	46	F	66	f
07	bel	27	’	47	G	67	g
08	bs	28	(	48	H	68	h
09	ht	29	)	49	I	69	i
0A	lf	2A	*	4A	J	6A	j
0B	vt	2B		4B	K	6B	k
0C	ff	2C	,	4C	L	6C	l
0D	cr	2D	-	4D	M	6D	m
0E	so	2E	.	4E	N	6E	n
0F	si	2F	/	4F	O	6F	o
10	dle	30	0	50	P	70	p
11	dc1	31	1	51	Q	71	q
12	dc2	32	2	52	R	72	r
13	dc3	33	3	53	S	73	s
14	dc4	34	4	54	T	74	t
15	nak	35	5	55	U	75	u
16	syn	36	6	56	V	76	v
17	etb	37	7	57	W	77	w
18	can	38	8	58	X	78	x
19	em	39	9	59	Y	79	y
1A	sub	3A	:	5A	Z	7A	z
1B	esc	3B	;	5B	[	7B	{
1C	fs	3C	<	5C	\	7C	|
1D	gs	3D	=	5D	]	7D	}
1E	rs	3E	>	5E	ˆ	7E	˜
1F	us	3F	?	5F	_	7F	

amplitron a classic crossed-field amplifier in which output current is obtained primarily by secondary emission from the negative electrode that serves as a cathode throughout all or most of the interaction space.

amplitude descriptor of the strength of a wave disturbance such as an electromagnetic or acoustic wave.

amplitude equations a form of the Schrödinger equation that describes the evolution of a quantum mechanical system in terms of only the coefficients of the preferred basis states. These coefficients are known as quantum mechanical amplitudes and contain both magnitude and phase information. Amplitude equations are often used to gain physical insight into interactions of quantum systems with electromagnetic fields. *See also* Schrödinger wave equation (SWE).

amplitude linearity qualitative measure of the extent to which the output amplitude of a device is a faithful reproduction of its input, with no new frequency harmonics added. A perfectly linear device would output a scaled version of its input, where the shape of the input waveform has been unaltered (i.e., there is no distortion of the input waveform). Viewed in the frequency domain, the output signal would contain only those spectral components found in the input signal, and each frequency line would be scaled by the same amount (i.e., by the gain of the device).

amplitude modulation (AM) the process of modulating a signal $x(t)$ by a carrier wave $c(t)$ for transmission:

$$y(t) = c(t)x(t),$$

where $y(t)$ is the signal to be transmitted. $c(t)$ is either a complex exponential of the form

$$c(t) = e^{j(\omega_c t + \theta_c)}$$

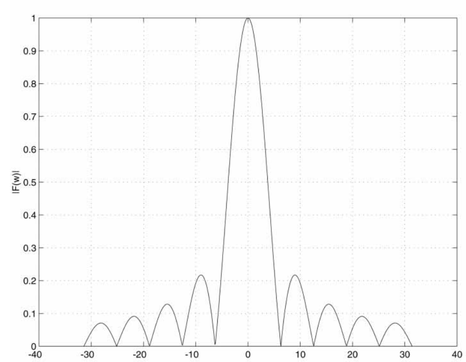
or a sinusoidal signal of the form

$$c(t) = \cos(\omega_c t + \theta_c).$$

ω_c is referred to as the *carrier frequency*. AM has the effect of shifting the frequency spectrum of $x(t)$ by ω_c. The signal is recovered by shifting the spectrum of $x(t)$ back to its original form. *See also* frequency modulation.

amplitude response the magnitude of the steady-state response of a fixed, linear system to a unit-amplitude input sinusoid.

amplitude spectrum the magnitude of the Fourier transform $|F(\omega)|$, $-\infty < \omega < \infty$ of a signal $f(t)$. For example, the amplitude spectrum of a rectangular pulse of unit width is given in the following figure: *See also* Fourier transform.



Amplitude spectrum.

amplitude stabilization circuit a circuit used to obtain a precise oscillation amplitude of oscillators. These circuits are used in instrumentation when it is required to increase the purity of output signal and reduce the frequency depression (especially in Meachem-bridge oscillator with crystal) of the main harmonic by higher harmonics (van der Pol effect). Three types of circuits are used:

1. An element of large inertia (tungsten lamp, thermistor) is included in the circuit at a point where it can change the magnitude of feedback, but not affect the frequency.

2. A controlled resistor (usually an FET operating in a triode regime) that is also part of the feedback circuit (the DC control signal is obtained with a rectifier and a filter of large time constant).

3. An automatic gain control circuit where the DC control signal obtained from a rectifier and filter is used to change the bias of oscillator active element.

amplitude-modulated link a transmitter–receiver system that utilizes amplitude-modulation for the transmission of signal frequencies.

amplitude-shift keying (ASK) a modulation technique in which each group of source bits determines the amplitude of the modulated carrier.

AMPS *See* advanced mobile phone system.

AMR *See* automated meter reading.

analog *See* analog signal, analog data.

analog data data represented in a continuous form with respect to continuous time, as contrasted with digital data represented in a discrete (discontinuous) form in a sequence of time instant.

analog multiplier a device or a circuit that generates an analog output signal that is proportional to the product or multiplication of two analog input signals.

analog optical computing optical computing that involves two-dimensional analog operations such as correlation and complex spatial frequency filtering primarily based on the property of lens to perform two-dimensional Fourier transform. In analog optical computing, operations to be performed are matched with and based on already known optical phenomena.

analog signal a signal represented in a continuous form with respect to continuous time, as contrasted with digital signal represented in a discrete (discontinuous) form in a sequence of time instant. *See also* analog data.

analog signal conditioning an interface between the sensor or transducer output, which represents an analog or physical world, and the analog-to-digital converter.

analog-to-digital (A/D) conversion a method by which a continuously varying signal (voltage) is sampled at regularly occurring intervals. Each sample is quantized to a discrete value by comparisons to preestablished reference levels. These quantized samples are then formatted to the required digital output (e.g., binary pulse code words). The A/D converter is "clocked" to provide updated outputs at regular intervals. In order not to lose any baseband information, sampling must occur at a rate higher than twice the highest incoming signal frequency component. *See also* Nyquist rate.

analog-to-digital (A/D) converter a device that changes an analog signal to a digital signal of corresponding magnitude. This device is also called an encoder, ADC, or A/C converter.

analysis-by-synthesis coding refers to the class of source coding algorithms where the coding is based on parametric synthetization of the source signal at the encoder. The synthesized signal is analyzed, and the parameters that give the "best" result are chosen and then transmitted (in coded form). Based on the received parameters the signal is resynthesized at the receiver.

analysis filter a filter in the analysis section of a sub-band analysis and synthesis system.

analyte the substance being measured by a chemical or bioanalytical sensor and instrumentation system.

analytic signal refers to a signal that has a Fourier transform that is zero valued for negative frequencies; i.e., the signal has a one-sided spectrum.

analytical Jacobian a mathematical representation computed via differentiation of the direct kinematic equation with respect to the joint variables q. Formally one can write $\dot{x} = \begin{bmatrix} \dot{\phi} \\ \dot{p} \end{bmatrix} = \begin{bmatrix} J_\phi(q) \\ J_p(q) \end{bmatrix} \dot{q} = J_A(q)\dot{q}$ where the analytical Jacobian is $J_A(q) = \frac{\partial k(q)}{\partial q}$. *See* external spacefor notation used in these equations. The analytical Jacobian is different from the geometric Jacobian, since the end-effector angular velocity with respect to the base frame is not given by $\dot{\phi}$. Both Jacobians are related as $J = T_A(\phi)J_A$ where $T_A(\phi)$ is a matrix that depends on the particular representation of the orientation representation. In particular $T_A(\phi)$ is an identity matrix when equivalent axis of rotation in the task space is the same as the equivalent axis of rotation of the end-effector. *See also* geometric Jacobian.

anamorphic lenses a lens system having a difference in optical magnification along the two mutually perpendicular axes (vertical plane or tilt vs. horizontal plane or panorama).

and *See* AND.

AND the Boolean operator that implements the conjunction of two predicates. The truth table for $\wedge \equiv X$ and Y is

X	Y	$X \wedge Y$
F	F	F
F	T	F
T	F	F
T	T	T

n-ary ands can be obtained as conjunction of binary ands.

AND gate a device that implements the Boolean AND operation. *See* AND.

angle diversity a diversity technique used in radio communications based on receiving a signal over multiple arrival angles. The signal components are typically affected by uncorrelated fading processes and are combined in the receiver to improve performance. The main combining methods are selection diversity, equal gain combining, and maximal ratio combining.

angle modulation a type of modulation where either the frequency (FM) or the phase (PM) of a carrier are varied.

angle of arrival (AOA) the direction to a source emitting a signal impinging on a sensor array. Also called direction of arrival (DOA).

angstrom popular unit not officially recognized as part of the SI unit system. Equal to 10^{-10} meters. Abbreviated Å. Named after Anders Ångström (1814–1874).

angular alignment loss the optical power loss in an optical connection between two optical fibers, between an optical source and a fiber, or between an optical fiber and a detector caused by the angular misalignment of the axes of the source and fiber, the two fibers, or the fiber and detector.

angular frequency the rate of change of the phase of a wave in radians per second.

anisotropic direction-dependent.

anisotropic diffraction diffraction when the refractive indices for the incident and diffracted optical waves are different.

anisotropic diffusion a process of progressive image smoothing as a function of a time variable t, such that the degree and orientation of smoothing at a point varies according to certain parameters measured at that point (e.g., gray-level gradient, curvature, etc.) in order to smooth image noise while preserving crisp edges. The progressively smoothed image $I(x, y, t)$ (where x, y are spatial coordinates and t is time) satisfies the differential equation

$$\partial I/\partial t = div(c\nabla I),$$

where the diffusion factor c is a decreasing function of the spatial gradient ∇I. When c is constant, this reduces to the heat diffusion equation

$$\partial I/\partial t = c\Delta I.$$

Other mathematical formulations have been given, where edge-preserving smoothing is realized by a selective diffusion in the direction perpendicular to the gradient. *See also* multiresolution analysis, mathematical morphology.

anisotropic etch an etch with an etch rate that is direction-dependent. In wet etching, the direction dependence has to do with crystallographic axis – some planes etch at different rates than others.

anisotropic medium (1) a medium in which the index of refraction varies with the light propagation direction within the medium. In such a medium, the constitutive relation involves a tensor.

(2) a medium that exhibits anisotropy. Examples are anisotropic crystals, ferrites in the presence of a static magnetic field, and plasma in the presence of a static magnetic field.

anisotropic scatterer inhomogeneous medium, usually consisting of suspension of anisotropic molecules, capable of producing effects like birefringence or dichroism. As such, its dielectric permittivity is a tensor acting differently upon each component of the electromagnetic field.

anisotropy (1) the degree of variation in a property such as index of refraction with light propagation direction.

(2) dependence of the response of a medium on the direction of the fields, for example, the x component of the electric displacement might depend in part on the y component of the fields.

annealing a process often used in semiconductor processing to cause a change in materials or device properties to improve the circuit performance and/or reliability. *See also* simulated annealing.

annealing schedule specifies the sequence of temperature values that are to be used in an application of simulated annealing and also specifies the number of parameter changes that are to be attempted at each temperature.

annihilation a process in which a particle and its anti-particle meet and convert spontaneously into photons.

annul bit a bit that is used to reduce the effect of pipeline breaks by executing the instruction after a branch instruction. The annul bit in a branch allows one to ignore the delay-slot instruction if the branch goes the wrong way. With the annul bit not set, the delayed instruction is executed. If it is set, the delayed instruction is annulled.

annular cathode a cathode of a vacuum tube with the shape of the emitting surface of the cathode is annular. The annular cathode can produce a hollow electron beam.

annular illumination a type of off-axis illumination where a doughnut-shaped (annular) ring of light is used as the source.

anode the positive electrode of a device. *Contrast with* cathode.

anomalous dispersion decrease of the index of refraction with increasing frequency; tends to occur near the center of absorbing transitions or in the wings of amplifying transitions.

ANSI American National Standards Institute, a body which administers numerous industrial standards in the USA including several which pertain to electric utility construction practices. *See* American National Standards Institute.

antenna a device used to couple energy from a guiding structure (transmission line, waveguide, etc.) into a propagation medium, such as free space, and vice versa. It provides directivity and gain for the transmission and reception of electromagnetic waves.

antenna beamwidth the effective angular extent of the antenna radiation pattern usually specified between points of fixed amplitude relative to the main lobe gain (e.g., -3 dB points).

antenna diversity a diversity technique based on the use of multiple antennas either at the receiver (receiver antenna diversity) or at the transmitter (transmitter antenna diversity) in a radio communication link. If the separation of antennas is sufficient, the signal components are affected by different fading processes and are combined in the receiver to improve performance. *See also* RAKE receiver. *Contrast with* angle diversity.

antenna gain the maximum ratio of an antenna's ability to focus or receive power in a given direction relative to a standard; the standard is usually an isotropic radiator or a dipole. The gain includes the efficiency of the antenna.

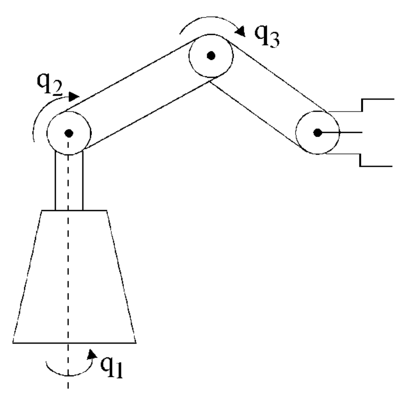
antenna noise temperature the effective noise temperature of the antenna radiation resistance appearing at the antenna terminals. At a given frequency, the antenna noise temperature, T_a (K), can be calculated as $\frac{P_n}{kB}$ where P_n is the noise power available at the antenna terminals (W), k is Boltzmann's constant (1.38×10^{-23} J/^{0}K), and B is the bandwidth (Hz). The antenna noise is the result of thermal noise generated in ohmic losses in the antenna structure and noise received by the antenna from external radiating sources.

antenna pattern graph or chart representing the absolute or normalized antenna gain as a function of angle (typically azimuth or elevation) and used to describe the directional properties of an antenna. In the near field, the antenna pattern is a function of the distance from the antenna whereas in the far field, the pattern is independent of distance from the antenna.

antenna Q ratio of the energy stored to the energy dissipated (ohmically or via radiation) per cycle.

antenna synthesis the process of determining or designing an antenna to yield a given radiation pattern. Several synthesis methods exist. Some are closed form solutions and some use numerical techniques.

anthropomorphic manipulator a manipulator that consists of two shoulder joints, one for rotation about a vertical axis and one for elevation out of the horizontal plane, an elbow joint with axis parallel to the shoulder elevation joint, and two or three wrist joints at the end of the manipulator (see figure). An anthropomorphic manipulator is sometimes called a jointed, elbow, or articulated manipulator.



An anthropomorphic manipulator.

anti-plugging a feature to prevent a motor from reversing direction directly across the line. The purpose of the anti-plugging coil and contact is to prevent the motor from starting in the opposite direction until the speed has slowed enough where the current and torque surges are within acceptable levels when changing direction.

anti-Stokes scattering the scattering of light accompanied by a shift to higher frequencies. *Contrast with* Stokes Law of light scattering.

antialiasing filter typically, a filter that provides a prefiltering operation to ensure that the frequency components of a signal above the Nyquist frequency are sufficiently attenuated so that, when aliased, they will cause a negligible distortion to the sampled signal. *See also* aliasing, Nyquist frequency.

anticollision radar a type of radar, generally operating in the millimeter wave frequency range, used to prevent collision between moving vehicles.

anticomet tail (ACT) a special type of electron gun designed to handle highlights by increasing beam current with a defocused beam during line retrace.

antidependency a potential conflict between two instructions when the second instruction alters an operand which is read by the first instruction. For correct results, the first instruction must read the operand before the second alters it. Also called a write-after-read hazard.

antidots regions of repulsive potential, but which are configured so that particles (usually electrons) can pass around the potential and proceed past it. In the limiting case, a repulsive Coulomb potential is the simplest antidot structure.

antiferromagnetic materials in which the internal magnetic moments line up antiparallel, resulting in permeabilities slightly greater than unity; unlike paramagnetic substances, these materials exhibit hysteresis and have a Curie temperature. Examples include manganese oxide, nickel oxide, and ferrous sulfide.

antifuse a fuse-like device that when activated becomes low-impedance.

antiparticle a particle having the same mass as a given fundamental particle, but whose other properties, while having the same magnitude, may be of opposite sign. Each particle has a partner called an antiparticle. For example, electrical charge in the case of the electron and positron, magnetic moment in the case of the neutron and antineutron. On collision a particle and its antiparticle may mutually annihilate with the emission of radiation. Some properties of the antiparticle will be identical in magnitude but opposite in sign to the particle it is paired with.

antipodal symmetry created by simultaneously mirroring an object in both the X and Y axes.

antiproton antiparticle to the proton. It is a strongly interacting baryon carrying unit negative charge. It has mass of 938 MeV and carries spin 1/2.

antireflection coating *See* antireflective coating.

antireflective coating (ARC) a coating placed on top or below the layer of photoresist to reduce the reflection of light, and hence reduce the detrimental effects of standing waves or thin film interference.

AOA *See* angle of arrival.

AOTF *See* acousto-optic tunable filter.

APART/PADE a computer code for analysis of stray light in optical systems developed by the University of Arizona and BRO, Inc.

APC-7 connector common term for amphenol precision connector - 7mm. A "sexless" coaxial connector with butt contact between both the inner and outer conductors capable of low standing wave ratios to frequencies up to 18 GHz.

APD *See* avalanche photodiode.

aperiodic convolution the convolution of two sequences. *See* convolution.

aperiodic signal a signal that is not periodic, i.e., one for which $x(t) \neq x(t+T)$. This means that the signal $x(t)$ has a property that is changed by a time shift T. *See also* periodic signal.

aperiodic waveform this phrase is used to describe a waveform that does not repeat itself in a uniform, periodic manner. *Compare with* periodic waveform.

aperture (1) an opening to a cavity, or wave-guide, from which radiation is either received or transmitted. Typically used as antenna or a coupling element.

(2) a physical space available for beam to occupy in a device. Aperture limitations are the physical size of the vacuum chamber; a magnetic field anomaly may deflect the beam so that the full available aperture cannot be used.

aperture antenna an antenna with a physical opening, hole, or slit.

aperture correction signal compensation used to correct the distortion caused by the non-zero aperture of a scanning electron beam. A standardized measure of the selectivity of a circuit or system. The -3 dB (or half-power) band width is taken to be the difference between the upper (f_2) and lower (f_1) frequencies where the gain vs. frequency response curve has decreased -3 dB from the passband reference gain. Note that f_1 and f_2 define the response passband by marking the points at which the output power has decreased to one-half the value of the input power. For band widths extending down to DC, the upper -3 dB frequency is cited as the 3 dB bandwidth.

aperture coupling a method of coupling a transmission line to an antenna in which fields leak through an aperture in a metallic ground plane separating the line from the antenna.

aperture efficiency a figure of merit that determines how much of the incident energy is captured by an aperture. It depends on the physical dimensions of the aperture.

aperture problem given a sequence of images over time we would like to infer the motion (optical flow) field. Based on local image information (i.e., based on the values of those pixels falling within some aperture) only the component of motion along the gray-level gradient can be inferred; that the component of motion perpendicular to the gray-level gradient can only be known by resorting to global methods is known as the aperture problem. *See* optical flow, optical flux.

APL *See* average picture level.

APLC *See* active power line conditioner.

apodization (1) a deliberate variation in the transmission of an optical aperture as a function of distance from the center or edges, in order to control optical transfer functions.

(2) a deliberate variation in the strength of a signal with time.

apparent concurrency within an interval of time more than one process executes on a computer, although at the instruction level, instructions from only one process run at any single point in time. *See also* concurrency.

apparent mean thermal conductivity the effective thermal conductivity of an assemblage of material (Pearlite, super insulation) between specified temperatures.

apparent power (1) in an AC system, the product of voltage, E and current, I. Apparent power (or total power) is composed of two mutually independent components — an active component (real power), and a reactive component (imaginary power). Apparent power is denoted by S, and has the unit of voltamperes.

(2) the scalar product of the voltage and current delivered to the load. It can also be expressed as the vector $S = P + jQ$, where $P =$ real power and $Q =$ reactive power.

application-specific integrated circuit (ASIC) an integrated circuit designed for one particular application.

appropriate technology the technology that will accomplish a task adequately given the resources available. Adequacy can be verified by determining that increasing the technological content of the solution results in diminishing gains or increasing costs.

approximate coding a process, defined with respect to exact coding, that deals with irreversible and information-lossy processing of two-level pictures to improve compression ratio with significant degradation of picture quality. Exact coding schemes depend on the ability to predict the color of a pixel or the progression of a contour from line to line. Irreversible processing techniques try to reduce prediction errors by maintaining the continuity of the contours from line to line. With predictive coding the number of pixels can be changed to reduce those having nonzero prediction error. With block coding the compression efficiency can be improved by increasing the probability of occurrence of the all zero block. The third approximate block coding scheme is pattern matching. In this scheme the identification codes of the repeated patterns are transmitted to the receiver. A library of patterns is maintained for continuous checking. *See also* exact coding.

approximate reasoning an inference procedure used to derive conclusions from a set of fuzzy if-then rules and some conditions (facts). The most used approximate reasoning methods are based on the generalized modus ponens. *See also* fuzzy IF-THEN rule, generalized modus ponens, linguistic variable.

approximately controllable system an infinite-dimensional stationary linear dynamical system where the attainable set K_∞ is dense in the infinite-dimensional state space X. The set is said to be approximately controllable in $[0, T]$ if the attainable set $K(0, T)$ is dense in the infinite-dimensional state space X.

Approximate controllability in $[0, T]$ always implies approximate controllability. The converse statement is not always true.

Ar+ laser laser in which the active medium consists of singly ionized argon atoms. Ar+ lasers have several wavelengths in the visible portion of the spectrum.

Arago, Dominique Francois (1786–1853) Born: Estagel, France

Arago is best known for the breadth and the volume of his contribution to the study of light and for his work with Ampere on the development of electrodynamics. Arago discovered that iron could be magnetized by the passage of current through a wire and, the phenomenon of magnetic rotation. It was left to Michael Faraday to properly explain this phenomenon. Arago spent a significant amount of time involved in politics and succeeded Jean Fourier as the permanent secretary to The Academy of Sciences in 1830. It has been suggested that Arago's enthusiasm and work ethic were an inspiration to many contemporary scientists.

arbiter a unit that decides when multiple requestors may have access to a shared resource.

arbitrary reference frame a two-dimensional space that rotates at an unspecified angular velocity ω. In electric machines/power system analysis, an orthogonal coordinate axis is established in this space upon which fictitious windings are placed. A linear transformation is established in which the physical variables of the system (voltage, current, flux linkage) are referred to variables of the fictitious windings. *See also* rotor reference frame, stationary reference frame, synchronous reference frame.

arbitration *See* bus arbitration.

ARC *See* antireflective coating.

arc detector a device placed within a microwave power tube or within one or more of the external cavities of a microwave power tube whose purpose is to sense the presence of an overvoltage arc.

arc fault interrupter the mechanism that breaks the fault current arc in a power circuit breaker.

arc lamp lamp made by driving a high current across a gap between two electrodes. Some types operate in air consuming the electrode, for example, a carbon arc in which the electrode material is made as a rod and fed into the discharge to replace what is consumed. Others operate in a vacuum envelop that reduces the electrode consumption.

arc resistance period of time that the surface of an insulating material can be submitted to the action of an electrical arc without becoming conductive.

architecture *See* computer architecture.

arcing fault *See* arcing ground.

arcing ground a ground fault on a power line which alternately clears and restrikes, causing high, repetitive voltage surges.

areal density a measure for the improvement in the capacity of a disk. It is the product of the number of tracks per inch and the number of bits per inch, i.e., it is the number of bits per square inch.

argon ion laser *See* Ar+ laser.

argument (1) an address or value that is passed to a procedure or function call, as a way of communicating cleanly across procedure/function boundaries.

(2) a piece of data given to a hardware operator block.

arithmetic and logic unit (ALU) a combinational logic circuit that can perform basic arithmetic and logical operations on n-bit binary operands.

arithmetic coding a method (due to Elias, Pasco, Rissanen and others) for lossless data compression. This incremental coding algorithm works efficiently for long block lengths and achieves an average length within one bit of the entropy for the block. The name comes from the fact that the method utilizes the structures of binary expansions of the real numbers in the unit interval.

arithmetic instruction a machine instruction that performs computation, such as addition or multiplication.

arithmetic operation any of the following operations and combination thereof: addition, subtraction, multiplication, division.

arithmetic radian center frequency the linear radian center frequency, it is the midpoint between the higher (ω_H) and lower (ω_L) band edges, expressed in units of radians/second. The band edges are usually defined as the highest and lowest frequencies within a contiguous band of interest at which the loss equals L_{Amax}, the maximum attenuation loss across the band.

$$\omega_{oa} = \frac{\omega_H + \omega_L}{2}$$

arithmetic shift a shift in which it is assumed that the data being shifted is integer arithmetic in nature; as a result, the sign bit is not shifted, thereby maintaining the arithmetic sign of the shifted result. *See also* logical shift.

arithmetic–logic unit *See* arithmetic and logic unit.

arm a part of a robot. A robot is composed of an arm (or mainframe) and a wrist plus a tool. For many industrial robots the arm subassembly can move with three degrees of freedom. Hence, the arm subassembly is the positioning mechanism. *See also* industrial robot.

arm pin a pin insulator .

ARMA *See* auto-regressive moving-average model.

armature the magnetic circuit of a rotating electrical machine, including the main current carrying winding, in which an alternating voltage is induced by the magnetic field.

armature circuit components of the machine that carry armature current. For example, in a DC machine the armature circuit could consist of the armature windings, brushes, series field winding, compensating windings, interpoles, starting resistor(s), main-line contacts, and overload sensor.

armature current limiting a condition wherein the stator currents are clamped at the maximum allowable limit due to excessive heating of the stator.

armature reaction (1) in DC machines, a distortion of the field flux caused by the flux created by the armature current. Armature reaction in a DC machine causes lower flux at one pole-tip and higher flux at the other, which may lead to magnetic saturation. It also shifts the neutral axis, causing sparking on the commutator.

(2) in AC synchronous machines, a voltage "drop" caused by the armature current. In the steady state model of the synchronous machine, the armature reaction is accounted for by a component of the synchronous reactance.

armature voltage control a method of controlling the speed of a DC motor by varying the voltage applied to the armature while keeping the voltage applied to the field circuit constant.

armature winding an arrangement of coils carrying the main current, typically wound on the stator of a synchronous machine or the rotor of a DC machine, in which an alternating voltage is induced by the magnetic field.

armless construction a method of distribution line construction, often used for aesthetic purposes, in which pin insulators are mounted on steel brackets bolted directly to a utility pole without the use of a crossarm.

Armstrong oscillator Hartley oscillators are usually not used at VHF of higher frequencies. Similarly, the circuit is avoided at very low audio frequencies. It is important to distinguish the Hartley oscillator from the Armstrong topology. In the Armstrong oscillator, no ohmic connection exists between the two inductors. Instead, coupling is entirely magnetic.

Armstrong, Edwin Howard (1890–1954) Born: New York, New York, U.S.A.

Armstrong is best known as the developer of frequency modulation (FM) radio and inventor of the superheterodyne receiver. Armstrong spent most of his career at Columbia University. During his life, his inventions made him quite wealthy. The superheterodyne receiver was purchased as a way for the military to detect the spark plug ignitions of approaching aircraft. Patent fights with Lee DeForest and the difficulty in promoting FM radio led to bitterness and frustration which many felt led to his suicide.

ARQ *See* automatic repeat request.

array several antennas arranged together in space and interconnected to produce a desired radiation pattern.

array factor in antenna theory, the resulting radiation pattern of an array when each antenna in the array is replaced by an isotropic radiator.

array processor an array of processor elements operating in lockstep in response to a single instruction and performing computations on data that are distributed across the processor elements.

array signal processing signal processing techniques used for extracting information based on signals from several (identical) sensors, for example an antenna array consisting of several antenna elements.

arrester discharge current the current in an arrester during a surge.

arrester discharge voltage the voltage in an arrester during a surge.

ART network *See* adaptive resonance theory network.

artifact an error or aberration in a signal that is the result of aliasing, a quantization error, some form of noise, or the distorting effects of some type of processing. *See also* outlier.

artificial constraint an additional constraint in accordance with the natural constraints to specify desired motion or force application. An artificial constraint occurs along the tangents and normals of the constraint surface. An artificial force constraint is specified along surface normals, and an artificial position constraint along tangents and hence consistency with the natural constraints is preserved. *See also* natural constraint.

artificial dielectric a dielectric material that has been modified to alter its properties. Common modifications include micromachining to remove material from the substrate under planar patch antenna to improve radiation properties and the fabrication of periodic arrays of holes to realize guiding or photonic bandgap structures.

artificial intelligence the study of computer techniques that emulate aspects of human intelligence, such as speech recognition, logical inference, and ability to reason from partial information.

artificial neural network a set of nodes called neurons and a set of connections between the neurons that is intended to perform intellectual operations in a manner not unlike that of the neurons in the human brain. In particular, artificial neural networks have been designed and used for performing pattern recognition operations. *See also* pattern recognition, perceptron.

artificial neuron an elementary analog of a biological neuron with weighted inputs, an internal threshold, and a single output. When the activation of the neuron equals or exceeds the threshold, the output takes the value $+1$, which is an analog of the firing of a biological neuron. When the activation is less than the threshold, the output takes on the value 0 (in the binary case) or -1 (in the bipolar case) representing the quiescent state of a biological neuron.

artificial skin artificial skin is a device which, when pressed against the surface by an object, causes local deformations that are measured as continuous resistance variations. The latter are transformed into electrical signals whose amplitude is proportional to the force being applied to any given point on the surface of the material of the device.

ASAP/RABET acronym for a computer code for optical systems by BRO, Inc., for standard optical analysis and stray-light analysis such as light-scattering.

ASCII *See* American standard code for information interchange.

ASCR *See* asymmetrical silicon controlled rectifier.

ASIC *See* application-specific integrated circuit.

ASK *See* amplitude-shift keying.

askarel a trade name for an insulating oil.

ASM *See* algorithmic state machine.

aspect ratio (1) the size invariant ratio of length to width for a rectangular box enclosing a shape, the orientation of the box being chosen to maximize the ratio. This measure is used to characterize object shapes as a preliminary to, or as a quick procedure for, object recognition.

(2) the ratio of width to height for an image or display.

(3) in television or motion pictures, the algebraic ratio of picture width to height. At present, the television format in the United States consists of a width to height ratio of 4 to 3.

aspheric description of optical elements whose curved surfaces are not spherical, often used to reduce aberrations in optical systems.

assembler (1) a computer program that translates an assembly-code text file to an object file suitable for linking.

(2) a program for converting assembly language into machine code.

assembly language a programming language that represents machine code in a symbolic, easier-to-read form. *See also* assembler.

assert (1) raising the voltage on a wire to the "high" state, usually as a signal to some other unit.

(2) to make an assertion.

assertion (1) a Boolean expression for stating the right behavior of the program or, if hardware implemented, of a circuit.

(2) a logical expression specifying a program state that must exist or a set of conditions that program variables must satisfy at a particular point during program execution.

associate mode an operating mode of content addressable memories, in which a stored data item is retrieved that contains a field that matches a given key.

associated reference directions a method assigning the current and voltage directions to an electrical element so that a positive current-voltage product always means that the element is absorbing power from the network and a negative product always means that the element is delivering power to the network. This method of assigning directions is used in most circuit simulation programs.

associative memory a memory in which each storage location is selected by its contents and then an associated data location can be accessed. Requires a comparative with each storage location and hence is more complex than random access memory. Used in fully associative cache memory and in some translation look-aside buffers or page translation tables of the hardware to support virtual memory. Given the user-space address of a page it returns the physical address of that page in main memory. Also called content addressable memory (CAM).

associative processor a parallel processor consisting of a number of processing elements, memory modules, and input–output devices under a single control unit. The capability of the processing elements is usually limited to the bit-serial operations.

associativity In a cache, the number of lines in a set. An n-way set associative cache has n lines in each set. (Note: the term "block" is also used for "line.")

astable multivibrator the circuit that is obtained from a closed-loop regenerative system that includes two similar amplifiers of high gain connected with each other via coupling circuits with reactance elements. More frequently are used RC-coupling circuits (free-running RC-multivibrators, emitter-coupled multivibrators), yet RL-circuits, usually as transformer coils, may be used as well (magnetic multivibrators).

astigmatism a defect associated with optical and electrostatic lenses where the magnification is not the same in two orthogonal planes; common where beam propagation is not along the axis of rotation of the system.

asymmetric digital subscriber line (ADSL) a digital subscriber line (DSL) in which the rate from central switching office (CO) to customer premise is much faster than the rate from customer premise to CO.

asymmetric multiprocessor (1) a machine with multiple processors, in which the time to access a specific memory address is different depending on which processor performs the request.

(2) in contrast with a symmetric multiprocessor, asymmetric multiprocessor is a multiprocessor in which the processors are not assigned equal tasks. The controller (master) processor(s) are assigning tasks to (slave) processors and controlling I/O for them.

asymmetric multivibrator a multivibrator where the output voltage represents a train of narrow pulses. Most asymmetric multivibrators use a slow charge of a large timing capacitor by a small current (or via a large resistor) and a fast discharge of this capacitor via a switch. The charge process determines the duration of space; the mark duration, which coincides with the time allowed for discharge of the timing capacitor, is usually determined by a small time constant of the circuit controlling the switch. Asymmetric multivibrators find applications in voltage-to-frequency converters. Also called multivibrators with a small mark/space ratio.

asymmetric resonator standing-wave resonator in which either the reflectivities or the curvatures of the primary mirrors are unequal.

asymmetrical silicon controlled rectifier (ASCR) (1) an inverter grade SCR fabricated to have limited reverse voltage capability. Fabrication with asymmetrical voltage blocking capability in the forward and reverse direction permits reduction of turn-on time, turn-off time, and conduction drop.

(2) a thyristor that has limited conduction in the reverse direction to gain increased switching speed and low forward voltage drop. *See also* silicon controlled rectifier (SCR).

asymptotic 2-D observer a system described by the equations

$$\begin{aligned} z_{i+1,j+1} &= F_1 z_{i+1,j} + F_2 z_{i,j+1} \\ &\quad + G_1 u_{i+1,j} + G_2 u_{i,j+1} \\ &\quad + H_1 y_{i+1,j} + H_2 y_{i,j+1} \\ \hat{x}_{i,j} &= L z_{i,j} + K y_{i,j} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) is called a full-order asymptotic observer of the second generalized Fornasini–Marchesini 2-D model

$$
\begin{aligned}
Ex_{i+1,j+1} &= A_1 x_{i+1,j} + A_2 x_{i,j+1} \\
&\quad + B_1 u_{i+1,j} + B_2 u_{i,j+1} \\
y_{i,j} &= Cx_{i,j} + Du_{i,j}
\end{aligned}
$$

$i, j \in Z_+$ if

$$
\lim_{i,j\to\infty} \left[x_{i,j} - \hat{x}_{i,j}\right] = 0
$$

for any $u_{i,j}$, $y_{i,j}$ and boundary conditions x_{i0} for $i \in Z_+$ and x_{0j} for $j \in Z_+$ where $z_{i,j} \in R^n$ is the local state vector of the observer at the point (i, j), $u_{ij} \in R^m$ is the input, $y_{i,j} \in R^p$ is the output, and $x_{i,j} \in R^n$ is the local semistate vector of the model, F_1, $F_2, G_1, G_2, H_1, H_2, L, K, E, A_1, A_2, B_1, B_2$, C, D are real matrices of appropriate dimensions with E possibly singular or rectangular. In a similar way a full-order asymptotic observer can be defined for other types of the 2-D generalized models.

asymptotic stability (1) an equilibrium state of a system of ordinary differential equations or of a system of difference equations is asymptotically stable (in the sense of Lyapunov) if it is stable and the system trajectories converge to the equilibrium state as time goes to infinity, that is, the equilibrium $\mathbf{x}_{eq}$ is asymptotically stable if it is stable and

$$
\mathbf{x}(t) \to \mathbf{x}_{eq} \text{ as } t \to \infty .
$$

(2) a measure of system damping with regard to a power system's ability to reach its original steady state after a disturbance.

asymptotic tracking refers to the ability of a unity feedback control to follow its setpoint exactly with zero error once all transients have decayed away. Clearly this is only achieved by stable systems.

asymptotically stable equilibrium a stable equilibrium point such that all solutions that start "sufficiently close," approach this point in time. *See also* stable equilibrium.

asymptotically stable in the large the equilibrium state of a stable dynamic system described by a first-order vector differential equation is said to be asymptotically stable in the large if its region of attraction is the entire space $\Re^n$. *See also* region of attraction.

asymptotically stable state the equilibrium state of a dynamic system described by a first-order vector differential equation is said to be asymptotically stable if it is both convergent and stable. *See also* stable state and convergent state.

asynchronous not synchronous.

asynchronous AC systems AC systems either with different operating frequencies or that are not in synchronism.

asynchronous bus a bus in which the timing of bus transactions is achieved with two basic "handshaking" signals, a request signal from the source to the destination and an acknowledge signal from the destination to the source. The transaction begins with the request to the destination. The acknowledge signal is generated when the destination is ready to accept the transaction. Avoids the necessity to know system delays in advance and allows different timing for different transactions. *See also* synchronous bus.

asynchronous circuit (1) a sequential logic circuit without a system clock.

(2) a circuit implementing an asynchronous system.

asynchronous demodulation a technique for extracting the information-carrying waveform from a modulated signal without requiring a phase-synchronized carrier for demodulation. *See also* synchronous demodulation.

asynchronous machine *See* induction machine.

asynchronous operation a term to indicate that a circuit can operate or a communication system can transmit information when ready without having to wait for a synchronizing clock pulse.

asynchronous system a (computer, circuit, device) system in which events are not executed in a regular time relationship, that is, they are timing-independent. Each event or operation is performed upon receipt of a signal generated by the completion of a previous event or operation, or upon availability of the system resources required by the event or operation.

asynchronous transfer mode (ATM) method of multiplexing messages onto a channel in which channel time is divided into small, fixed-length slots or cells. In ATM systems the binding of messages to slots is done dynamically, allowing dynamic bandwidth allocation. ATM is asynchronous in the sense that the recurrence of cells containing information from an individual user is not necessarily periodic.

asynchronous updating one unit at a time is selected from within a neural network to have its output updated. Updating an output at any time is achieved by determining the value of the unit's activation function at that time.

AT bus bus typically used in personal computer IBM AT for connecting adapters and additional memory boards. It is called also 16 bit ISA bus since it presents a data bus at 16 bit. It presents an additional connector with respect to the classical ISA bus (at 8 bit) of IBM PCs based on Intel 8088. *See also* EISA.

Atanasoff, John Vincent (1903–) Born: Hamilton, New York, U.S.A.

Atanasoff is best known for his invention, along with Clifford Berry, of the first digital computer, known as the ABC (Atanasoff-Berry Computer). Unlike the many World War II computer pioneers, Atanasoff's interest in the topic dated to his Ph.D. thesis research at the University of Wisconsin. After graduation Atanasoff taught physics and mathematics at Iowa State College and continued to work on the problem of solving lengthy calculation by electronic means. Legend has it that Atanasoff worked out the basic structure for his new machine while having a drink at an Illinois road house. Clifford Berry, an electrical engineer joined Atanasoff to help with the construction of the device based on Atanasoff's ideas. John Mauchly, another computer pioneer often visited and consulted with Atanasoff. These discussions resulted in a later lawsuit that established Atanasoff as the first person to build an electronic digital computer.

ATM *See* asynchronous transfer mode.

ATM adaptation layer (AAL) a layer in the ATM protocol hierarchy that adapts the (small) cell-sized payloads to a form more suitable for use by higher layer protocols. For example, AAL5 performs segmentation and reassembly to map between 48-byte payloads and variable length data segments.

atmosphere a convenient measure of pressure. 1 std atm = 14.696 psia (pounds per square inch absolute).

atmospheric attenuation decrease in the amplitude of a signal propagating through the atmosphere, due primarily to absorption and scatter.

atmospheric duct a thin layer of atmosphere near the earth that acts as a waveguide, the electromagnetic field, trapped within the duct, can travel over long distances with very little attenuation.

atom a particle of matter indivisible by chemical means, which is chemically neutral. It is the fundamental building block of the chemical elements.

atomic beam a source of atoms traveling primarily in one direction. In practice, atomic beams are usually realized by the expansion of an atomic vapor into a vacuum through a small aperture. The resulting expanding cloud of atoms is usually made nearly unidirectional by a collimator that blocks or otherwise removes all atoms not propagating within a narrow range of angles.

atomic force microscope (AFM) a microscope in which a sharp probe tip is scanned across a surface, with piezoelectric ceramics being used to control position in three dimensions. The lateral (in-plane, or x-y) positions are raster scanned, while the vertical dimension is controlled by a feedback circuit that maintains constant force. The image produced is a topograph showing surface height as a function of position in the plane.

atomic instruction an instruction that consists of discrete operations that are all executed as a single and indivisible unit, without interruption by other system events. *See also* test-and-set instruction, atomic transaction.

atomic transaction the same as an atomic instruction, except that the notion of being atomic applies to a transaction, which may be a sequence of operations, no intermediate states of which may be seen or operated upon by another transaction. *See also* atomic instruction.

atomic transition coupling of energy levels in an atom by means of absorption or emission processes.

atomic vapor a material composed of atoms that preferentially exist as monomers in the vapor phase.

ATRC *See* Advanced Television Research Consortium.

attachment one of the events which precede a lightning stroke to the earth. Attachment occurs when the stepped leader from the thundercloud makes contact with one of several streamers which emanate from the ground or structures on the earth. The return stroke follows immediately. *See* streamer, stepped leader, return stroke.

attachment process a process that occurs in lightning when one or more stepped leader branches approach within a hundred meters or so of the ground and the electric field at the ground increases above the critical breakdown field of the surrounding air. At that time one or more upward-going discharges is initiated. After traveling a few tens of meters, one of the upward discharges, which is essentially at ground potential, contracts the tip of one branch of the stepped leader, which is at a high potential, completing the leader path to ground.

attainable set for discrete system the set of all the possible ends of system trajectories at time t_1 starting from zero initial conditions at time t_0. Denteod $K(t_0, t_1)$.

$K(t_0, t_1)$ is defined for zero initial state as follows

$$K(k_0, k_1) = \Big(x \in R^n : \\ x = \sum_{j=k_0}^{j=k_1-1} F(k_1, j+1)\, B(j) u(j) : \\ u(j) \in R^m\Big)$$

Therefore, controllability in $[k_0, k_1]$ for discrete dynamical system is equivalent to the condition

$$K(t_0, t_1) = R^n$$

Using the concept of the attainable set it is possible to express the remaining types of controllability for discrete system.

attenuated total reflection the phenomenon associated with the appearance of a reflection minimum identified with the generation of surface waves at the metal — air interface in a prism, air, metal arrangement.

attenuation the exponential decrease with distance, in the amplitude of an electric signal traveling along a very long transmission line due to losses in the supporting medium. In electromagnetic systems attenuation is due to conductor and dielectric losses. In fiber optic systems attenuation arises from intrinsic material properties (absorption and Rayleigh scattering) and from waveguide properties such as bending, microbending, splices, and connectors.

attenuation coefficient *See* absorption coefficient.

attenuation constant the real part of the complex propagation constant for an electromagnetic wave.

attenuator a device or network that absorbs part of a signal while passing the remainder with minimal distortion.

attractor an asymptotic state of a dynamical system of which there are three basic types. Either (i) the system comes to rest and the attractor is a fixed point in state space, (ii) the system settles into a periodic motion known as a limit cycle, or (iii) the system enters a chaotic motion, in which case the attractor is called strange.

attribute a special function in Pawlak's information system. Pawlak's information system S is a pair (U, A) where the set U is called the universe and has n members denoted x_i, while the set A consists on m function on the universe U. These functions are called the attributes and denoted $\mathbf{a}_j$. The attributes are vector-valued functions that may be interpreted, for example, as issues under negotiation by the members of the universe U. An example of an attribute is a function of the form

$$\mathbf{a}_j : U \to \{-1, 0, 1\}^n .$$

attribute set a set of vectors (signals) lying in metric space that possess prescribed properties.

audio science of processing signals that are within the frequency range of hearing, that is, roughly between 20 hertz and 20 kilohertz. Also, name for this kind of signal.

audio channels the portion of the circuit containing frequencies that correspond to the audible sound waves. Audio frequencies range from approximately 15 hertz to 20,000 hertz.

audio coding the process of compressing an audio signal for storage on a digital computer or transmission over a digital communication channel.

audio follow-video switcher (AFV) a switcher that simultaneously switches the video and audio information. The term is associated with the action of the audio signal and corresponding video signal switching together.

augmented code a code constructed from another code by adding one or more codewords to the original code.

aural subcarrier in a composite television signal, the frequency division multiplexed carrier placed outside the visual passband that carries the audio modulation. In the NTSC (United States) system, it is placed 4.5 Mhz higher than the visual carrier.

auto-regressive moving-average model (ARMA) the discrete-time input–output model in which the current output depends both on its past values (auto-regressive part) and the present and/or past values of the input (moving-average part).

autoassociative backpropagation network a multilayer perceptron network that is trained by presenting the same data at both the input and output to effect a self-mapping. Such networks may be used for dimensional reduction by constraining a middle, hidden layer to have fewer neurons than the input and output layers.

autobank an array of autotransformers .

autoconfiguration a process that determines what hardware actually exists during the current instance of the running kernel at static configuration time. It is done by the autoconfiguration software that asks the devices to identify themselves and accomplishes other tasks associated with events occurring during the autoconfiguration of devices. For instance, PCI devices have autoconfiguration capabilities and do not have to be configured by users.

autocorrelation a measure of the statistical dependence between two samples of the same random process. For a random process $X(t)$, the auto-correlation is the expectation

$$R_{xx}(t_1, t_2) = E\left[X(t_1)\, X(t_2)\right].$$

See also cross-correlation.

autocorrelation function the expected value of the product of two random variables generated from a random process for two time instants; it represents their interdependence. The Fourier transform of the autocorreclation function is the power spectrum (power spectral density) for the random process.

autocorrelator a circuit that computes the autocorrelation function.

autocovariance (1) for a random process $f(t)$, a measure of the variability of the mean-removed process:

$$C_f(t_1, t_2) = E\left[f(t_1) f(t_2)^T\right] - E[f(t_1)]E[f(t_2)^T].$$

(2) for a random vector $\boldsymbol{x}$, a measure of the mean-square variability of a random vector $\boldsymbol{x}$ about its mean:

$$\Lambda_x = E\left[(\boldsymbol{x} - E[\boldsymbol{x}])(\boldsymbol{x} - E[\boldsymbol{x}])^T\right].$$

See also autocorrelation, covariance.

autodecrementing (1) an addressing mode in which the value in a register is decremented by one word when used as an address.

(2) in high-level languages, operation

$$i-- \Rightarrow i = i - 1$$

where i is arbitrary variable, register or memory location.

(3) in machine code, more generally, the processor decrements the contents of the register by the size of the operand data type; then the register contains the address of the operand. The register may be decremented by 1, 2, 4, 8, or 16 for byte, word, longword, quadword, or octaword operands, respectively.

autoincrementing (1) an addressing mode in which the value in a register is incremented by one word when used as an address.

(2) in high-level languages: operation

$$i++ \Rightarrow i = i + 1$$

where i is arbitrary variable, register or memory location.

(3) in machine code, after evaluating the operand address contained in the register, the processor increments the contents of the register by 1, 2, 4, 8, or 16 for a byte, word, longword, quadword, or octaword, respectively.

automated meter reading (AMR) the use of meters which have the capability of transmitting at the least consumption information to the utility through some means of electronic communication.

automatic (1) property pertaining to a process or a device that functions without intervention by a human operator under specified conditions.

(2) a spring-loaded tension sleeve into which a conductor or other wire is inserted for tensioning and attachment to a pole or other fixture.

automatic allocation allocation of memory space to hold one or more objects whose lifetimes match the lifetime of the activation of a module, such as a subroutine. Automatic allocations are usually made upon entry to a subroutine.

automatic black-level control electronic circuitry used to maintain the black levels of the video signal at a predetermined level. The black level reference is either derived from the image or from the back porch of the horizontal blanking interval.

automatic chroma control (ACC) ACC is used to correct the level of the input chroma signal. Typically, the ACC circuitry makes corrections to the chroma, based on the relative degeneration of the color burst reference signal, since this signal will have been subjected to the same degradation.

automatic circuit recloser *See* recloser.

automatic fine tuning (AFT) one of the input circuits of a color television receiver specifically designed to maintain the correct oscillator frequency of the tuner for best color reproduction of the picture. The circuit is sometimes called the automatic frequency control. *See also* automatic frequency control (AFC).

automatic focusing on an optical disk, the process in which the distance from the objective focal plane of the disk is continuously monitored and fed back to the disk control system in order to keep the disk constantly in focus.

automatic frequency control (AFC) (1) an automatic feedback control system that is used to maintain active power balance by means of the speed governor system. In an interconnected system, scheduled power interchanges are maintained by means of controlling area generations.

(2) electronic circuitry used to keep the received signal properly placed within the desired IF frequency range. In televisions, the AFC circuitry is also called the AFT or "automatic fine tuning" section. The AFC circuit will generate an error signal if the input frequency to the IF drifts above or below the IF frequency. The error signal is fed back to vary the local oscillator frequency in the tuner section. *See also* automatic fine tuning (AFT).

automatic gain control (AGC) a method to control the power of the received signal in order to be able to use the full dynamic range of the receiver and to prevent receiver saturation.

automatic generation control (AGC) phrase describing the computer-based process by which electric utilities control individual generating stations to maintain system frequency and net interchange of power on a highly interconnected transmission grid. Automatic generation control (AGC) systems monitor grid frequency, actual and scheduled power flows, and individual plant output to maintain balance between actual and scheduled power production, both within transmission control areas and at individual generating stations. Control is generally accomplished by adjusting the speed control (or droop) characteristics of individual generating units. Control actions are determined by planned production schedules and power exchange agreements among participating utilities.

automatic level control (ALC) a feedback system where an RF signal from a source is sampled, detected, and sent to a voltage controlled attenuator to maintain a constant amplitude output over a specified band of frequencies.

automatic repeat request (ARQ) an error control scheme for channels with feedback. The transmitted data is encoded for error detection and a detected error results in a retransmission request.

automatic tracking on an optical disk, the process in which the position of the disk head relative to the disk surface is constantly monitored and fed back to the disk control system in order to keep the read/write beam constantly on track.

automatic transfer switch a self-acting switch which transfers one or more load conductor connections from one power source to another.

automatic voltage regulator (AVR) an automatic feedback control system that is responsible for maintaining a scheduled voltage either at the terminals of a synchronous generator or at the high-side bus of the generator step-up transformer. The control is brought about by changing the level of excitation.

automation refers to the bringing together of machine tools, materials handling process, and controls with little worker intervention, including

1. a continuous flow production process that integrates various mechanisms to produce an item with relatively few or no worker operations, usually through electronic control;

2. self-regulating machines (feedback) that can perform highly precise operations in sequence; and

3. electronic computing machines.

In common use, however, the term is often used in reference to any type of advanced mechanization or as a synonym for technological progress; more specifically, it is usually associated with cybernetics.

automaton (1) a fundamental concept in mathematics, computer engineering, and robotics.

(2) a machine that follows sequence of instructions.

(3) any automated device (robots, mechanical and electromechanical chess automata). Automata (plural of automaton) theory studies various types of automata, their properties and limitations. *See also* cellular automaton, finite state machine (FSM).

autonomic that part of the nervous system which controls the internal organs.

autonomous operation operation of a sequential circuit in which no external signals, other than clock signals, are applied. The necessary logic inputs are derived internally using feedback circuits.

autonomous system a dynamic system described by a first-order vector differential equation that is unforced and stationary. In other words, such a system is governed by an equation of the form

$$\dot{x}(t) = f(x(t))$$

See also unforced system and stationary .

autoregressive (AR) a pth order autoregressive process is a discrete random process that is generated by passing white noise through an all-pole digital filter having p poles. Alternatively, $x[n]$ is a pth order AR process if

$$x[n] = \sum_{i=n-p}^{n-1} \alpha[i]x[i] + q[n].$$

Autoregressive processes are often used to model signals since they exhibit several useful properties. *See also* moving average.

autotransformer a power transformer that has a single continuous winding per phase, part of this winding being common to both the primary and the secondary sides. As a result, these voltages are not isolated but the transformer is reduced in weight and size. Autotransformers are most suited for relatively small changes in voltage. Three phase autotransformers are by necessity connected in a wye configuration.

autotransformer starter a single three-phase autotransformer or three single phase transformer used to start induction motors at a reduced voltage.

auxiliary memory *See* secondary memory.

auxiliary relay a relay employed in power system protection schemes that does not directly sense fault presence and location. Typical auxiliary relays include lockout relays, reclosing relays, and circuit breaker anti-pump relays.

auxiliary winding a winding designed to be energized occasionally for a specific purpose, such as starting a single-phase motor. The power to the winding may be controlled by various means including a timer, centrifugal switch, current sensing relay, or voltage (counter EMF) sensing relay.

availability the probability that a system is operating correctly and is available to perform list functions at the instant of time t. Also defined as the value

$$1 - \text{outage}$$

See also outage.

available bit rate (ABR) ATM congestion control algorithm that enables a source to discover the bit rate available between it and a destination in a network. The source transmits a resource manager cell containing the desired bit rate; each switch this cell passes through adjusts the bit rate down to what it can support. Upon reaching the destination, the cell contains the available bit rate and is returned to the source.

available power gain ratio of power available from a network to the power available from the source.

avalanche breakdown process that occurs in a semiconductor space charge region under a sufficiently high voltage such that the net electron/hole generation rate due to impact ionization exceeds certain critical value, causing the current to rise indefinitely due to a positive feedback mechanism. The I-R heating caused during this process can permanently degrade or destroy the material.

avalanche injection the physics whereby electrons highly energized in avalanche current at a semiconductor junction can penetrate into a dielectric.

avalanche photodiode (APD) a photodiode (detector) that provides internal current gain. Used in optical communication systems when there is limited optical power at the receiver.

average optical power time average of the optical power carried by a non-CW optical beam.

average picture level (APL) describes the average (mean) changes in a video signal due to a changing brightness of the visual image. The APL is typically expressed in terms of a percentage (10-15% for dark pictures and 75-90% for bright pictures). Changes in the APL can effect linearity unless DC restoration or clamping circuits are included in the video circuitry.

average power the average value, taken over an interval in time, of the instantaneous power. The time interval is usually one period of the signal.

average-value model a mathematical representation in which the average value of variables are used to model a system. In electric machines and drives, system variables are typically averaged over various switching intervals. This eliminates the high-frequency dynamics, but preserves the slower dynamics of the system.

averaging the sum of N samples, images or functions, followed by division of the result by N. Has the effect of reducing noise levels. *See also* blurring, image smoothing, mean filter, noise smoothing, noise suppression, smoothing.

AVR *See* automatic voltage regulator.

AWG American Wire Gauge, a system of wire sizing used in the USA especially in smaller conductors used in residential and commercial wiring.

AWGN *See* additive white Gaussian noise.

axon the conducting portion of a nerve fiber — a roughly tubular structure whose wall is composed of the cellular membrane and is filled with an ionic medium.

Ayrton, William Edward (1847–1908)
Born: London, England

Ayrton is best known as the inventor of a number of electrical measurement devices and as an engineering educator. Ayrton's early work was with the Indian Telegraph Service, after which he studied with William Thomson (Lord Kelvin) in Glasgow. After several more telegraph assignments Ayrton traveled to Tokyo, where he established the first electrical engineering teaching laboratory at the Imperial Engineering College. Among his many inventions he is credited with the ammeter and an improved voltmeter. His wife Bertha was also an active researcher and became the first woman to be admitted to the Institute of Electrical Engineers.

azimuth recording a recording scheme whereby the data is recorded at an acute angle from the direction of movement of the recording medium. Used in the recording scheme of video information, FM radio, and audio in VCRs.

B

B coefficient *See* loss coefficient.

B-ISDN *See* broadband integrated services digital network.

B-mode display returned ultrasound echoes displayed as brightness or gray-scale levels corresponding to the amplitude versus depth into the body.

B-site in a ferroelectric material with the chemical formula ABO_3, the crystalline location of the B atom.

B-spline the shortest cubic spline consisting of different three-degree polynomial on four intervals; it can be obtained by convolving four box functions.

Babbage, Charles (1792–1871) Born: Totnes, England

Babbage is best known for his ideas on mechanical computation. Babbage is said to have been disgusted with the very inaccurate logarithm tables of his day, as well as appalled by the amount of time and people it took to compute them. Babbage attempted to solve the problem by building mechanical computing engines. The government-funded Difference Engine was beyond the technology of the craftsman who attempted to build it. Undeterred, Babbage followed this failure with the larger and more complex Analytical Engine (also unfinished). The ideas behind the Analytical Engine formed the basis for Howard Aiken's 1944 Mark I computer. Babbage's assistant, Ada Augusta, the Countess of Lovelace and the poet Lord Byron's daughter, is honored as the first programmer for her work and because her meticulous notes preserved the descriptions of Babbage's machines.

Babinet principle principle in optics that states that the diffraction patterns produced by complementary screens are the same except for the central spot. It can be rigorously proved both for acoustic and electromagnetic waves. The Babinet's principle for scalar fields is the following: let p be the resultant field in $z > 0$ due to the incident field p_i from $z < 0$ and let p_t be the total field when the same incident wave falls on the complementary screen. Then, in $z > 0$,

$$p + p_t = p_i$$

back in a motor, the end that supports the major coupling or driving pulley.

back EMF *See* counter-EMF.

back end that portion of the nuclear fuel cycle which commences with the removal of spent fuel from the reactor.

back porch a 4.7 microsecond region in the horizontal blanking interval of the NTSC composite video signal that contains a burst of eight to ten cycles of the 3.579545 MHz (3.58 MHz) color subcarrier. The back porch occupies 7% of the total horizontal line time; starting at the end of the horizontal line sync signal and ending with the start of the video.

backbone wiring that runs within and between floors of a building and connects local-area network segments together.

backfeed in power distribution work, power which flows from the secondary lines into the primary lines through the distribution transformer, *e.g.*,from an emergency generator connected to customer load.

backflash an arc which forms along a tower during a lightning strike due to high tower or footing impedance.

background (1) refers to the received vector power level of an electromagnetic measurement (usually radar cross section) with no target present. The background includes the collective unwanted power received from sources other than the desired target under test such as positioners, foam columns, fixtures necessary to support a target, and the room or ground environment. The background level is vectorially subtracted from the received level with the target present to obtain the raw data set for a particular target.

(2) any unwanted signal. The background is a lower limit on the detection of small signals when devices are used to make a measurement in an experimental set up. The measurement is a superposition of events from the experiment itself and events from all other sources including the background.

background noise the noise that typically affects a system but is produced independent of the system. This noise is typically due to thermal effects in materials, interpreted as the random motion of electrons, and the intensity depends on the temperature of the material. In radio channels, background noise is typically due to radiation that is inherent to the universe and due mainly to radiation from astronomical bodies. There is a fundamental lower bound on the intensity of such noise which is solely dependent on the universe and independent of antenna and receiver design. *See also* thermal noise, noise temperature, noise figure.

background subtraction for images, the removal of stationary parts of a scene by subtracting two images taken at different times. For 1-D functions, the subtraction of a constant or slowly varying component of the function to better reveal rapid changes.

backing memory the largest and slowest level of a hierarchical or virtual memory, usually a disk. It is used to store bulky programs or data (or parts thereof) not needed immediately, and need not be placed in the faster but more expensive main memory or RAM. Migration of data between RAM and backing memory is under combined hardware and software control, loading data to RAM when it is needed and returning it to the backing store when it has been unused for a while.

backing storage *See* backing memory.

backoff a technique used in amplifiers when operated near saturation that reduces intermodulation products for multiple carriers. In its implementation, the drive signal is reduced or backed off. Input backoff is the difference in decibels between the input power required for saturation and that employed. Output backoff refers to the reduction in output power relative to saturation.

backplane *See* backplane bus.

backplane bus a special data bus especially designed for easy access by users and allowing the connection of user devices to the computer. It is usually a row of sockets, each presenting all the signals of the bus, and each with appropriate guides so that printed circuit cards can be inserted. A backplane differs from a motherboard in that a backplane normally contains no significant logic circuitry and a motherboard contains a significant amount of circuitry, for example, the processor and the main memory.

backplane optical interconnect *See* board-to-board optical interconnect.

backprojection an operator associated with the Radon transform

$$g(s,\theta) = \int_{-infty}^{+infty} \int_{-infty}^{+infty} f(x,y) \\ \delta(x\cos\theta + y\sin\theta - s)\ dx\ dy.$$

The backprojection operator is defined as

$$b(x,y) = \int_0^{\pi} g(x\cos\theta + y\sin\theta, \theta)\ d\theta.$$

$b(x,y)$ is called the backprojection of $g(s,\theta)$. $b(x,y)$ is the sum of all rays that pass through the point (x,y).

backpropagation the way in which error terms are propagated in a multilayer neural network. In a single layer feedforward network, the weights are changed if there are differences between the computed outputs and the training patterns. For multiple layer networks, there are no training patterns for the outputs of intermediate ('hidden') layer neurons. Hence the errors between the outputs and the training patterns are propagated to the nodes of the intermediate neurons. The amount of error that is propagated is proportional to the strength of the connection.

backpropagation algorithm a supervised learning algorithm that uses a form of steepest descent to assign changes to the weights in a feedforward network so as to reduce the network error for a particular input or set of inputs. Calculation of the modifications to be made to the weights in the output layer allows calculation of the required modifications in the preceding layer, and modifications to any further preceding layers are made a layer at a time proceeding backwards toward the input layer; hence the name of the algorithm.

backscatter energy from a reflected electromagnetic wave. In optics, the optical energy that is scattered in the reverse direction from the transmitted optical energy in an optical fiber transmission link or network. The backscattered energy comes from impurities in the fiber; mechanical or environmental effects that cause changes in the attenuation in the fiber; connectors, splices, couplers, and other components inserted into the optical fiber network; and faults or breaks in the optical fiber.

backscattering the reflection of a portion of an electromagnetic wave back in the direction of the wave source. *See also* backscatter.

backside bus a term for a separate bus from the processor to the second level cache (as opposed to the frontside bus connecting to the main memory).

backward error recovery a technique of error recovery (also called rollback) in which the system operation is resumed from a point, prior to error occurrence, for which the processing was backed up.

backward wave interaction interaction between backward propagating microwave electric fields against an electron stream and the electron in the electron beam. The direction of propagating microwaves and the direction of motion of electrons in the beam are opposite each other.

backward wave oscillator (BWO) a microwave oscillator tube that is based on a backward wave interaction.

balanced *See* balanced line.

balanced amplifier an amplifier in which two single-ended amplifiers are operated in parallel with 90 degree hybrid. Balanced amplifiers feature a low voltage standing wave ratio because of an absorption of reflected power at the terminating resistor of the hybrids.

balanced code a binary line code that ensures an equal number of logic ones and logic zeros in the encoded bit sequence. Also called a DC-free code because the continuous component of the power spectral density of a balanced encoded sequence falls to zero at zero frequency.

balanced line symmetric multiconductor transmission line in which the voltage on each conductor along the transmission line has the same magnitude, but the phases are such that the voltage would sum to zero. In a two conductor transmission line, the voltages would be equal and 180 degrees out of phase. This is the equivalent of a virtual ground plane or zero E-field plane at the geometric center plane of the transmission line cross section, or balanced with respect to virtual ground. Balanced wiring configurations are often used to prevent noise problems such as ground loops. *Contrast with* unbalanced line.

balanced load a load on a multi-phase power line in which each line conductor sees the same impedance.

balanced mixer a nonlinear 3-port device (two inputs, one output) used to translate an input signal's frequency component either up or down the frequency spectrum by generating the sum and difference of two or more frequencies present at its inputs. The three ports are termed RF (radio frequency), LO (local oscillator), and IF (intermediate frequency). A balanced mixer translates the frequency components found in the RF input signal to the IF output in such a manner as to minimize the amount of LO noise arriving at the IF. This reduces the mixer's overall noise figure and increases its sensitivity. Other advantages of these mixers include improved local oscillator isolation and linearity and higher power handling ability.

balanced modulator a modulator in which the carrier and modulating signal are introduced so that the output contains the two sidebands without the carrier.

balanced operation in n-phase circuits ($n > 1$), an operating condition in which the voltages (currents) of the phases are equal-amplitude sinusoids with phase-angles displaced by a specific angle ϕ. The angle (ϕ) is a function of the number of phases (n). For $n = 2$, $\phi = 90$ degrees, for $n = 3$, $\phi = 120$ degrees. In machine analysis the term "balanced" is also used to describe a machine that has symmetrical phase windings.

balanced slope detector an arrangement of two detectors designed to convert an FM signal to AM for detection. This is accomplished by setting the IF center frequency so that it falls on the most linear portion of the response curve. Frequency changes (FM) will result in corresponding amplitude changes that are then sent to an AM detector. The balanced version is two slope detectors connected in parallel and 180 degrees out of phase.

ball grid array (BGA) a modern high I/O count packaging method. It reduces the package size and its pin-to-pin trace gap in order to integrate more functions and reliability in a single space. It can have as many as 324 pins. BGA sockets are high speed, high reliability, surface-mountable, and can be installed without soldering. The related terms are PBGA—plastic ball grid array, CBGA—ceramic ball grid array, TBGA—tape automated bonded ball grid array. The disadvantage of BGA packaging is that new tools and skills are required to mount or replace the chipset manually for repair purposes.

ballast a starting and control mechanism for fluorescent and other types of gas-discharge lamps. Initially a ballast supplies the necessary starting (or striking) voltage in order to ionize the gas to establish an arc between the two filaments in the lamp. Once the gas is ionized, the ballast controls the input power and thus the light output to maximize the efficiency and life of the lamp.

balun a network for the transformation from an unbalanced transmission line, system or device to a balanced line, system or device. Baluns are also used for impedance transformation. Derived from "balanced to unbalanced."

In antenna systems, baluns are used to connect dipole-type antennas to coaxial cable, to balance the current on dipole armatures, and to prevent currents from exciting the external surface of the coaxial shield.

See also balanced, unbalanced line.

band reference name for a range of frequencies. Current defined bands include the following.

Band Name	Reference Range
L-band	1.12 - 1.7 GHz
X	8.2 - 12.4 GHz
Ku	12.4 - 18 GHz
Ka	26.5 - 40 GHz
V	50 - 75 GHz
W	75 - 110 GHz

band gap the energetic gap between the conduction and valence band edges of a material (usually referred to semiconductors).

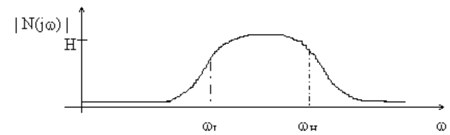
band stop filter filter that exhibits frequency selective characteristic such that frequency components of an input signals pass through unattenuated from input to output except for those frequency components coincident with the filter stop-band region, which are attenuated. The stop-band region of the filter is defined as a frequency interval over which frequency components of the input signal are attenuated.

band structure the energy versus momentum relationship for an electron in a periodic crystal.

band-limited signal a signal $x(t)$ is said to be band limited if its Fourier transform $X(\omega)$ is zero for all frequencies $\omega > \omega_c$, where ω_c is called the cutoff frequency.

band-pass filter (1) a circuit whose transfer function, or frequency response, $H(\omega)$ is zero or is very small for frequencies not in a specified frequency band. In a strict sense $H(\omega) = 0$ for $|\omega| \notin [\omega_1, \omega_2]$ for some $0 < \omega_1 < \omega_2$. *Compare with* low-pass filter, high-pass filter, notch , band-reject filter.

(2) an electronic or electrical circuit which has the response shown in the figure below. There are two cut-off frequencies, ω_L and ω_H . In the passband $\omega_L < \omega < \omega_H$, $|\ N(j\omega)\ |$ is constant. In the stopbands, $\omega < \omega_L$ and $\omega > \omega_H$, $|\ N(j\omega)\ |$ is very small and there is practically no transmission of the signal.



Band-pass filter response.

band-pass network a configuration of solely passive components or combination of active and passive components that will attenuate all signals outside of the desired range of frequency.

band-pass signal a signal whose Fourier transform or spectrum approaches zero outside a given frequency band. Ideally, the spectrum should equal zero outside the band, but this is difficult to achieve in practice. This may be described mathematically as follows: let $X(\omega)$ be the Fourier transform of the signal. Then, for a band-pass signal we have $X(\omega) = 0$ for $|\omega| \notin [\omega_1, \omega_2]$, for some $0 < \omega_1 < \omega_2$.

band-reject filter *See* band-stop filter.

band-stop filter a filter which attenuates only within a finite frequency band and leaves the signal unaffected outside this band. *See also* band-pass filter, high-pass filter, low-pass filter.

bandgap energy in materials with band energy levels, the minimum energy needed to excite a charge carrier from a lower to an upper band. *See also* absorption edge.

bandgap engineering in materials such as compound semiconductors and superlattice structures, the fabrication of materials with specific bandgap energies by varying the fractional proportions of the constituents and by varying superlattice layer thicknesses.

bandgap narrowing reduction of the forbidden energy gap of a semiconducting material due to the narrowing influence of impurities.

bandgap reference a voltage reference based on the 1.205 V bandgap voltage of silicon.

bandgap wavelength the optical wavelength corresponding to a photon energy equal to the bandgap energy.

bandlimited a waveform is described as bandlimited if the frequency content of the signal is constrained to lie within a finite band of frequencies. This band is often described by an upper limit, the Nyquist frequency, assuming frequencies from DC up to his upper limit may be present. This concept can be extended to frequency bands that do not include DC.

bandwidth (1) the frequency range of a message or information processing system measured in hertz.

(2) width of the spectral region over which an amplifier (or absorber) has substantial gain (or loss); sometimes represented more specifically as, for example, full width at half maximum.

(3) the property of a control system or component describing the limits of sinusoidal input frequencies to which the system/component will respond. It is usually measured at the half-power points, which are the upper and lower frequencies at which the output power is reduced by one half. Bandwidth is one measure of the frequency response of a system, i.e., the manner in which it performs when sine waves are applied to the input.

(4) the lowest frequency at which the ratio of the output power to the input power of an optical fiber transmission system decreases by one half (3 dB) compared to the ratio measured at approximately zero modulation frequency of the input optical power source. Since signal distortion in an optical fiber increases with distance in an optical fiber, the bandwidth is also a function of length and is usually given as the bandwidth-distance product for the optical fiber in megahertz per kilometer. *See also* bandwidth-distance product.

bandwidth efficiency the ratio of the information rate in bits per second to the required bandwidth in hertz for any digital modulation technique.

bandwidth improvement (BI) a dB reading that is a comparison of the RF bandwidth of a receiver to the IF bandwidth. Designated as BI, it is $10 \log B_{rf}/B_{if}$.

bandwidth-distance product a measure of the information carrying capacity of an optical fiber which emphasizes that the bandwidth is a function of distance. For example, an optical fiber with a specification of 500 MHz-km bandwidth-distance product would have a 500 MHz bandwidth over 1 km, a 50 MHz bandwidth over 10 km or a 1 GHz bandwidth over 0.5 km. *See also* bandwidth, optical fiber.

bang-bang control control action achieved by a command to the actuator that tells it to operate in either one direction or the other at any time with maximum energy.

Bang-bang control is an optimal or suboptimal piecewise constant control whose values are defined by bounds imposed on the amplitude of control components. The control changes its values according to the switching function which may be found using Pontryagin maximum principle. The discontinuity of the bang-bang control leads to discontinuity of a value function for the considered optimal control problem. Typical problems with bang-bang optimal control include time-optimal control for linear and bilinear control systems.

Bardeen, John (1908–1991) Born: Madison, Wisconsin, U.S.A.

Bardeen is best known for his two Nobel Prizes. The first prize he received was in 1956 for his development at Bell Labs, along with Walter Brattain and William Schockley, of the first transistor. When the three applied for a patent for the device in 1948 they called it a germanium transfer resistance unit; hence the name transistor. This device was a significant step in the development of integrated circuits. Bardeen's second Nobel, which he shared with Leon Cooper and John R. Schrieffer, was for his work at the University of Illinois in describing the theory of superconductivity.

bare-hand refers to a method of servicing energized overhead conductors in which the line worker's body is maintained at the same potential as the conductor on which he is working, thus enabling the conductor to be contacted without danger of shock.

BARITT barrier injection transit time, a microwave transit time device that uses injection over a forward biased barrier and transit time delay through a reverse biased junction to produce negative resistance at microwave frequencies, useful in low power and self-oscillating mixer applications.

Barkhausen criterion two conditions placed on a feedback oscillator necessary for sustained oscillation. The Barkhausen criterion states

1. The total loop amplitude transmission factor must be at least unity.

2. The frequency of oscillation will be that frequency characterized by a total loop phase transmission factor of $N2\pi$ radians. N is either zero or an integer. Simply, for sustained oscillation, a disturbance that makes a complete trip around the feedback loop of the oscillator must be returned at least as strong as the original disturbance and in phase with that disturbance.

Barkhausen effect the series of irregular changes in magnetization that occur when a magnetic material is subjected to a change in magnetizing force.

Barkhausen noise noise arising in magnetic read heads because the interlocking magnetic domains cannot rotate freely in response to an applied field. The response to an external magnetic field is randomly discontinuous as domains "stick," and then release. Barkhausen noise is particularly important in very small heads and thin-film heads where very few domains are involved; in larger heads the effects of many domains tend to average out and Barkhausen noise is relatively less important.

barrel distortion a geometric distortion of a raster display in which vertical lines appear to bow outward away from the display center line. The bowing of the vertical lines increases as the distance from the vertical center increases. The appearance of these vertical lines is similar to the staffs of a barrel. Barrel distortion is a result of the overcorrection for pincushion distortion.

barrel shifter an implementation of a shifter, which contains $\log_2$(max number of bits shifted) stages, where each stage shifts the input by a different power of two number of positions. It can be implemented as a combinational array with compact layout that can shift the data by more than one bit using only one gate. For instance, for a 4-bit word, it can execute instructions shl, shl2, shl3, and shl4. This shifter lends itself well to being pipelined.

barrier layer layer of deposited glass adjacent to the inner tube surface to create a barrier against OH diffusion.

barrier voltage a voltage that develops across the junction due to uncovered immobile ions on both sides of the junction. Ions are uncovered due to the diffusion of carriers across the junction.

Bartlett window a triangular window $w[n]$ of width $2M$ defined as follows:

$$w[n] = \begin{cases} 1/2[1+\cos(\pi n/M)], & -M \leq n \leq M \\ 0, & \text{otherwise} \end{cases}$$

Multiplying a signal $x[n]$ by the finite duration window signal $w[n]$ leads to the triangularly scaled, finite duration signal $z[n] = x[n]w[n]$, which is then processed. Windowing is used in the spectral analysis of measured signals and the design of finite impulse response, linear time invariant systems.

baryon a collective term for all strongly interacting particles with masses greater than or equal to the mass of the proton. These include the proton, neutron, and hyperons.

base (1) the number of digits in a number system (10 for decimal, 2 for binary).

(2) one of the three terminals of a bipolar transistor.

(3) a register's value that is added to an immediate value or to the value in an index register in order to form the effective address for an instruction such as LOAD or STORE.

base address (1) an address to which an index or displacement is added to locate the desired information. The base address may be the start of an array or data structure, the start of a data buffer, the start of page in memory, etc.

(2) as a simpler alternative to a full virtual memory, the code space or data space of a program can be assumed to start at a convenient starting address (usually 0) and relocated in its entirety into a continuous range of physical memory addresses. Translation of the addresses is performed by adding the contents of an appropriate base address register to the user address.

base dynamic parameters a set of dynamic parameters that appear in the canonical equations of motion. Canonical equations of motion of robot dynamics do not include linearly dependent equations. These are eliminated by making use of various procedures. As a result, dynamic equations of motion contain only independent equations which are used for the purpose of control. Each base dynamic parameter is a linear combination of the inertial parameters of the individual links. Base dynamic parameters are subject to the identification in adaptive control schemes applied to robot control.

base frame a frame attached to the nonmoving base of the manipulator. Sometimes the base frame is called the reference frame.

base quantity *See* per-unit system.

base register the register that contains the component of a calculated address that exists in a register before the calculation is performed (the register value in "register+immediate" addressing mode, for example).

base register addressing addressing using the base register. Base register is the same as base address register, i.e., a general-purpose register that the programmer chooses to contain a base address.

base speed corresponds to speed at rated torque, rated current, and rated voltage conditions at the temperature rise specified in the rating. It is the maximum speed at which a motor can operate under constant torque characteristics or the minimum speed to operate at rated power.

base station the fixed transceiver in a mobile communication system. *See also* fixed station (FS).

base vector a unit vector in a coordinate direction.

baseband in communication systems, the information-carrying signal that is modulated onto a carrier for transmission.

baseband signal in digital communications, a signal that appears in the transmitter prior to passband modulation. For example, in the case of pulse amplitude modulation, $s(t) = \sum_i b_i p(t - iT)$ is a baseband signal, where b_i is the transmitted symbol at time i, and $p(t)$ is the baseband pulse shape (e.g., raised-cosine). *See also* low-pass signal.

basic impulse insulation level (BIL) a measurement of the impulse withstand capability of a piece of electric power equipment based on its ability to withstand 50% of impulses applied at the BIL voltage.

basic input–output system (BIOS) part of a low-level operating system that directly controls input and output devices.

basic lightning impulse level (BIL) the strength of insulation in terms of the withstand voltage crest value using a standard voltage level impulse.

basin of attraction the region in state space from which a dynamical system moves asymptotically toward a particular attractor.

basis function one of a set of functions used in the transformation or representation of some function of interest. A linear transformation T of continuous functions is of the form

$$y(s) = T\{x(t)\} = \int_{-infty}^{+infty} x(t)b(s,t)\ dt.$$

where $b(s,t)$ is a basis function. For discrete sequences T would be of the form

$$y[k] = T\{x[n]\} = \sum_{n=-infty}^{+infty} x[n]b[k,n].$$

The function to be transformed is projected onto the basis function corresponding to the specified value of the index variable s or k. $y(s)$ is the inner product of $x(t)$ and the basis function $b(s,t)$. For the Laplace transform $b(s,t) = e^{-st}$, and for the Fourier transform $b(\omega,t) = e^{-j\omega t}$. For the discrete-time Fourier transform $b[k,n] = e^{\frac{j2\pi kn}{N}}$, and for the Z-transform $b[z,n] = z^{-n}$.

$BaTiO_3$ (barium titanate) a ferroelectric crystalline material that is particularly useful for photorefractive and optical multibeam coupling.

battery one or more cells connected so as to produce energy.

baud the signaling rate, or rate of state transitions, on a communications medium. One baud corresponds to one transition per second. It is often confused with the data transmission rate, measured in bits per second.

Numerically, it is the reciprocal of the length (in seconds) of the shortest element in a signaling code. For very low-speed modems (up to 1200 bit/s) the baud rate and bit rate are usually identical. For example, at 9600 baud, each bit has a duration of 1/9600 seconds, or about 0.104 milliseconds.

Modems operating over analog telephone circuits are bandwidth limited to about 2500 baud; for higher user data speeds each transition must establish one or more decodable states according to amplitude or phase changes. Thus, if there are 16 possible states, each can encode 4 bits of user data and the bit rate is 4 times the baud rate.

At high speeds, the reverse is true, with run-length controlled codes needed to ensure reliable reception and clock recovery. For example FDDI uses a 4B/5B coding in which a “nibble” of 4 data bits is encoded into 5 bits for transmission. A user data rate of 100 Mbit/s corresponds to transmission at 125 Mbaud.

baud rate *See* baud.

Baum–Welch algorithm the algorithm used to learn from examples the parameters of hidden Markov models. It is a special form of the EM algorithm.

Bayes envelope function given a the prior distribution of a parameter Θ and a decision function ϕ, the Bayes envelope function $\rho(F_\Theta)$ is defined as

$$\rho(F_\Theta) = \min \phi r(F_\Theta, \phi),$$

where $r(F_\Theta, \phi)$ is the Bayes risk function evaluated with the prior distribution of the parameter Θ and decision rule ϕ.

Bayes risk function with respect to a prior distribution of a parameter Θ and a decision rule ϕ, the expected value of the loss function with respect to the prior distribution of the parameter and the observation X.

$$r(F_\Theta, \phi) = \int_\Theta \int_X L[\theta, \phi(x)] \\ f_{X|\Theta}(x|\theta) f_{|\Theta}(\theta) \; dx \; d\theta.$$

the loss function is the penalty incurred for estimating the parameter Θ incorrectly. The decision rule $\phi(x)$ is the estimated value of the parameter based on the measured observation x.

Bayes' rule Bayes' rule relates the conditional probability of an event A given B and the conditional probability of the event B given A:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}.$$

Bayesian classifier a Bayesian classifier is a function of a realization of an observed random vector $\mathbf{X}$ and returns a classification w. The set of possible classes is finite. A Bayesian classifier requires the conditional distribution function of $\mathbf{X}$ given w and the prior probabilities of each class. A Bayesian classifier returns the w_i such that $P(w_i|\mathbf{X})$ is maximized. By Bayes' rule

$$P(w_i|\mathbf{X}) = frac P(\mathbf{X}|w_i)P(w_i)P(\mathbf{X}).$$

Since $P(\mathbf{X})$ is the same for all classes, it can be ignored and the w_i that maximizes $P(\mathbf{X}|w_i)P(w_i)$ is returned as the classification.

Bayesian detector a detector that minimizes the average of the false-alarm and miss probabilities, weighted with respect to prior probabilities of signal-absent and signal-present conditions.

Bayesian estimation an estimation scheme in which the parameter to be estimated is modeled as a random variable with known probability density function. *See* Bayesian estimator.

Bayesian estimator an estimator of a given parameter Θ, where it is assumed that Θ has a known distribution function and a related random variable X that is called the observation. X and Θ are related by a conditional distribution function of X given Θ. With $P(X|\Theta)$ and $P(\Theta)$ known, an estimate of Θ is made based on an observation of X. $P(\Theta)$ is known as the *a priori* distribution of Θ.

Bayesian mean square estimator for a random variable X and an observation Y, the random variable

$$\hat{X} = E[X|Y],$$

where the joint density function $f_{XY}(x, y)$ is known. *See also* mean-square estimation, linear least squares estimator.

Bayesian reconstruction an algorithm in which an image u is to be reconstructed from a noise-corrupted and blurred version v.

$$v = f(Hu) + \eta.$$

A prior distribution $p(u|v)$ of the original image is assumed to be known. The equation

$$\hat{u} = \mu_u + R_u H^T D R_\eta^{-1}[v - f(H\hat{u})],$$

where R_u is the covariance of the image u, R_η is the covariance of the noise η, and D is the diagonal matrix of partial derivatives of f evaluated at $\hat{u}$. An initial point is chosen and a gradient descent algorithm is used to find the closest $\hat{u}$ that minimizes the error. Simulated annealing is often used to avoid local minima.

Bayesian theory theory based on Bayes' rule, which allows one to relate the *a priori* and *a posteriori* probabilities. If $P(c_i)$ is the *a priori* probability that a pattern belongs to class c_i, $P(\mathbf{x_k})$ is the probability of pattern $\mathbf{x_k}$, $P(\mathbf{x_k}|c_i)$ is the class conditional probability that the pattern is $\mathbf{x_k}$ provided that it belongs to class c_i, $P(c_i|\mathbf{x_k})$ is the *a posteriori* conditional probability that the given pattern class membership is c_i, given pattern $\mathbf{x_k}$, then

$$P\left(c_i|\mathbf{x_k}\right) = \frac{P\left(\mathbf{x_k}|c_i\right) P\left(c_i\right)}{P\left(\mathbf{x_k}\right)}.$$

The membership of the given pattern is determined by

$$\max_{c_i} P\left(c_i|\mathbf{x_k}\right) = \max_{c_i} P\left(\mathbf{x_k}|c_i\right) P\left(c_i\right).$$

Hence, the *a posteriori* probability can be determined as a function of the *a priori* probability.

BCD *See* binary-coded decimal.

BCH code cyclic block forward error control codes developed by Bose and Chaudhuri, and independently by Hocquenghem. These codes are a superset of the Hamming codes, and allow for correction of multiple errors.

BCLA *See* block carry lookahead adder.

beam (1) transverse spatial localization of the power in a wave field.

(2) a slender unidirectional stream of particles or radiation.

beam cooling the process by which a particle beam's phase space volume is reduced, while conserving Liouville's theorem (empty spaces between particles exist). Beam cooling is manifest by a reduction in the transverse beam size (betatron cooling) or by a smaller momentum spread (momentum cooling).

beam divergence the geometric spreading of a radiated electromagnetic beam as it travels through space.

beam hardening a phenomenon that occurs when a polychromatic X-ray beam passes through a material. Lower energy photons are absorbed more readily than higher energy photons, increasing the effective energy of the beam as it propagates through the material.

beam intensity the average number of particles in a beam passing a given point during a certain time interval. For example the number of protons (electrons) per pulse or protons per second.

beam loading the beam being accelerated by an RF cavity and it changes the gradient and phase of the RF in the cavity.

beam mode confined electromagnetic field distributions of a propagating wave that match the boundary conditions imposed by a laser or aperture. For example, Hermite–Gaussian or Laguerre–Gaussian.

beam parameter one of several complex numbers employed to characterize the propagation of a beam; most common parameter combines in its real and imaginary parts the phase front curvature and spot size of a Gaussian beam.

beam pulsing a method used to control the power output of a klystron in order to improve the operating efficiency of the device.

beam roll a periodic change in horizontal and/or vertical positions during spill. This does not include changes caused by humans.

beam solid angle a parameter that qualitatively describes the angular distribution of radiated power from an antenna. The values range from very small numbers for very focused antennas to 4π steradians for an isotropic radiator.

beam stop a thick metal shield that moves into the beam line to prevent beam from entering a specific area.

beam toroid a device used for measuring beam intensities by measuring the magnetic field fluctuations produced by the passing beam. The magnetic field fluctuations produce a current in a coil, that is wound around a closed circular ring (torus) through which the beam passes.

beam waist position at which a beam is most highly confined; for Gaussian beams in real media the position at which the phase fronts are flat.

beamformers system commonly used for detecting and isolating signals that are propagating in a particular direction.

beamforming a form of filtering in spatial rather than time domain to obtain a desired spatial impulse response in order to suppress or to reject signal components coming from certain directions. The technique involves directing one or more beams in certain directions by adjusting, for example, the element excitation of an array antenna. Used in communications applications to suppress other signals than the desired source signal. Also termed spatial filtering.

beamline a series of magnets placed around a vacuum pipe that carry the proton beam from one portion of the accelerator to another. Also known as transport line.

beamsplitter any of a number of passive optical devices that divide an optical wavefront into two parts. Wavefront division may be according to intensity, polarization, wavelength, spatial position, or other optical properties.

beamwidth the angular width of the major lobe of a radiation pattern. It is usually at the half-power level, i.e., 3 dB below the peak of the major lobe. It can also be specified as the width between the nulls on either side of the major lobe (BWFN).

bearing currents current flow in the bearings of electrical machines, because of electromagnetic unbalance in the machine or from using high $\frac{dv}{dt}$ inverters. The latter is able to charge up the stray capacitance present between the stator and rotor and between the rotor and shaft and thus allows motor bearing currents to flow, with resulting bearing damage.

beat frequencies the two frequencies, sum and difference frequencies, generated during the heterodyning process or during the amplitude-modulating process. For example, if a 500 kHz carrier signal is amplitude-modulated with a 1 kHz frequency, the beat frequencies are 499 kHz and 501 kHz.

beat frequency oscillator an adjustable oscillator used in superheterodyne receivers generating a frequency when combined with the final IF produces a difference or beat frequency in audio range.

becky a knot used to secure a handline.

bed of nails a test fixture for automated circuit qualification in which a printed wiring board is placed in contact with a fixture that contacts the board at certain nodes required for exercising the assembly.

bel *See* decibel.

Bell, Alexander Graham (1847–1922)
Born: Edinburgh, Scotland

Bell is best know as the first patent holder for a device to electronically transmit human speech. Bell's early interest in the mechanisms of speech come from living with his grandfather, a London speech tutor. Work with the deaf was to be a lifelong vocation for Bell. Bell's inventions were not limited to the telephone. He was the first person to transmit speech without wires, he invented the gramophone, an early tape recorder, an air-cooling system, an iron lung, and he had several patents in telegraphy.

bell insulator a type of strain insulator, shaped like saucer with ribs on its lower side and frequently used in insulator strings.

Bello functions a group of alternative methods of characterizing a wideband communication channel, named after their proposer, P. Bello. The four functions characterizing deterministic channels are the Input Delay-spread Function, the Output Doppler-spread function, the Time-variant Transfer Function and the Delay Doppler-spread function.

BEM *See* boundary-element method.

benchmark standard tests that are used to compare the performance of computers, processors, circuits, or algorithms.

bending loss in a fiber depends exponentially on the bend radius R. It is proportional to $\exp(-R/R_c)$ where the critical radius

$$R_c = \frac{a}{2n\left(n_{co} - n_{cl}\right)} \,,$$

a is the fiber radius, n_{co} is the refractive index of the core, and n_{cl} is the refractive index of the cladding.

BER *See* bit error rate.

Bernoulli distribution a random variable X with alphabet $\{0, 1\}$ and parameter α such that its probability mass function is

$$p(x) = (1 - \alpha)^x \alpha^{1-x} .$$

Bernoulli process a binary valued, discrete-time random process defined on an index set corresponding to fixed increments in time. A typical example is a sequence of coin tosses where the values of the process are denoted as "Heads" or "Tails" depending on the outcome of the tosses. The output values of the process is a sequence of statistically independent random variables with the same probability distribution. The two outcomes may or may not have equal probabilities.

Berry, Clifford Edward Berry is best known as the co-developer, along with John Vincent Atanasoff, of the first functioning electronic digital computer. Berry was recommended to Atanasoff by the Dean of Engineering at Iowa State College as a most promising student who understood the electronics well enough to help Atanasoff implement his ideas for a computing machine. Unfortunately, Berry's contributions as a computing pioneer were not honored until after his death.

beryllium oxide a compound commonly used in the production of ceramics for electrical applications and whose dust or fumes are toxic.

Bessel beam transverse wave amplitude distribution in which the radial variation is approximately describable in terms of truncated Bessel functions; collimation for Bessel beams is sometimes considered better than for more usual polynomial-Gaussian beams.

Bessel functions a collection of functions, denoted as $J_\nu(x)$ and $Y_\nu(x)$, that satisfy Bessel's equation

$$x^2 \frac{d^2 f}{dx^2} + x \frac{df}{dx} + \left(x^2 - \nu^2\right) f = 0 \,,$$

where f is equal to either J_ν or Y_ν; ν is the order of the function and x is its argument. Typically, Bessel functions arise in boundary value problems that are based upon a cylindrical coordinate system.

best-fit memory allocation a memory allocator for variable-size segments must search a table of available free spaces to find memory space for a segment. In "best-fit" allocation, the free spaces are linked in increasing size and the search stops at the smallest space of sufficient size. *Compare with* buddy memory allocation.

beta function a measure of beam width. The beta function details how the beam changes around the accelerator. There are separate beta functions for the x and y planes. The square root of bx is proportional to the beam's x-axis extent in phase space.

beta particle an electron or positron emitted from a radioactive source.

betatron oscillation stable oscillations about the equilibrium orbit in the horizontal and vertical planes. First studied in betatron oscillators, betatron oscillation is the transverse oscillation of particles in a circular accelerator about the equilibrium orbit. The restoring force for the oscillation is provided by focusing components in the magnetic field that act to bend a particle that is off the equilibrium orbit back toward it.

Beverage antenna simple traveling wave antenna consisting of an electrically long horizontal wire above ground with a termination resistance between the end of the wire and ground equal to the characteristic impedance of the wire/ground transmission line.

Bezout identity of 2-D polynomial matrices a systems identity defined as follows: let $N_R(z_1, z_2)$, $D_R(z_1, z_2)$ ($N_L(z_1, z_2)$, $D_L(z_1, z_2)$) be two right (left) coprime polynomial matrices, then there exists a polynomial matrix in z_2, say $E_R(z_2)$, ($E_L(z_2)$) and two polynomial matrices $X_R(z_1, z_2)$, $Y_R(z_1, z_2)$ ($X_L(z_1, z_2)$, $Y_L(z_1, z_2)$) such that

$$\begin{aligned} &X_R(z_1, z_2)\, D_R(z_1, z_2) \\ &\quad + Y_R(z_1, z_2)\, N_R(z_1, z_2) = E_R(z_2) \\ &(N_L(z_1, z_2)\, Y_L(z_1, z_2) \\ &\quad + D_L(z_1, z_2)\, X_L(z_1, z_2) = E_L(z_2)) \end{aligned}$$

BGA *See* ball grid array.

BI *See* bandwidth improvement.

bi-anisotropic media (1) a class of material in which the electric and magnetic flux densities, **D** and **B**, are each linearly related to both the electric and magnetic field intensities, **E** and **H**, via dyadic constitutive parameters. The permittivity, permeability, and magnetoelectric coupling parameters are tensor quantities.

(2) media for which the electric and magnetic fields displacements, **D** and **B** respectively, are related to the electric and magnetic field strength **E** and **H** by general dyadics.

bi-isotropic media media for which the electric and magnetic fields displacements, **D** and **B**, respectively, are scalarly dependent by both the electric and magnetic field strength **E** and **H**. For these media the constitutive relations are

$$\begin{aligned} \mathbf{D} &= \epsilon\mathbf{E} + (\chi - j\kappa)\sqrt{\mu_0\epsilon_0}\,\mathbf{H} \\ \mathbf{B} &= \epsilon\mathbf{H} + (\chi + j\kappa)\sqrt{\mu_0\epsilon_0}\,\mathbf{E} \end{aligned}$$

where ϵ is the permittivity, μ the permeability, and the subscript 0 refers to free-space. Bi-isotropic media can be reciprocal ($\chi = 0$) or nonreciprocal ($\chi \neq 0$); nonchiral ($\kappa = 0$) or chiral ($\kappa \neq 0$).

bi-stable pertaining to a device with two stable states, e.g., bi-stable multivibrator; circuit that has two possible output states and that will remain in its current state without requiring external inputs; a flip-flop.

bi-stable device *See* flip-flop.

bias the systematic (as opposed to random) error of an estimator.

bias current the arithmetic average of the currents that flow in the input leads of an op-amp.

bias lighting technique used in video tubes to correct for undesirable artifacts such as lag. Applying a uniform light source to the surface of the tube (the photoconductive layer) will create a bias current in the tube, thereby minimizing the undesirable characteristics.

bias network a key aspect of microwave circuit design is to apply the proper DC bias to the appropriate terminals of transistors (e.g., FETs) without disturbing the AC microwave operation of the circuit. In some cases, "on-chip" DC circuitry needs to be designed so as to provide stable bias voltage/current conditions for the device even when the chip DC supply voltages vary (due to weakening batteries, etc.). The other aspect of bias network design is to isolate the DC network from interfering with the AC or RF/microwave operation of the circuit, and vice-versa. In a lumped element design, this is generally accomplished by a combination of spiral inductors and MIM capacitors.

bias voltage or current the DC power applied to a transistor allowing it to operate as an active amplifying or signal generating device. Typical voltage levels in GaAs FETs used in receivers are 1 to 7 volts between the drain and source terminals, and 0 to -5 volts on, or between, the gate and source terminals. For microwave systems, DC voltages and currents, provided by batteries or AC/DC converters required to "bias" transistors to a region of operation where they will either amplify, mix or frequency translate, or generate (oscillators) microwave energy. Since energy can be neither created nor destroyed, microwave energy amplification or creation is accomplished at the expense of DC energy.

biasing the technique of applying a direct-current voltage to a transistor or an active network to establish the desired operating point.

bible nickname for the National Electrical Code.

BIBO stability *See* bounded-input bounded-output stability.

BIBO stability of 2-D linear system a system described by the equation

$$y_{i,j} = \sum_{k=0}^{i} \sum_{l=0}^{j} g_{i-k,j-l} u_{k,l}$$

$i, j \in Z_+$ (the set of nonnegative integers) is said to be bounded-input bounded-output (BIBO) stable if for every constant $M > 0$ there exist a constant $N > 0$ such that if $\|u_{k,l}\| \leq M$ for all $k, l \in Z_+$, then $\|y_{i,j}\| \leq N$ for all $i, j \in Z_+$ where $u_{k,l} \in R^m$ is the input, $y_{i,j} \in R^p$ is the output, $g_{i,j} \in R^{p\times m}$ is the matrix impulse response of the system and $\|v\|$ denotes a norm of the vector v. The system is BIBO stable if and only if

$$\sum_{i=0}^{\infty} \sum_{j=0}^{\infty} \|g_{i,j}\| < \infty$$

BIBS *See* bounded-input bounded-state stability.

BiCMOS integrated circuit technology/process that incorporates bipolar and complementary metal oxide semiconductor devices on the same die.

bicycle a chain-driven drill for boring holes.

bidirectional bus a bus that may carry information in either direction but not in both simultaneously.

bi-directional laser a ring laser with both clockwise and counter-clockwise circulating waves. Useful as a rotation rate sensor.

bidirectional pattern a microphone pickup pattern resembling a figure eight, in which the device is most sensitive to sounds on either side of the pickup element.

bi-directional resonator a standing-wave resonator or a ring-resonator in which the electromagnetic waves circulate in both the clockwise and counter-clockwise directions.

bidirectional transducer a surface acoustic wave (SAW) transducer which launches energy from both acoustic ports which are located at either end of the transducer structure.

bidirectional transmission distribution function (BTDF) the optical scattering function for transmissive optics. The scattering function vs. angle is normalized to signal at zero degrees and with respect to solid angle of detector, including obliquity factor.

bifilar winding a two-wire winding. It is often utilized in stepper motors to permit a unipolar power supply to produce alternating magnetic poles by energizing only half of the bifilar winding at any one time.

bifurcation a term from Chaos Theory referring to a sudden change in the qualitative behavior of the solutions.

bifurcation diagram a diagram where the sampled variable is plotted versus a parameter. The sampling period is equal to the source period. Similar to a Poincare map.

big endian a storage scheme in which the most significant unit of data or an address is stored at the lowest memory address. For example, in a 32-bit, or four-byte word in memory, the most significant byte would be assigned address i, and the subsequent bytes would be assigned the addresses: $i+1$, $i+2$, and $i+3$. Thus, the least significant byte would have the highest address of $i+3$ in a computer implementing the big endian address assignment. "Big endian" computers include IBM 360, MIPS R2000, Motorola M68000, SPARC, and their successors.

The little endian approach stores the least significant unit at the lowest address. (The terms big endian and little endian are taken from Jonathan Swift's satirical story, *Gulliver's Travels.*

See also little endian.

BIL *See* basic lightning impulse level and basic impulse insulation level.

bilateral Laplace transform a Laplace transform of the form

$$\mathcal{L}\{f\} = \int_{-\infty} +\infty f(t)e^{-st}dt,$$

where s is a complex number. *See* Laplace transform.

bilateral Z-transform a Z-transform of the form

$$\mathcal{Z}x = \sum_{n=-\infty}^{+\infty} x[n]z^{-n}.$$

bilinear control systems a class of nonlinear control system models that are linear in state, output and control variables treated separately but they contain the products of those variables. Such models arose naturally in modeling the number of chemical processes where the controls are flow rates that appear in the system equations as products with state variables. The bilinear control systems may also be used to model population dynamics perturbed by control actions which enter growth equations as multipliers of state variables. Bilinear control systems can arise also in connection with adaptive control nominally linear systems where uncertain parameters regarded as additional state variables leads to bilinear terms in model equations. Bilinear time-continuous control systems may be represented by the state equations having the form

$$\dot{x} = Ax + Bu + \sum_{i=1}^{m} D_i u_i x$$

where x is the state vector, u the control vector with components $u_i, i = 1, 2, \ldots, m$, A, B, D_i are matrices of the appropriate dimensions. *See also* population dynamics.

bilinear interpolation interpolation of a value in 2-D space from four surrounding values by fitting a hyperbolic paraboloid. The value at (x, y), denoted $f(x, y)$ is interpolated using $f(x, y) = ax + by + cxy + d$, where a, b, c and d are obtained by substituting the four surrounding locations and values into the same formula and solving the system of four simultaneous equations so formed.

bilinear transformation (1) conformal mapping of the complex plane of the form $f(z) = \frac{az+b}{cz+d}$, where the real values a, b, c, d satisfy $ad - bc \neq 0$. Also called linear fractional transformation or Möbius transformation.

(2) a special case of (1) is a mapping from the $j\omega$ axis in the s-plane to the unit circle $|z| = 1$ in the z- plane, given by $x = \frac{2}{T}\frac{1-z^{-1}}{1+z^{-1}}$, where T is the time interval between samples.

Such bilinear transformations are used in the design of recursive digital filters from equivalent analogue filters in the following procedure:

1. define characteristic digital frequencies Ω_i.

2. prewarp these to analog frequencies ω_i using $\omega_i = \frac{2}{T} \tan \frac{\Omega_i T}{2} \quad 1 \leq i \leq k$.

3. design a suitable analog filter with frequencies ω_i.

4. use the bilinear transformation to replace s in the analog filter with $s = \frac{2}{T}\frac{1-z^{-1}}{1+z^{-1}}$.

bimetal overload device an overload device that employs a bimetal strip as the actuating element. The bimetal strip consists of two metals bonded together. When heated, the bimetal strip will bend due to the different coefficients of linear expansion of the two metals. The bending operates a set of contacts that automatically removes the affected load from the source of electrical power. *See also* overload heater, overload relay.

bimodal histogram a histogram with two main groupings of values, such as the sum of two displaced Gaussians. *See also* histogram.

binary (1) a signal or other information item that has two possible states.

(2) representation of quantities in base 2.

binary code a code, usually for error control, in which the fundamental information symbols which the codewords consist of are two-valued or binary and these symbols are usually denoted by either "1" or "0," Mathematical operations for such codes are defined over the finite or Galois field consisting of two elements denoted by GF(2). The mathematical operations for such a Galois field are addition and multiplication. For addition over GF(2) one finds that

$$1 + 1 = 0,\ 1 + 0 = 1 \text{ and } 0 + 0 = 0.$$

For multiplication over GF(2) one finds that

$$1 \cdot 1 = 1,\ 1 \cdot 0 = 0 \text{ and } 0 \cdot 0 = 0.$$

See also block coding, convolutional coding, error control coding.

binary-coded decimal (BCD) (1) a weighted code using patterns of four bits to represent each decimal position of a number.

(2) decimal digits 0 to 9, encoded by their four-bit binary representation. Thus: 0 = 0000, 1 = 0001, 2 = 0010, 3 = 0011, 4 = 0100, 5 = 0101, 6 = 0110, 7 = 0111, 8 = 1000, 9 = 1001.

binary erase channel a channel where an error detecting circuit is used and the erroneous data is rejected as erasure asking for retransmission. The inputs are binary and the outputs are ternary, i.e., 0, 1 and erasure. Used for ARQ (automatic request for retransmission) type data communication.

binary hypothesis testing a special two-hypothesis case of the M-ary hypothesis testing problem. The problem is to assess the relative likelihoods of two hypotheses H_1, H_2, normally given prior statistics $P(H_1)$, $P(H_2)$, and given observations $\boldsymbol{y}$ whose dependence $p(\boldsymbol{y}|H_1)$, $p(\boldsymbol{y}|H_2)$ on the hypotheses is known. The receiver operating characteristic is an effective means to visualize the possible decision rules. *See also* m-ary hypothesis testing. *See also* conditional statistic, prior statistics, posterior statistics.

binary image an image whose pixels can have only two values, 0 or 1 (i.e., "off" or "on"). The set of pixels having value 1 ("on") is called the *figure* or foreground, while the set of pixels having value 0 ("off") is called the background.

binary image coding compression of two-level (black/white) images, typically documents. Bilevel coding is usually lossless and exploits spatial homogeneity by run-length, relative address, quadtree, or chain coding. Also called bilevel image coding.

binary notation *See* binary.

binary operator any mathematical operator that requires two data elements with which to perform the operation. Addition and Logical-AND are examples of binary operators; in contrast, negative signs and Logical-NOT are examples of unary operators.

binary optics optical filters constructed with only two amplitude or two phase values to perform the functions of bulk optical components such as lenses.

binary phase frequency modulation converting signals from a binary-digit pattern [pulse form] to a continuous wave form. FM is superseded by MFM (modified frequency modulation) is an encoding method used in floppy disk drives and older hard drives. A competing scheme, known as RLL (run length limited), produces faster data access speeds and can increase a disk's storage capacity by up to 50 percent. MFM is superseded by RLL, which is used on most newer hard drives.

binary phase grating a diffraction grating where alternating grating lines that alter the optical phase by 180° more than neighboring lines.

binary signal a signal that can only have two values: off and on, low and high, or zero and one.

binary symmetric channel the binary-input, binary-output symmetric channel, where the channel noise and other disturbances cause statistically independent errors in the transmitted binary sequence with average probability. The channel is memoryless.

binary tree recursively defined as a set of nodes $(n_1, \ldots n_k)$ one of which is designated the root and the remaining $k - 1$ nodes form at most two sub-trees.

binary tree predictive coding predictive image coding scheme in which pixels are ordered in a pyramid of increasingly dense meshes. The sparsest mesh consists of subsamples of the original image on a widely spaced square lattice; succeeding meshes consist of the pixels at the centers of the squares (or diamonds) formed by all preceding meshes. Each mesh has twice the number of pixels as its predecessor. Pixel values are predicted by non-linear adaptive interpolation from surrounding points in preceding meshes. The prediction errors, or differences, are quantized, ordered into a binary tree to provide efficient coding of zeros, and are then entropy coded.

binaural attribute psychoacoustic effects (e.g., cocktail-party effect) that depend on the fact that we have two ears.

binocular imaging the formation of two images of a scene from two different positions so that binocular vision can be performed, in a similar manner to the way humans deploy two eyes.

binocular vision the use of two images of a scene, taken (often simultaneously) from two different positions, to estimate depth of various *point features*, once correspondences between pairs of image features have been established.

binomial coefficients the coefficients of the polynomial resulting from the expansion of $(a+b)^n$. These coefficients are equal to

$$\binom{n}{k} = \frac{n!}{k!(n-k)!},$$

where n is the order of the polynomial and k is the index of the coefficient. The kth coefficient is multiplied by the term $a^k b^{n-k}$.

binomial distribution the binomial distribution is the distribution of a random variable Y that is the sum of n random variables that are *Bernoulli distributed*.

$$Y = X_1 + X_2 + \cdots + X_n.$$

The probability mass function of such a Y is

$$p_Y(k) = \binom{n}{k} p^k (1-p)^{n-k},$$

where p is the parameter of the Bernoulli distribution of any X_i.

bioanalytical sensor a special case of a chemical sensor for determining the amount of a biochemical substance. This type of sensor usually makes use of one of the following types of biochemical reactions: enzyme-substrate, antigen-antibody, or ligand-receptor.

bioluminescence *See* luminescence.

biomass General term used for wood, wood wastes, sewage, cultivated herbaceous and other energy crops, and animal wastes.

biomedical sensor a device for interfacing an instrumentation system with a biological system such as biological specimen or an entire organism. The device serves the function of detecting and measuring in a quantitative fashion a physiological property of the biological system.

biometric verifier device that helps authenticate by measuring human characteristics.

biorthogonal filter bank a filter bank that satisfies the perfect reconstruction condition, i.e., the product of the polyphase transfer function of the analysis and synthesis filters is a pure delay. In general, the analysis and synthesis filters are different, as opposed to the situation for an orthogonal filter bank.

biorthogonal wavelet a generalization of orthogonal wavelet bases, where two dual basis functions span two sets of scaling spaces, V_j and $\hat{V}_j$, and two sets of wavelet spaces, W_j and $\hat{W}_j$, with each scaling space orthogonal to the dual wavelet space, *i.e.,* $V_j \perp \hat{W}_j$ and $\hat{V}_j \perp W_j$. *See also* biorthogonal filter bank.

BIOS *See* basic input–output system.

bipolar (1) a type of transistor that uses both polarities of carriers (electrons and holes) in its operation as a junction transistor.

(2) a type of data encoding that uses both positive and negative voltage excursions.

bipolar device *See* bipolar.

bipolar junction transistor (BJT) a three-terminal nonlinear device composed of two bipolar junctions (collector-base, base-emitter) in close proximity. In normal operation, the voltage between base and emitter terminals is used to control the emitter current. The collector current either equals this (with BC junction in reverse bias), or goes into saturation (the BC junction goes into forward bias). Used for medium power (700 A) and medium speed (10 kHz) applications.

In power electronics applications, BJTs are typically operated as switches, in either their fully on or off states, to minimize losses. The base current flowing into the middle of the device controls the on–off state, where continuous base current is required to be in the on state. A disadvantage is the low current gain.

The base current is generally much smaller than collector and emitter currents, but not negligible as in MOSFETs.

bipolar memory memory in which a storage cell is constructed from bipolar junction transistors. *See also* static random access memory (SRAM).

bipolar neuron a neuron with a signal between -1 and $+1$.

bipolar transistor *See* bipolar junction transistor.

bipole DC system with two conductors, one positive and the other negative polarity. The rated voltage of a bipole is expressed as ± 100 kV, for example.

biquad an active filter whose transfer function comprises a ratio of second-order numerator and denominator polynomials in the frequency variable.

biquadratic transfer function a rational function that comprises a ratio of second-order numerator and denominator polynomials in the frequency variable.

bird's beak feature seen in cross-sectional photomicrographs of silicon gate transistors caused by encroachment of oxide under the gate.

birefringence The property of certain materials to display different values of the refractive index for different polarizations of a light beam.

birefringent fiber optical fiber that has different speeds of propagation for light launched along its (two distinct) polarization axes.

birefringent material material that can be described by two or more refractive indices along the directions for principle axes.

birthmark a stamp on a wooden utility pole which denotes its manufacturer, date of manufacture, size, and method of preservation.

bispectra computation of the frequency distribution of the EEG exhibiting nonlinear behavior.

bispectrum the Fourier transform of the triple correlation function. It preserves phase information and uniquely represents a given process in the frequency domain. It can be used to identify different types of nonlinear system response.

BIST *See* built-in self-test.

bistable pertaining to a device with two stable states. Examples: bistable multivibrator, flip-flop. *See also* bistable system.

bistable device *See* bistable.

bistable optical device a device whose optical transmission can take on two possible values.

bistable system an optical system where the transmission can take on two possible values. *See also* bistable.

bistatic scattering a measure of the reradiated power (back-scattered) from an illuminated target in the direction other than that of the illuminating source.

bit (1) the fundamental unit of information representation in a computer, short for "binary digit" and with two values usually represented by "0" and "1." Bits are usually aggregated into "bytes" (7 or 8 bits) or "words" (12–60 bits).

A single bit within a word may represent the coefficient of a power of 2 (in numbers), a logical TRUE/FALSE quantity (masks and Boolean quantities), or part of a character or other compound quantity. In practice, these uses are often confused and interchanged.

(2) in Information Theory, the unit of information. If an event E occurs with a probability $P(E)$, it conveys information of $\log_2(1/P(E))$ binary units or bits. When a bit (binary digit) has equiprobable 0 and

1 values, it conveys exactly 1.0 bit (binary unit) of information; the average information is usually less than this.

bit allocation the allocation of bits to symbols with the aim of achieving some compression of the data. Not all symbols occur with the same frequency. Bit allocation attempts to represent frequently occurring symbols with fewer bits and assign more bits to symbols that rarely appear, subject to a constraint on the total number of bits available. In this way, the average string requires fewer bits. The chosen assignment of bits is usually the one that minimizes the corresponding average coding distortion of the source over all possible bit assignments that satisfy the given constraint. Typically sub-sources with larger variances or energy are allocated more bits, corresponding to their greater importance. *See also* transform coding.

bit energy the energy contained in an information-bearing signal received at a communications receiver per information bit. The power of an information bearing signal at a communications receiver divided by the information bit rate of the signal. Usually denoted by E_b as in the signal to noise ratio E_b/N_0.

bit error rate (BER) the probability of a single transmitted bit being incorrectly determined upon reception.

bit line used in, for example, RAM memory devices (dynamic and static) to connect all memory cell outputs of one column together using a shared signal line. In static RAM, the "bit" line together with its complemented signal "-bit" feeds a "sense amplifier" (differential in this case) at the bottom of the column serving as a driver to the output stage. The actual cell driving the bit line (and -bit) is controlled via an access transistor in each cell. This transistor is turned on/off by a "word" line, a signal run across the cells in each row.

bit parallel a method to transmit or process information in which several bits are transmitted in parallel. Examples: a bit parallel adder with 4-bit data has 8 input ports for them (plus an initial carry bit); an 8-bit parallel port includes true 8-bit bi-directional data lines.

bit per second (bps) measure of transfer rate of a modem or a bus or any digital communication support. (*See also* baud and baud rate. bps and baud are not equivalent since bps is a low-level measure and media; thus, it includes the number of bits sent for the low-level protocol, while baud is typically referred to a higher level of transmission).

bit period the time between successive bits in data transmission or data recording. At the transmitter (or recorder) the timing is established by a clock. At the receiver (or reader) an equivalent clock must be recovered from the bit stream.

bit plane the binary $N \times N$ image formed by selecting the same bit position of the pixels when the pixels of an $N \times N$ image are represented using k bits.

bit plane encoding lossless binary encoding of the bit planes is termed bit plane encoding. The image is decomposed into a set of k, $N \times N$ bit planes from the least significant bit to $k-1$ most significant bits and then encoded for image compression.

bit rate (1) a measure of signaling speed; the number of bits transmitted per second. Bit rate and baud are related but not identical. Bit rate is equal to baud times the number of bits used to represent a line state. For example, if there are sixteen line states, each line state encodes four bits, and the bit rate is thus four times the baud. *See also* baud.

(2) the number of bits that can be transmitted per unit time.

bit serial processing of one bit per clock cycle. If word length is W, then one sample or word is processed in W clock cycles. In contrast, all W bits of a word are processed in the same clock cycle in a bit-parallel system.

For example: a bit serial adder with 4-bit data has one input signal for each of data them, one bit for carry-in, and two 4-bit shift registers for data.

bit-line capacitance the equivalent capacitance experienced in each "bit line" in a RAM or ROM device. *See also* bit line.

bit-oriented block transfer (bitBLT) a type of processing used mainly for video information characterized by minimal operations performed on large data blocks; a processor designed for such operations. bitBLT operations include transfers, masking, exclusive-OR, and similar logical functions.

bit-serial system a system that uses bit serial data transfer.

bit-slice processor a processor organization that performs separate computations (via multiple processing units) separately upon subsections of an incoming channel.

bitBLT *See* bit-oriented block transfer.

bitmapped image a digital image composed of pixels. Bitmapped images are resolution-dependent, i.e., if the image is stretched, the resolution changes. Also called a raster image. *See also* image, pixel, vector image.

bits per pixel the number of bits used to represent each pixel in a digital image. Typical grayscale images have 8 bits per pixel, giving 256 different gray levels. True color images have 24 bits per pixel, or 8 bits for each of the red, green, and blue pixels. Compressed image sizes are often represented in bits per pixel, i.e., the total number of bits used to represent the compressed image divided by the total number of pixels.

BJT *See* bipolar junction transistor.

black burst a TV black video signal containing horizontal and vertical sync, color burst, and setup (i.e., a composite video black signal). Black burst is also called "color black." A black burst signal is often used in the video studio to provide synchronizing pulses.

black level the portion of the video signal pertaining to the lower luminance (brightness) levels.

black start the task of re-starting an isolated power system which is completely de-energized. Most generating plants require substantial external electric power to start. Thus a black start may be initiated by hand-starting gas turbine generators or by opening the gates of a hydroelectric generator somewhere in the system.

blackbody theoretically contrived object that gives rise to the so-called "black body radiation." One might imagine a closed surface object (say of metal) possessing one opening that connects the interior surface with the outside world. When the object is heated, the opening becomes a perfect "black" radiator. Such radiation depends on temperature only.

blackout total loss of power to the entire power system.

blanket an insulating rubber mat which is fitted temporarily over energized conductors to protect nearby workers.

blanking the electronic control circuitry that blanks the television raster during horizontal and vertical retrace.

blanking time the short time interval when both switches in a leg of an inverter bridge must be off in order to prevent short circuiting the DC input. This is necessary because non-ideal switches cannot turn on and off instantaneously. Thus, after one switch is turned off in an inverter leg, the complimentary switch is not turned on until the designated blanking time has elapsed.

blind deconvolution the recovery of a signal $x[n]$ from $y[n]$ — the convolution of the signal with an unknown system $h[n]$:

$$y[n] = h[n] * x[n].$$

Occasionally, some knowledge of $h[n]$ is available (e.g., that it is a high-pass or low-pass filter). Frequently, detailed knowledge is available about the structure of x. *See also* convolution.

blind via a via connected to either the preliminary side or secondary side and one or more internal layers of a multilayer packaging and interconnecting structure.

blink in computer display systems, a technique in which a pixel is alternatively turned on and off.

Bloch vector a set of linear combinations of density matrix elements, written in vector form, that can often be related to specific observables in a quantum mechanical system. For example, in two-level systems the Bloch vector components are $2Re(\rho_{12})$, $2Im(\rho_{12})$, and $\rho_{11} - \rho_{22}$, which are related to nonlinear refractive index, absorption, and population differences, respectively. The time evolution of two-level systems can be described in terms of rotations of the Bloch vector.

block a group of sequential locations held as one unit in a cache and selected as whole. Also called a line. *See also* memory block.

block cipher an encryption system in which a successive number of fundamental plaintext information symbols, usually termed a block of plaintext information, are encrypted according to the encryption key. All information blocks are encrypted in the same manner according to the transformation determined by the encryption key. This implies that two identical blocks of plaintext information will always result in the same ciphertext when a particular block cipher is employed for encryption. *See also* encryption, stream cipher.

block code a mapping of k input binary symbols into n output symbols.

block coding (1) an error control coding technique in which a number of information symbols, and blocks, are protected against transmission errors by adding additional redundant symbols. The additional symbols are usually calculated according to a mathematical transformation based on the so-called generator polynomial of the code. A block code is typically characterized by the parameters (n, k), where k is the number of information symbols per data word, and n the final number of symbols in the code word after the addition of parity symbols or redundant symbols. The rate of a block code is given by k/n.

Typically, the lower the rate of a code the greater the number of errors detectable and correctable by the code. Block codes in which the block of information symbols and parity symbols are readily discernable, are known as systematic block codes. The receiver uses the parity symbols to determine whether any of the symbols were received in error and either attempts to correct errors or requests a retransmission of the information. *See also* automatic repeat request, binary code, convolutional coding, error control coding.

(2) refers to (channel) coding schemes in which the input stream of information symbols is split into nonoverlapping blocks which then are mapped into blocks of encoded symbols (codewords). The mapping only depends on the current message block. *Compare with* trellis coding.

block diagram a diagrammatic representation of system components and their interconnections. In elementary linear systems, the blocks are often defined by transfer functions or state space equations while the interconnecting signals are given as Laplace transformations. Although the system blocks and signals have the same mathematical form, the blocks represent operators that act on the incoming signals while the signals represent functions of time.

block matching the process of finding the closest match between a block of samples in a signal and a block of equal size in another signal (or a different part of the same signal) over a certain search range. Closeness is measured by correlation or an error metric such as mean square error. Used in data compression, motion estimation, vector quantization, and template matching schemes.

block multiplexer channel an I/O channel can be assigned to more than one data transfer at a time. It always transfers information in blocks, with the channel released for competing transfers at the end of a block. *See also* byte multiplexer channel, selector channel.

block transfer the transmission of a significantly larger quantity of data than the minimum size an interconnect is capable of transmitting, without sending the data as a number of small independent transmissions (the goal being to reduce arbitration and address overhead).

block transform a transform that divides the image into several blocks and treats each block as an independent image. The transform is then applied to each block independently. This occurs in the JPEG standard image compression algorithm, where an image is divided into 8×8 blocks and the DCT is applied independently to each block. Usually the blocks do not overlap each other, that is, they have no signal samples in common. *See also* transform coding, lapped orthogonal transform.

block truncation coding (BTC) technique whereby an image is segmented into $n \times n$ nonoverlaping blocks of pixels, and a two-level quantizer is designed for each block. Encoding is essentially a local binarization process consisting of a $n \times n$ bit map indicating the reconstruction level associated with each pixel. Decoding is a simple process of associating the reconstructed value at each pixel as per the bit map.

block carry lookahead adder (BCLA) an adder that uses two levels of carry lookahead logic.

block-diagram simulator a simulator that allows the user to simulate systems as a combination of block diagrams, each of which performs a specific function. Each function is described using a mathematical equation or a transfer function.

blocked state *See* blocking.

blocked-rotor current *See* locked-rotor current.

blocked-rotor test an induction motor test conducted with the shaft held so it cannot rotate. Typically about 25% of rated voltage is applied, often at reduced frequency and the current is measured. The results are used to determine the winding impedances referred to the stator.

blocking state entered if a new user finds all channels or access mechanisms busy and hence is denied service. Generally accompanied by a busy signal. The call blocking probability may be given by the Erlang B or Erlang C formula. *See also* adequate service, multiple access interference (MAI).

blocking artifact the visibility in an image of rectangular subimages or blocks after certain types of image processing. Also called blocking effect distortion.

blocks world a visual domain, typical of early studies on machine vision, in which objects are light, plane-faced solids over a dark background.

blooming an area of the target that is unstable due to insufficient beam current. The area normally appears as a white puddle without definition. Insufficient beam currently may be the result of low beam control setting.

blow up a relatively sudden and usually catastrophic increase in beam size generally caused by some magnetic field error driving the beam to resonance.

Blumlein a water-filled transmission line that serves as a pulse generator using a wave propagation principle. The line is folded over on itself and is capable of voltage doubling across its load due to having initially both sides of the load on high potential.

Blumlein bridge an AC bridge, two arms of which are two serially connected tightly coupled inductive coils. The point of connection of these coils is usually grounded, and the coupling is arranged in such a way that for the currents simultaneously entering or leaving the other ends of the coils the voltage drop between the ends is close to zero. If one of the currents is entering and another is leaving, then the voltage drop is essential. This creates a sensitive current-comparing bridge having application in capacitance transducers.

blurring (1) the defocusing effect produced by the attenuation of high-frequency components, e.g., obtained by local averaging operators, possibly applied directionally (motion blurring).

(2) the broadening of image features, relative to those which would be seen in an ideal image, so that features partly merge into one another, thereby reducing resolution. The effect also applies to 1-D and other types of signal.

BNC connector "Baby" N connector. Commonly used coaxial connector with both male and female versions used below microwave frequencies.

board the physical structure that houses multiple chips, and connects them with traces (busses).

board-to-board optical interconnect optical interconnection in which the source and the detector are connected to electronic elements in two separate boards.

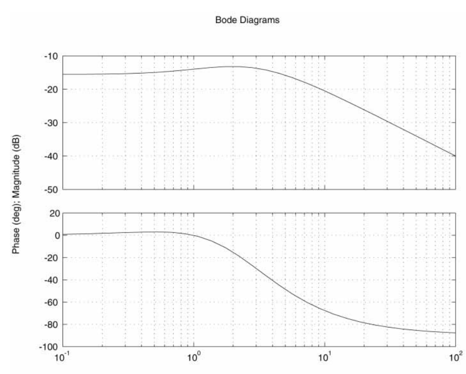
BOB *See* break-out box.

Bode diagram *See* Bode plot.

Bode plot a graphical characterization of the system frequency response: the magnitude of the frequency response $|H(j\omega)|, -\infty < \omega < \infty$ in decibels, and the phase angle $\angle H(j\omega), -\infty < \omega < \infty$, are plotted. For example, a system described by the transfer function

$$H(s) = \frac{Y(s)}{F(s)} = \frac{s+1}{(s+2)(s+3)}$$

has the Bode plot shown in the following figure. *See also* frequency response.



Bode plot.

Bode–Fano criteria a set of rules for determining an upper limit on the bandwidth of an arbitrary matching network.

boiler a steam generator that converts the chemical energy stored in the fuel (coal, gas, etc.) to thermal energy by burning. The heat evaporates the feedwater and generates high-pressure steam.

boiling water reactor a nuclear reactor from which heat is transferred in the form of high-pressure steam.

bolted fault a bolted fault is a short circuit fault with no fault resistance. Bolted faults deliver the highest possible fault current for a given location and system configuration, and are used in selecting equipment withstand and interrupting ratings and in the setting of protective relays.

Boltzmann machine in its simplest form, a discrete time Hopfield network that employs stochastic neurons and simulated annealing in its procedure for updating output values. More generally it can have hidden units and be subjected to supervised training so as to learn probabilities of different outputs for each class of inputs.

Boltzmann relation relates the density of particles in one region to that in an adjacent region, with the potential energy between both regions.

bond that which binds two atoms together.

bond pad areas of metallization on the IC die that permit the connection of fine wires or circuit elements to the die.

bonded magnet a type of magnet consisting of powdered permanent magnet material, usually isotropic ceramic ferrite or neodymium-iron-boron, and a polymer binder, typically rubber or epoxy, this magnet material can be molded into complex shapes.

bonding the practice of ensuring a low-resistance path between metallic structures such as water lines, building frames, and cable armor for the purpose of preventing lightning arcs between them.

Boolean an operator or an expression of George Boole's algebra (1847). A Boolean variable or signal can assume only two values: TRUE or FALSE. This concept has been ported in the field of electronic circuits by Claude Shannon (1938). He had the idea to use the Boole's algebra for coding the status of circuit: TRUE/FALSE as HIGH/LOW as CLOSE/OPEN, etc.

Boolean algebra the fundamental algebra at the basis of all computer operations. See also the other definitions with Boolean as the first word.

Boolean expression an expression of the Boole's algebra, in which can appear Boolean variables/signals and Boolean operators. Boolean expressions are used for describing the behavior of digital equipments or stating properties/conditions in programs.

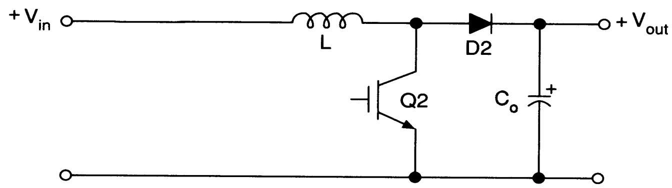
Boolean function common designation for a binary function of binary variables.

Boolean logic the set of rules for logical operations on binary numbers.

Boolean operator the classical Boolean operators are AND, OR, NOT. Other operators such as XOR, NAND, NOR, etc., can be easily obtained based on the fundamental ones. In hardware these are implemented with gates, see for example AND gate.

boost converter a circuit configuration in which a transistor is switched by PWM trigger pulses and a diode provides an inductor-current continuation path when the transistor is off. During the transistor on-time, the current builds up in the inductor. During the transistor off-time, the voltage across the inductor reverses and adds to the input voltage, as a result, the output voltage is greater than the input voltage.

A boost converter can be viewed as a reversed buck converter. The output voltage v_o is related to the input voltage v_i by $v_o = v_i/(1-d)$ and it can be controlled by



Boost converter.

varying the duty ratio d. Its main application is in regulated DC power supplies and the regenerative braking of DC motors. Also called a step-up converter.

boot *See* bootstrap.

boot record structure at the beginning of a hard disk that specifies information needed for the start up and initialization of a computer and its operating system. This record is kept and displayed by the booting program.

bootstrap (1) a technique using positive feedback to change the effective impedance at a node, for example, to reduce capacitance.

(2) to initialize a computer system into a known beginning state by loading the operating system from a disc or other storage to computer's working memory. This is done by a firmware boot program. Also called boot for short.

boson an integral spin particle to which Bose-Einstien statistics apply. Such particles do not follow the Pauli exclusion principle. Photons, pions, alpha particles, and nuclei of even mass numbers are examples of bosons.

bottle slang for glass insulator.

bottom antireflective coating an antireflective coating placed just below the photoresist to reduce reflections from the substrate.

bottom-up development an application development methodology that begins creating basic building blocks and uses them to build more complex blocks for higher levels of the system.

bound mode a type of mode of limited spatial extension. Open waveguides can support, apart for a continuous spectrum, also a few mode, which do not extend up to infinity since they decay exponentially outside of a certain region. In an optical waveguide this is a mode whose field decays monotonically in the direction transverse to propagation and which does not lose power to radiation. Bound modes can also be interpreted in terms of guided rays and total internal reflection. Note: Except in a monomode fiber, the power in bound modes is predominantly contained in the core of the fiber. *See also* continuous spectrum.

boundary a curve that separates two sets of points.

boundary bus one of a set of buses which define the boundary between the portion of a power system to be analyzed and the rest of the system. Boundary buses are connected to both the internal and external systems.

boundary condition (1) the conditions satisfied by a function at the boundary of its interval of definition. They are generally distinguished in hard or soft also called Neumann (the normal derivative of the function is equal to zero) or Dirichlet (the function itself is equal to zero).

(2) the conditions satisfied from the electromagnetic field at the boundary between two different media.

(3) rules that govern the behavior of electromagnetic fields as they move from one medium into another medium.

boundary layer a method of smoothing out a discontinuous controller or a sliding mode state estimator. For example, a boundary layer version of the discontinuous controller

$$u = -Us(e)/|s(e)| = -U\mathrm{sign}(s(e)),$$

where e is the control error and s is a function of e, may have the form

$$u = \begin{cases} -U\mathrm{sign}(s(e)) & \text{if } |s(e)| > \nu \\ -Us(e)/\nu & \text{if } |s(e)| \le \nu, \end{cases}$$

where $\nu > 0$ is called the boundary layer width.

boundary layer controller *See* boundary layer.

boundary layer observer *See* boundary layer state estimator.

boundary layer state estimator a continuous version of a sliding mode type state estimator, that is, a sliding mode type state estimator in which the right-hand side of the differential equation describing the estimator is continuous due to the introduction of a boundary layer to smooth out the discontinuous part of the estimator's dynamics.

boundary scan a technique for applying scan design concepts to control/observe values of the signal pins of IC components by providing a dedicated boundary-scan register cell for each signal I/O pin.

boundary scan interface a serial clocked interface used to shift in test pattern or test instruction and to shift out test responses in the test mode. Boundary scan interface comprises shift-in, shift-out, clock, reset, and test select mode signals.

boundary scan path a technique that uses a standard serial test interface to assure easy access to chip or board test facilities such as test registers (in an external or internal scan paths) or local BIST. In particular it assures complete controllability and observability of all chip pins via shift in and shift out operations.

boundary scan test a technique for applying scan design concepts to control/observe values of signal pins of IC components by providing a dedicated boundary-scan register cell for each signal I/O pin.

boundary value problem a mathematical problem in which the unknown is a solution to a partial differential equation and is subject to a set of boundary conditions on the problem domain.

boundary values of 2-D general model let $x_{i,j}$ be a solution (semistate vector) to the 2-D generalized model

$$\begin{aligned} x_{i+1,j+1} = A_0 x_{i,j} &+ A_1 x_{i+1,j} \\ &+ A_2 x_{i,j+1} + B_0 u_{i,j} \\ &+ B_1 u_{i+1,j} + B_2 u_{i,j+1} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) where $u_{i,j} \in R^m$ is the input and A_k, B_k ($k = 0, 1, 2$) are real matrices of the model. The vectors $x_{i,j} \in R^n$ whose indices lie on the boundary of the rectangle $[0, N_1] \times [0, N_2]$, i.e., $x_{i,0}$, x_{i,N_2} for $1 \le i \le N_1$ and $x_{0,j}$, $x_{N_1,j}$ for $0 \le j \le N_2$, are called boundary values of the solution $x_{i,j}$ to the 2-D general model. The boundary values may be also given in other ways.

boundary-element method (BEM) a numerical method (integral equation technique) well suited to problems involving structures in which the dielectric constant does not vary with space.

bounded control *See* saturating control.

bounded distance decoding decoding of an imperfect t-error correcting forward error correction block code in which the corrected error patterns are limited to those with t or fewer errors, even though it would be possible to correct some patterns with more than t errors.

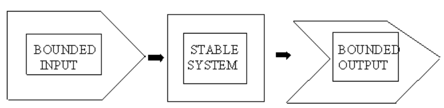
bounded function a function $x \in \mathcal{X}_e$ is said to be bounded if it belongs also to the original (unextended) space $\mathcal{X}$, where $\mathcal{X}$ is a space of functions with its corresponding extension $\mathcal{X}_e$. *See also* extended space and truncation.

bounded state an equilibrium state x_e of a dynamic system is said to be bounded if there exists a real number $B = B(x_0, t_0)$, where x_0 and t_0 represent the initial values of the state and time, respectively, such that

$$\| x(t) \| < B \qquad \forall t \geq t_0$$

See also stable state.

bounded-input bounded-output (BIBO) a signal that has a certain value at a certain instant in time, and this value does not equal infinity at any given instant of time. A bounded output is the signal resulting from applying the bounded-input signal to a stable system. See diagram below.



Bounded-input bounded-output system.

bounded-input bounded-output stability a linear dynamic system where a bounded input yields a bounded zero-state response. More precisely, let be a bounded-input with as the least upper bound (i.e., there is a fixed finite constant such that for every t or k), if there exists a scalar such that for every t (or k), the output satisfies, then the system is said to be bounded-input bounded-output stable.

bounded-input bounded-state (BIBS) stability if for every bounded input (*See* BIBO stability), and for arbitrary initial conditions, there exists a scalar such that the resultant state satisfies, then the system is said to be bounded-input bounded-state stable.

bounds fault an error that holds the mapper whet it detects the offset requested into an object exceeds the object's size.

Boyle macromodel A SPICE computer model for an op amp. Developed by G. R. Boyle in 1974.

Boys camera a rotating camera used to photograph lightning and establish the multiplicity of individual flashes in a lightning stroke.

BPI bits per inch.

bps *See* bit per second.

Bragg angle the required angle of incidence for light into a Bragg cell to produce a single diffraction order of maximum intensity. The sine of the Bragg angle is approximately the light wavelength divided by the grating.

Bragg cell an acousto-optic cell designed where only a single diffraction order is produced, generally by making the acoustic column thick along the light propagation direction.

Bragg cell radiometer similar to an acousto-optic spectrum analyzer in the Bragg mode, but with generally much longer photo-integration times such as via a long integration time photo detector array.

Bragg diffraction the interaction of light with a thick grating or acoustic wave, producing a single diffraction order with maximum intensity.

Bragg diffraction regime regime where the acoustic beam width is sufficiently wide to produce only two diffracted beams, i.e., the undiffracted main beam (also called the zero order or DC beam), and the principal diffracted beam.

Bragg scattering the scattering of light from a periodically varying refractive index variation in a thick medium, so-called by analogy to the Bragg scattering of X-rays from the atomic arrays in a crystal. For instance, an acousto-optic modulator can be said to operate in the Bragg regime or alternatively in the Raman–Nath regime. *See also* Raman–Nath diffraction regime.

braking operating condition in an electric motor in which the torque developed between the stator and rotor coils opposes the direction of rotation of the rotor. Typical braking methods in DC machines include "plugging" in which the polarity of either the field or the armature coil, but not both, is reversed while the rotor is turning, "dynamic braking" in which generator action in the armature is used to dissipate rotor energy through a braking resistor, and "regenerative braking" in which generator action in the rotor is used to dissipate rotor energy by returning electric power to the power source as the rotor slows. Typical braking methods in AC machines include switching of the phase sequence of the supply voltage, dynamic braking through the armature coils, and varying the frequency of the AC supply voltage. *See also* phase sequence.

braking resistor resistive elements which can be switched into the electrical system to create additional load in the event of a transient disturbance, thus limiting the generator rotor acceleration such that the system can more readily return to synchronism.

branch address the address of the instruction to be executed after a branch instruction if the conditions of the branch are satisfied. Also called a branch target address.

branch circuit the three components of an electrical circuit are source, load, and interconnecting circuit conductors. A branch circuit is an electrical circuit designed to deliver power to the lowest-order load(s) served on a facility. It includes the overcurrent device, circuit conductors, and the load itself.

branch current the current in a branch of a circuit.

branch history table a hardware component that holds the branch addresses of previously executed branch instructions. Used to predict the outcome of branch instructions when these instructions are next encountered. Also more accurately called a branch target buffer.

branch instruction an instruction is used to modify the instruction execution sequence of the CPU. The transfer of control to another sequence of instructions may be unconditional or conditional based on the result of a previous instruction. In the latter case, if the condition is not satisfied, the transfer of control will be to the next instruction in sequence. It is equivalent to a jump instruction, although the range of the transfer may be limited in a branch instruction compared to the jump. *See also* jump instruction.

branch line coupler coupler comprised of four transmission lines, each of 90° electrical length, arranged in a cascaded configuration with the end of the last transmission line section connected to the beginning of the first transmission line to form a closed path. The input, coupled, direct, and isolated ports are located at the connection point of one transmission line with the next one.

branch penalty the delay in a pipeline after a branch instruction when instructions in the pipeline must be cleared from the pipeline and other instructions fetched. Occurs because instructions are fetched into the pipeline one after the other and before the outcome of branch instructions are known.

branch prediction a mechanism used to predict the outcome of branch instructions prior to their execution.

branch relation the relationship between voltage and current for electrical components. Common branch relations are Ohm's Law and the lumped equations for capacitors and inductors. More complex branch relationships would be transistor models.

branch target buffer (BTB) a buffer that is used to hold the history of previous branch paths taken during the execution of individual branch instructions. The BTB is used to improve prediction of the correct branch path whenever a branch instruction is encountered.

The *branch target buffer* or *branch target cache* contains the address of each recent branch instruction (or the instructions themselves), the address of the branch "target" and a record of recent branch directions. The Pentium BTB is organized as an associative cache memory, with the address of the branch instruction as a tag; it stores the most recent destination address plus a two-bit history field representing the recent history of the instruction.

branch target cache *See* branch target buffer.

branch voltage the voltage across a branch of a circuit.

Branly, Edouard Eugene (1844–1940) Born: Amiens, France

Branly is best known for his work in wireless telegraphy. Branly invented the coherer, a detection device for radio waves. Branly did much theoretical work in electrostatics, electrodynamics, and magnetism. He did not, however, develop the practical side of his work, hence Marconi and Braun received the Nobel Prize for work Branly had pioneered.

Brattain, Walter (1902–1987) Born: Amoy, China.

Brattain is best known as one of the developers of the transistor. In 1956 Brattain, along with John Bardeen and William Shockley, received the Nobel Prize for their development of the point-contact transistor. It was Brattain who, along with Bardeen, observed the significant increase in power output from a metal contact resulting from a small increase in current applied through a second contact attached to the same germanium surface. This research led to the development of integrated circuits.

Braun, Karl Ferdinand (1850–1918) Born: Fulda, Germany

Braun is best known for his invention of the oscilloscope and for improvements to Marconi's telegraph. Braun was to share the Nobel Prize in Physics with Marconi in 1909. Braun held a number of teaching posts throughout Germany. His research resulted in the principle of magnetic coupling, which allowed significant improvements in radio transmission. He discovered crystal rectifiers, which were a significant component in early radio sets.

breadboard a preliminary, experimental circuit, board, device or group of them. It is built only to investigate, test, analyze, evaluate, validate, determine feasibility, develop technical data, and to demonstrate the technical principles related to a concept, device, circuit, equipment, or system. It is designed in a rough experimental form, only for laboratory use, and without regard to final physical appearance of a product.

breadth-first search a search strategy for tree or trellis search where processing is performed breadth first, i.e., the processing for the entire breadth of the tree/trellis is completed before starting the processing for the next step forward.

break frequency the critical frequency in a frequency - dependent response: especially that frequency which may separate two modes of the response, e.g. the frequency that defines where the low frequency region ends and the midband response begins.

break point *See* breakpoint.

break-out box (BOB) a testing device that allows the designer to switch, cross, and tie interface leads. It often has LEDs to permit monitoring of the leads. Typical use is for RS-232 interfaces.

breakaway points of the root loci breakaway points on the root loci correspond to multiple-order roots of the equation.

breakaway torque minimum torque needed to begin rotating a stationary load. Breakaway torque represents the absolute minimum starting torque specification for a motor used to drive the load.

breakdown as applied to insulation (including air), the failure of an insulator or insulating region to prevent conduction, typically because of high voltage.

breakdown strength voltage gradient at which the molecules of medium break down to allow passage of damaging levels of electric current.

breakdown torque maximum torque that can be developed by a motor operating at rated voltage and frequency without experiencing a significant and abrupt change in speed. Sometimes also called the stall torque or pull-out torque.

breakdown voltage the reverse biased voltage across a device at which the current begins to dramatically deviate and increase relative to the current previously observed at lower voltages close to the breakdown voltage. This effect is attributed to avalanche or zener breakdown. It is usually specified at a predetermined value of current.

In a diode, applying a voltage greater than the breakdown voltage causes the diode to operate in the reverse breakdown region.

breakpoint (1) an instruction address at which a debugger is instructed to suspend the execution of a program.

(2) a critical point in a program, at which execution can be conditionally stopped to allow examination if the program variables contain the correct values and/or other manipulation of data. Breakpoint techniques are often used in modern debuggers, which provide nice user interfaces to deal with them. *See also* breakpoint instruction.

breakpoint instruction a debugging instruction provided through hardware support in most microprocessors. When a program hits a break point, specified actions occur that save the state of the program, and then switch to another program that allows the user to examine the stored state. The user can suspend the execution of a program, examine the registers, stack, and memory, and then resume the program's execution, which is very helpful in a program's debugging.

breath noise the noise that is commonly produced when talking at the microphone. It is due to breathing.

breeder reactor a nuclear reactor in which a non-fissile isotopes are converted to fissile isotopes by irradiation. Ideally, such a reactor produces more fissile products than it consumes.

Bremsstrahlung electromagnetic radiation, usually in the X-ray region of the spectrum produced by electrons in a collision with the nucleus of an atom. Bremsstrahlung radiation is produced in regions of high electric potential such as areas surrounding electrostatic septa and RF cavities. Bremsstrahlung is German for breaking.

Brewster angle the angle from normal at which there is no reflection at a planar interface between two media. The Brewster angles for perpendicular and parallel polarizations are different. For nonmagnetic media, in which the relative permeability is unity, the Brewster angle for perpendicular polarization does not exist.

Brewster mode a bound radiative surface mode when one of the media is a plasma medium and has a positive dielectric function.

Brewster window transmission window oriented at Brewster's angle with respect to an incident light beam; light polarized in the plane of incident experiences no reflection.

bridge a simple device that connects two or more physical local-area networks (LANs). It forwards packets of data from one LAN segment to another without changing it, and the transfer is based on physical addresses only. The separate LAN segments bridged this way must use the same protocol.

bridge balance condition represents the relationship between bridge circuit components when the current in the balance indicator is absent. Most of the technically useful bridges include a regular connection (series, parallel, series-parallel, or parallel-series) of two two-ports. The condition of balance can be reformulated in terms of two-port parameters, so that depending on structure, the sum of two forward transfer parameters or the sum of one forward and another backward transfer parameter is equal to zero.

bridge calibration used in bridge transducer applications. It is achieved connecting two auxiliary circuits to the bridge. One circuit including two resistors and a potentiometer is connected in parallel to the bridge power supply diagonal, and the potentiometer tap and one end of detector are connected to the same bridge node. Sliding the tap, one can eliminate the bridge offset. Another circuit, usually including a constant and a variable resistor, is connected in series with power supply. This circuit allows one to change the voltage applied to the bridge, and to establish the correspondence between the maximal deflection of the detector and maximum of the physical variable applied to the bridge resistors playing the role of active gauges.

bridge circuit the circuit that includes four lateral impedances, Z_1, Z_2, Z_3, Z_4, a diagonal impedance Z_o, and a voltage source E_g of the output impedance Z_g is an example of the so-called bridge circuit. This and other similar circuits are characterized by the bridge balance condition, which represents a relationship between the bridge elements when the current in the diagonal impedance is absent (in the case shown this condition is $Z_1 Z_3 = Z_2 Z_4$). The bridge circuits find application in instrumentation and transducers.

bridge linearization necessary design concern in transducer application of the bridge circuits. It is achieved by reduction of the bridge sensitivity in the bridges where only one arm is a transducer. Linearization can also be achieved with two transducers providing the signals of opposite signs and connected in the opposite arms of the bridge or using a current source instead of the voltage source as a bridge power supply.

bridge rectifier a full-wave rectifier to convert ac to dc, that contains four rectifying elements for single phase, and six elements for three phase, connected as the arm of a bridge circuit.

bridge sensitivity the ratio of the variation of the voltage or the current through the detector to the variation of the component that causes the disbalance of the bridge circuit.

bridge-controlled multivibrators using switches in a two-operational amplifier or in an amplifier-comparator multivibrator so that the bridge is "rotated" each half of the period, one can obtain control of the oscillation frequency by detuning a resistive bridge. The circuit can be applied in sensors with limited number of access wires.

bridging using bridges for local-area networks.

brightness the perceived luminance or apparent intensity of light. This is often different from the actual (physical) luminance, as demonstrated by brightness constancy, Mach band, and simultaneous contrast.

brightness adaptation the ability of the human visual system (HVS) to shift the narrow range in which it can distinguish different light intensities over a large span of luminances. This permits the overall sensitivity of the HVS to gray levels to be very large even though the number of gray levels that it can simultaneously differentiate is fairly small. *See also* gray level, human visual system (HVS), luminance.

brightness constancy the perception that an object has the same brightness despite large changes in its illumination. Thus a piece of paper appears to be approximately as white in moonlight as in sunlight, even though the illumination from the sun may be one million times greater than that from the moon. *See also* brightness, human visual system (HVS), illumination, simultaneous contrast.

Brillouin flow a stream of electron beam emitted from an electron gun that is not exposed to a focusing magnetic field.

Brillouin frequency shift the frequency shift that a wave experiences in undergoing Brillouin scattering. The shift can be to either lower or higher frequency, and typically has a value in the range 0.1 to 10 GHz. *See also* Stokes scattering, anti-Stokes scattering.

Brillouin laser acoustic maser in which the amplification mechanism is considered to be Brillouin scattering.

Brillouin scattering the scattering of light from sound waves. Typically in Brillouin scattering the sound waves have frequencies in the range 0.1 to 10 GHz, whereas in acousto-optics the sound waves have frequencies <0.1 GHz. Brillouin scattering can be either spontaneous or stimulated. *See also* acousto-optic effect, spontaneous light scattering, stimulated light scattering.

broadband a service or system requiring transmission channels capable of supporting bit rates greater than 2 Mbit/s.

broadband antenna an antenna whose characteristics (such as input impedance, gain, and pattern) remain almost constant over a wide frequency band. Two such types of antennas are the log periodic and the biconical.

broadband emission an emission having a spectral distribution sufficiently broad in comparison to the response of a measuring receiver.

broadband integrated services digital network (B-ISDN) a generic term that generally refers to the future network infrastructure that will provide ubiquitous availability of integrated voice, data, imagery, and video services.

broadband system a broadband communication system is one that employs a high data transmission rate. In radio terminology it implies that the system occupies a wide radio bandwidth.

broadcast (1) the transfer of data to multiple receiver units simultaneously rather than to just one other subsystem.

(2) a bus-write operation intended to be recognized by more than one attached device.

broadcast channel a single transmitter, multiple receiver system in which identical information is transmitted to each receiver, possibly over different channels. *See also* interference channel, multiple access channel.

broadcast channel allocations a frequency of a width prescribed by a nation's communications governing agency that are standardized throughout the country for use in one-way electronic communication.

broadcast picture quality the acceptable picture performance for NTSC terrestrial telecast signals. A panel of untrained observers subjectively evaluates the NTSC received picture and sound quality as signal impairments are inserted into the broadcast signal. The evaluation scores are used to determine the values for objectionable signal impairment levels. The signal impairments tested are the video and audio signal-to-noise ratios, the interference due to adjacent channel signals, the interference due to co-channel signals, and the echoes (ghosts) caused by multipath signals effects.

broadcasting sending a message to multiple receivers.

broadside when the pattern factor is maximum in the H plane (for a dipole antenna along the z axis this is the plane where theta=90 degrees).

broadside array an array where the main beam of the array is directed perpendicular to the array axis. In many applications it is desirable to have the maximum radiation of an array directed normal to the axis of the array.

broadside coupled microstrip lines microstrip lines that share the same ground plane but separated from each other in normal direction to the ground plane. Both the microstrip lines are aligned at their centers along the normal direction to the ground plane.

Brown book *See* IEEE Color Books.

Brownian motion a stochastic process with independent and stationary increments. The derivative of such a process is a white noise process. A Brownian motion process X_t is the solution to a stochastic differential equation of the form

$$\frac{dX}{dt} = b(t, X_t) + \sigma(t, X_t) \cdot W_t,$$

where W_t is a white noise process.

brownout an intentional lowering of utility voltage to reduce loading on the system.

brush a conductor, usually carbon or a carbon–copper mixture, that makes sliding electrical contact to the rotor of an electrical machine. Brushes are used with sliprings on a synchronous machine to supply the DC field and are used with a commutator on a DC machine.

brush rigging the components used to hold the brushes of a rotating machine in place, and to insure proper brush tension is applied.

brush tension the force required on the brushes of a rotating machine to insure proper contact between the brush and the commutator or slipring. Proper brush tension is usually provided by springs, and is specified in the manufacturer's technical manual of the machine.

brushless DC motor *See* electronically commutated machine.

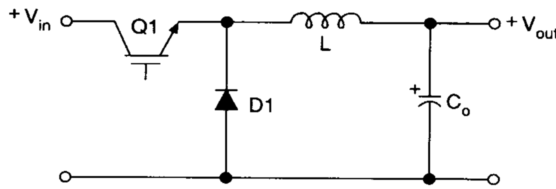
brushless exciter *See* rotating-rectifier exciter.

brushless rotary flux compressor a rotating machine designed to deliver pulsed output (1 MJ in 100 μs). The stator coils are excited by an external capacitor bank. The rotor is a salient structure that compresses the flux resulting in amplification of the electric pulse, by converting the rotating kinetic energy of the rotor to electrical energy.

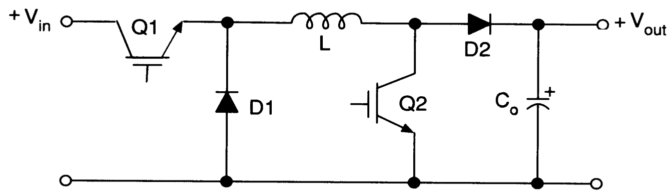
BSO abbreviation for bismuth silicon oxide, Bi_4SiO_{20}. A photoconductive insulating crystal that exhibits photorefractive effects. Useful in applications such as multi-beam coupling and phase conjugation.

BTB *See* branch target buffer.

BTC *See* block truncation coding.



Buck converter.



Buck-boost converter.

BTDF *See* bidirectional transmission distribution function.

BTMA *See* busy tone multiple access. *See also* ISMA.

bubble chamber an instrument for rendering visible the tracks of ionizing particles. It is characterized by a vessel filled with a superheated transparent liquid, commonly hydrogen or deuterium. The passage of an ionizing particle through this liquid is marked by the appearance of a series of bubbles along the particle trajectory. If the liquid is subjected to a magnetic field, as is usually the case, the charged particle trajectories will be curved, the curvature providing information about the particles' charge and momentum.

buck converter a transistor is switched by PWM trigger pulses and a diode provides a current continuation path when the transistor is off, thus the input voltage is chopped. A lowpass LC filter is used to attenuate the switching ripple at the output. The input current to a basic buck converter is discontinuous; therefore, in many applications an LC prefilter is applied to reduce EMI. The output voltage v_o is related to the input voltage v_i by $v_o = v_i d$ and it can be controlled by varying the duty ratio d. Isolated version of a buck converter include forward, push-pull, halfbridge, and bridge converters. Also called chopper or step-down converter.

buck-boost converter *See* buck-boost transformer.

buck-boost transformer a special purpose 2- or 4-coil transformer used to produce modest increases or decreases in the utilization voltage at a load site. The low-voltage coil(s), which typically have rated voltages of 5% to 15% of the high-voltage coils, and in use, the high- and low-voltage, coils, are connected in series to produce an autotransformer arrangement. If primary voltage is applied to the high voltage coil and load voltage is taken from the series coil combination, the low-voltage coil adds to, or boosts, the load utilization voltage. Conversely, reductions in load utilization voltage occur when these primary and secondary connections are reversed causing the low-voltage coil to buck the supply voltage. A typical 4-coil buck-boost transformer would have two 120 V primary coils and two 12 V secondary coils, which could be used to produce voltage ratios of (120/132), (120/144), (240/252), and (240/264).

In a basic buck-boost converter, the inductor accumulates energy from the input voltage source when the transistor is on and releases energy to the output when the transistor is off. It can be viewed as a buck converter followed by a boost converter with topologic simplification. In a buck-boost converter, the output voltage v_o is related to the input voltage v_i by $v_o = v_i d/(1-d)$ and it can be controlled by varying the duty ratio d. Note that the output voltage is opposite polarity to the input. Also called a buck-boost converter, up-down transformer or up-down converter. *See also* flyback converter.

bucket a stable phase space area where the particle beam may be captured and accelerated. An RF bucket is the stable region in longitudinal phase space. The bucket width gives the maximum phase error or timing error at the RF cavity, which a particle may have, and still complete the whole acceleration cycle. The bucket height is the corresponding limit on momentum error.

bucket truck a motor truck equipped with a shell or bucket at the end of a hydraulically-operated insulated arm. A line worker stands in the bucket and is thus raised to gain access to overhead conductors.

bucking fields *See* differentially compounded.

buddy memory allocation a memory allocation system based on variable sized segments will usually allocate space for a new segment from a free area somewhat larger than necessary, leaving an unallocated fragment of the original space. In "buddy" allocation, this fragment cannot be used until its adjacent allocated space is released. Buddy allocation reduces memory fragmentation by ensuring that available areas cannot be repeatedly subdivided.

Buff book *See* IEEE Color Books.

buffer a temporary data storage area in memory that compensates for the different speeds at which different elements are transferred within a system. Buffers are used when data transfer rates and/or data processing rates between sender and receiver vary, for instance, a printer buffer, which is necessary because the computer sends data to the printer faster than the data can be physically printed. *See also* buffered input/output.

buffered input/output input/output that transfers data through a "buffer," or temporary storage area. The main purpose of the buffer is to reduce time dependencies of the data and to decouple input/output from the program execution. Data may be prepared or consumed at an irregular rate, whereas the transfer to or from disk is at a much higher rate, or in a burst.

A buffer is used in "blocked files," where the record size as seen by the user does not match the physical record size of the device.

buffering (1) the process of moving data into or out of buffers or to use buffers to deal with input/output from devices. *See also* buffer, buffered input/output.

(2) in optics, material surrounding the optical fiber that provides the first layer of protection from physical and environmental damage. The buffering is usually surrounded by one or more layers of jacketing material for additional physical protection of the fiber.

bug (1) an error in a programmed implementation (may be either hardware or software). Bugs may refer to errors in correctness or performance.

(2) a syntactical or logical error in a computer program. A name attributed to early computers and electronic testing.

built-in logic block observer technique that combines the basic features of scan designs, pseudo-random test pattern generation, and test result signature analysis.

built-in self-test (BIST) special hardware embedded into a device (VLSI chip or a board) used to perform self testing. On-line BIST assures testing concurrently with normal operation (e.g., accomplished with coding or duplication techniques). Off-line BIST suspends normal operation and is carried out using built-in test pattern generator and test response analyzer (e.g., signature analyzer).

bulb generator a free-standing generator contained in a streamlined, waterproof bulb-shaped enclosure and driven by a waterwheel resembling a ship's propeller on a shaft which extends from one end of the enclosure. They are used in tidal power installations.

bulk power a term inclusive of the generation and transmission portions of the power system.

bulk scattering scattering at the volume of an inhomogeneous medium, generally also possessing rough boundaries. It is due to inhomogeneities in the refractive index.

bulk substation a substation located on a high-voltage transmission line which supplies bulk power to a non-generating utility.

bulldog an attachment for a wire or hoist.

bump a localized orbit displacement created by vertical or horizontal correction element dipoles used to steer beam through available aperture or around obstacles.

bunch a group of particles captured in a phase space bucket.

bundle the practice of paralleling several conductors per phase in an overhead transmission line for the purpose of increasing ampacity and decreasing inductive reactance.

bundle spacer a rigid structure which is used to maintain the spacing of wires in a bundled conductor on an overhead electric power transmission line *See* bundle.

bundled services utility services which are sold together, like power transmission and distribution services in non-deregulated electric utilities.

buried via a via connected to neither the primary side nor the secondary side of a multilayer packaging and interconnecting structure, i.e., it connects only internal layers.

burndown breakage of an overhead electric power line due to heating from excess current.

burnup a measure (e.g., megawattt-days / ton) of the amount of energy extracted from each unit of fissile material invested in a nuclear reactor.

burn-in component testing where infant mortality failures (defective or weak parts) are screened out by testing at elevated voltages and temperatures for a specified length of time.

burst refresh in DRAM, carrying out all required refresh actions in one continuous sequence—a *burst*. *See also* distributed refresh.

burst transfer the sending of multiple related transmissions across an interconnect, with only one initialization sequence that takes place at the beginning of the burst.

burstiness factor used in traffic description, the ratio of the peak bit rate to the average bit rate.

bus (1) a data path connecting the different subsystems or modules within a computer system. A computer system will usually have more than one bus; each bus will be customized to fit the data transfer needs between the modules that it connects.

(2) a conducting system or supply point, usually of large capacity. May be composed of one or more conductors, which may be wires, cables, or metal bars (busbars).

(3) a node in a power system problem

(4) a heavy conductor, typically used with generating and substation equipment.

bus admittance matrix *See* Y-bus.

bus acquisition the point at which a bus arbiter grants bus access to a specific requestor.

bus arbiter (1) the unit responsible for choosing which subsystem will be given control of the bus when two or more requests for control of the bus happen simultaneously. Some bus architectures, such as Ethernet, do not require a bus arbiter.

(2) the device that performs bus arbitration. *See also* bus arbitration.

bus arbitration the process of determining which competing bus master should be granted control of the bus. The act of choosing which subsystem will be given control of the bus when two or more requests for control of the bus happen simultaneously. The element that make the decision is usually called the bus arbiter. *See also* bus priority.

bus architecture a computer system architecture in which one or more buses are used as the communication pathway between I/O device controllers, the CPU, and memory. *See also* channel architecture.

bus bandwidth (1) the data transfer rate in bits per second or bytes per second. In some instances the bandwidth average rate is given and in others the maximum rate is given. It is approximately equal to the width of the data bus, multiplied by the transfer rate in bus data words per second. Thus a 32 bit data bus, transferring 25 million words per second (40 ns clock) has a bandwidth of 800 Mb/s.

The useful bandwidth may be lowered by the time to first acquire the bus and possibly transfer addresses and control information.

(2) the transfer rate that is guaranteed that no user will exceed.

bus bar a heavy conductor, typically without insulation and in the form of a bar of rectangular cross-section.

bus broadcast *See* broadcast.

bus controller the logic that coordinates the operation of a bus.

A device connected to the bus will issue a bus request when it wishes to use the bus. The controller will arbitrate among the current requests and grant one requester access. The bus controller also monitors possible errors, such as use of an improper address, a device not releasing the bus, and control errors.

Bus control logic may reside in multiple subsystems, distributed control, or may be centralized in a subsystem. *See also* bus cycle, bus master.

bus cycle the sequence of steps involved in a single bus operation. A complete bus cycle may require that several commands and acknowledgments are sent between the subsystems in addition to the actual data that is sent.

For example,

1. the would-be bus master requests access to the bus

2. the bus controller grants the requester access to the bus as bus master

3. the bus master issues a read command with the read address

4. the *bus slave* responds with data

5. the master acknowledges receipt of the data

6. the bus master releases the bus.

The first two steps may be overlapped with the preceding data transfer.

See also bus controller, bus master.

bus differential relay a differential relay specifically designed to protect high power buses with multiple inputs.

bus driver the circuits that transmit a signal across a bus.

bus grant an output signal from a processor indicating that the processor has relinquished control of the bus to a DMA device.

bus hierarchy a network of busses linked together (usually multiple smaller busses connected to one or more levels of larger busses), used to increase the number of elements that may be connected to a high-performance bus structure.

bus idle the condition that exists when the bus is not in use.

bus impedance matrix *See* Z-bus.

bus interface unit in modern CPU implementations, the module within the CPU directly responsible for interactions between the CPU and the memory bus.

bus line one of the wires or conductors that constitute a bus. A bus line may be used for data, address, control, or timing.

bus locking the action of retaining control of a bus after an operation which would normally release the bus at completion. In the manipulation of memory locks, a memory read must be followed by a write to the same location with a guarantee of no intervening operation. The bus must be locked from the initial read until after the update write to give an indivisible read/write to memory.

bus master a bus device whose request is granted by the bus controller and thereby gains control of the bus for one or more cycles or transfers. The bus master may always reside with one subsystem, or may be transferred between subsystems, depending on the architecture of the bus control logic. *See also* bus controller, bus cycle.

bus owner the entity that has exclusive access to a bus at a given time.

bus phase a term applying especially to synchronous buses, controlled by a central clock, with alternating "address" and "data" transfers. A single transfer operation requires the two phases to transfer first the address and then the associated data. Bus arbitration may be overlapped with preceding operations.

bus priority rules for deciding the precedence of devices in having bus requests honored.

Devices issue requests on one of several bus request lines, each with a different bus priority. A high priority request then "wins" over a simultaneous request at a lower priority.

The request grant signals then "daisy chains" through successive devices along the bus or is sent directly to devices in appropriate order. The requesting device closest to the bus controller then accepts the grant and blocks its propagation along the bus.

Buses may have handle interrupts and direct memory accesses with separate priority systems.

bus protocol (1) a set of rules that two parties use to communicate.

(2) the set of rules that define precisely the bus signals that have to be asserted by the master and slave devices in each phase of a bus operation.

bus request an input signal to a processor that requests access to the bus; a hold signal. Competing bus requests are resolved by the bus controller. *See also* bus controller.

bus slave a device that responds to a request issued by the bus master. *See also* bus master.

bus snooping the action of monitoring all traffic on a bus, irrespective of the address. Bus snooping is required where there are several caches with the same or overlapping address ranges. Each cache must then "snoop" on the bus to check for writes to addresses it holds; conflicting addresses may be updated or may be purged from the cache.

Bus snooping is also useful as a diagnostic tool.

bus state triggering a data acquisition mode initiated when a specific digital code is selected.

bus tenure the time for which a device has control of the bus, so locking out other requesters. In most buses, the bus priority applies only when a device completes its tenure; even a low priority device should keep its tenure as short as possible to avoid interference with higher priority devices. *See also* bus priority.

bus transaction the complete sequence of actions in gaining control of a bus, performing some action, and finally releasing the bus. *See also* bus cycle.

bus watching *See* bus snooping.

bus width the number of data lines in a given bus interconnect.

bus-connected reactor *See* shunt reactor.

bus yard an area of a generating station or substation in which bus bars *cf* and switches are located.

Bush, Vannevar (1890–1974) Born: Everett, Massachusetts, U.S.A.

Bush is best know as the developer of early electromechanical analog computers. His "differential analyzer," as it was called, arose from his position as a professor of power engineering at the Massachusetts Institute of Technology. Transmission problems involved the solution of first- and second-order differential equations. These equations required long and laborious calculations. His interest in mechanical computation arose from this problem. Bush's machines were used by the military during World War II to calculate trajectory tables for artillery. Vannevar Bush was also responsible for inventing the antecedent of our modern electric meter. He was also scientific advisor to President Roosevelt on the Manhattan Project.

bushing a rigid, hollow cylindrical insulator which surrounds a conductor and which extends through a metal plate such as a the wall of a transformer tank so as to insulate the conductor from the wall.

bushing transformer a potential transformer which is installed in a transformer bushing so as to take advantage of the insulating qualities of that bushing.

busway a specialized raceway which holds un-insulated bus bars in a building.

busy tone multiple access (BTMA) synonym for idle tone multiple access.

busy waiting a processor state in which it is reading a lock and finding it busy, so it repeats the read until the lock is available, without attempting to divert to another task. The name derives from the fact that the program is kept busy with this waiting and is not accomplishing anything else while it waits. The entire "busy loop" may be only 2 or 3 instructions.

"Busy waiting" is generally deplored because of the waste of processing facilities.

Butler matrix a feed system (also called beam-forming system), that can excite an antenna array so that it produces several beams, all offset from each other by a finite angle. The system makes use of a number of input ports connected through a combination of hybrid junctions and fixed phase shifters.

Butterworth alignment a common filter alignment characterized by a maximally flat, monotonic frequency response.

Butterworth filter an IIR (infinite impulse response) lowpass filter with a squared magnitude of the form:

$$|H(\omega)|^2 = \frac{1}{1 + (\frac{j\omega}{j\omega_c}^{2N})}$$

buzz stick a tester for insulators, especially strain insulators in a string. It consists of a pair of probes connected to each side of a small sphere gap. When the probes are touched to each terminal of a good insulator, the gap will break down and emit a buzzing sound.

BV_{GD} common notation for FET gate-to-drain reverse breakdown voltage.

BV_{GS} common notation for FET gate-to-source reverse breakdown voltage.

bw common notation for radian bandwith in radians per second.

bw_a common notation for fractional arithmetic mean radian bandwidth in radians per second.

bw_g common notation for fractional geometric mean radian bandwidth in radians per second.

BWO *See* backward wave oscillator.

BX cable a flexible, steel-armored cable used in residential and industrial wiring.

bypass *See* forwarding.

bypass switch a manually-operated switch used to connect load conductors when an automatic transfer switch is disconnected.

byte in most computers, the unit of memory addressing and the smallest quantity directly manipulated by instructions. The term "byte" is of doubtful origin, but was used in some early computers to denote any field within a word (e.g., DEC PDP-10). Since its use on the IBM "Stretch" computer (IBM 7030) and especially the IBM System/360 in the early 1960s, a byte is now generally understood to be 8 bits, although 7 bits is also a possibility.

byte multiplexer channel an I/O channel that can be assigned to more than one data transfer at a time and can be released for another device following each byte transfer. (In this regard, it resembles a typical computer bus.) Byte multiplexing is particularly suited to lower speed devices with minimal device buffering. (IBM terminology) *See also* selector channel, multiplexer channel.

byte serial a method of data transmission where bits are transmitted in parallel as bytes and the bytes are transmitted serially. For example, the Centronics-style printer interface is byte-serial.

C

c common symbol for speed of light in free space. $c = 3 \times 10^{10}$ cm/s.

C_{GD} common notation for FET gate-to-drain capacitance.

C_{GS} common notation for FET gate-to-source capacitance.

C-band microwave frequency range, 3.95-5.85 Ghz.

C-element a circuit used in an asynchronous as an interconnect circuit. The function of this circuit is to facilitate the handshaking communication protocol between two functional blocks.

cable an assembly of insulated conductors, either buried or carried on poles (aerial cable).

cable limiter a cable connector that contains a fuse. Cable limiters are used to protect individual conductors that are connected in parallel on one phase of a circuit.

cable tray a specialized form of raceway used to hold insulated electric power cables in a building.

cache an intermediate memory store having storage capacity and access times somewhere in between the general register set and main memory. The cache is usually invisible to the programmer, and its effectiveness comes from being able to exploit program locality to anticipate memory-access patterns and to hold closer to the CPU: most accesses to main memory can be satisfied by the cache, thus making main memory appear to be faster than it actually is.

A hit occurs when a reference can be satisfied by the cache; otherwise a miss occurs. The proportion of hits (relative to the total number of memory accesses) is the hit ratio of the cache, and the proportion of misses is the miss ratio. *See also* code cache, data cache, direct mapped cache, fully associative cache, set associative cache, and unified cache.

cache aliasing a situation where two or more entries (typically from different virtual addresses) in a cache correspond to the same address(es) in main memory. Considered undesirable, as it may lead to a lack of consistency (coherence) when data is written back to main memory.

cache block the number of bytes transferred as one piece when moving data between levels in the cache hierarchy or between main memory and cache). The term *line* is sometimes used instead of block. Typical block size is 16-128 bytes and typical cache size is 1-256 KB. The block size is chosen so as to optimize the relationship of the "cache miss ratio," the cache size, and the block transfer time.

cache coherence the problem of keeping consistent the values of multiple copies of a single variable, residing either in main memory and cache in a uniprocessor, or in different caches in a multiprocessor computer. In a uniprocessor, the problem may arise if the I/O system reads and writes data into the main memory, causing the main memory and cache data to be inconsistent, or if there is aliasing. Old (stale) data could be output if the CPU has written a newer value in the cache, and this has not been transported to the memory. Also, if the I/O system has input a new value to main memory, new data would reside in main memory, but not in the cache.

cache hit when the data referenced by the processor is already in the cache.

cache line a block of data associated with a cache tag.

cache memory *See* cache.

cache miss a reference by the processor to a memory location currently not housed in the cache.

cache replacement when a "cache miss" occurs, the block containing the accessed location must be loaded into the cache. If this is full, an "old" block must be expelled from the cache and replaced by the "new" block. The "cache replacement algorithm" decides which block should be replaced. An example of this is the "Least Recently Used (LRU)" algorithm, which replaces the block that has gone the longest time without being referenced.

cache synonym *See* cache aliasing.

cache tag a bit field associated with each block in the cache. It is used to determine where (and if) a referenced block resides in the cache. The tags are typically housed in a separate (and even faster) memory (the "tag directory") which is searched for in each memory reference. In this search, the high order bits of the memory address are associatively compared with the tags to determine the block location. The number of bits used in the tag depends on the cache block "mapping function" used: "Direct-mapped," "Fully associative," or the "Block-set-associative" mapped cache.

CAD *See* computer-aided design.

cage-rotor induction motor an induction motor whose rotor is occupied by copper or aluminum bars, known as rotor bars, instead of windings. Also commonly referred to as a squirrel-cage induction motor.

calculating board a single-phase scale model of a power system that was used to calculate power flows before the advent of electronic computers.

calibration the procedure of characterizing the equipment in place for a particular measurement set-up relative to some known quantity, usually a calibration standard traceable to the National Institute for Standards and Technology (NIST).

calibration kits designed for use with vector network analyzers. With these kits you can make error-corrected measurements of devices by measuring known devices (standards) over the frequency range of interest. Calibration standards include shorts, open, sliding, and fixed loads.

calibration standards a precision device used in the process of calibrating an EM measurement system. It can be a standard gain horn, an open, a short, a load, sphere, etc., used to characterize an RCS, antenna, or transmission line measurement system. Most calibration standards are provided with documentation that can be traced to a set of standards at the NIST.

call instruction (1) command within a computer program that instructs the computer to go to a subroutine.

(2) an instruction used to enter a subroutine. When a call instruction executes, the current program counter is saved on stack, and the address of the subroutine (provided by the call instruction) is used as the new program counter.

calorimeter a device used to determine particle energies by measuring the ionization of a particle shower in a heavy metal, usually iron and lead.

CAM acronym for content-addressable memory or computer-aided manufacturing. *See* associative memory, computer-aided manufacturing.

CAMAC acronym for computer automated monitor and control — an internationally accepted set of standards for electronic instrumentation, which specifies mechanical, electrical, and functional characteristics of the instrument modules.

camera a device for acquiring an image, usually in a photographic or electronic form — in the latter case typically as a TV camera. Cameras may operate in optical, infra red, or other wavelength bands.

camera calibration a process in which certain camera parameters, or equivalently some quantities that are required for determination of the perspective projection on an image plane of a point in the 3-D world, are calculated by using the known correspondence between some points in the 3-D world and their images in the image plane.

camera model (1) the representation of the geometric and physical features of a stereovision system, with relative references between the two camera coordinate systems, and absolute references to a fixed coordinate system.

(2) a mathematical model by which the perspective projection on an image plane of a point in the 3-D world can be determined.

can slang for a pole-top distribution transformer.

candela (cd) unit of measurement for luminous intensity (illuminating power in lumens/sr). The luminous intensity of 1/60 of 1 cm^2 of projected area of a blackbody radiator operating at the temperature of solidification of platinum (2046K). Historically, the unit of measurement for the light emitted by one flame of a specified make of candle.

candle *See* candela.

candle power *See* candela.

candlepower distribution a curve, generally polar, representing the variation of luminous intensity of a lamp or luminaire in a plane through the light center.

canned magnet a magnet that is completely encased in its own vacuum jacket.

Canny edge detector an edge detector that uses an approximation to the optimal filter. *See* infinite symmetric exponential filter.

Canny operator an edge detector devised by John Canny as the optimal solution to a variational problem with three constraints. The general solution obtained numerically can be approximated in practical contexts by the first derivative of a Gaussian. Canny operator usually refers to the extension to two dimensions of this approximation, i.e., to use of a set of oriented operators whose orthogonal cross sections are a Gaussian and the derivative of a Gaussian. Its advantage is its capability for allowing edges and their orientations to be detected to sub-pixel accuracy. It uses a convolution with a Gaussian to reduce noise and a derivative to enhance edges in the resulting smoothed image. The two are combined into one step — a convolution with the derivative of a Gaussian. A hysteresis thresholding stage is included, to allow closed contours to remain closed.

CAP *See* carrierless amplitude/phase modulation.

capability an object that contains both a pointer to another object and a set of access permissions that specify the modes of access permitted to the associated object from a process that holds the capability.

capability curve *See* capability diagram.

capability diagram also called capability curve. Graphical representation of the complex power limits for safe operation of a synchronous machine. The vertical axis is average power P and the horizontal axis is reactive power Q. The region of allowable operation is determined by factors such as rotor thermal limit, stator thermal limit, rated power of prime mover (alternator operation), and stability torque limit.

capability list a list of capabilities, usually associated with a process, defining a set of objects and the modes of access permitted to those objects. Computer systems have been designed to use capability lists to define the memory environment for process execution.

capacitance the measure of the electrical size of a capacitor, in units of farads. Thus a capacitor with a large capacitance stores more electrons (coulombs of charge) at a given voltage than one with a smaller capacitance.

In a multiconductor system separated by nonconductive mediums, capacitance (C) is the proportionality constant between the charge (q) on each conductor and the voltage (V) between each conductor. The total equilibrium system charge is zero. Capacitance is dependent on conductor geometry, conductor spatial relationships, and the material properties surrounding the conductors.

Capacitors are constructed as two metal surfaces separated by a nonconducting electrolytic material. When a voltage is applied to the capacitor the electrical charge accumulates in the metals on either side of the nonconducting material, negative charge on one side and positive on the other. If this material is a fluid then the capacitor is electrolytic; otherwise, it is nonelectrolytic.

capacitance bridge a circuit that includes two branches which form a balanced drive (two sinusoidal voltage sources connected in series with common point grounded) and two capacitances connected in series between free ends of the voltage sources. The detector of current (virtual ground of an operational amplifier is a suitable choice) is connected between the common point of the capacitors and ground. The circuit finds application in capacitive sensors.

capacitive reactance the opposition offered to the flow of an alternating or pulsating current by capacitance measured in ohms.

capacitively coupled current *See* capacitively coupled field.

capacitively coupled field field applied to the affected limb by electrodes touching the skin (the current from the electrodes has both displacement and conduction components).

capacitor bank (1) an assembly at one location of capacitors and all necessary accessories, such as switching equipment, protective equipment, and controls, required for a complete operating installation.

(2) a group of (typically 3) capacitors mounted on an electric power line for voltage boosting or power factor correction.

capacitor-start induction motor (CSIM) a single-phase induction motor with a capacitor in series with its auxiliary winding, producing nearly a 90° phase difference between the main winding and the auxiliary winding currents at starting. This results in a high starting torque, so this motor is used for hard-to-start loads. The auxiliary winding and capacitor are removed from the circuit by a centrifugal switch as the machine approaches operating speed.

capacity miss a category of cache misses denoting the case where the cache is not large enough to hold all blocks needed during execution of a program. *See also* conflict miss, cold start miss.

capacity region for a multiple terminal communications system. The entire set of rate-vectors for which there exist channel codes such that the probability of making a decoding error can be made arbitrarily small. *See also* achievable rate region, multiple access channel.

capture effect a phenomenon found in packet switched networks in which nonequal powers in packet radio networks using contention protocols lead to higher throughputs. In contention protocols used in packet radio networks, the transmitted packets are allowed to collide. If two packets collide and one is significantly stronger in power, this packet is more likely to be captured (detected) by the receiver.

capture range the range of input frequencies over which the PLL can acquire phase lock.

capture register internal register which, triggered by a specified internal or external signal, store or "capture" the contents of an internal timer or counter.

carbon brush a block of carbon used to make an electrical contact to a rotating coil via the commutator of a DC machine or the slip rings of a synchronous machine.

carbon dioxide (CO_2) linear gas molecule consisting of one carbon and two oxygen atoms, medium for an important class of lasers.

carbon dioxide laser laser in which the amplifiying medium is carbon dioxide gas; efficient, powerful, and commercially important laser that is pumped and configured in many ways and has its principal output lines in the mid-infrared.

carbon resistor thermometer a carbon resistor whose temperature sensitivity provides good temperature resolution.

carcinotron a forward radial traveling wave amplifier in which microwave signals are fed to the radial slow wave structure.

card a printed circuit board that can be plugged into a main board to enhance the functionality or memory of a computer.

card cage mechanical device for holding circuit cards into a backplane.

cardinal series the formula by which samples of a bandlimited signal are interpolated to form a continuous time signal.

cardinal vowel according to English phonetician Daniel Jones, a vowel corresponding to one of the extreme positions of the vowel diagram.

carrier amplitude amplitude of the radio frequency sinusoid used as a vehicle for transporting intelligence from the sending end of a communications link to the receiving end. For an AM, FM, or PM wave, the peak amplitude of the spectral component in the frequency domain about which symmetry exists. The carrier amplitude (as a function of time) contains a portion of the intelligence for angle modulation (*See* frequency modulation and phase modulation). In contrast, the carrier amplitude contains no information for AM or any of the SSB variations (*See* amplitude modulation and single sideband modulation), but is merely used as a frequency marker.

carrier concentration the number of mobile charge carriers per unit volume, positive (holes) or negative (electrons). In a semiconductor, both concentrations are present and are modifiable by externally applied electric fields.

carrier current communication the use of electric lines to carry communication signals.

carrier frequency in pulse-width-modulated (PWM) switching schemes, the switching frequency that establishes the frequency at which the converter switches are switched. In sine-triangle PWM, the carrier frequency is the frequency of the triangle waveform that the control or modulating signal is compared to.

carrier lifetime the average duration an electron or a hole stays in a certain state.

carrier phase the phase of a sinusoidal signal that is the carrier in a modulation scheme such as AM, FM, SSB, etc. The carrier may be defined in the form $A \cos(\omega_c t + \phi)$. The carrier is specified by the parameters A (amplitude), ω_c (carrier frequency), and ϕ (carrier phase).

carrier shift the difference in frequency between the steady state, mark, and space in frequency shift keying (FSK) systems.

carrier signal the RF signal in a communications system that has the modulating signal superimposed on it. This signal may have its frequency, amplitude, or phase varied to form a modulated signal. Without modulation it is a simple RF signal.

Many communication systems rely on the concept of sinusoidal amplitude modulation, in which a complex exponential signal c(t) has its amplitude multiplied (modulated) by the information-bearing signal $x(t)$. This signal $x(t)$ is typically referred to as the modulating signal and the signal $c(t)$ as the carrier signal. The modulated signal $y(t)$ is then the product of these two signals.

$$y(t) = x(t)c(t)$$

carrier suppression in SSB communications, the degree to which the carrier amplitude is reduced from its original value out of the modulator. (*See also* balanced modulator.) Carrier suppression is generally used as a method to significantly reduce the amount of unnecessary transmitted power, based upon the fact that no information is contained within the carrier amplitude in an AM waveform. It is sometimes desirable to only partly suppress the carrier, leaving what is termed a "pilot tone" at the carrier frequency.

carrier synchronization a synchronization technique used in radio receivers. In all radio receivers some sort of carrier frequency synchronization is required; the phase synchronization is needed only if phase coherent demodulation is desired. Can be categorized as open and closed loop carrier synchronization.

carrier-sense multiple access (CSMA) a random-access method of sharing a bus-type communications medium in which a potential user of the medium listens before beginning to transmit. The channel sensing significantly reduces the probability of collisions. *Compare with* ALOHA.

carrier-to-interference ratio (CIR) similar to signal-to-interference ratio but usually used in cellular communication systems where the carrier refers to the signal of interest and the interference refers to interference from other transmitters in the system. *See also* signal-to-interference ratio.

carrier-to-noise ratio the ratio of the amplitude of the carrier signal to that of the noise in the IF bandwidth measured at any point in the receiver before any nonlinear process such as amplitude limiting or detection. The carrier to noise ratio is typically expressed in decibels.

carrierless amplitude/phase modulation (CAP) an implementation of a quadrature amplitude modulation transmitter in which the passband in-phase and quadrature signals are generated directly via quadrature digital filters. A recent application for CAP is high-speed digital subscriber lines. *See also* quadrature amplitude modulation.

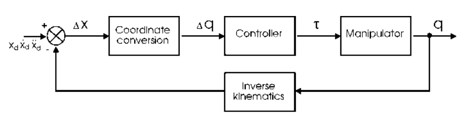
carry overflow signal that occurs when the sum of the operands at the inputs of the adder equals the base. A binary adder, adding $1 + 1$ will produce a sum of 0 and carry of 1.

carry bit *See* carry.

carry flag *See* carry.

carry look-ahead adder high-speed adder that uses extra combinational logic to generate all carries in an m-bit block in parallel. A method of generating the signals corresponding to the carries (borrows) in an addition (subtraction) circuit that does not require all the lower order carries to be determined; a high-speed carry.

Cartesian-based control the system depicted in the figure. Notice that inverse kinematics is embedded into the feedback control loop. Due to the inverse kinematics calculations, Cartesian-based control is of greater computational complexity. Here X_d, $\dot{X}_d$, and $\ddot{X}_d$ denote position, velocity, and acceleration of the desired trajectory in Cartesian space. τ is a vector of generalized forces and q is a vector of generalized positions.



Cartesian-based control scheme.

Cartesian product a mathematical operation on two sets. The Cartesian product of two sets, say A and B, denoted $A \times B$, is the set of all ordered pairs with the first element of each pair an element of A and the other an element of B. That is,

$$A \times B = \{(a, b) \mid a \in A \text{ and } b \in B\}$$

Cartesian space *See* external space.

cartridge fuse replaceable electrical safety device in which metal melts and interrupts the circuit when the current exceeds a preset limit in duration and magnitude.

cascade connection a series connection of amplifier stages or networks in which the output of one feeds the input of the next.

cascade system a 3-level system containing high-, intermediate-, and low-energy states. Resembling a cascade, these states are coupled, in that sequence, by two electromagnetic fields. *See also* cathodoluminescent.

cascode a circuit technique in which the current output of the collector (drain) of a BJT (FET) is buffered by a common base (common gate) amplifier stage. The purpose is to increase the bandwidth and/or output resistance.

cascode amplifier an amplifier consisting of a grounded-emitter input stage that drives a grounded-base output stage; advantages include high gain and low noise; widely used in television tuners. *See also* cascode.

CASE *See* computer-aided software engineering.

castellation recessed metallized feature on the edges of a chip carrier that interconnect conducting surfaces or planes within or on the chip carrier.

casual filter a filter of which the transition from the passband to the stopband is gradual, not ideal. This filter is realizable.

catadioptric an optical system made up of both refractive elements (lenses) and reflective elements (mirrors).

catastrophic code a convolutional code in which a finite number of code symbol errors can cause an unlimited number of decoded symbol errors.

catastrophic encoder a convolutional encoder with at least one loop in the state-transition diagram with zero accumulated code symbol weight, at least one nonzero information symbol and not visiting the zero state. After decoding, a finite number of (channel) errors can result in an infinite number of errors (catastrophic error propagation).

catastrophic error propagation when the state diagram contains a zero distance path from some nonzero state back to the same state, the transmission of a 1 causes an infinite number of errors. *See also* catastrophic encoder.

catastrophic thermal failure an immediate, thermally induced total loss of electronic function by a component or system.

catcher a cavity resonator of a multicavity klystron proximate to the collector to catch microwave energy from the bunched electrons.

categoric input a nonnumeric (symbolic) input, e.g., gender, color, which is usually fed to a network using one-out-of-N coding.

catenation symbols strung together to form a larger sequence, as the characters in a word and the digits in a number.

cathode the negative electrode of a device. *Contrast with* anode.

cathode ray tube (CRT) a vacuum tube using cathode rays to generate a picture on a fluorescent screen. These cathode rays are in fact the electron beam deflected and modulated, which impinges on a phosphor screen to generate a picture according to a repetitive pattern refreshed at a frequency usually between 25 and 72 Hz.

cathodoluminescent the property of luminescent crystals (phosphors) to emit visible light with bombarded electrons.

catoptric an optical system made up of only reflective elements (mirrors).

CATV *See* community-antenna television.

Cauchy distribution the density function for a Cauchy distributed random variable X is

$$f_X(x) = \frac{1}{1+x^2}$$

Note that the moments for this random variable do not exist, and that the cumulative distribution function is not defined. *See also* probability density function, moment.

Caurer filter *See* elliptic filter.

causal system a system whose output does not depend on future input; the output at time t may depend only on the input signal $\{f(\tau) : \tau \leq t\}$. For example, the voltage measured across a particular element in a passive electric circuit does not depend upon future inputs applied to the circuit, and hence is a causal system.

If a system is not causal, then it is noncausal. An ideal filter which will filter in real time all frequencies present in a signal $f(t)$ requires knowledge of $\{f(\tau) : \tau > t\}$, and is an example of a noncausal system.

causality a system $H : \mathcal{X}_e \to \mathcal{X}_e$, or equivalently, an operator that maps inputs from the extended space $\mathcal{X}_e$ into outputs from the same space where the output at time t is not a function of future inputs. This can be expressed using truncations as follows: A system H is causal if

$$[Hx(\cdot)]_T = [Hx_T(\cdot)]_T \qquad \forall x \in \mathcal{X}_e$$

See also extended space and truncation.

cavity (1) a fully enclosed, hollow conductor, in which only time-harmonic electromagnetic fields of specific frequencies (i.e., resonant frequencies) exist. Each resonant frequency is identified by a collection of numbers in conjunction with a mode designator of the transverse electric, transverse magnetic, or transverse electromagnetic type.

(2) in optics, region of space that is partially or totally enclosed by reflecting boundaries and that therefore supports oscillation modes.

cavity dumping fast removal of energy stored in a laser cavity by switching the effective transmission of an output coupling mirror from a low value to a high value.

cavity lifetime one of several names used to indicate the time after which the energy density of an electromagnetic field distribution in a passive cavity maybe expected to fall to $1/e$ of its initial value; the name photon lifetime is also common.

cavity ratio (CR) a number indicating cavity proportions calculated from length, width, and height. It is further defined into ceiling cavity ratio, floor cavity ratio, and room cavity ratio.

cavity short a grounded metal rod connecting the body of an RF cavity. By grounding the cavity, it is kept from resonating.

Cayley–Hamilton theorem for 2-D general model let T_{pq} be transition matrices defined by

$$ET_{pq} = \begin{cases} A_0T_{-1,-1} + A_1T_{0,-1} + A_2T_{-1,0} \\ +I_n \text{ for } p = q = 0 \\ A_0T_{p-1,q-1} + A_1T_{p,q-1} \\ +A_2T_{p-1,q} \\ for\ \ p \neq 0 \text{ and/or } q \neq 0 \end{cases}$$

and

$$[Ez_1z_2 - A_0 - A_1z_1 - A_2z_2]^{-1}$$
$$= \sum_{p=-n_1}^{\infty} \sum_{q=-n_2}^{\infty} T_{pq} z_1^{-(p+1)} z_2^{-(q+1)}$$
$$Ex_{i+1,j+1} = A_0x_{ij} + A_1x_{i+1,j} + A_2x_{i,j+1} + B_0u_{ij} + B_1u_{i+1,j} + B_2u_{i,j+1}$$

$i, j \in Z_+$ (the set of nonnegative integers) where $x_{i,j} \in R^n$ is the semistate vector, $u_{i,j} \in R^m$ is the input, and E, A_k, B_k $(k = 0, 1, 2)$ real matrices with E possibly singular or rectangular. A pair (n_1, n_2) of positive integers n_1, n_2 such that $T_{pq} = 0$ for $p < -n_1$ and/or $q < -n_2$ is called the index of the model. Transition matrices T_{pq} of the generalized 2-D model satisfy

$$\sum_{p=0}^{n_1} \sum_{q=0}^{n_2} d_{pq} T_{p-k-1,q-t-1} = 0$$

for

$$\begin{cases} k < 0 \text{ and } m_1 < k \leq 2n_1 - 1 \\ t < 0 \text{ and } m_2 < t \leq 2n_2 - 1 \end{cases}$$

where d_{pq} are coefficients of the polynomial

$$\det\ [Ez_1z_2 - A_0 - A_1z_1 - A_2z_2] = \sum_{p=0}^{n_1} \sum_{q=0}^{n_2} d_{pq} z_1^p z_2^q$$

and m_1, m_2 are defined by the adjoint matrix

$$\text{adj}\ [Ez_1z_2 - A_0 - A_1z_1 - A_2z_2] = \sum_{i=0}^{m_1} \sum_{j=0}^{m_2} H_{ij} z_1^i z_2^j$$
$$(m_1 \leq n - 1, m_2 \leq n - 1)$$

Cayley–Hamilton theorem for 2-D Roesser model let T_{ij} be transition matrix defined by

$$T_{ij} = \begin{cases} I \text{ (the identity matrix)} \\ \text{for } i, j = 0 \\ T_{10} := \begin{bmatrix} A_1 & A_2 \\ 0 & 0 \end{bmatrix}, T_{01} := \begin{bmatrix} 0 & 0 \\ A_3 & A_4 \end{bmatrix} \\ T_{10}T_{i-1,j} + T_{01}T_{i,j-1} \text{ for } i, j \in Z_+ \\ 0 \text{ for } i < 0 \text{ or/and } j < 0 \end{cases}$$

(Z_+ is the set of nonnegative integers) of the 2-D of the Roesser model

$$\begin{bmatrix} x_{i+1,j}^h \\ x_{i,j+1}^v \end{bmatrix} = \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \begin{bmatrix} x_{ij}^h \\ x_{ij}^v \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} u_{ij}$$

$i, j \in Z_+$ where $x_{ij}^h \in R^{n_1}$ and $x_{ij}^v \in R^{n_2}$ are the horizontal and vertical state vectors, respectively, $u_{ij} \in R^m$ is the input vector, and A_1, A_2, A_3, A_4, B_1, B_2 are real matrices. The transition matrices T_{ij} satisfy the equation

$$\sum_{i=0}^{n_1}\sum_{j=0}^{n_2} a_{ij} T_{i+h,j+k} = 0$$

for $h = 0, 1, \ldots$ and $k = 0, 1, \ldots$ where a_{ij} are coefficients of the 2-D characteristic polynomial

$$\det \begin{bmatrix} I_{n_1} z_1 - A_1 & -A_2 \\ -A_3 & I_{n_2} z_2 - A_4 \end{bmatrix} = \sum_{i=0}^{n_1}\sum_{j=0}^{n_2} a_{ij} z_1^i z_2^j \quad (a_{n_1 n_2} = 1)$$

CB *See* Citizen's band.

CBE *See* chemical beam epitaxy.

CBR *See* constant bit rate.

CCD *See* charge-coupled device.

CCD memory *See* charge-coupled-device memory.

CCDF *See* complementary cumulative distribution function.

CCI *See* cochannel interference.

CCIR *See* International Radio Consultative Committee.

CCITT *See* Comité Consulatif International Télégraphique et Téléphonique.

CCITT two-dimensional a modified relative element address designate scheme. The position of each changing element on the present line is coded with respect to the changing element on the reference line or the preceding changing element on the present line. The reference line lies immediately above the present line.

CCR *See* cochannel reuse ratio.

CCS *See* common channel signaling.

CCVT *See* coupling capacitor voltage transformer.

CD *See* compact disk, critical dimension.

CD *See* critical dimension.

cd *See* candela.

CD-I *See* compact disk-interactive.

CD-ROM a read-only compact disk. *See also* compact disk.

CDF *See* cumulative distribution function.

CDMA *See* code division multiple access.

CdS abbreviation for cadmium sulfide, a photoconductor with good visible light response.

CEL *See* contrast enhancement layer.

CELL *See* surface-emitting laser logic.

cell (1) in mobile radio communications, the area serviced by one base station. One way of categorizing the cells is according to their size. Cell sizes may range from a few meters to many hundred kilometers. *See also* picocell, nanocell, nodal cell, microcell, macro cell, large cell, megacell, satellite cell.

(2) in ATM systems a small packet of fixed length. The CCITT chose a cell size of 53-bytes comprising a 5-byte header and 48-byte payload for their ATM network.

cell library a collection of simple logic elements that have been designed in accordance with a specific set of design rules and fabrication processes. Interconnections of such logic elements are often used in semi-custom design of more complex IC chips.

cell switching means of switching data among the ports (inputs and outputs) of a switch such that the data is transferred in units of a fixed size.

cell-cycle-specific control a type of control arising in scheduling optimal treatment protocols in the case when treated population is sensitive to the therapy only in chosen phases of its cell cycle. A mathematical model of population dynamics used to solve the problem of such control should be composed of subsystems sensitive and insensitive to the drug. It may be achieved by the use of compartmental models. Typical types of perturbations of the cell cycle considered as cel-cycle-specific control are as follows: cell arrest, cell killing, and alteration of the transit time. They could be applied for representation of cell synchronization, cell destruction, and cell recruitment from the specific phase.

cellular automaton system designed from many discrete cells, usually assembled in one- or two-dimensional regular arrays, each of which is a standard finite state machine. Each cell may change its state only at fixed, regular intervals, and only in accordance with fixed rules that depend on cells' own values and the values of neighbors within a certain proximity (usually two- for one-dimensional, and four- for two-dimensional cellular automata). Cellular automata are a base of cellular computers; fine grain systems that are usually data-driven and used to implement neural networks, systolic arrays, and SIMD architectures.

cellular communications traditionally, an outside-of-building radio telephone system that allows users to communicate from their car or from their portable telephone.

cellular manufacturing grouping of parts by design and/or processing similarities such that the group (family) is manufactured on a subset of machines which constitute a cell necessary for the group's production.

cellular spectral efficiency the cellular spectral efficiency of a system is defined as the sum of the maximum data rates that can be delivered to subscribers affiliated to all base stations in a re-use cluster of cells, occupying as small a physical area as possible. Mathematically, the cellular spectral efficiency, η, is defined as

$$\eta = \frac{\sum_{j=1}^{r} \sum_{i=1}^{K} R_{ij}}{B A_{cluster}} \text{bit/s/Hz/km}^2$$

where r denotes the number of cells in a re-use cluster, R_{ij} denotes the data rate measured in bits/s at some predefined BER available to subscriber I in cell j of the re-use cluster, B denotes the total bandwidth measured in hertz allocated to all cells in the re-use cluster, and $A_{cluster}$ denotes the physical area, measured in square kilometers occupied by the re-use cluster.

CELP *See* code excited linear prediction.

center frequency (1) the frequency of maximum or minimum response for a band-pass or a bandstop filter, respectively; often taken as the geometric mean of the lower and upper cutoff frequencies.

(2) the frequency at the center of a spectrum display.

(3) the average frequency of the emitted wave after modulation by a sinusoidal signal.

(4) the frequency of a non-modulated wave. *See also* channel.

center of average an approach of defuzzification that takes the weighted average of the centers of fuzzy sets with the weights equal to the firing strengths of the corresponding fuzzy sets.

center of gravity method *See* centroid method.

center of projection the point within a projector from which all the light rays appear to diverge; the point in a camera toward which all the light rays appear to converge before they cross the imaging plane or photographic plate.

central absolute moment for random variable x, the pth central absolute moment is given by $E[|x - E[x]|^p$. *See also* central moment, absolute moment, expectation.

central limit theorem (CLT) in probability, the theorem that the density function of some function of n independent random variables tends towards a normal curve as n tends to infinity, as long as the variances of the variables are bounded: $0 < \sigma \leq v_i \leq \gamma < \infty$. Here σ and γ are positive constants, and v_i is the variance of the ith random variable. *See also* Gaussian distribution.

central moment for random variable X the nth central moment is given by

$$E[(X-m)^2] = \int_{-\infty}^{\infty} (x-m)^2 f_X(x)dx$$

where $f_X(x)$ is the probability density function of X. *See also* central absolute moment, absolute moment. *See also* expectation.

central processing unit (CPU) a part of a computer that performs the actual data processing operations and controls the whole computing system. It is subdivided into two major parts:

1. The arithmetic and logic unit (ALU), which performs all arithmetic, logic, and other processing operations,

2. The control unit (CU), which sequences the order of execution of instructions, fetches the instructions from memory, decodes the instructions, and issues control signals to all other parts of the computing system. These control signals activate the operations performed by the system.

centralized arbitration a bus arbitration scheme in which a central bus arbiter (typically housed in the CPU) accepts requests for and gives grants to any connected device, wishing to transmit data on the bus. The connected devices typically have different priorities for bus access, so if more than one device wants bus access simultaneously, the one with the highest priority will get it first. This prioritization is handled by the bus arbiter.

centrifugal switch a speed-sensitive switch operated by centrifugal force, mounted on the shaft of a motor, used to perform a circuit switching function. Used in single-phase induction motors to disconnect the starting winding when the motor approaches operating speed.

centripetal force force that is present during the robot motion. The force depends upon the square of the joint velocities of the robot and tend to reduce the power available from the actuators.

centroid (1) a region in the pattern space to which a remarkable number of patterns belong.

(2) the center of a mass.

(3) description of the center of a particle beam profile.

centroid defuzzification a defuzzification scheme that builds the weighted sum of the peak values of fuzzy subsets with respect to the firing degree of each fuzzy subset. Also called height defuzzification.

centroid method a widely used method of defuzzification whereby the centroid of the membership function of the fuzzy set is used as the defuzzified or crisp value. It is also known as the center of gravity method or the composite moments method.

centroidal profile a method for characterizing and analyzing the shape of an object having a well defined boundary. The centroid of the shape is first determined. Then a polar (r, θ) plot of the boundary is computed relative to this origin: this plot is the centroidal profile, and has the advantage of permitting template matching for a 2-D shape to be performed relatively efficiently as a 1-D process.

centrosymmetric medium a material that possesses a center of inversion symmetry. Of importance because, for example, second-order nonlinear optical processes are forbidden in such a material.

cepstrum inverse Fourier transform of the logarithm of the Fourier power spectrum of a signal. The complex cepstrum is the inverse Fourier transform of the complex logarithm of the Fourier transform of the signal.

ceramic ferrite a relatively inexpensive permanent magnet material with decent coercivity and low energy product that is composed of strontium or barium oxide and iron oxide. Also called hard ferrite.

cerebellar model articulation (CMAC) network a feedforward network developed originally as a model of the mammalian cerebellum. Several variants now exist, but basic operation involves the first layer of the network mapping the input into a higher-dimensional vector and a second layer forming the network output by means of a weighted sum of the first layer outputs. The weights can be trained using the LMS rule. Developed mainly for application in robotics, it has also been used in pattern recognition and signal processing. Often called a CMAC network.

Cerenkov counter a detector for charged particles. It consists essentially of a transparent medium such as a gas, which emits Cerenkov radiation when a charged particle passes through at a velocity greater than the velocity of light in the medium. The mass of a particle in a beam of known momentum can be determined with such a counter by measuring the characteristic angle at which the Cerenkov radiation is emitted.

Cerenkov radiation light emitted when a charged particle traverses a medium with a velocity greater than the velocity of light in the medium. The Cerenkov light is emitted in a cone centered on the particle trajectory. The opening angle of this cone depends on the velocity of the particle and on the velocity of light in the medium. The phenomenon involved is that of an electromagnetic shock wave and is the optical analogue of sonic boom. Cerenkov radiation provides an important tool for particle detection.

certainty equivalence principle a design method in which the uncertainties of process parameters are not considered. Found in self-tuning regulators where the controller parameters or the process parameters are estimated in real-time and are then used to design the controller as if they were equal to the true parameters. Although many estimation methods could provide estimates of parameter uncertainties, these are typically not used in the control design.

CFD *See* crossed field devices.

CFIE *See* combined field integral equation.

CGA *See* color graphics adapter.

chain code a method for coding thin contours or lines, for example, in a bilevel picture, which encodes the direction of movement from one point to the next. For 8-connected contours, a three-bit code may be used at each point to indicate which of its eight neighbors is the succeeding point.

chain matrix *See* ABCD matrix.

chain parameters *See* ABCD parameters.

chain reaction a process in which high-energy neutrons emitted from fissile radioactive material are directed into more fissile material such that more neutrons are emitted. The process creates heat which is used to power thermal power plants.

chaining when the output stream of one arithmetic pipeline is fed directly into another arithmetic pipeline; used in vector computers to improve their performance.

chaining of fuzzy rules a reasoning strategy which searches the knowledge base and chain from rule to rule to form inferences and draw conclusions. In forward chaining, a chain of data-driven rules are evaluated for which the conditional parts are satisfied to arrive at the conclusion. Backward chaining is goal-driven in which subgoals are established, where necessary, through which a chain of rules are selected, eventually satisfying the goal.

chamfer distance a digital distance based on a chamfer mask, which gives the distance between a pixel and those in its neighborhood; then the chamfer distance between two non-neighboring pixels (resp., voxels) is the smallest weighted length of a digital path joining them. The word "chamfer" comes from the fact that with such a distance a circle is in fact a polygon. The n-dimensional Manhattan and chessboard distances are chamfer distances; the Euclidean distance is not. In the 2-D plane, the best chamfer distances are given by the $(3, 4)$ and $(5, 7, 11)$ Chamfer masks: in the $(3, 4)$ mask, a pixel is at distance 3 from its horizontal/vertical neighbors and at distance 4 from its diagonal neighbors, while in the $(5, 7, 11)$ mask, it is at distance 5 from its horizontal/vertical neighbors, at distance 7 from its diagonal neighbors, and at distance 11 from its neighbors distant by 1 and 2 respectively along the two axes. *See* chessboard distance, Euclidean distance, Manhattan distance.

channel (1) the medium along which data travel between the transmitter and receiver in a communication system. This could be a wire, coaxial cable, free space, etc. *See also* I/O channel.

(2) the conductivity path between the source and the drain of a field effect transistor.

(3) a single path for transmitting electrical signals. Example 1: The band of frequencies from 50 Hz to 15 KHz (Channel A) and 15 KHz to 75 KHz (Channel B) which frequency modulate the main carrier of an FM stereo transmitter. Example 2: A portion of the electromagnetic spectrum assigned for operation of a specific carrier from the FM broadcast band (88 to 108 MHz) of frequencies 200 KHz wide designated by the center frequency beginning at 88.1 MHz and continuing in successive steps to 107.9 MHz.

channel allocation the act of allocating radio channels to cells, base stations, or cell sectors, in a radio network, also referred to as frequency allocation, or frequency planning. The allocation typically follows an algorithm that attempts to maximize the number of channels used per cell and minimize the interference in the network.

channel architecture a computer system architecture in which I/O operations are handled by one or more separate processors known as channel subsystems. Each channel subsystem is itself made up of subchannels, in which control unit modules control individual I/O devices. Developed by IBM, and used primarily in mainframe systems, the channel architecture is capable of a very high volume of I/O operations.

channel capacity a fundamental limit on the rate at which information can be reliably communicated through the channel. Also referred to as "Shannon capacity," after Claude Shannon, who first formulated the concept of channel capacity as part of the noisy channel coding theorem.

For an ideal bandlimited channel with additive white Gaussian noise, and an input average power constraint, the channel capacity is $C = 0.5 \log(1 + S/N)$ bit/Hz, where S/N is the received signal-to-noise ratio.

channel code a set of codewords used to represent messages, introducing redundancy in order to provide protection against errors introduced by transmission over a channel. *See also* source code.

channel coding the process of introducing controlled redundancy into an information sequence mainly to achieve reliable transmission over a noisy channel. Channel coding can be divided into the areas of block coding and trellis coding. Also called error control coding. *See also* block coding, trellis coding and convolutional coding.

channel command word an "instruction" to an I/O channel. The commands consists of parameters (e.g., "operation," "data address," "count") giving the channel processor information on type of I/O operation requested (e.g., "read" or "write"), where the data is to be read or written, and the number of bytes involved in the data transfer.

In the IBM mainframe architecture there are six different types of channel control words: READ, READ BACKWARD, WRITE, CONTROL, SENSE, and JUMP.

channel control word *See* channel command word.

channel encoder a device that converts source-encoded digital information into an analog RF signal for transmission. The type of modulation used depends on the particular digital audio broadcasting (DAB) system, although most modulation techniques employ methods by which the transmitted signal can be made more resistant to frequency-selective signal fading and multipath distortion effects.

channel estimation estimation of the radio channel parameters in the receiver. Typically delays, amplitudes, carrier phases, and direction-of-arrivals need to be estimated depending on the receiver configuration. Channel estimation is a modern way to look at receiver synchronization based mainly on feedback control loops, since in principle any method known to estimation theory can be applied to achieve synchronization of the receiver over an unknown radio channel.

channel I/O an approach to I/O processing in which I/O operations are processed independent from the CPU by a channel system. *See also* channel architecture.

channel matched VQ *See* channel optimized vector quantization.

channel measurement *See* channel sounding.

channel modeling the act of describing the effect of the (radio) channel on the transmitted signal in a form suitable for mathematical analysis, computer simulation or hardware simulation. A channel model is a collection of channel characteristics essential to the performance of the communication system under study, organized in such a way that the basic performance trade-offs of the system can be analyzed or simulated without having to construct prototypes or carry out field tests.

channel optimized vector quantization (COVQ) a combined source-channel code for block-based source coding (vector quantization) and block channel coding. A channel optimized vector quantizer can be designed using a modified version (taking channel induced distortion into account) of the generalized Lloyd algorithm). Also referred to as channel matched VQ. *See also* noisy channel vector quantization.

channel program the set of channel control words that make up the instruction sequence that controls an I/O channel. *See also* channel control word.

channel reliability function the rate function with infinitesimal error probability expressed by

$$E(R) = \begin{cases} \frac{1}{2}C_\infty & 0 \le R \le \frac{1}{4}C_\infty \\ \left(\sqrt{C_\infty} - \sqrt{R}\right)^2 & \frac{1}{4}C_\infty \le R \le C_\infty \end{cases}$$

for transmission of orthogonal or simplex signal over infinite bandwidth AWGN channel. C_∞ is the capacity of the infinite bandwidth white Gaussian noise channel, defined as

$$C_\infty = \frac{P_{av}}{N_o ln2} \text{bit/s} .$$

channel robust vector quantization a vector quantizer that has been made robust against channel errors. *See also* noisy channel VQ.

channel robust VQ *See* channel robust vector quantization.

channel sounding the act of recording from a real, physical channel a selected set of characteristics describing the channel. This involves transmitting a known signal to the channel under study, and at the receiver processing the received signal to extract the required information, typically the impulse response or the transfer function of the channel.

channel spill leakage of RF energy from a radio channel n into a radio channel $n \pm i$, $i \geq 1$, due to finite channel filter attenuation outside of the bandwidth of n.

channel step *See* frequency synthesizer.

channel subsystem the I/O processing component of a computer system conforming to the channel architecture model.

channel waveguide a light guide that is either raised above or diffused into a substrate.

channel-to-case thermal resistance the proportionality constant (denoted θ_{cc}) at thermal equilibrium between the temperature difference of the FET channel ($T_{channel}$) and a specified case surface (T_{case}) to the dissipated power in the channel (P_w), in units of $°C/W$. The specified surface is usually the most effective in reducing the temperature. It includes the thermal resistance of the chip, die attach material (solder or adhesive), packaging and mounting medium, as applicable.

$$\theta_{cc} = \left. \frac{T_{channel} - T_{case}}{P_w} \right|_{equilibrium}$$

channelizer a system that decomposes an RF signal into narrow-band output channels; term often applied to acousto-optic spectrum analyzers that are driven by RF frequency signals. *See also* acousto-optic spectrum analyzer.

chaos (1) erratic and unpredictable dynamic behavior of a deterministic system that never repeats itself. Necessary conditions for a system to exhibit such behavior are that it be nonlinear and have at least three independent dynamic variables.

(2) in microelectronics, deterministic motion, in which the statistics are essentially those of a Gaussian random process.

chaotic behavior a highly nonlinear state in which the observed behavior is very dependent on the precise conditions that initiated the behavior. The behavior can be repeated (i.e., it is not random), but a seemly insignificant change, such as voltage, current, noise, temperature, rise times, etc., will result in dramatically different results, leading to unpredictability. The behavior may be chaotic under all conditions, or it may be well behaved (linear to moderately nonlinear) until some parametric threshold is exceeded, at which time chaotic behavior is observed. In a mildly chaotic system, noticeable deviations resulting from small changes in the initial conditions may not appear for several cycles or for relatively long periods. In a highly chaotic system, the deviations are immediately apparent.

character (1) letter, number or symbol as used on a computer keyboard.

(2) data type that represents an alphanumeric character as a group of bits, usually as an eight-bit byte.

character recognition *See* optical character recognition.

character string (1) a series of continuous bytes in memory, where each byte represents one character.

(2) data structure corresponding to ordered sequence of characters.

characteristic equation the polynomial equation that results when the characteristic function is equated to zero. Its roots gives the singularities of the transfer function model, which in turn determine its transient behavior. Specifically, any root of the characteristic equation that has a negative real part indicates a stable decaying transient, while any root with a positive real part indicates an unstable growing transient. Any root with zero real part indicates a marginally stable transient that neither decays nor grows. The imaginary part of the root gives the frequency of oscillation of the transient signal. *See also* characteristic function.

characteristic function (1) the name given to the denominator polynomial of a transfer function model. Through partial fraction expansion of a transfer function and subsequent inverse Laplace transformation, it is obvious that the characteristics of the system dynamics are defined by this function. For example, the transfer function

$$g(s) = \frac{9}{6 + 5s + s^2}$$

has characteristic function

$$\phi(s) = 6 + 5s + s^2 = (s+2)(s+3)$$

so its output response will contain terms like

$$y(t) = \alpha e^{-2t} + \beta e^{-3t} + \ldots$$

that are characteristic of the system itself. (Other terms in the response are attributed to the forcing input signal.) *See also* characteristic equation.

(2) a transformed probability density function,

$$\Phi_{\boldsymbol{x}}(\boldsymbol{\omega}) = E\left[\exp(j\boldsymbol{\omega}^T \boldsymbol{x})\right]$$

useful in the analytic computation of higher order moments and convolutions of probability densities.

characteristic impedance inherent property of a transmission line that defines the impedance that would be seen by a signal if the transmission line were infinitely long. If a signal source with a “source” or “reference” impedance equal to the characteristic impedance is connected to the line there will be zero reflections.

characteristic loci the plots of the eigenvalues of transfer function matrices, evaluated over a range of frequencies. These traces, which are parametrized by frequency, are shown on a single Nyquist plot and used to predict the closed loop stability of multiinput-multioutput systems, by application of the principle of the argument for complex variable functions. Unlike the Nyquist plots for single-input-single-output systems, an individual eigenvalue might not encircle the plane an integral number of times, yet the total encirclements of all the eigenvalues will be an integral number.

characteristic polynomial and equation of generalized 2-D model the determinant

$$\begin{aligned} & p(z_1, z_2) \\ &= \det\left[E z_1 z_2 - A_0 - A_1 z_1 - A_2 z_2\right] \\ &= \sum_{i=0}^{n_1} \sum_{j=0}^{n_2} a_{ij} z_1^i z_2^j \end{aligned}$$

($n_1, n_2 \leq rank\ E$) is called the 2-D characteristic polynomial of the generalized 2-D model

$$\begin{aligned} E x_{i+1,j+1} = {} & A_0 x_{ij} + A_1 x_{i+1,j} + A_2 x_{i,j+1} \\ & + B_0 u_{ij} + B_1 u_{i+1,j} + B_2 u_{i,j+1} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) where $x_{ij} \in R^n$ is the semistate vector, $u_{ij} \in R^m$ is the input vector, and E, A_k, B_k ($k = 0, 1, 2$) are real matrices with E possibly singular or rectangular.

$p(z_1, z_2) = 0$ is called the 2-D characteristic equation of the model.

characteristic polynomial assignment of 2-D Roesser model consider the 2-D Roesser model

$$\begin{bmatrix} x^h_{i+1,j} \\ x^v_{i,j+1} \end{bmatrix} = \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} u_{ij}$$

$i, j \in Z_+$ (the set of nonnegative integers) with the state-feedback

$$u_{ij} = K \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} + v_{ij}$$

where $x^h_{ij} \in R^{n_1}$, and $x^v_{ij} \in R^{n_2}$ are the horizontal and vertical state vectors, respectively, $u_{ij} \in R^m$ is the input vector, and A_1, A_2, A_3, A_4, B_1, B_2 are real matrices of the model,

$$K = [K_1, K_2] \in R^{m \times (n_1 + n_2)}$$

and $v_{ij} \in R^m$ is a new input vector. Given the model and a desired 2-D characteristic polynomial of the closed-loop system $p_c(z_1, z_2)$, find a gain feedback matrix K such that

$$\det \begin{bmatrix} I_{n_1} z_1 - A_1 - B_1 K_1 & -A_2 - B_1 K_2 \\ -A_3 - B_2 K_1 & I_{n_2} z_2 - A_4 - B_2 K_2 \end{bmatrix}$$

$$= p_c(z_1, z_2) = \sum_{i=0}^{n_1} \sum_{j=0}^{n_2} d_{ij} z_1^i z_2^j \ \left(d_{n_1 n_2} = 1\right)$$

characteristic polynomial of 2-D Fornasini–Marchesini model the determinant

$$p(z_1, z_2) = \det \left[I_n z_1 z_2 - A_1 z_1 - A_{z_2} z_2 \right] = \sum_{i=0}^{n_1} \sum_{j=0}^{n_2} a_{ij} z_1^i z_2^j \ (a_{nn} = 1)$$

is called the 2-D characteristic polynomial of the 2-D Fornasini–Marchesini model

$$x_{i+1,j+1} = A_1 x_{i+1,j} + A_2 x_{i,j+1} + B_1 u_{i+1,j} + B_2 u_{i,j+1}$$

$i, j \in Z_+$ (the set of nonnegative integers) where $x_{ij} \in R^n$ is the local state vector, $u_{ij} \in R^m$ is the input vector, and A_k, B_k $(k = 1, 2)$ are real matrices.

$p(z_1, z_2) = 0$ is called the 2-D characteristic equation of the model.

characteristic polynomial of 2-D Roesser model the determinant

$$p(z_1, z_2) = \det \begin{bmatrix} I_{n_1} z_1 - A_1 & -A_2 \\ -A_3 & I_{n_2} z_2 - A_4 \end{bmatrix} = \sum_{i=0}^{n_1} \sum_{j=0}^{n_2} a_{ij} z_1^i z_2^j \ \left(a_{n_1} n_2 = 1\right)$$

is called the 2-D characteristic polynomial of the 2-D Roesser model

$$\begin{bmatrix} x^h_{i+1,j} \\ x^v_{i,j+1} \end{bmatrix} = \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} u_{ij}$$

$i, j \in Z_+$ (the set of nonnegative integers) where $x^h_{ij} \in R^{n_1}$, and $x^v_{ij} \in R^{n_2}$ are the horizontal and vertical state vectors, respectively, $u_{ij} \in R^m$ is the input vector, and A_1, A_2, A_3, A_4, B_1, B_2 are real matrices.

$p(z_1, z_2) = 0$ is called the 2-D characteristic equation of the model.

characterization the process of calibrating test equipment, measuring, de-embedding and evaluating a component or circuit for DC RF and/or digital performance.

charge a basic physical quantity that is a source of electromagnetic fields.

charge carrier a unit of electrical charge that when moving, produces current flow. In a semiconductor two types of charge carriers exist: electrons and holes. Electrons carry unit negative charge and have an effective mass that is determined by the shape of the conduction band in energy-momentum space. The effective mass of an electron in a semiconductor is generally significantly less than an electron in free space. Holes have unit positive charge. Holes have an effective mass that is determined by the shape of the valence band in energy-momentum space. The effective mass of a hole is generally significantly larger than that for an electron. For this reason, electrons generally move much faster than holes when an electric field is applied to the semiconductor.

charge conservation physical law (derived from Maxwell's equations) indicating that no change in the total charge within a certain volume can exist without the proper flow of charge (current) through that volume.

charge density describes the distribution of charge along a line, on a surface or in a volume. May be discrete or continuous.

charge-coupled device (CCD) a solid-state device used to record images. A CCD is a digital device which counts the photons that strike it by making use of the photoelectric effect. In a typical CCD array, a large number of such devices is collected into a 2-D grid. Each device corresponds to a single pixel, and the number of electrons in the device is linearly related to the brightness or intensity value at that point in the CCD.

charge-coupled device detector a charge-coupled device (CCD) connected to photodetectors, where the photocharge is put into the CCD potential wells for transport and processing.

charge-coupled-device memory large-capacity shift registers making use of charge-coupled devices (CCD), i.e., MOS devices in which data bits are stored dynamically as charge between a gate and the substrate. This forms a multigate MOS transistors with the source and drain terminals "stretched" apart, and a number of gate terminals in between. The first gate terminal (closest to the source) inserts bits (charge) into the register, and the following gates are controlled with overlapping clocks allowing the charge to move along the array. At the far (drain) end, the bit under the final gate terminal is detected as a change in current.

charge-spring model *See* electron oscillator model.

charging current that portion of an electric power line's current which goes to charge the capacitance of the line. The charging current is not available for power transmission.

chattering fast switching. The term comes from the noise generated by the sustained rapid opening and closing of a switching element. *See also* discontinuous control.

Chattuck coil a finely wound solenoid about a flexible, nonmagnetic core that is usually used in conjunction with a fluxmeter to measure magnetic potential between two points; a magnetic analog of a voltmeter.

CHDL *See* computer hardware description language.

Chebyshev alignment a common filter alignment characterized by ripples of equal amplitude within the pass-band and a steep rolloff in the vicinity of cutoff frequency.

Chebyshev filter one of a class of commonly used low pass, high pass, band pass and band stop filters with an equiripple characteristic, designed to achieve relatively rapid rolloff rates (*See also* Butterworth filter) near cutoff frequencies, at the expense of a loss of monotonicity in either the passbands or the stopbands.

checkerboarding *See* fragmentation.

checkpoint time in the history of execution at which a consistent version of the system's state is saved so that if a later event causes potential difficulties, the system can be restarted from the state that had been saved at the checkpoint. Checkpoints are important for the reliability of a distributed system, since timing problems or message loss can create a need to "backup" to a previous state that has to be consistent in order for the overall system to operate functionally.

checkpointing method used in rollback techniques in which some subset of the system states (data, program, etc.) is saved at specific points (checkpoints), during the process execution, to be used for recovery if a fault is detected.

checksum checksum is a value used to determine if a block of data has changed. The checksum is formed by adding all of the data values in the block together, and then finding the 2's complement of the sum. The checksum value is added to the end of the data block. When the data block is examined (possibly after being received over a serial line), the sum of the data values and checksum should be zero.

checksum character in data communication and storage devices, an extra character is often added at the end of the data so that the total number of ones in a block, including the checksum character is even. The checksum character is used to detect errors within the data block.

chemical beam epitaxy (CBE) a material growth technique that uses metal organic molecules in high vacuum growth chamber and a controlled chemical reaction on a heated substrate to grow a variety of II-VI, III-V, and group IV materials with atomic layer control. Used to create material structures for a variety of electronic and optical devices using quantum wells, heterostructures, and superlattices. This growth technique combined aspects of both MBE and MOCVD growth.

chemical laser a laser in which the amplification results from one or more chemical reactions; potentially very powerful with principal output lines in the mid-infrared.

chemical sensor the interface device for an instrumentation system that determines the concentration of a chemical substance.

chemical vapor deposition (CVD) a process used in the manufacture of integrated circuits or optical fibers whereby a thin solid film of one material is deposited on the surface of another by using a radio frequency or other electrical energy source to dissociate a reactive gas.

chemically amplified resist a type of photoresist, most commonly used for deep-UV lithography, which, upon post-exposure bake, will multiply the number of chemical reactions through the use of chemical catalysis.

chemiluminescence light emitted as a result of a chemical reaction.

Chernobyl typically refers to a fire at a nuclear power plant near Kiev in the Republic of the Ukraine.

chessboard distance the distance between discrete points arising from the L^∞ norm. Given two discrete points $x = (x_1, \ldots, x_n)$, $y = (y_1, \ldots, y_n)$ on an n-dimensional integer lattice, the *chessboard distance* between x and y is $\max\{|x_1 - y_1|, \ldots, |x_n - y_n|\}$. So called because it equals the number of moves made by a King when going from one position to another in the game of chess. *See* norm.

chi-squared distribution a probability distribution with n degrees of freedom and probability density function

$$f(x) = \frac{x^{\frac{n}{2}-1} e - \frac{x}{2} u(x)}{2^{\frac{n}{2}} \Gamma(\frac{n}{2})}.$$

chip (1) a small piece of semiconductor material upon which miniaturized electronic circuits can be built.

(2) an individual MMIC circuit or subsystem that is one of several identical chips that are produced after dicing up an MMIC wafer.

(3) in direct-sequence spread-spectrum transmission, the high bandwidth symbols, or pulses making up the signature sequence. They are used to spread the bandwidth of the data in frequency. Usually the time duration

of these pulses are many times smaller than that of the information symbols leading to significantly greater spreading of the signal bandwidth.

chip carrier a low-profile rectangular component package, usually square, whose semiconductor chip cavity or mounting area is a large fraction of the package size and whose external connections are usually on all four sides of the package.

chip chart this term is often used for the "gray scale" chart used in the process of aligning television camera systems. The gray scale provides logarithmic reflectance relationships.

chip select a control signal input to, e.g., a memory chip, used to make this particular chip "active" in reading or writing the data bus. Read or write is determined by another control input signal: the "R/W-signal." Typically, some of the high order bits from the CPU's address bus are decoded to form the chip select signals.

chip-to-chip optical interconnect optical interconnect in which the source and the detector are connected to electronic elements in two separate chips.

chirp the varying in time of a carrier frequency signal. *See also* chirp function.

chirp function a signal whose frequency varies monotonically with time, e.g., a linear chirp possesses a linear-frequency or a quadratic-phase variation.

chirp signal *See* chirp function.

chirping a shifting of the optical frequency often observed in modulated semiconductor lasers where the laser gain is modulated at high bandwidth; arises due to the later portions of the modulating signal seeing a different refractive index, or carrier density, than the earlier portions.

Cholesky decomposition a matrix-algebraic theorem that states that, for any positive definite square matrix $\mathbf{A}$**,** there exists a lower-left triangular matrix $\mathbf{G}$ such that $\mathbf{A} = \mathbf{G}\,\mathbf{G}^T$.

chopper *See* buck converter and DC chopper.

chopper - depth of modulation a marker normally associated with the monitoring of the depth of modulation of a television broadcast signal on a waveform monitor. The chopper reference is used to set the 0% modulation point relative to the video signal. The sync signal is typically at the 100% modulation level.

chroma the portion of the video signal defining the color information in the image. The chroma signal is defined by changes in the 3.579545 Mhz interlaced sinewave. Phase changes create changes in color, peak-to-peak changes in the sinewave alter the saturation of the color while changes in the DC level of the chroma signal alter the luminance (brightness).

chromatic aberration (1) beam spreading due to different momentum of the particles that are being bent by the quadrupole fields at different angles.

(2) the failure of a lens to simultaneously focus all colors of light. It arises since the refractive index of a material depends on the wavelength of light.

chromaticity (1) the ratio of tune spread to momentum spread of the beam. Chromaticity affects the focusing and bending properties of magnets by making them sensitive to particle momentum. This results in focusing and bending dispersion of the beam in a manner analogous to an optical system.

(2) specification of color stimuli. The chromaticity coordinates are relative RGB values correlated with hue and saturation.

chrominance (1) the color information in the video signal that is defined in terms of hue and saturation.

(2) the component of color which is independent of, and complementary to *luminance*; *chrominance* is 2-D: for example, it can be decomposed into *hue* and *saturation*. *See* hue, intensity, luminance, saturation.

chronaxie the minimum duration of a unidirectional square-wave current needed to excite a nerve when the current magnitude is twice rheobase.

CIE *See* Commision International d'Eclairage.

CIE diagram the projection of the plane $(X + Y + Z) = 1$ onto the XY plane, where X, Y, Z are the respective tristimulus values as defined by the CIE (*See* tristimulus value and Commision International d'Eclairage). The CIE diagram shows all of the visible chromaticity values and maps all colors with the same chromaticity but different value (luminances) onto the same points.

CIM *See* computer-integrated manufacturing.

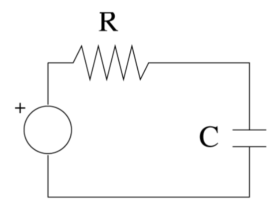
CIR *See* carrier-to-interference ratio.

circle detection the location of circles in an image by a computer. Often accomplished with the Hough transform.

circle diagram (1) graphical representation of the operation of an induction machine. It is based on the approximate equivalent circuit and expresses stator and rotor current relations for all operating modes (motor, braking, generator) and all values of slip. Several variations of the diagram exist.

(2) graphical representation of the power flow through a transmission line. The maximum power flow through the line can be determined by the impedance of the line.

circuit a physical device consisting of an interconnection of elements, or a topological model of such a device. For example, an electric circuit may be constructed by interconnecting a resistor and a capacitor to a voltage source. A representation of this circuit is shown by the diagram in the figure.



Circuit example.

circuit (STM) switching technology that provides a direct connection between two endpoints; data is transferred directly between the endpoints of a circuit without being stored in any intermediate nodes.

circuit breaker a circuit breaker is a device that makes and breaks the electrical contact between its input and output terminals. The circuit breaker is capable of clearing fault currents (tripping) as well as load currents. The circuit breaker consists of power contacts with arc clearing capability and associated control and auxiliary circuits for closing and tripping the breaker under the required conditions.

circuit protection devices or control measures used to safeguard electrical circuits from unsafe operating regions, such as overcurrents and overvoltages.

circuit switching a method of communication in which a physical circuit is established between two terminating equipments before communication begins to take place. This is analogous to an ordinary phone call.

circuit-set a closed path where all vertices are of degree 2, thus having no endpoints in the path.

circuit-switched service a telecommunications service, where the communications resource is retained for the whole period of communication. For example wired telephone services or mobile telephone services in the first- and second-generation systems can be classified to circuit-switched services.

circulant matrix a square $N \times N$ matrix $\boldsymbol{M} = \{m_{i,j}\}$ such that $m_{i,j} = m_{(i+n)\mathrm{mod}N,(j+n)\mathrm{mod}N}$; that is, that each row of M equals the previous row rotated one element to the right. All circulant matrices are diagonalized by the discrete Fourier transform.

circular cavity a section of the circular waveguide closed at both ends by conducting plates.

circular convolution *See* periodic convolution.

circular mil the area of a circle which measures 0.001 inch in diameter.

Used to specify the cross-sectional area of a wire.

circular polarization a polarization state of a radiated electromagnetic field in which the tip of the electric field vector traces a circle as a function of time for a fixed position. The sense of rotation of the electric field vector is either right-hand or left-hand (clockwise or counter-clockwise).

circular register buffer a set of general purpose CPU registers organized to provide a large number of registers, which may be accessed a few at a time. The group of registers accessible at any particular time may be readily changed by incrementing or decrementing a pointer, with wraparound occurring from the highest numbered registers to the lowest numbered registers, hence the name circular register buffer. There is overlap between the groups of adjoining registers that are accessible when switching occurs. The overlapping registers can be used for passing arguments during subroutine calls and returns. The circular register buffer is a feature of the SPARC CPU architecture. In the SPARC CPU there are 256 registers, available 32 at a time, with an overlap of eight registers above and eight registers below the current group.

circular self-test path a BIST technique based on pseudorandom testing assured by arranging flip-flops of a circuit (during test) in a circular register in which each flip-flop output is ex-ored with some circuit signal and feeds the input of the subsequent flip-flop. This register simultaneously provides test pattern generation and test result compaction.

circularity measure the size invariant ratio of area divided by perimeter squared for small shapes and much used as a preliminary discriminant or measure of shape, so-called because it is a maximum for circular objects.

circularly polarized light light composed of two orthogonal polarizations that are 90 degrees out of phase; the resultant light amplitude vector thus rotates about the direction of propagation at the optical frequency.

circulator a multiport nonreciprocal device that has the property that an electromagnetic wave incident in port 1 is coupled to port 2 only, an electromagnetic wave incident in port 2 is coupled into port 3 only and so on.

CIRF *See* cochannel interference reduction factor.

CISC processor *See* complex instruction set computer.

Citizen's band (cb) 40 channels where the carrier frequency is between 26.965 MHz and 27.405 MHz established by the FCC for short-distance personal or business communication.

city-block distance a distance measure between two real valued vectors ($x_1, x_2, \ldots, x_n$) and ($y_1, y_2, \ldots, y_n$) defined as

$$D_{\textit{city block}} = \sum_{i=1}^{n} |x_i - y_i|$$

City-block distance is a special case of Minkowski distance when $\lambda = 1$. *See also* Minkowski distance. Also called Manhattan distance.

cladding the optical material that concentrically surrounds the fiber core and provides optical insulation and protection for the core. The refractive index of the cladding must be lower than that of the core material so that optical power is guided through the fiber by total internal reflection at the core-cladding boundary. *See also* total internal reflection, Snell's Law.

clamping the process of fixing either the minima or maxima of a voltage.

Clapp oscillator an oscillator whose frequency is determined by a tuned parallel LC circuit with a split capacitance, i.e., two series capacitances, in the capacitive branch and an additional series tuning capacitance in the inductive branch. The Clapp oscillator is a variation of the Colpitts oscillator.

class (1) in general, patterns are commonly discriminated into different categories according to certain properties they share. The categories in which a given set of patterns are partitioned are referred to as classes.

(2) in object orientation, is an entity that defines a set of objects which share the same attributes and processes.

class fuse *See* UL classes.

class A amplifier an amplifier in which the active device acts as a modulated current source biased midway between saturation and conduction cutoff. In a class A amplifier, as the amplitude of an applied sinusoidal signal is increased, the output will start to clip at both ends simultaneously. This is equivalent to a conduction angle of 360 degrees as long as the output signal is not clipping, which is avoided. This term is often used to include any amplifier operating with signal levels low enough such that signal clipping is not present (i.e., small signal conditions).

class A-B amplifier most current source amplifiers fall into this category, which includes all amplifiers biased somewhere between class A and class B. As the amplitude of a sinusoidal signal is increased, the output will start to cut off first. Further increases will cause clipping due to saturation. Thus the conduction angle is between 180 and 360 degrees, dependent on applied signal amplitude. Device saturation is usually avoided.

class B amplifier an amplifier in which the active device acts as a modulated current source biased at conduction cutoff. In a class B amplifier, an applied sinusoidal signal will result in only half of the sinusoid being amplified, while the remaining half is cut off. Further increases in the signal amplitude will eventually cause the remaining half of the signal to saturate and clip, which is usually avoided. This is equivalent to a conduction angle of 180 degrees, regardless of signal amplitude.

class B-D amplifier switched mode amplifier where the device is biased at cutoff, and the input signal is large enough to drive the amplifier into heavy saturation such that only a small percentage of time is spent in transition. The amplifier is literally switched between cutoff and saturation, and thus the saturation angle is a significant percentage of the conduction angle, which is 180 degrees. The unfiltered, broadband output current waveform of a class B-D amplifier resembles a stepped squarewave. It is important to note that only frequency related information (FM) is preserved in a class B-D amplifier, while all amplitude information (AM) is lost. Usually, class B-D power amplifiers are designed in a push-pull configuration to take advantage of both halves of a cycle.

class B-E amplifier transient switched mode amplifier where the device is biased at cutoff, the input signal is large enough to drive the amplifier into heavy saturation such that only a small percentage of time is spent in transition, and the design is such that during saturation the waveform is determined by the switch circuit transient response, while the waveform during cutoff is determined by the transient response to the entire circuit, including the load. The amplifier is literally switched between cutoff and saturation, the transient responses are well controlled, and thus the saturation angles approach the conduction angle, which is 180 degrees. The final tuned output current wave form of a class B-E amplifier resembles an ideal squarewave. It is important to note that only frequency related information (FM) is preserved in a class B-E amplifier, while all amplitude information (AM) is lost.

class C amplifier a current source amplifier biased beyond the conduction cutoff such that operation will not begin until the input signal reaches a specific amplitude, and results in less than half of an input sinusoid being amplified. If the signal amplitude is increased sufficiently, saturation and the associated clipping will occur. Thus the conduction angle is between 0 and 180 degrees, regardless of amplitude. Device saturation is usually avoided.

class D amplifier switched mode amplifier where the device is biased somewhere between class A and class B cutoff, and the input signal is large enough to drive the amplifier from cut-off to heavy saturation such that only a small percentage of time is spent in transition. The amplifier is literally switched between cutoff and saturation, and thus the saturation angle is a significant percentage of the conduction angle, which is 180 degrees. The unfiltered, broadband output current waveform of a class D amplifier resembles a stepped squarewave. It is important to note that only frequency related information (FM) is preserved in a class D amplifier, while all amplitude information (AM) is lost. Usually, class D power amplifiers are designed in a push-pull configuration to take advantage of both halves of a cycle.

class E amplifier a transient switched mode amplifier where the device is biased somewhere between class A and class B cutoff, the input signal is large enough to drive the amplifier into heavy saturation such that only a small percentage of time is spent in transition, and the design is such that during saturation the waveform is determined by the switch circuit transient response, while the waveform during cutoff is determined by the transient response to the entire circuit, including the load. The amplifier is literally switched between cutoff and saturation, the transient responses are well controlled, and thus the saturation angles approach the conduction angle, which is 180 degrees. The final tuned output current waveform of a class E amplifier resembles an ideal squarewave. It is important to note that only frequency related information (FM) is preserved in a class E amplifier, while all amplitude information (AM) is lost.

class E-F amplifier a harmonic tuned or harmonic reaction amplifier (HRA) in which devices, biased for class B operation, are arranged in a push/pull configuration, and are utilized to inject each other with large harmonic currents in order to modulate the amplitude of the fundamental output current through the device, resulting in improved switching efficiency. The even order harmonics must be shorted at the output, while the odd order harmonics must be provided an open at the output.

class F amplifier a high-efficiency operation in amplifiers. The class F amplifier has a load impedance optimized not only for a fundamental wave but also for harmonic waves to improve efficiency. An efficiency of the class F amplifier is 100% under an ideal condition, where the optimum load impedance for even harmonic waves is short and that for odd harmonic waves is open.

class G amplifier a frequency multiplying or harmonic amplifier biased somewhere between class A and class C, in which the input is tuned to the fundamental input frequency and the output is tuned to a frequency multiple of the input.

class H amplifier frequency mixing amplifier biased somewhere between class A and class C, in which the inputs are tuned to the input frequencies and the output is tuned to either the sum or difference frequency.

class S amplifier sampling or pulse width modulation amplifier in which a sampling circuit (or pulse width modulator), pulse amplifier and a low pass filter are cascaded. The input signal is sampled at a significantly higher rate than the input frequency (this requires a high frequency sampling signal), and the original signal is transformed into a constant amplitude pulse chain in which the pulse widths are proportional to the original signal's amplitude. The resulting pulse chain is amplified using any of the highly efficient switching methods desired. The output is then demodulated using a low pass filter, replicating the original signal. It is important to note that rapid variations in the input signal amplitude relative to the sampling signal will cause significant distortion or loss of information.

classified VQ *See* classified vector quantization.

classified vector quantization (CVQ) a vector quantization technique where different codebooks are developed based image edge features. The codebook used to encode a particular block is determined by a classifier with differentiating capability between the types of features. A number of codebooks are developed each to encode blocks of pixels containing specific types of features. *See also* vector quantization.

classifier (1) given a set of patterns of different classes, a classifier is a system capable of determining the membership of each pattern.

(2) a method of assigning an object to one of a number of predetermined classes.

clean cache block a cache block (or "line") is clean if it is a copy of the information stored in memory. A clean block can be overwritten with another block without any need to save its state in memory.

clear (1) to set the value of a storage location to zero (often used in the context of flip-flops or latches).

(2) clearing a bit (register) means writing a zero in a bit (register) location. Opposite to "set."

clearing time the total time required to melt and clear, and thus totally open, a fuse-type overcurrent device.

cleaved coupled cavity semiconductor laser configuration in which the amplifying region has been cleaved to introduce a mid-cavity reflecting boundary; added reflector is intended to improve mode-selectivity characteristics.

click noise in a fading channel, the noise associated with a threshold crossing. In a fading radio channel situation, the moving user crosses the standing wave patterns in the propagation environment. As the user crosses the minima, the service quality temporarily downgrades and, in analogue systems, is noticeable as clicking.

climbers two metal spikes, each of which is strapped to the inside of a line worker's legs, pointing down near the ankle. Plunged into the sides of a wooden utility pole, they provide purchase for the worker to scale the pole.

clipping nonlinear distortion that occurs when the input to an amplifier exceeds the amplifier's linear range. The amplifier output saturates at its limit, giving a "clipped" appearance to the output waveform.

clock (1) the oscillator circuit that generates a periodic synchronization signal.

(2) a circuit that produces a series of electrical pulses at regular intervals that can be used for timing or synchronization purposes.

clock cycle one complete event of a synchronous system's timer, including both the high and low periods.

clock doubling a technique in which the processor operates internally at double the external clock frequency.

clock duty cycle the percentage of time that the electronic signal remains in the true or 1 state.

clock pulse a digital signal that, via its rising edge or falling edge, triggers a digital circuit. Flip-flops and counters typically require clock pulses to change state.

clock recovery in synchronous systems, the act of extracting the system clock signal from the received sequence of information symbols. *See also* symbol synchronization.

clock replacement algorithm a page replacement algorithm described as follows: A circular list of page entries corresponding to the pages in the memory is formed. Each entry has a use bit which is set to a 1 when the corresponding page has been referenced. A pointer identifies a page entry. If the use bit of the page entry is set to a 1, the use bit is reset to a 0 and the pointer advances to the next entry. The process is repeated until an entry is found with its use bit already reset, which identifies the page to be replaced. The pointer advances to the next page entry for the next occasion that the algorithm is required. The word "clock" comes from viewing the pointer as an arm of a clock. Also known as a first-in-not-used-first-out replacement algorithm.

clock skew the phenomenon where different parts of the circuit receive the same state of clock signal at different times because it travels in wires with different lengths. This skew of the signals causes a processing element to generate an erroneous output. Distribution of the clock by means of optical fibers, waveguides, a lens, or a hologram, eliminates clock skew.

clock speed the rate at which the timing circuit in a synchronous system generates timing events.

closed convex set a set of vectors C such that of $\mathbf{x}, \mathbf{y} \in C$ then $\lambda\mathbf{x} + (1-\lambda)\mathbf{y} \in C$ for all $0 \leq \lambda \leq 1$.

closed kinematic chain in vision engineering, a sequence of links which forms a loop.

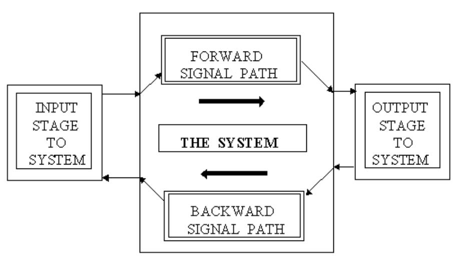
closed-loop control control action achieved by a closed feedback loop, i.e., by measuring the degree to which actual system response conforms to desired system response and applying the difference to the system input to drive the system into conformance.

closed-loop DC motor acceleration the use of sensors to provide feedback to the motor control circuit indicating the motor is actually accelerating before the starting resistors are removed from the armature circuit. Two popular methods to sense motor acceleration are CEMF coils, and current sensing coils.

closed-loop gain the gain of an operational amplifier circuit with negative feedback applied (with the negative feedback loop "closed").

closed-loop optimal control operation or structure of the controller with the decision mechanism which, under uncertainty, uses in the best possible way — with respect to a given *a priori* criterion — all information available to the controller; in particular, the closed-loop optimal control takes into account all future time instants at which new decisions will be made; the best known example of a closed-loop optimal control rule is the solution of the linear-quadratic-Gaussian problem (LQG problem).

closed-loop system any system having two separate paths inside it. The first path conducts the signal flow from the input of that system to the output of that same system. The second path conducts the signal flow from the output to the input of the system, thus establishing a feedback loop for the system. See the figure below for a general description of a closed-loop system. The forward and backward signal path construct the closed loop, which conduct the signal flow from the input stage to the output stage and then back to the input stage of that system.



A closed-loop system.

closing a basic morphological operation. Given a structuring element B, the closing by B is the composition of the *dilation by* B followed by the erosion by B; it transforms X into $X \bullet B = (X \oplus B) \ominus B$. The closing by B is what one calls an algebraic closing; this means that: (a) it is a morphological filter; (b) it is extensive, in other words it can only increase an object. *See* dilation, erosion, morphological filter, structuring element.

closing/opening filter one of an important class of morphological filters. Let γ and φ be opening and closing operators respectively. The following operators can be obtained by composing γ and φ (i.e., by applying them in succession): $\gamma\varphi$, $\varphi\gamma$, $\gamma\varphi\gamma$, and $\varphi\gamma\varphi$. These are all morphological filters, and collectively they are called closing/opening filters or opening/closing filters. No further operators can be obtained by composing γ and φ. *See* closing, morphological filter, opening.

clothes pin slang for a wood or plastic clip used to secure a blanket to conductors.

CLT *See* central limit theorem.

cluster a group of data points on a space or a group of communicating computer machines. A cluster of computers on a local network can be installed to provide their service as a unique computer. This is frequently used for building large data storage and Web servers. In computer disks, a cluster consists of a fixed number of sectors. Each sector contains several bytes, for example 512.

cluster analysis in pattern recognition, the unsupervised analysis of samples to cluster them into classes based on (a) a distance metric and (b) a clustering algorithm. Typical algorithms minimize a cluster criterion (e.g., representation error) by grouping samples hierarchically or by iteratively reassigning samples to clusters. The K-means algorithm is an example of the latter. In the case of 2-D measurements, cluster analysis becomes a method of image segmentation.

clustering (1) any algorithm that creates the major clusters from a given set of patterns.

(2) a method of unsupervised learning that aims to discover useful structure in unlabeled data by grouping similar patterns.

See hierarchical clustering. *See also* distance measure, similarity measure.

clutter the name given to background signals which are currently irrelevant to a detection system; clutter is a form of structured noise.

CMA *See* constant modulus algorithm.

CMAC network *See* cerebellar model articulation network.

CMMR *See* common mode rejection ratio.

CMOS *See* complementary metal oxide semiconductor.

CO abbreviation for central switching office.

CO_2 *See* carbon dioxide.

CO_2 laser *See* carbon dioxide laser.

co-linear array a phased array of straight elements in which the axes of the elements lie along a common line. The elements are typically center fed half-wave dipoles or folded dipoles.

co-occurrence matrix an array of numbers that relates the measured statistical dependency of pixel pairs. Co-occurrence matrices are used in image processing to identify the textural features of an image.

co-prime polynomials polynomials that have no common factors. For example, polynomials $(s^2+9s+20)$ and (s^2+7s+6) are co-prime, while (s^2+5s+6) and $(s^2+9s+14)$ are not, since they have a common $(s+2)$ factor.

co-tunneling a cooperative process, whereby electrons can tunnel through two series connected tunneling barriers. In this process, the tunneling of an electron through one of the barriers causes a self-consistent shift of potential onto the second barrier, which results in the immediate inducing of a particle tunneling through this latter barrier.

coarticulation the transient process corresponding to the utterance of two phonemes. It is due to the movement of the articulatory organs between the different positions corresponding to the two phonemes.

coax *See* coaxial cable.

coaxial cable A transmission line formed by two concentric conductors separated by a dielectric designed to confine the fields and their energy in the medium between said conductors. It is often used in applications where signal interference between the cable and its surrounds must be kept to a minimum. Also called coax.

coaxial magnetron a radial magnetron where the anode and cathode are gradually transformed into a coaxial line.

cochannel interference (CCI) interference caused by radio transmitters operating on the same radio frequency as that of a particular wanted radio frequency signal.

cochannel interference reduction factor (CIRF) a key factor used to design a cellular system to avoid the cochannel interference.

cochannel reuse ratio (CRR) the reuse ratio between radio communication cells using the same radio channels.

cochannels radio channels occupying the same radio frequency allocation n.

cochlea a snail-shaped passage communicating with the middle ear via the round and oval window. Its operation consists of transducing the acoustical vibration to nerve impulses, subsequently processed in the brain.

Cockroft–Walton circuit a cascading voltage multiplier invented in 1932 by John Cockroft and Ernest Walton.

code (1) a technique for representing information in a form suitable for storage or transmission.

(2) a mapping from a set of messages into binary strings.

code acquisition the process of initial code synchronization (delay estimation) between the transmitter and receiver in a spread-spectrum system before the actual data transmission starts. It usually requires the transmission of a known sequence. *See also* code tracking.

code cache a cache that only holds instructions of a program (not data). Code caches generally do not need a write policy, but see self-modifying code. Also called an instruction cache. *See also* cache.

code combining an error control code technique in which several independently received estimates of the same codeword are combined with the codeword to form a new codeword of a lower rate code, thus providing more powerful error correcting capabilities. This is used in some retransmission protocols to increase throughput efficiency.

code converter a device for changing codes from one form to another.

code division multiple access (CDMA) a technique for providing multiple access to common channel resources in a communication system. CDMA is based on spread spectrum techniques where all users share all the channel resources. Multiple users are distinguished by assigning unique spreading codes to each user. Traditionally, individual detection is accomplished at the receiver through correlation or matched filtering.

code efficiency the unitless ratio of the average amount of information per source symbol to the code rate, where the amount of information is determined in accordance with Shannon's definition of entropy. It is a fundamental measure of performance of a coding algorithm.

code excited linear prediction (CELP) a class of linear predictive speech coding methods where the excitation is composed of sample vectors from VQ codebooks.

code hopping the use of a new spreading code for each transmitted bit in a spread-spectrum system. *Compare with* frequency hopping.

code letter *See* NEMA code letter.

code rate in forward error control and line codes, the ratio of the source word length to the code word length, which is the average number of coded symbols used to represent each source symbol.

code segment area in a process' virtual address space used to contain the program's instructions.

code tracking the process of continuously keeping the code sequences in the receiver and transmitter in a spread-spectrum system synchronized during data transmission. *See also* code acquisition.

code V a widely employed computer code for design of optical systems by Optical Research Associates.

codebook a set of codevectors (or codewords) that represent the centroids of a given pattern probability distribution. *See also* vector quantization.

codebook design a fundamental problem in vector quantization (VQ). The main question addressed by codebook design is how the codebook should be structured to allow for efficient searching and good performance. Several methods (tree-structured, product codes, M/RVQ, I/RVQ, G/SVQ, CVQ, FSVQ) for codebook design are employed to reduce computational costs low. *See also* vector quantization, tree structured VQ.

codebook generation a fundamental problem in vector quantization. Codebooks are typically generated by using a training set of images that are representative of the images to be encoded. The best training image to encode a single image is the image itself. This is called a local codebook. The main question addressed here is what codevectors should be included in the codebook. *See also* vector quantization.

codebook training the act of designing a codebook for a source coding system. The LBG algorithm is often used to design the codebook for vector quantizers.

codec word formed from encoder and decoder. A device that performs encoding and decoding of communications protocols.

coded modulation an integrated modulation and coding approach for bandwidth-constrained channel where the redundancy introduced by the code is compensated by increasing the number of signals, for performance improvement without additional bandwidth or transmission power.

codeword the channel symbol assigned by an encoder to a source symbol. Typically the codeword is a quantized scalar or vector.

coding the process of programming, generating code in a specific language. The process of translating data from a representation form into a different one by using a set of rules or tables. *See also* ASCII, EBCDIC, binary.

coding at primary rates for videoconferencing *See* image coding for videoconferencing.

coding gain (1) the reduction in signal-to-noise ratio required for a specified error performance in a block or convolutional forward error control system as compared to an uncoded system with the same information rate, channel impairments, and modulation and demodulation techniques. In a trellis coded modulation system, it is the ratio of the squared free distance in the coded system to that of the uncoded system.

(2) the difference between the SNR/bit (dB) required for an uncoded and a coded system to attain the same arbitrary error probability. Depends on the code parameters and also on the SNR per bit.

coding of graphics use of a representation scheme for graphics. Graphics coding is typically a two-level coding scheme. Both exact and approximate methods are applicable to this type of coding. Run-length coding, predictive coding, line-to-line predictive differential coding, and block coding are typical for graphic coding.

coding of line drawings use of a representation scheme for line drawings. Line drawings are typically coded using chain codes where the vector joining two successive pixels are assigned a codeword. Higher efficiency is obtained by differential chain coding in which each pixel is represented by the difference between two successive absolute codes.

coding redundancy *See* redundancy.

coefficient of thermal expansion (CTE) mismatch the difference between the coefficients of thermal expansion of two components, i.e., the difference in linear thermal expansion per unit change in temperature. (This term is not to be confused with thermal expansion mismatch).

coefficient of utilization (CU) the ratio of the lumens reaching the working plane to the total lumens generated by the lamp. This factor takes into account the efficiency and distribution of the luminaire, its mounting height, the room proportions, and the reflectances of the walls, ceiling, and floor.

coefficient sensitivity let a transfer function be a ratio of polynomials

$$F(s) = \frac{N(s)}{D(s)} = \frac{a_0 + a_1 s + \ldots + a_m s^m}{d_0 + d_1 s + \ldots + d_n s^n}$$

in which the coefficients a_i and d_i are real and can be functions of an arbitrary circuit element x. For such an element x one may define the relative coefficient sensitivities as follows:

$$\mathbf{S}_x^{a_i} = \frac{\partial a_i}{\partial x} \frac{x}{a_i} \qquad \mathbf{S}_x^{d_i} = \frac{\partial d_i}{\partial x} \frac{x}{d_i}$$

The relationship between the function sensitivity and coefficient sensitivities can be established as well.

coercive field the electric field value at which the polarization is zero when a ferroelectric material is cycled through the hysteresis loop. A material has a negative and a positive coercive field and these are usually, but not always, equal in magnitude to each other.

coercive force the demagnetizing field applied to a permanent magnet that reduces its magnetic induction to zero; the x-intercept of the normal demagnetization curve. A commonly listed material property that indicates magnet performance in static conditions.

coercivity *See* coercive force. *See also* intrinsic coercive force.

COGEN *See* cogeneration.

cogeneration (1) any of a number of energy generation systems in which two (or more) forms of energy are produced in forms practical for use or purchase by an end user. Typical systems produce electrical energy for sale to a utility and process steam for local space heating or other process uses. Cogeneration designs are generally adopted to increase the overall efficiency of a power generation process.

(2) typically, the production of heat energy, e.g. to heat buildings, as an adjunct to the production of electric power.

cognitive map the cognitive map, introduced by R. Axelrod to study decision making processes, consists of points, or nodes, and directed links between the nodes. The nodes correspond to concepts. *See also* fuzzy cognitive map.

coherence (1) measure of the extent to which knowledge of a field at one point in space permits prediction of the field at another point.

(2) in an optical fiber.

(3) the coherence between two wide-sense stationary random processes is equal to the cross power spectrum divided by the square root of the product of the two auto-power spectra. The magnitude of the coherence so defined is thus between 0 and 1.

coherence bandwidth the bandwidth over which the effect of communication channel can be assumed constant. Signals of bandwidth less than this can be transmitted without significant distortion.

coherence distance *See* coherence length.

coherence length distance over which the amplitude and phase of a wave can be predicted.

coherence time the time over which the effect of communication channel can be assumed constant. Signals of duration less than this can be transmitted without significant distortion.

coherency a property of a control area that has stiff interconnections between generators. Such an area thus may be described with the use of only a single frequency state variable.

coherent integration where magnitude and phase of received signals are preserved in summation.

coherent acousto-optical processor acousto-optical (AO) signal processor where the light is amplitude-modulated by the acoustic wave in the AO device as opposed to intensity or power modulated.

coherent detection detection technique in which the signal beam is mixed with a locally generated laser beam at the receiver. This results in improved receiver sensitivity and in improved receiver discrimination between closely spaced carriers.

coherent illumination a type of illumination resulting from a point source of light that illuminates the mask with light from only one direction. This is more correctly called "spatially coherent illumination."

coherent light light having a relatively long coherence length; laser light.

coherent optical communication optical communication approaches where information is conveyed in the phase of the optical signal, therefore requiring that the phase of the optical sources be well controlled. *See also* optical communications.

coherent population trapping a technique for creating a quantum mechanical coherence in a lambda system by a dissipative process. Ideally, the intermediate excited state in the lambda system decays rapidly compared to the other two states. The coherence arises because a particular linear combination of ground states is not coupled to the excited state. Atoms accumulate into this uncoupled superposition state by a process analogous to optical pumping, thereby creating a quantum mechanical coherence. This system often has counterintuitive properties, because it uses a dissipative process to create, rather than destroy, a quantum coherence.

coil a conductor shaped to form a closed geometric path. Note that the coil will not be a closed conducting path unless the two ends of the coil are shorted together. Coils may have multiple turns, and may have various constructions including spool, preformed, and mush-wound. The coil may be wrapped around an iron core or an insulating form, or it may be self-supporting. A coil offers considerable opposition to AC current but very little to DC current.

coil pitch *See* coil span.

coil side that portion of a motor or generator winding that cuts (or is cut by) lines of magnetic flux and, thus, contributes to the production of torque and Faraday EMF in the winding.

coil span the distance, measured either in number of coil slots or in spatial (mechanical) degrees, between opposite sides of a winding of an electric machine. A full-span (full-pitch) winding is one in which the winding span equals the span between adjacent magnetic poles. Windings with span less than the distance between adjacent magnetic poles are called short-pitch, fractional-pitch, or chorded windings. Also called coil pitch.

cold plasma a simplified model of the plasma state where the effects that depend on electron temperature are neglected. The particles are assumed to have no kinetic thermal motion of their own. The particles are at rest except for their induced velocities through the action of the self consistent electromagnetic fields.

cold reserve the state of an idle thermal generating plant whose boilers and turbine are cold and must be brought up to operating temperature before power can be generated.

cold start (1) a complete reloading of the system with no reassumption. All executed processes are lost.

(2) the starting of a computer system from a power-off condition.

(3) the state from which a thermal generation unit must be brought after being in cold reserve.

cold start miss in a cache, a cold start miss occurs when a computer program is referencing a memory block for the first time, so the block has to be brought into the cache from main memory. Also called first reference misses or compulsory misses. When the cache is empty, all new memory block references are cold misses. *See also* capacity miss, conflict miss.

collapsible reel a take-up reel used in line work which fits on the power-take-off of a line truck.

collector wall the collector of a bipolar transistor is located below the surface of the substrate. The wall, or sidewall, is the vertical boundary of the collector that meets the substrate material. The boundary usually forms a p-n junction that provides isolation from.

collet a circular spring fingerstock connection element for a power vacuum tube.

colliding-pulse-modelocked (CPM) laser a dye laser resonator design for producing femtosecond pulses; right and left travelling pulses collide in a thin intracavity absorber.

collimated beam with nearly flat phase fronts and slow longitudinal variations of the transverse amplitude distribution.

collinear geometry acousto-optical tunable filter acousto-optical tunable filter device where the acoustic and light waves propagate in the same direction. Also abbreviated collinear geometry AOTF.

collinear geometry AOTF *See* collinear geometry acousto-optical tunable filter.

collision (1) in a pipeline, a situation when two or more tasks attempt to use the same pipeline stage at the same time.

(2) in a hash table, when $n + 1$ different keys are mapped by a hashing function to the same table index (where n entries can be stored).

collision broadening broadening of the spectral profile of an amplifying or absorbing transition due to inelastic or phase-interrupting elastic collisions.

collision vector a binary number in which the ith bit is a 1 if submitting a task into the pipeline i cycles after a task will cause a collision.

color visual sensation associated with the wavelength or frequency content of an optical signal.

color blooming phenomenon where the excess charge at a photo receptor can spread to neighboring receptors, and change their values in proportion to the overload. For RGB cameras, this effect can modify not only the luminance but also the chrominance of pixels. *See* color clipping, chrominance, luminance.

color burst burst of eight to ten cycles of the 3.579545 MHz (3.58 MHz) chrominance subcarrier frequency that occurs during the horizontal blanking of the NTSC composite video signal. The color burst signal synchronizes the television receiver's color demodulator circuits.

color clipping phenomenon where the intensity of the light on a photoreceptor exceeds some threshold, the receptor becomes saturated and its response is no longer linear, but limited to some bound. For RGB cameras, this effect can modify not only the luminance but also the chrominance of pixels. *See* color blooming, chrominance, luminance.

color coding the process of identifying components' values and tolerances by means of a set of colored bands or dots.

color correction in practical photometry it is known that the system used to measure luminescence will not possess the standard eye spectral response as specified by the 1931 International Commission on Illumination (CIE). The measurement "system" will undoubtedly consist of a photodetector, an optical filter and associated lenses. Unfortunately, system output is highly dependent on its spectral response.

color difference signals the chrominance signal component that results from subtracting the luminance (Y) component from a primary color. The luminance signal corresponds to the changes in brightness as from a monochrome video signal. The three primary colors for color television signals are located in Maxwell's chromaticity diagram. Red is at a wavelength of 0.7 micrometer, green at 0.546 micrometer and blue at 0.436 micrometer. The luminance signal component results from the matrix addition of the primary colors. The matrix proportions are 30% red, 59% green, and 11% blue. Two color difference signals, (R-Y) and (B-Y) are sufficient to convey all the information necessary to reproduce full color at the TV receiver. The color difference signal (G-Y) can be determined by proper proportions of the (R-Y), (B-Y) and Y signals at the receiver.

color graphics adapter (CGA) a video adapter proposed by IBM in 1981. It is capable of emulating MDA. In graphic mode, it allows one to reach 640×200 (wide per high) pixels with 2 colors or 320×200 with 4 colors.

color image coding compression of color images is usually done by transforming RGB color space into a YC_1C_2 space, where Y represents luminance and C_1 and C_2 are color difference signals. The C_1 and C_2 signals are then subsampled, but coded with the same algorithm as the Y signal. Standard algorithms do not attempt to exploit correlations between the three signals.

color matching the process of mixing three fixed and independent primary colors so that an observer (trichromat) interprets the formulation as being the same as a specified but arbitrary color. In color television, the three primary colors are fixed at specific wavelengths bands λ_R, λ_G, and λ_B corresponding to colors red, green, and blue.

color preference index (CPI) measure appraising a light source for appreciative viewing of colored objects or for promoting an optimistic viewpoint by flattery.

color representation a method of defining a signal or an image pixel value to be associated with a color index.

color saturation a color with the dominant wavelength located at the periphery of Maxwell's chromaticity diagram. A fully saturated color is pure because it has not been contaminated by any other color or influence.

color signal the portion of a modulated signal that determines the colors of the intended output display.

color space the space $\mathcal{C}$ within which colors are represented in the image function $I : \mathcal{R}^2 \rightarrow \mathcal{C}$.

color temperature the color a black object becomes when it is heated. The standard color "white" occurs when a tungsten filament is heated to a temperature of 6800 degrees Kelvin. The temperature of 6800 K corresponds to a standard white raster as defined by the NTSC. The color temperature for white is useful for comparing color matching and color decoding among different displays that use different color phosphors. The standard "white" is obtained by mixing the 30% red, 59% green, and 11% blue color signals. Differences in the color saturation for the different phosphors found in television CRTs will modify the required proportions of red, green, and blue to produce the standard "white."

color-bar patterns a standard color-bar pattern for an NTSC video signal consisting of a composite video signal containing a 77% and a 100% white chip, and yellow, cyan, green, magenta, red, blue, and black chips. These patterns represent ideal color and luminance levels that can be input in a video system for setting levels and verifying system performance.

Colpitts oscillator a particular case of an LC-oscillator when X_1 and X_2 are capacitors (hence, $X_m = 0$), X_3 an inductance.

column decoder logic used in a direct-access memory (ROM or RAM) to select one of a number of rows from a given column address. *See also* two-dimensional memory organization.

column distance the minimum Hamming distance between sequences of a specified length encoded with the same convolutional code that differ in the first encoding interval.

column-access strobe *See* two-dimensional memory organization.

comb filter an electric wave filter that exhibits an amplitude versus frequency plot of periodically spaced pass bands interspersed with periodic stop bands. This plot resembles the teeth of an ordinary hair comb, from which the filter derives its name.

comb function a function made of evenly spaced, equal amplitude time or frequency components (the Fourier transform of the Comb function is another Comb function). The comb function is useful for discretizing continuous signals and can be represented as the infinite sum of delta functions evenly spaced through time or frequency.

comb-line filter filter consisting of parallel coupled transmission line resonators where all resonators are grounded on one side and capacitively loaded to ground on the other. Adjacent resonators are grounded on the same side. When fabricated as strip conductors in microstrip or stripline form, the metalized patterns have the appearance of a comb.

combination tone various sum and difference frequency that are generated when two intense monochromatic fields interact with the same semiclassically described laser medium.

combinational lock interconnections of memory-free digital elements.

combinational logic a digital logic, in which external output signals of a device are totally dependent on the external input signals applied to the circuit.

combined cycle plant a gas-turbine power plant in which the exhaust gases are used to heat water in a boiler to provide steam to run a turbogenerator.

combined field integral equation (CFIE) a mathematical relationship obtained by combining the electric field integral equation (EFIE) and magnetic field integral equation (MFIE). It is normally used in electromagnetic scattering calculations from a conducting body to avoid non-physical interior resonances that appear by using either EFIE or MFIE alone.

combined source-channel coding a general term for approaches to source-channel coding, where the source and channel codes are combined into one overall code. In the literature, the term is also used, more loosely, for approaches where (any kind of) joint optimization of the source and channel coding is utilized. Also commonly referred to as joint source-channel coding.

combo trouble-shooter in combined electric and gas utilities, a practice which is growing in popularity is the use of combo troubleshooters. The combo troubleshooter is cross trained in both electric and gas service practices. The cross functionality permits more efficient deployment of resources.

come-a-long a ratcheted winch or block-and-tackle for pulling conductors into place.

command (1) directives in natural language or symbolic notations entered by users to select computer programs or functions.

(2) instructions from the central processor unit (CPU) to controllers and other devices for execution.

(3) a CPU command, or a single instruction, ADD, LOAD, etc.

Commision International d'Eclairage (CIE) International standards body for lighting and color measurement. Known in English as the International Commission on Illumination.

commit the phase of a transaction in which the new states are written to the global memory or database. The commit phase should not be started until it has been verified that performing the commit will not violate the system's consistency requirements. In most designs, the commit phase itself must be performed under more strict locking than the remainder of the transaction.

Comité Consulatif International Télégraphique et Téléphonique (CCITT) *International Consultative Committee for Telegraphy and Telephony*. This institution, based in Geneva, Switzerland, issues recommendations concerning all fields related to telecommunications.

common base amplifier a single transistor BJT amplifier in which the input signal is applied to the emitter terminal, the output is taken from the collector terminal, and the base terminal is connected to a constant voltage.

common centroid a technique in the physical design of integrated circuits in which two transistors, which must be matched, are actually composed of multiple devices connected in parallel. By appropriately connecting the multiple devices, the effective center ("centroid") of the two transistors can be located at the same point, thus improving the matching in the presence of nonidealities in the integrated circuit fabrication process. *See also* cross-quad.

common channel signaling (CCS) a technique for routing signaling information through a packet-switched network.

common collector amplifier a single-transistor BJT amplifier in which the input signal is applied to the base terminal, the output is taken from the emitter terminal, and the collector terminal is connected to a constant voltage. Also referred to as an emitter follower, since the voltage gain of this configuration is close to unity (the emitter voltage "follows" the base voltage).

common drain amplifier a single transistor FET amplifier in which the input signal is applied to the gate terminal, the output is taken from the source terminal, and the drain terminal is connected to a constant voltage. Also referred to as a source follower, since the voltage gain of this configuration is close to unity (the source voltage "follows" the gate voltage).

common emitter a basic transistor amplifier stage whose emitter is common to both input and output loops. It amplifies voltage, current, and hence power.

common emitter amplifier a single-transistor BJT amplifier in which the input signal is applied to the base terminal, the output is taken from the collector terminal, and the emitter terminal is connected to a constant voltage.

common gate amplifier a single-transistor FET amplifier in which the input signal is applied to the source terminal, the output is taken from the drain terminal, and the gate terminal is connected to a constant voltage.

common mode gain for a differential amplifier, the ratio of the output signal amplitude to the amplitude of a signal applied to both the amplifier input terminals (in common). For an ideal differential amplifier, the common mode gain would be zero; the deviation of a real differential amplifier from the ideal is characterized by the common mode rejection ratio (CMRR).

common mode noise undesired electrical signals in lines that are equal in amplitude and phase with respect to a reference ground. Common mode voltages and currents can be generated by power electronic switching circuits and can interfere with control or other electronic equipment. Common mode currents will also sum into neutrals and grounding conductors, which may cause sensitive fault current detection relays to trip.

common mode rejection ratio (CMRR) a measure of quality of an amplifier with differential inputs, defined as the ratio between the common-mode gain and the differential gain.

common source amplifier a single-transistor FET amplifier in which the input signal is applied to the gate terminal, the output is taken from the drain terminal, and the source terminal is connected to a constant voltage.

common-channel interoffice signaling the use of a special network, dedicated to signaling, to establish a path through a communication network, which is dedicated to the transfer of user information.

common-mode coupling pick-up from an electromagnetic field that induces a change in potential on both signal leads of equal magnitude and phase relative to the ground reference potential.

communication link a point-to-point communication system that typically involves a single information source and a single user. This is in contrast to a communications network, which usually involves many sources and many users.

communication theory *See* information theory.

community-antenna television (CATV) a television receiving and distribution system in which signals from television stations and sometimes FM stations are received by antennas, amplified, and then distributed to community subscribers via coaxial or fiber-optic cable. The system is known as cable TV.

commutating inductance in switched circuits (converters, inverters, etc.), the inductance that is in series with the switching elements during the process of commutation from one topological state to another. This inductance results in noninstantaneous commutation due to the fact that current in an inductor cannot change instantaneously.

commutating pole *See* interpole.

commutating winding *See* interpole.

commutation the process by which alternating current in the rotating coil of a DC machine is converted to unidirectional current. Commutation is accomplished via a set of stationary electrical contacts (brushes) sliding over multiple, shaft-mounted electrical contacts that turn with the machine rotor. The contacts are the connection points in a series-connected loop of the coils that make up the rotor winding. The brushes, sliding over these contacts, continually divide the loop into two parallel electrical paths between the brushes.

The brushes are positioned such that they make contact with those commutator segments that are connected to coils that are moving through a magnetic neutral point between poles of the machine's field flux. As a result, all coils making up one parallel path are always moving under a north magnetic pole, and the others are always moving under a south magnetic pole. The movement of the commutator contacts underneath the brushes automatically switches a coil from one path to the other as it moves from a north pole region to a south pole region. Since the coils in both paths move in the same direction, but through opposite flux regions, the voltages induced in the two paths are opposite. Consequently, the positive and negative ends of each path occur at the same points in the series loop, which are at the points where the brushes contact the commutator. The brush positions, thus, represent a unidirectional (or DC) connection to the rotating coil. *See also* commutator.

commutation angle time in electrical degrees from the start to the completion of the commutation process. Also called overlap angle.

commutativity a property of an operation; an operation is commutative if the result of the operation is not affected by any reordering of the operands of the operation. Additions and multiplication are commutative, whereas subtraction and division are not.

commutator a cylindrical assembly of copper segments, insulated from each another, that make electrical contact with stationary brushes, to allow current to flow from the rotating armature windings of a DC machine to the external terminals of the machine. It also, enables reversal of current in the armature winding. *See also* commutation.

commutator film an oxide layer on the commutator surface, indicated by a dark color or a "film," that is required for proper commutator action and full loading of the machine. On a new DC machine commutator, or on a commutator that has just been stoned, there is no "film" on the commutator. It is advisable to refer to the manufacturer's technical manual for the proper procedure to "break in" the commutator and develop the film so the machine can be operated at rated conditions.

compact disk (CD) a plastic substrate embossed with a pattern of pits that encode audio signals in digital format. The disk is coated with a metallic layer (to enhance its reflectivity) and read in a drive (CD player) that employs a focused laser beam and monitors fluctuations of the reflected intensity in order to detect the pits.

compact disk-interactive (CD-I) a specification that describes methods for providing audio, video, graphics, text, and machine-executable code on a CD-ROM.

compact range an electromagnetic measurement facility in which far-field conditions are achieved by the use of an offset parabolic reflector. The reflector is fed using a source antenna or other subreflector system located at its focus. The term "compact" range is used to describe the relative difference in its size compared to a true far-field range requiring a large separation distance between the source antenna and the device under test to achieve the same far-field conditions.

compactness measure an alternative name for *circularity measure*.

compander a point operation that logarithmically compresses a sample into fewer bits before transmission. The inverse logarithmic function is used to expand the code to its original number of bits before converting it into an analog signal. Typically used in telecommunications systems to minimize bandwidth without degrading low-amplitude signals.

companding a process designed to minimize the transmission bit rate of a signal by compressing it prior to transmission and expanding it upon reception. It is a rudimentary data compression technique that requires minimal processing.

companion matrix the coefficient matrix in the state-equation representation of the network describable by a linear differential equation.

comparator (1) a logic element that compares two binary numbers (A and B) to determine if $A = B$, $A < B$, or $A > B$. An exclusive NOR gate operates like a 1-bit comparator.

(2) a software tool that compares two computer programs, files, or sets of data to identify commonalities or differences. Typical objects of comparison are similar versions of source code, object code, data base files, or test results.

compare instruction an instruction used to compare two values. The processor flags are updated as a result. For example, the instruction CMP AL,7 compares the contents of register AL with 7. The zero flag is set if AL equals 7. An internal subtraction is used to perform the comparison.

compartmental model a dynamical model used in analysis of biomedical, pharmacokinetic, and ecological systems. The main idea in compartmental modeling is to "lump" in reality distributed system into a finite number of homogeneous, well-mixed subsystems called compartments or pools, which exchange materials with each other and with the environment. Usually the compartments are described by the first-order differential or difference equations, and in this sense they form a system of state equations. Although the most popular application of compartmental models is in modeling population dynamics and other biomedical phenomena, they may be also used to describe some engineering processes, e.g., distillation columns. The case of linear time-invariant compartments in which exchange rates are proportional to the state of the donor compartments may be treated by Laplace transforms and transfer function analysis.

compatibility (1) two different implementations of the same component whereby they may both be used in a system with no modification (often used in the context of new microprocessors running software compiled for older microprocessors).

(2) the capability of a functional unit to meet the requirements of a specified interface.

compensated pulsed alternator (CPA) *See* compulsator.

compensating winding a winding found in DC machines that is placed in the faces of the main field poles, and connected in series with the armature winding, to produce an mmf equal and opposite to the mmf of the armature, thereby reducing the effect of armature reaction.

compensation (1) operations employed in a control scheme to counteract dynamic lags or to modify the transformation between measured variables and controller output to produce prompt stable response.

(2) the alteration of the dynamic behavior of a process by the addition of system blocks. These are usually connected in cascade with the original process on either its input or its output variables, or both. *See also* compensator, pre-compensator and post-compensator.

compensator a system block added to an existing system (or process) to produce a combined transfer function that improves its performance when connected in a closed loop configuration. *See also* compensation, pre-compensator and post-compensator.

compensatory behavior human dynamic behavior in which the operator's actions are conditioned primarily by the closed-loop man-machine system errors.

compensatory display for the simplest case, a display which shows only the difference between the desired input command and the system output.

compiler a program that translates a high level language program into an executable machine instruction program or other lower-level form such as assembly language. *See also* linker, assembler, interpreter, cross-assembler, cross-compiler.

complement (1) to swap 1's for 0's and 0's for 1's in a binary number.

(2) opposite form of a number system.

complement of a fuzzy set the members outside of a fuzzy set but within the universe of discourse. Represented by the symbol ¬.

Let A be a fuzzy set in the universe of discourse X with membership function $\mu_A(x)$, $x \in X$. The membership function of the complement of A , for all $x \in X$, is

$$\mu_{\neg A}(x) = 1 - \mu_A(x)$$

See also complement, fuzzy set, membership function.

complement operator the logical NOT operation. In a crisp (non-fuzzy) system, the complement of a set A is the set of the elements that are not members of A. The fuzzy complement represents the degree to which an element is not a member of the fuzzy set.

complementary arithmetic a method of performing integer arithmetic within a computer, in which negative numbers are represented in such a way that the arithmetic may be performed without regard to the sign of each number.

complementary cumulative distribution function (CCDF) a function describing the probability $p(x)$ of achieving all outcomes in an experiment greater than x.

complementary metal oxide semiconductor (CMOS) (1) refers to the process that combines n-channel and p-channel transistors on the same piece of silicon (complementary). The transistors are traditionally made of layers of metal, oxide, and semiconductor materials, though the metal layer is often replaced by polysilicon. There are a number of variations such as HCMOS, high-speed CMOS which scales down the elements compared to the standard MOS process and thus increases the speed and reduces the power consumption for each transistor in the CPU.

(2) a CMOS memory device used in computers to store information that must be available at startup. The information is maintained in the device by a small battery.

complete statistic a sufficient statistic T where every real-valued function of T is zero with probability one whenever the mathematical expectation of that function of T is zero for all values of the parameter. In other words, if W is real-valued function, then T is complete if

$$E_\theta W(T) = 0 \forall\theta \in \Theta \Rightarrow P_\theta[W(T) = 0] = 1 \forall\theta \in \Theta$$

completion unit *See* retire unit.

complex amplitude magnitude of a nearly harmonic function, complex to include phase deviations from a reference wave.

complex amplitude transmittance transmittance of the complex amplitude, square root of the intensity transmission.

complex beam parameter *See* beam parameter.

complex envelope a low-pass complex valued signal used to represent a real band-pass signal. The complex envelope is obtained from the analytic signal with center frequency ω_c by multiplying the analytic signal by $e^{-j\omega_c t}$.

complex exponential signal a signal of the form $x(t) = C \exp j\omega t$, where C is a constant and ω is the frequency in radians per second.

complex frequency a complex number used to characterize exponential and damped sinusoidal motion in the same way that an ordinary frequency characterizes simple harmonic motion; designated by the constant s corresponding to a motion whose amplitude is given by Ae^{st}, where A is a constant and t is time, and $s = \sigma + j\omega$ where σ is the real part of s and ω is the imaginary part of s. ω is also known as the real angular frequency.

complex instruction set computer (CISC) a processor with a large quantity of instructions, some of which may be quite complicated, as well as a large quantity of different addressing modes, instruction and data formats, and other attributes. The designation was put forth to distinguish CPUs such as those in the Motorola M68000 family and the Intel Pentium from another approach to CPU design that emphasized a simplified instruction set with fewer but possibly faster executing instructions, called RISC processors. One CISC processor, the Digital VAX, has over 300 instructions, 16 addressing modes, and its instruction formats may take up 1 to 51 bytes.

A CISC processor usually has a relatively complicated control unit. Most CISC processors are microprogrammed.

One of the benefits of a CISC is that the code tends to be very compact. When memory was an expensive commodity, this was a substantial benefit. Today, speed of execution rather than compactness of code is the dominant force.

See also microprogramming, reduced instruction set computer processor.

complex number a number consisting of a real part and an imaginary part, usually expressed in the form $a + bi$, where the "i" is used to distinguish that b represents the complex part of the number. i is mathematically defined as the positive root of -1.

complex power a complex number that represents electric power flow for an AC circuit. When expressed in rectangular form its real part is average power P in watts and its imaginary part is reactive power Q in reactive volt-amperes. When expressed in polar form its magnitude is apparent power S in volt-amperes and its angle is the power factor angle (the same angle as the impedance angle for a passive load). *See also* apparent power.

complex process (system) term used rather colloquially to denote controlled process (control system) possessing such characteristic features which, separately or jointly, allow to treat this process (system) as a complex entity; the features worth consideration are:

1. The process is large in a physical sense — it occupies large space and there are large distances among its different elements,

2. The model of the process is complicated and involves many variables, in particular control inputs,

3. The process is composed of several interacting subprocesses and there are identifiable local objectives and local sets of decision variables,

4. The control problem is seen as complicated due to the nature of the control objectives and the way by which free inputs are formed and influence the controlled process

— even when the underlying physical process does not seem to be complex.

complex propagation constant propagation constant or wave number in a medium with gain or loss.

complex system *See* complex process.

complex transmittance the effect of a medium on both optical phase and amplitude of light traversing the medium.

complexity-constrained maximum-likelihood the maximum of the likelihood function given some quantifiable complexity constraint, M, i.e., $\max\{p(y|x, M)\}$. Breadth-first search algorithms can perform complexity-constrained maximum-likelihood detection on tree and trellis structured problems.

compliance matrix for the arm end point is defined formally by the following expression: $J_A K^{-1} J_A^T$ where J_A is an analytical Jacobian of the manipulator and K a positive definite matrix describing joint stiffness of the manipulator. Matrix K is invertible. Notice that the compliance matrix depends on the structure of the manipulator and changes with its position in Cartesian space. *See also* stiffness of a manipulator arm and analytical Jacobian.

compliant motion motion of the manipulator (robot) when it is in contact with its "environment," such as writing on a chalkboard or assembling parts.

component mounting site a location on a packaging and interconnecting structure, consisting of a land pattern and conductor fan-out to additional lands for testing or vias, used for mounting a single component.

composite a material usually consisting of a resin supporting fibers of a lightweight fabric that may be woven and treated in order to produce certain strength and/or electrical characteristics.

composite maximum method a method of defuzzification in which the defuzzified or crisp value is arrived at using the maximum value of the membership function of the fuzzy set.

composite moments method *See* centroid method.

composite second order (CSO) ratio of the power in the second-order distortion products to power in the carrier in a cable television channel.

composite sync a synchronizing signal consisting of both horizontal and vertical sync information. Composite sync is used for providing synchronizing pulses to video equipment in the studio.

composite transform a transform that can be factored into two or more transforms.

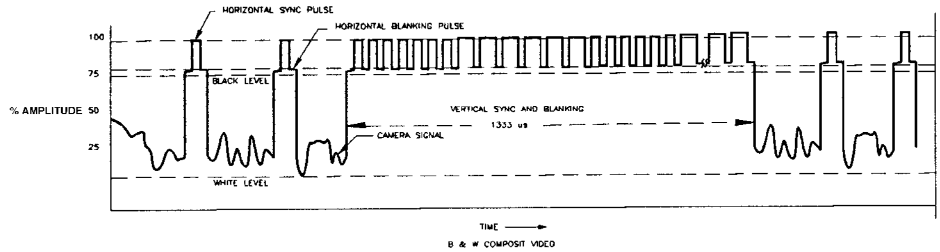
composite triple beat (CTB) same as composite second order but for third-order distortion. *See* composite second order.

composite video (1) a single video signal that contains luminance, color, and synchronization information. NTSC, PAL, and SECAM are all examples of composite video formats.

(2) the complete video signal. For B&W, it consists of the picture signal, blanking pulses, and synchronizing signals. For color, color synchronizing and color picture information are added. *See* figure.

compositional rule of inference generalization of the notion of function. Let X and Y be two universes of discourse, A be a fuzzy set of X, and R is a fuzzy relation in $X \times Y$. The compositional rule of inference associates a fuzzy set B in Y to A in three steps:

1. Cylindrical extension of A in $X \times Y$;



Computed torque control.

2. Intersection of the cylindrical extension with R;

3. B is the projection of the resulting fuzzy set on Y.

If we choose *intersection* as *triangular norm* and *union* as *triangular co-norm*, then we have the so-called *max-min composition* $B = A \circ R$, i.d.

$$\mu_B(y) = \bigvee_x \left[\mu_A(x) \bigwedge \mu_R(x, y)\right].$$

If we choose *algebric product* for *triangular norm* and *union* as *triangular co-norm*, then we have the so-called *max-product composition* $B = A \tilde{\circ} R$, i.d.

$$\mu_B(y) = \bigvee_x [\mu_A(x)\mu_R(x, y)].$$

The compositional rule of inference is the principal rationale behind *approximate reasoning.*

See also approximate reasoning, cylindrical extension of a fuzzy set, fuzzy relation, intersection of fuzzy sets, projection of a fuzzy set.

compound-connected DC machine a direct current machine with two field windings in which one field winding is connected in series and one field winding is connected in parallel (shunt) with the armature winding. The shunt winding may be connected ahead of the series winding (long-shunt connection), or behind the series winding (short-shunt connection).

compound-rectifier exciter a source of field current of a synchronous machine derived from the phase voltages and currents of the machine. The phase voltages and currents of the machine are fed through transformers, then rectified in order to provide DC quantities to the field winding. The components of the exciter are the transformers (voltage and current), rectifiers (including possible gate-circuitry), and power reactors; exclusive of all input control elements.

compression (1) in information theory, the compact encoding (with a smaller number of bits) I_c of a digital image or signal I obtained by removing redundant or nonsignificant information, thus saving storage space or transmission time. Compression is termed lossless, if the transformation of I into I_c is reversible, otherwise it is termed lossy.

(2) in signal processing, at given bias levels and frequency, the ratio between the small signal power gain $(p_{outSS}/p_{incidentSS})$ under small signal conditions and the large signal power gain $(p_{outLS}/p_{incidentLS})$ at a given input power, expressed in decibels. As the input amplitude of a signal is increased, the output signal will eventually cutoff and/or clip due to saturation, resulting in compression. If the large signal is insufficiently large to cause cutout and/or clipping, then the compression will be at or near 0 dB.

$$G_{CR} = 10 \log_{10} (p_{outSS}/p_{incidentSS}) - 10 \log_{10} (p_{outLS}/p_{incidentLS})$$

compression coding the lossy (irreversible) or loseless (reversible) process of reducing the amount of digital information required to represent a digital signal.

compression ratio the ratio of the number of bits used to represent a signal before compression to that used after compression.

Compton laser free-electron laser in which the amplification mechanism is considered to be Compton scattering.

compulsator the compulsator (compensated pulsed alternator or CPA), is a specially designed rotating electrical alternator with a very low internal impedance that allows it to produce large, repetitive pulses of current. These machines produce an alternating current output whose frequency is dependent upon the rotor speed and number of magnetic poles in the CPA. Typical output voltages of a CPA are 1,000–10,000 volts with output currents of up to 5,000,000 amperes and frequencies of 100–1,000 hertz.

compulsory miss *See* cold start miss.

computational cut-off rate *See* cut-off rate.

computational electromagnetics the use of modern digital hardware to obtain solutions to Maxwell's equations and to visualize these solutions.

computational intelligence *See* soft computing.

computed tomography (CT) *See* tomography.

computer (1) an electronic, electromechanical, or purely mechanical device that accepts input, performs some computational operations on the input, and produces some output.

(2) functional unit that can perform substantial computations, including numerous arithmetic operations, or logic operations, without human intervention during a run.

(3) general or special-purpose programmable system that is able to execute programs automatically. It has one or more associated processing units, memory, and peripheral equipment for input and output. Uses internal memory for storing programs and/or data.

computer architecture an image of a computing system as seen by a most sophisticated computer user and programmer. The above concept of a programmer refers to a person capable of programming in machine language, including the capability of writing a compiler. The architecture includes all registers accessible by any instruction (including the privileged instructions), the complete instruction set, all instruction and data formats, addressing modes, and other details that are necessary in order to write any program. This definition stems from the IBM program of generating the 360 system in the early 1960s. *Contrast with* computer organization. *See also* Flynn's taxonomy.

computer communication network collection of applications hosted on different machines and interconnected by an infrastructure that provides intercommunications.

computer generated hologram a hologram where the required complex amplitude and phase functions are generated by computer and written onto an optical medium.

computer hardware description language (CHDL) examples include VHDL and Verilog, current work in CHDL includes mainly languages for verification, and extensions of existing languages for system description and analog design. CHDL conferences are organized every year.

computer model a computer model of a device consists of a mathematical/logical model of the behavior of the device represented in the form of a computer program. A good computer model reproduces all the behaviors of the physical device in question and can be confidently used to simulate the device in a variety of circumstances.

computer organization describes the details of the internal circuitry of the computer with sufficient detail to completely specifies the operation of the computer hardware. *Contrast with* computer architecture.

computer relay a protective relay that digitizes the current and/or voltage signals and uses a microprocessor to condition the digitized signal and implement the operating logic. *See* digital relay.

computer simulation a set of computer programs that allows one to model the important aspects of the behavior of the specific system under study. Simulation can aid the design process by, for example, allowing one to determine appropriate system design parameters or aid the analysis process by, for example, allowing one to estimate the end-to-end performance of the system under study.

computer torque control computed torque control is depicted in figure. The feedback controller sends its output through the inverse dynamic model. The feedback control law comprises and independent-joint PD controller with velocity reference, plus the desired acceleration. In the figure q_d, $\dot{q}_d$, and $\ddot{q}_d$ denote desired position, velocity, and acceleration vectors, respectively. q and $\dot{q}$ denote measured generalized position and velocity vectors. Finally, K_p and K_d are positive definite constant PD controller matrices.

computer vision *See* robot vision.

computer word data path of a computer (the size of virtual addresses); (1) datum consisting of the number of bits that forms the fundamental registers, etc.; (2) sequence of bits or characters that is stored, addressed, transmitted, and operated as a unit within a given computer. Computer words are one to eight bytes long, but can be longer for special applications.

computer-aided design (CAD) field of electrical engineering concerned with producing new algorithms/programs which aid the designer in the complex tasks associated with designing and building an integrated circuit. There are many subfields of electrical CAD: simulation, synthesis, physical design, testing, packaging, and semiconductor process support.

computer-aided engineering (CAE) software tools for use by engineers.

computer-aided manufacturing (CAM) manufacturing of components and products when based heavily on automation and computer tools. *See also* computer-integrated manufacturing.

computer-aided software engineering (CASE) a computer application automating the development of graphic and documentation of application design.

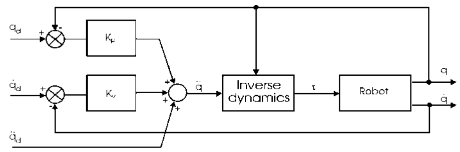
computer-integrated manufacturing (CIM) manufacturing approach that makes substantial use of computers to control manufacturing processes across several manufacturing cells. *See also* computer-aided manufacturing.

concatenated code (1) a code that is constructed by a cascade of two or more codes, usually over different field sizes.

(2) the combination of two or more forward error control codes that achieve a level of performance with less complexity than a single coding stage would require. Serially concatenated coding systems commonly use two levels of codes, with the inner code being a convolutional code and the outer code being a Reed–Solomon code. Parallel concatenated codes improve performance through parallel encoding and iterative serial decoding techniques. *See also* turbo code.

concentration gradient a difference in carrier concentration.

concentric resonator usually a symmetric laser resonator in which the mirror spacing



Computer torque control.

is equal to twice the mirror curvature; mirrors have a common center of curvature.

concept formation the process of the incremental unsupervised acquisition of categories and their intentional descriptions.

The representative concept formation systems include EPAM, CYRUS, UNIMEM, COBWEB, and SGNN. *See also* self-generating neural network.

concurrency the notion of having multiple independent tasks available (tasks in this definition means any work to be done, not a formal computational entity).

concurrent processing having one logical machine (which may be a multiprocessor) execute two or more independent tasks simultaneously.

concurrent read and concurrent write (CRCW) shared memory model, in which concurrent reads and writes are allowed.

concurrent read and exclusive write (CREW) shared memory model, in which concurrent reads but only exclusive writes are allowed.

condenser lens lens system in an optical projection system that prepares light to illuminate the mask.

condition code internal flag used in the construction of CPUs. Many computers provide a mechanism for saving the characteristics of results of a particular calculation. Such characteristics as sign, zero result, carry or borrow, and overflow are typical of integer operations. The program may reference these flags to determine whether to branch or not.

condition code register register that contains the bits that are the condition codes for the CPU arithmetic or compare instructions.

condition variable a variable set as the result of some arithmetic or logical comparison.

conditionability of generalized 2-D model a mathematical relationship of interest in control systems.

The generalized 2-D model

$$\begin{aligned} Ex_{i+1,j+1} = {} & A_0 x_{ij} + A_1 x_{i+1,j} \\ & + A_2 x_{i,j+1} + B_0 u_{ij} \\ & + B_1 u_{i+1,j} + B_2 u_{i,j+1} \end{aligned}$$

is called conditionable if no two distinct solutions to the model for the same input sequence u_{ij} for $(i,j) \in [0, N_1] \times [0, N_2]$ coincide in all their boundary values (*See* boundary values of 2-D general model), where $x_{ij} \in R^n$ is the semistate vector $u_{ij} \in R^m$ is the input vector and E, A_k, B_k $(k = 0, 1, 2)$ are real matrices with E possibly singular or rectangular.

conditional coding an approach to the solution of the problem of large code words and lookup tables in block coding. In this scheme one assumes that the receiver already knows the components $b_1, b_2, \ldots b_{N-1}$ of N-tuple b. Current component b_N can now be coded using this information. The assumption that there is statistical dependence between pixels is made.

conditional instruction an instruction that performs its function only if a certain condition is met. For example, the instruction JNZ TOP only jumps to TOP if the zero flag is clear (the "not zero" condition).

conditional statistic a statistic premised on the occurrence of some event. The probability of event E_1 given that E_2 has occurred is denoted by $p(E_1|E_2)$. *See also* Bayes' rule.

conditionally addressed ROM read-only memory in which not every address can be used to access a valid word. Usually implemented from a PLA.

conductance (1) the reciprocal of resistance.

(2) a characteristic that describes the availability and the mobility of conduction electrons within a material. The values range from zero for a perfect insulator to infinity for a perfect conductor. The units are siemans.

(3) the ability of a substance to carry a thermodynamic flow, such as current, heat, energy, etc.

conducted emission an RF current propagated through an electrical conductor.

conducted noise unwanted electrical signals that can be generated by power electronic switching circuits. Conducted noise can travel through the circuit cables as common-mode or differential mode currents and can interfere with control circuits or other electronic equipment.

conduction angle the period during which a device is conducting, i.e., carrying current. While the device could be a switch or any other electrical element, such as inductor, phase coil, capacitor, resistor, this term is primarily applied to power electronic switching devices, which are gated to operate for some fraction of a power cycle.

The conduction angle is the sum of the positive transition angle (θ_+), the saturation angle (θ_{sat}), and the negative transition angle (θ_-). Hence, the conduction angle θ_{cond} is

$$\theta_{cond} = \theta_+ + \theta_{sat} + \theta_-$$

conduction band the lowest energy band that is not completely occupied by electrons in a crystalline solid. *See also* valence band.

conduction current the drift of electrons in a conductor (or of electrons and holes in a semiconductor).

conduction electron a free electron in the conduction band of a semiconductor.

conductivity (1) the reciprocal of resistivity.

(2) a measure of a material's ability to conduct electrical current. Conductivity σ is the ratio of the conduction current to the electric field in Ohm's Law:

$$J_c = \sigma E$$

conduit a pipe through which an electrical cables are laid.

cone beam term describing the shape of the beam formed with an X-ray source and beam restricter. Because the source is a finite distance from the target, beam divergence occurs because the photons in the beam are not travelling along truly parallel paths. Processing can be applied to correct for the beam shape during image reconstruction.

cone of protection a method used to determine the extent of protection to surrounding structures afforded by a tall, grounded structure like a steel tower. Proposed prior to the "rolling ball" model, this method suggests that any structure which can fit within a right circular cone whose vertex is at the top of the tower will be protected from lightning strikes by that tower. The angle of the cone's vertex is a matter of some controversy. *See* rolling ball.

confidence interval an interval around the estimator. The interval contains the unknown parameter with this probability.

confidence level a probability that indicates the quality of an experiment.

configuration operation in which a set of parameters is imposed for defining the operating conditions. The configuration of a personal computer regarding low-level features is frequently called set-up. At that level, the memory, the sequence of boot, the disk features, etc., are defined. The configuration of a computer also involves that of its operating system. For example, per MS-DOS see CONFIG.SYS and AUTOEXEC.BAT. The configuration of applicative software depends on the software under configuration itself.

confinement condition according to which the amplitude of a beam falls to zero at large distances from the beam axis.

confinement condition *See* confinement.

confinement diagram diagram showing the values of the mirror curvatures of a two-mirror laser such that the electromagnetic modes are confined (satisfy the confinement condition); sometimes called a stability diagram because beam confinement can be associated with ray stability.

conflict miss a cache miss category used to denote the case where, if the cache is direct-mapped or block-set-associative, too many blocks map to a set leading to that blocks can be expelled from the cache, even if the cache is not full, and later retrieved again. These are also called "collision misses." *See also* capacity miss.

conflict-free multiple access protocol class of multiple access protocols in which any transmission from a given user is guaranteed to have exclusive access to the channel. It will not be interfered with by a transmission from another user. One way of achieving this is to allocate the channel to the users either statically of dynamically. In static channel allocation schemes the channel can be divided into exclusive sub-channels in the time domain (TDMA), frequency domain (FDMA), code domain (CDMA), polarization domain (PDMA), or in the space (SDMA). In the dynamic channel allocation scheme, the channel is allocated on a demand basis using a reservation scheme or token passing.

conflicting goals objectives of several decision units in charge of given partitioned system, for example objectives of local decision units in a large-scale system, which would lead to mutually conflicting actions of the decision makers; a conflict may also arise between the objectives as perceived by a supremal unit and the local objectives; conflict between local and, eventually, between global and local objectives may or may not be alleviated by using the coordination instruments.

confocal parameter measure of the waist size of a Gaussian beam, 2 pi times waist spot size squared divided by wavelength; twice the Rayleigh length.

confocal resonator usually a symmetric laser resonator in which the mirror spacing is equal to the mirror curvature; mirrors have a common focal point.

conformal mapping a transformation $w = f(z)$ defined on a domain D with angle-preserving properties. The method of conformal mapping finds application, for example, in the quasi-static analysis of several transmission lines such as microstrips, coplanar waveguides, etc.

confusion matrix a matrix describing the likelihood of misclassification.

Let c_i, $i = 1, \ldots, n$ be the classes in which a given set of patterns can be partitioned. Let e_{c_i,c_j} be the percentage of patterns of class c_i that are erroneously recognized as patterns of class c_j. The matrix $E \doteq \left[e_{c_i,c_j}\right] \in \mathcal{R}^{n,n}$ is called a confusion matrix. Of course

$$\sum_{j=1}^{n} e_{c_i,c_j} = 1$$

congestion a state of a packet-based system where too many packets are present in the network and the overall performance degrades. To resolve the congestion, the system must employ some form of congestion control. *See also* preventive congestion control and reactive congestion control.

conical diffraction a scattering phenomenon in photorefractive crystals in which the scattered beam forms a cone of light. When a laser beam of finite transverse cross section passes through a photorefractive crystal, beam fanning often occurs. The hologram formed by the incident beam and the fanned light consists of a multitude of gratings because the fanned light spans a wide solid angle in space. When such a multitude of gratings is read out by a laser beam, only a subset of these gratings matches the Bragg condition with readout beam. The wave vectors of the Bragg-matched readout beams form hollow cones in momentum space. Therefore, conical diffractions are observed most of the time when fanning occurs. Conical diffraction is also often referred to as conical scatterings.

conical scattering *See* conical diffraction.

conjugate symmetric transform a property of a real-valued function that relates to its Fourier transform. If $x(t)$ is a real-valued function and its Fourier transform has the property that $X(-w) = X^*(w)$, where * denotes the complex conjugate. The transform $X(w)$ is said to be conjugate symmetric.

conjunction rule of inference a rule of reasoning which states that if two propositions A and B are both individually true, then the combined proposition "A AND B" is also true.

connect/disconnect bus *See* split transaction.

connected component a maximal-sized connected region. Also termed "blob."

connectedness a graph or subgraph is said to be connected if there is at least one path between every pair of its vertices.

connection matrix in a network of general topology, the connection matrix identifies how the circuit elements are connected together.

connection weight in neural networks, within the processing element, an adaptive coefficient associated with an input connection. It is also referred to as synaptic efficacy.

connection-oriented service a mode of packet switching in which a call is established prior to any information exchange taking place. This is analogous to an ordinary phone call, except that no physical resources need to be allocated.

connectionist model one of many names given to the learning systems. The notion of learning systems has been developed in the fields of artificial intelligence, cybernetics and biology. In its most ambitious form learning systems attempt to describe or mimic human learning ability. Attainment of this goal is still far away. The learning systems that have actually been implemented are simple systems that have strong relations to adaptive control. The learning systems are also known under the names of neural nets, parallel distributed processing models, etc. Examples of learning systems most commonly used are perceptron, Boltzmann machine, Hopfield network. An interesting feature of the neural networks is that they operate in parallel and that they can be implemented in silicon. Using such circuits may be a new way to implement adaptive control systems.

connectionless service a mode of packet switching in which packets are exchanged without first establishing a connection. Conceptually, this is very close to message switching, except that if the destination node is not active, then the packet is lost.

connectivity specifies that sets are considered to be connected. Generally it is based on an adjacency relation between pixels (or voxels), so that a set X is connected if and only if for any $p, q \in X$ there is a sequence $p_0, \ldots, p_n$ $(n \geq 0)$ such that $p = p_0$, $q = p_n$, and for each $k < n$, p_k is adjacent to p_{k+1}. *See* pixel adjacency, voxel adjacency.

connectivity check a computerized procedure applied to a semiconductor chip's physical layout database which verifies the actual circuit on the chip is a correct implementation of the circuit described on the schematic diagrams of the chip.

consistency a correctness criterion based on testing whether the result that is achieved by a set of operations being performed in parallel is identical to the result that would be obtained if the operations were performed sequentially without any overlap. Weaker tests have been proposed in order to trade hardware complexity for software responsibility and faster execution.

consistency of interests situation in which there are several decision units with consistent goals. *Compare with* disagreement of interests.

consistency principle a principle from possibility theory relating to the consistency between probability and possibility which states that the possibility of an event is always at least as great as its possibility.

consistent estimator an estimator whose value converges to the true parameter value as the sample size tends to infinity. If the convergence holds with probability 1, then the estimator is called strongly consistent or consistent with probability 1.

consistent goals objectives of several decision units in charge of a controlled partitioned system which, when followed, would lead jointly to overall optimal decisions (actions) of these units; independent decision makers contributing to common objectives, with consistent goals, form a team.

constant angular velocity normally used in disk storage units where the disk platter rotate at a constant rotational speed. Because of this, and to have the same amount of data in each track, sectors on the inner tracks are more densely recorded than the outer tracks.

constant bit density on a disk, recording pattern in which the number of bits per unit distance is the same over all tracks.

constant bit rate (CBR) describes a traffic pattern in which the bits are sent at a fixed or constant rate. An 8-bit analog to digital converter sampling at 8 kilo-samples per second produces a CBR traffic stream with a bit rate of 64 kbps.

constant gain circle locus of input and output impedance points plots on the Smith chart that provide constant gain to an amplifier.

constant linear velocity used for example, in some optical disks where the platter rotates at different speed, depending on the relative position of the referenced track. This allows more data to be stored on the outer tracks than on the inner tracks. Because it takes time to vary the speed of rotation, the method is best suited for sequential rather than random access. *See also* constant angular velocity.

constant modulus algorithm (CMA) one of a number of algorithms (i.e., maximum ratio combining, Bartlett, Capon, and LMS) proposed in the literature for the adaptation of the weights associated with each radiating element and for combining signals received on radiating elements.

constant-current transformer two-coil transformer with a moveable secondary coil used to provide constant output current to a variable load. Constant current is maintained by mounting both the primary and secondary coils on the center element of a shell-type core and allowing the secondary coil to move up and down with changes in demand for load current. Increasing current demand due to a reduction in load impedance causes the secondary coil to move away from the primary coil. Increasing the coil separation increases flux leakage and reduces the secondary output voltage. The reduced output voltage counteracts the demand for more current. Increases in load impedance reverse the process. Movement of the secondary coil is controlled automatically by attaching the secondary coil to a counterweight and pulley assembly and orienting the coil windings such that their flux directions oppose. Increases in secondary current increase the magnetic repulsion between the coils, which, aided by the counterweight, moves the secondary coil away from the primary. Reductions in secondary current produce the opposite effect.

constant-horse power drive a variable speed drive that is operating in a speed region where it is capable of delivering rated power. For DC machines, this region is above base speed and is achieved by field weakening. For AC induction motors, this region is above rated speed and is achieved by increasing the frequency of the applied voltage.

constant-torque drive a variable-speed drive that is operating in a speed region where it is capable of maintaining rated torque. For DC machines, this region is below base speed and is achieved by reducing the applied armature voltage. For AC induction motors, this region is below rated speed and is achieved by reducing the frequency of the applied voltage.

constitutive relation describes the relation between the intensity vectors and the flux density vectors in a medium.

constitutive relationships a set of equations that couple the electric-field intensity E, magnetic-field intensity H, the electric flux density D, and the magnetic flux density B to one another. For simple media, the constitutive relationships are $D = \epsilon E$, and $B = \mu H$, where ϵ and μ are the scalar permittivity and permeability of the medium, respectively.

constraining core an internal supporting plane in a packaging and interconnecting structure, used to alter the structure's coefficient of thermal expansion.

constraint length in convolutional codes, an indication of the number of source words that affect the value of each coded word. Two typical forms are:

1. A code with constraint length K, in which the value of each coded word is affected by the present source word and up to $K - 1$ previous source words.

2. The number of shifts over which a single message bit can influence the output of a convolutional encoder.

constraint propagation artificial intelligence technique in which a hypothesis generates constraints that reduce the search space over the rest of the data. If no eventual contradiction is derived, then a "match" is achieved.

constructive algorithm learning algorithm that commences with a small network and adds neural units as learning proceeds until the problem of interest is satisfactorily accommodated.

constructive solid geometry method by which complex 3-D objects are defined as the combination of simpler solids.

contact head *See* disk head.

contact potential the internal voltage that exists across a p-n junction under thermal equilibrium conditions, when no external bias voltage is applied.

contact printing a lithographic method whereby a photomask is placed in direct contact with a photoresist coated wafer and the pattern is transferred by exposing light through the photomask into the photoresist.

contactor electromechanically actuated spring-loaded relay contacts normally used to control lights, heat, or other non-motor loads. In essence, it is an electromechanically operated switch that usually requires some form of pilot device for its actuation.

containment building (1) a steel and concrete structure which encloses and isolates the radioactive portion of a nuclear power plant.

(2) a heavily re-inforced structure which surrounds the reactor and other radioactive portions of a nuclear power plant so as to contain radioactive gases or debris in the event of an explosion.

containment vessel the heavy steel container which encloses the core of a pressurized-water reactor *cf* in a nuclear power plant.

content-addressable memory (CAM) *See* associative memory.

contention additional latency incurred as the result of multiple requestors needing access to a shared resource, which can only be used by one at a time.

contention protocol class of a multiple access protocol where the users transmissions are allowed to conflict when accessing the communication channel. The conflict is then resolved through the use of a static or dynamic conflict resolution protocol. Static resolution means that the conflict resolution is based on some preassigned priority. A static resolution can be probabilistic if the statistics of the probabilities are fixed. A common example is the p-persistent ALOHA protocol. The dynamic resolution allows for changing the parameters of the conflict resolution algorithm to reflect the traffic state of the system. A common example is the Ethernet protocol.

context the privilege, protection and address-translation environment of instruction execution.

context switching an operation that switches the CPU from one process to another, by saving all of the CPU registers for the first and replacing them with the CPU registers for the second.

context units a set of memory units added to a feedforward network that receives information when an input is presented to the network and passes this information to the hidden layer when the next input is presented to the network.

contingency analysis a plan for dealing with any of the probable faults which might befall a particular electric power system, the goal being to maintain power to the maximum number of customers and/or the most critical customers.

contingency list in security analysis, a list, necessarily incomplete, of everything which could possibly go wrong in a section of an electric power system.

contingency ranking the process of ranking the list of probable contingencies in order of severity.

contingency selection the process of narrowing the list of probable contingencies, or disturbances, that can be further processed and studied to determine the extent of security violations in the system.

continuity equation axiom that charge is a conserved quantity. In point-form, the continuity equation is stated as

$$-\frac{\partial \rho}{\partial t} = \nabla \cdot J,$$

where ρ is the charge density and J is the current density.

continuous duty National Electrical Manufacturers Association (NEMA) classification describing an application in which a machine operates for long periods of time at relatively constant loads.

continuous Hopfield network a Hopfield network with the same structure as the discrete version, the one difference being the replacement of the linear threshold units by neurons with sigmoidal characteristics. Any initial setting of the neuron outputs leads to a motion in the network's state space towards an attractor which, so long as the weights in the network are symmetric, is a fixed point. This allows the network to be employed for the solution of combinatorial optimization problems (its main application) by arranging the network's weights so that an optimal solution lies at a fixed point of the network's dynamics. *Compare with* discrete Hopfield network.

continuous rating term often used to refer to the manufacturer's nameplate ratings for an electrical machine, which are the rated operating conditions guaranteed by the manufacturer for continuous-duty operation. *See also* continuous duty.

continuous signal a continuous function of one or more independent variables such as time, that typically contains information about the behavior or nature of some phenomenon.

continuous spectrum when an eigenvalue problem is defined over an infinite domain, the eigenvalues bunch together to form a continuum or a continuous spectrum. This concept is of fundamental importance for open waveguides either of electromagnetic or acoustic type.

continuous speech recognition the process of recognizing speech pronounced naturally with no pauses between different words.

continuous system *See* incremental gain.

continuous time signal *See* signal.

continuous time system a process that transforms continuous time input signals to continuous time output signals. *See also* system.

continuous tone image coding a process that converts a digitized continuous tone image to a binary bit stream which has fewer bits than the original image for the purpose of efficient storage and transmission. *See* still image coding.

continuous wave (CW) periodic and usually sinusoidal wave, in contrast to a pulsed or modulated wave.

continuous-valued logic similarity by using the definition of the equivalence in continuous-valued logic, similarity between two variables $x = (x_0, \ldots, x_n)$ and $y = (y_0, \ldots, y_n)$, all components of which are continuous in the open interval $(0, 1)$, can be defined as

$$S_C(x, y) = \sqrt[\rho]{\sum_{i=1}^{n} (e(x_i, y_i))^{\rho}}$$

where ρ takes real value.

See equivalence in continuous-valued logicfor definition of $e(x_i, y_i)$.

contour the edge that separates an object from other objects and the background. It must consist of one or several closed curves, one for the outer contour, and the others (if any) for the inner contours surrounding any holes. *See* contour filling, contour following, edge.

contour filling an object contour is generally built with an edge detector, but such a contour can be open, because some of its pieces, not recognized by the edge detector, may be missing. To close the contour, missing pieces can be added by an operator filling small holes in a contour. *See* contour, edge detection.

contour following an operator which, starting from a contour point, follows the closed curve made by that contour. *See* contour.

contrast (1) a measure of the intensity difference (ratio) between an object and the image background.

(2) the difference in the perception of visual energy between picture white and picture black. The ratio between the darkest and lightest portions of a TV picture.

contrast enhancement alteration of the contrast in an image to yield more details or more information. *See also* contrast, histogram stretching, histogram equalization.

contrast enhancement layer (CEL) a highly bleachable coating on top of the photoresist that serves to enhance the contrast of an aerial image projected through it.

contrast rendition factor (CRF) the ratio of visual task contrast with a given lighting environment to the contrast with sphere illumination.

contrast sensitivity the responsiveness of the human visual system to low contrast patterns. In psychophysics, the threshold contrast is the minimum contrast needed to distinguish a pattern (such as a spatial sinusoid) from a uniform field of the same mean luminance, and the contrast sensitivity is the inverse of the threshold contrast. *See also* human visual system.

control intervention, by means of appropriate manipulated inputs, into the controlled process in the course of its operation; some form of observation of the actual controlled process behavior is usually being used by the controller.

control and status register (CSR) an internal CPU register that contains a packed bit array of I/O control information. CSRs can reside on I/O devices as well.

control bus contains processor signals used to interface with all external circuitry, such as memory and I/O read/write signals, interrupt, and bus arbitration signals.

control channel the control channel used to transmit network control information. No user information is sent on this channel. *Compare with* traffic channel.

control chart plot of data over time indicating the fluctuation of the main statistical characteristics applied in statistical quality control. Control charts can be used to determine if a process is in a state of statistical control by examining past data and to determine control limits that would apply to future data in order to check if the process maintains in this state.

The individual observations are plotted against three lines. The center one represents an estimate of the process mean, standard deviation or other statistic, two others represent the lower control limit (LCL) and the upper control limit (UCL), respectively. If the control charts are being used for the first time, it is necessary to determine trial control limits.These limits should be revised if the points outside them are traced to a special cause which can be removed. The most frequently used control charts are $\bar{X}, s$ (mean, standard deviation) and $\bar{X}, R$ (mean, range) charts. Control charts are used to aid in identification of special causes of variation, reduction in product variability, and keeping good records.

control horizon end time of the control interval over which the operation of the control system is considered; if the control interval is infinite then the control horizon is also infinite.

control input *See* manipulated input.

control instruction machine instruction that controls the actions of a processor such as setting flags to enable specific modes of operation. Generally, control instructions do not perform computations. Sometimes control instructions include instructions that can effect sequential execution of a program, such as branch instructions.

control interval time interval over which the operation of the control system is considered; control interval can be finite or infinite. The notion of a control interval is essential when the controlled process features various accumulation phenomena.

control layer part of the controller responsible for performing tasks associated with a particular aspect of the control; particular control layer results from vertical decomposition of the controller into a multilayer control structure; the layers may differ in their function, or the control interval considered, or both. Typical examples of control layers would be regulation layer of a continuous industrial process (see direct control) and set point control layer of such process. *See also* optimizing control layer.

control line in a bus, a line used in a computer bus to administrate bus transfers. Examples are bus request (a device wants to transmit on the bus), or bus grant (the bus arbiter gives a device transmit access on the bus).

control memory a semiconductor memory (typically RAM or ROM) used to hold the control data in a microprogrammed CPU. This data is used to control the operation of the data path (e.g., the ALU, the data path busses, and the registers) in the CPU. If the control memory uses RAM, the CPU is said to be microprogrammable, which means that the CPU's instruction set can be altered by the user and the CPU can thus "emulate" the instruction set of another computer. Same as control store and micromemory.

control policy *See* control rule.

control problem a design problem concerned with constructing a device called the controller whose goal is to force the controlled variable of the plant or process to behave in a desired manner. The elements of the control problem are control objective, a model of the process to be controlled, admissible controllers, and a means of evaluating the performance of a control strategy. *See also* controller, controlled variable.

control rod an assembly of neutron-absorbing material, typically boron, which is extended into the core of a nuclear reactor to dampen the chain reaction.

control rule decision mechanism (sequence of such mechanisms), used — within the considered control layer — to specify on-line the values of the control inputs; for example, the values of the manipulated inputs in case of the direct control layer or the set-point values in case of the optimizing control layer. Also known as control policy.

control scene initial entity, a given "world," which is then partitioned into the controlled process and its (process) environment; control scene is the initial "world" which is of interest to a control engineer or a system analyst.

control store *See* control memory.

control structure essentially the same as the control system; this term is used when one wants to indicate that the controller is composed of several decision units, suitably interlinked; decision units of a control structure usually differ in their tasks, scope of authority and access to information; depending on the context one speaks of a control structure or of a decision structure; decentralized control, multilayer control, hierarchical control are examples of control structures.

control surface any of the movable parts such as tabs, panels, or wings that control the depth of a submarine or the attitude of a flight vehicle moving through the atmosphere. For example, the yaw angle of an airplane is controlled by the rudder, the pitch angle by the elevators, while the roll angle by the ailerons. In fuzzy logic community, control surface may mean a plot of a typical fuzzy logic controller output as a function of its two inputs. The inputs to a typical fuzzy logic controller are the error between the desired and the actual plant output, and the change-in-error.

control system (1) the entity comprising the controlled process and the controller. Control system is influenced by the environment of the process both through the free inputs to the process itself and through any current information concerning the behavior of these free inputs that is made available to the controller.

(2) an arrangement of interconnecting elements that interact and operate automatically to maintain a specific system condition or regulate a controlled variable in a prescribed manner.

control transformer a step-down transformer used to provide power to the control portion of a power or motor circuit.

control under uncertainty operation of the control system in a situation when there is a significant uncertainty regarding current or future values of the free inputs, which leads to uncertainty in the envisaged behavior of the controlled process and, eventually, there is uncertainty concerning the internal behavior of the controlled process; in particular when the forecasted scenarios of the future free input values tend to appear to be largely different from the actual future free input realization.

controllability (1) the property of a system that ensures the existence of bounded control inputs to drive any arbitrary initial state to any arbitrary final state in finite time. For linear systems, an algebraic condition that involves system and input matrices can be used to test this property.

(2) the ability to establish the required test stimuli at each node in a circuit by setting appropriate values on the circuit inputs.

controllability at a given time a characteristic of some dynamical systems. A linear dynamical system is said to be controllable at a given time if there exists a finite time t_1, such that it is controllable in a time interval $[t_0, t_1]$.

controllability condition for nonstationary discrete system a condition found in some dynamical systems. A linear dynamical nonstationary discrete-time system is controllable in an interval $[k_0, k_1]$ if and only if the controllability matrix

$$\sum_{j=k_0}^{k_1-1} F\,(k_1, j+1)\, B(j) B^T(j) F^T\,(k_1, j+1)$$

is nonsingular. *See also* dynamical linear nonstationary discrete-time finite-dimensional system.

controllability in a fixed interval a characteristic of some dynamical systems. A dynamical discrete system is said to be controllable in an interval $[k_0, k_1]$ if for any initial state $x(k_0) \in R^n$ and any vector $x_1 \in R^n$ there exists a sequence of admissible controls $u(k)$, $k = k_0, k_0+1, \ldots, k_1-2, k_1-1$ such that the corresponding trajectory of the dynamical system satisfies the condition

$$x(k_1, x(k_0), u) = x_1$$

controllability in a given time interval a characteristic of some dynamical systems. A dynamical continuous system is said to be controllable in a given time interval $[t_0, t_1]$ if for any initial state

$$x(t_0) \in R^n$$

and any vector

$$x_1 \in R^n$$

there exists an admissible control

$$u \in L^2\left([t_0, t_1], R^m\right)$$

such that the corresponding trajectory of the dynamical system $x(t, x(t_0), u)$ satisfies the following condition:

$$x(t_1, x(t_0), u) = x_1$$

controllability of nonstationary systems a characteristic of some dynamical systems. A linear dynamical nonstationary system is controllable in time interval $[t_0, t_1]$ if and only if the $n \times n$ dimensional controllability matrix

$$W(t_0, t_1) = \int_{t_0}^{t^1} F(t_1, t)\, B(t) \times B^T(t) F^T(t_1, t)\, dt$$

is nonsingular. *See also* dynamical linear nonstationary continuous-time finite-dimensional system.

controllability of stationary systems a characteristic of some dynamical systems. A linear dynamical stationary system is controllable if and only if

$$\text{rank}\left[B|AB|A^2B|\ldots|A^kB|\ldots|A^{n-1}B\right] = n$$

See also dynamical linear stationary continuous-time finite-dimensional system.

controlled process part of the control scene that can be influenced by the manipulated inputs set by the controller and the free inputs from the (process) environment; manipulated inputs will be set (adjusted) to realize specified control objectives. Control objectives can be stated in terms of constraints imposed on specified quantities, in terms of performance indices to be minimized or maximized, or in other form; free inputs to the process from its environment do not depend, by definition, on the process behavior.

controlled process model model, usually stated in form of a set of differential or difference equations, describing the behavior of the controlled process as caused by its inputs; different models of the same controlled process may be used for various purposes, for steady-state control or for model-based predictive control.

controlled rectifier a rectifier that uses switching elements that have forward voltage blocking capability to allow a variable voltage DC output. *See also* thyristor.

controlled source a voltage or current source whose intensity is controlled by a circuit voltage or current elsewhere in the circuit. Also called dependent source.

controlled variable (1) the quantity, usually the output of a plant or process, that is being controlled for the purpose of the desired behavior, for example, transient response or steady-state response.

(2) variable associated with the behavior of the controlled process and such that one wants this variable either to follow a desired trajectory over a given time interval or to be kept at a prescribed constant value, i.e., at a specified set-point; introduction of a set of controlled variables is necessary to define a two-layer industrial controller with the reg-

ulation direct control layer and the set point optimizing control layer.

See also controller.

controller (1) the entity that enforces the desired behavior — as specified by the control objectives — of the controlled process by adjusting the manipulated inputs. The values of these inputs are either predetermined or decided upon (computed) using on-line, i.e., real time, decision mechanism of the controller — based on the currently available information. *See also* controlled variable.

(2) a device that generates the input to the plant or process. The role of the controller is to force the controlled variable of the plant or process to behave in a desired manner.

(3) a unit that directs the operation of a subsystem within a computer. For instance, a disk controller interprets data access commands from host computer (via a bus), and sends read/write, track seeking, and other control signals to the drive. During this time, the computer can perform other tasks, until the controller signals DATA READY for transfer via the CPU bus.

convection current a current in which electrons are released for movement outside of a material.

convective heat transfer the process by which a moving fluid transfers heat to or from a wetted surface.

convergence the condition when the electron beams from a multi-beam CRT meet at a single point. For example, the correct registration of the three beams in the color picture tube.

convergence in probability for some sequences of random numbers, the tendency to a single number.

To wit, for a sequence of numbers x_n, and a random variable x, if for all $\epsilon > 0$,

$$P\{| x_n - x |> \epsilon\} \to 0$$

for $n \to \infty$, then the sequence x_n tends to x in probability.

convergent state the equilibrium state of a dynamic system described by a first order vector differential equation is said to be convergent if there exists a $\delta = \delta(t_0)$, such that,

$$\| x(t_0) - x_e \| < \delta \Rightarrow \lim_{t\to\infty} x(t) = x_e$$

See also stable state.

converter a generic term used in the area of power electronics to describe a rectifier, inverter, or other power electronic device that transforms electrical power from one frequency and voltage to another.

convex fuzzy set (1) a fuzzy set that has a convex type of membership function.

(2) a fuzzy set in which all α-level sets are convex. *See also* α-level set.

convolution the mathematical operation needed to determine the response of a system from its stimulus signal and its weighting function. The convolution operation is denoted by the symbol "$*$." The convolution of two continuous time signals $f_1(t)$ and $f_2(t)$ is defined by

$$\begin{aligned} f_1(t) * f_2(t) &= \int_{-\infty}^{\infty} f_1(\tau) f_2(t-\tau) d\tau \\ &= \int_0^t f_1(\tau) f_2(t-\tau) d\tau \text{ if } f_1(t), f_2(t) \\ &= 0, t < 0 \end{aligned}$$

The integral on the right-hand side of the above equation is called the convolution integral, and exists for all $t \geq 0$ if $f_1(t)$ and $f_2(t)$ are absolutely integrable for all $t > 0$. f_1 is the weighting function that characterizes the system dynamics in the time domain. It is equivalent to the response of the system when subjected to an input with the shape of a Dirac delta impulse function. Laplace transformation of the weighting function yields the transfer function model for the system.

The convolution of two discrete time signals $f_1[k]$ and $f_2[k]$ is defined by

$$f_1[k] * f_2[k] = \sum_{i=-\infty}^{\infty} f_1[i] f_2[k-i]$$

$$= \sum_{i=0}^{k} f_1[i] f_2[k-i] \text{ if } f_1[k], f_2[k] = 0, k < 0$$

The summation on the right-hand side of the above equation is called the convolution sum. Convolution is useful in computing the system output of LTIL systems.

convolution integral *See* convolution, superposition integral.

convolutional code (1) a code generated by passing the information sequence to be transmitted through a linear finite-state shift register and the coder memory couples the currently processed data with a few earlier data blocks. Thus the coder output depends on the earlier data blocks that have been processed by the coder.

(2) a channel code based on the trellis coding principle but with the encoder function (mapping) determined by a linear function (over a finite alphabet). The name "convolutional code" comes from the fact that the output sequence is a (finite alphabet) convolution between the input sequence and the impulse response of the encoder.

convolutional coding a continuous error control coding technique in which consecutive information bits are combined algebraically to form new bit sequences to be transmitted. The coder is typically implemented with shift register elements. With each successive group of bits entering the shift register a new, larger set of bits are calculated for transmission based on current and previous bits. If for every k information bits shifted into the shift register, a sequence of n bits are calculated, the code rate is k/n. The length of the shift register used for storing information bits is known as the constraint length of the code. Typically, the longer the constraint length, the higher the code protection for a given code rate. *See also* block coding, error control coding.

cooling tower a reinforced-concrete, spool-shaped structure in a thermal power plant in which condenser cooling water is itself cooled by convectively-driven air streams.

Cooper, Leon Niels (1930–) Born: New York, New York, U.S.A.

Cooper is best known for his work on superconductivity, resulting in a Nobel Prize he shared with John Bardeen and J. Robert Schrieffer. He postulated the idea that is now known as Cooper pairs, as part of the explanation of why some metals loose their conductivity at very low temperatures.

coordinate system a system for defining the location of a point in space relative to some reference point and for defining a set of reference directions at each and every point in space.

coordinated rotation digital computer (CORDIC) algorithm for calculating trigonometric functions using only additions and shift operations.

coordinating unit *See* coordinator unit.

coordination process of influencing — by the coordinator — the local units in such a way as to make their behavior or decisions consistent with the objectives of the coordinator unit; coordination can be either iterative or periodic; iterative coordination plays an essential role in multilevel optimization. *See also* direct method, mixed method coordination, price method coordination.

coordination by exception coordination performed only in unusual (emergency) situations, otherwise the control or decision making is designed to be fully decentralized.

coordination instrument any means by which the coordinator unit influences behavior or decisions of the subordinate (local) units; coordination instruments are often expressed in terms of vectors of values assumed by the coordination variables. In the case of price method, the coordination variables are the prices by which the interaction input and output variables are multiplied.

coordination strategy mechanism (algorithm) used to generate the values of the coordination instruments in the course of either iterative or periodic coordination; in case of iterative coordination, the convergence and the speed of convergence of the coordination strategy is of main concern; in case of periodic coordination, other issues are important — these can be stability of the coordination process as well as quantitative aspects of the controlled process behavior.

coordinator unit control (decision) agent in a hierarchical control structure, being in charge of decisions (control instruments) influencing operation of the local decision units; coordinator unit performs either iterative or periodic coordination of the local decisions; coordinator unit is often regarded as the supremal unit of the hierarchical control structure. Also called coordinating unit.

copolarized the plane wave whose polarization is the same as that of the reference plane wave (e.g., radiated wave from an antenna) is said to be copolarized (otherwise it is crosspolarized).

copper jacket timer a magnetic time-off timer that can be used in definite time DC motor acceleration starters and controllers. The copper jacket relay functions by slowing the dissipation of the magnetic field when the coil is turned off. After a certain amount of time the spring tension on the contactor overcomes the strength of the dissipating magnetic field — and causes the contacts to change state. Time delays with the copper jacket timer are adjusted by adding, or removing, permeable shims between the coil and copper jacket. The more shims in place the slower the magnetic field dissipates, hence the longer the time delay becomes.

copper loss electric loss due to the resistance in conductors, windings, brush contacts or joints, in electric machinery or circuits. Also referred to as I^2R, the losses are manifested as heat.

coprime 2-D polynomial matrices *See* coprimeness of 2-D polynomial matrices.

coprime 2-D polynomials *See* coprimeness of 2-D polynomials.

coprimeness of 2-D polynomial matrices a mathematical relationship of interest in control systems.

A 2-D polynomial matrix $C(z_1, z_2)$ ($B(z_1, z_2)$) is called a right (left) divisor of $A(z_1, z_2)$ if there exists a matrix $B(z_1, z_2)$ ($C(z_1, z_2)$) such that

$$A(z_1, z_2) = B(z_1, z_2)\, C(z_1, z_2)$$

A 2-D polynomial matrix $R(z_1, z_2)$ ($L(z_1, z_2)$) is called a common right (left) divisor of $A(z_1, z_2)$, and $B(z_1, z_2)$ if there exist two 2-D polynomial matrices $A_1(z_1, z_2)$, $B_1(z_1, z_2)$, ($A_2(z_1, z_2)$, $B_2(z_1, z_2)$) such that

$$A(z_1, z_2) = A_1(z_1, z_2)\, R(z_1, z_2)$$

and

$$B(z_1, z_2) = B_1(z_1, z_2)\, R(z_1, z_2)$$
$$(A(z_1, z_2) = L(z_1, z_2)\, A_2(z_1, z_2)$$

and

$$B(z_1, z_2) = L(z_1, z_2)\, B_2(z_1, z_2))$$

A 2-D polynomial matrix $P(z_1, z_2)$, ($Q(z_1, z_2)$) is called greatest common right (left) divisor of $A(z_1, z_2)$ and $B(z_1, z_2)$ if $P(z_1, z_2)$ ($Q(z_1, z_2)$) is a greatest right (left) divisor of $A(z_1, z_2)$ and $B(z_1, z_2)$ and any common right divisor of $A(z_1, z_2)$ and $B(z_1, z_2)$ is a right divisor of $P(z_1, z_2)$.

2-D polynomial matrices $A(z_1, z_2)$, $B(z_1, z_2)$ are called factor right (left) coprime if their greatest common right (left) divisor is a unimodular matrix $U(z_1, z_2)$ (nonzero $det U(z_1, z_2) \in R$).

2-D polynomial matrices $A \in R^{p\times m}[z_1, z_2]$, $B \in R^{p\times m}[z_1, z_2]$ $(p+q \geq m \geq 1)$ are called zero right coprime if there exists a pair (z_1, z_2) which is a zero of all $m \times m$ minors of the matrix $\begin{bmatrix} A \\ B \end{bmatrix}$. The minor coprimeness of two 2-D polynomial matrices implies their factor coprimeness.

coprimeness of 2-D polynomials a mathematical relationship of interest in control systems.

A 2-D polynomial

$$p(z_1, z_2) = \sum_{i=0}^{n_2} a_i(z_1) z_2^i = \sum_{j=0}^{n_1} a_j(z_2) z_1^j$$

is called primitive if $a_i(z_1)$, $i = 1, 2, \ldots, n_2$ and $a_j(z_2)$, $j = 1, 2, \ldots, n_1$ are coprime (have not a common factor). Two primitive 2-D polynomials are called factor coprime if their greatest common divisor is a constant. The primitive 2-D polynomials

$$\begin{aligned}
a(z_1, z_2) &= a_{n_1}(z_2)\,\bar{a}(z_1, z_2) \\
&= a_{n_2}(z_1)\,\hat{a}(z_1, z_2) \\
b(z_1, z_2) &= b_{m_1}(z_2)\,\bar{b}(z_1, z_2) \\
&= b_{m_2}(z_1)\,\hat{b}(z_1, z_2) \\
\bar{a}(z_1, z_2) &= z_1^{n_1} + \bar{a}_{n_1-1} z_1^{n_1-1} + \cdots \\
&\quad + \bar{a}_1 z_1 + \bar{a}_0 \quad (\bar{a}_i = \bar{a}_i(z_2)) \\
\hat{a}(z_1, z_2) &= z_2^{n_2} + \hat{a}_{n_2-1} z_2^{n_2-1} + \cdots \\
&\quad + \hat{a}_1 z_2 + \hat{a}_0 \quad \left(\hat{a}_i = \hat{a}_i(z_1)\right) \\
\bar{b}(z_1, z_2) &= z_1^{m_1} + \bar{b}_{m_1-1} z_1^{m_1-1} + \cdots \\
&\quad + \bar{b}_1 z_1 + \bar{b}_0 \quad \left(\bar{b}_i = \bar{b}_i(z_2)\right) \\
\hat{b}(z_1, z_2) &= z_2^{m_2} + \hat{b}_{m_2-1} z_2^{m_2-1} + \cdots \\
&\quad + \hat{b}_1 z_2 + \hat{b}_0 \quad \left(\hat{b}_i = \hat{b}_i(z_1)\right)
\end{aligned}$$

are factor coprime if and only if

$$\det\left[\bar{B}^{n_1} + \bar{a}_{n_1-1}\bar{B}^{n_1-1} + \cdots + \bar{a}_1\bar{B} + \bar{a}_0 I_{m_1}\right] \neq 0$$

and

$$\det\left[\hat{B}^{n_2} + \hat{a}_{n_2-1}\hat{B}^{n_2-1} + \cdots + \hat{a}_1\hat{B} + \hat{a}_0 I_{m_2}\right] \neq 0$$

or

$$\det\left[\bar{A}^{m_1} + \bar{b}_{m_1-1}\bar{A}^{m_1-1} + \cdots + \bar{b}_1\bar{A} + \bar{b}_0 I_{n_1}\right] \neq 0$$

and

$$\det\left[\hat{A}^{m_2} + \hat{b}_{m_2-1}\hat{A}^{m_2-1} + \cdots + \hat{b}_1\hat{A} + \hat{b}_0 I_{n_2}\right] \neq 0$$

where

$$\bar{A} = \begin{bmatrix} 0 & 1 & 0 & \ldots & 0 \\ 0 & 0 & 1 & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & 0 & \ldots & 1 \\ -\bar{a}_0 & -\bar{a}_1 & -\bar{a}_2 & \ldots & -\bar{a}_{n_1-1} \end{bmatrix}$$

$$\hat{A} = \begin{bmatrix} 0 & 1 & 0 & \ldots & 0 \\ 0 & 0 & 1 & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & 0 & \ldots & 1 \\ -\hat{a}_0 & -\hat{a}_1 & -\hat{a}_2 & \ldots & -\hat{a}_{n_2-1} \end{bmatrix}$$

$$\bar{B} = \begin{bmatrix} 0 & 1 & 0 & \ldots & 0 \\ 0 & 0 & 1 & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & 0 & \ldots & 1 \\ -\bar{b}_0 & -\bar{b}_1 & -\bar{b}_2 & \ldots & -\bar{b}_{m_1-1} \end{bmatrix}$$

$$\hat{B} = \begin{bmatrix} 0 & 1 & 0 & \ldots & 0 \\ 0 & 0 & 1 & \ldots & 0 \\ \ldots & \ldots & \ldots & ,,, & \ldots \\ 0 & 0 & 0 & \ldots & 1 \\ -\hat{b}_0 & -\hat{b}_1 & -\hat{b}_2 & \ldots & -\hat{b}_{m_2-1} \end{bmatrix}$$

coprocessor a processor that is connected to a main processor and operates concurrently with the main processor, although under the control of the main processor. Coprocessors are usually special-purpose processing units, such as floating point, array, DSP, or graphics data processors.

copy-back in cache systems an operation that is the same as write-back—a write operation to the cache that is not accompanied with a write operation to main memory. In copy-back, the data is written only to the block in the cache. This block is written to main memory only when it is replaced by another block.

CORDIC *See* coordinated rotation digital computer.

core (1) the operating image of a process (sometimes used to refer to the part residing in physical memory), often written to disk if the program crashes (dumping core). Since magnetized ferrite rings (cores) were once used in main memory to store a single bit each. The name remained and now core memory means the same as main memory, although currently, main memory is chip-based. *See also* magnetic core memory.

(2) the ferromagnetic portion of a transformer or electric machine on which the coils are mounted. Typically made of laminated magnetic material, encircled by the windings, that provides a low reluctance path for magnetic flux.

(3) the central region of an optical fiber. The refractive index of the core must be higher than that of the cladding so that the optical power is guided through the fiber by total internal reflection at the core-cladding boundary. The core refractive index may be constant or may decrease with distance from the axis to the cladding. *See also* graded index and step index optical fiber.

(4) the section of a nuclear reactor in which the chain reaction is contained, comprising fuel rods, control rods, moderator, and coolant.

core lamination *See* lamination.

core loss loss in the ferromagnetic material comprising the core of an electric machine or transformer, composed of the sum of hysteresis losses and eddy current losses. These magnetic losses are caused by time varying fluxes in a ferromagnetic structure. Hysteresis losses are caused by friction in molecules as the dipoles in a structure change direction of alignment in response to an applied alternating voltage, while eddy current losses are resistive losses (I^2R), due to circulating currents in the core.

core memory *See* magnetic core memory.

core-type transformer a transformer in which the magnetic circuit upon which the windings are wound takes the form of a single ring. When the coils are placed on the core, they encircle the core. *See also* core.

coriolis forces forces/torques that depend upon the product of joint velocities.

corner cube antenna a traveling wave antenna typically four wavelengths long and placed 1.2 wavelengths from the apex of a 90-degree corner reflector other used in the submillimeter wave and terahertz frequency range for mixers and detectors.

corner detection the detection of corners, often with a view to locating objects from their corners, by a process of inference, in digital images.

corona a visible glow discharge which emanates from high-voltage conductors in regions of extremely high electric field intensity.

corona effect flow of electrical energy from a high-voltage conductor to the surrounding ionized air. This effect only becomes significant for potentials higher than 1000 V. This effect is characterized by a faint glow, a crackling noise and conversion of atmospheric oxygen to ozone.

corona loss the electric power lost in high voltage lines due to the radiation of energy by corona discharge. *See* corona.

corona resistance capacity of a material to bear the action of the corona effect.

This capacity is particularly important for polymeric materials, which have to withstand the chemical degrading effect promoted by ozone generated by the corona effect. *See also* corona effect.

corona ring a toroidal metal ring connected to discontinuities on high-voltage conductors to reduce local field intensity and thus discourage the formation of corona discharge.

coronal projection a projection image formed on a plane parallel to the chest and perpendicular to the transverse and sagittal planes.

corporate feed also known as parallel feed, a method of feeding a phased array antenna in which the signal from a transmitter is successively split until there are enough feedlines to carry the signal to each array element. The name comes from the resemblance of the feed structure to the organizational chart of a corporation.

correction layer control layer of a multilayer controller, usually situated above the direct control layer and below the optimizing control layer, required to make such modifications of the decisions supplied by the optimizing layer — before these decisions are passed to the direct layer — that some specified objectives are met; for example, a correction layer of the industrial process controller may be responsible for such adjustment of a particular set point value that an important constraint is satisfied by the controlled process variables — in case when the optimizing layer is using inaccurate model of this controlled process.

correlation (1) the mathematical operation of comparing the behavior of two signals to determine how closely they are related. It is usefully applied to system identification when the input and output signals of a given system are compared by correlation to give the system transfer function model. The relevant equation is

$$\hat{g}(j\omega) = \frac{y(j\omega)u^*(j\omega)}{u(j\omega)u^*(j\omega)}$$

in terms of the FFTs of the input and output signals. The $*$ superscript indicates the complex conjugate. As the system output $y(t)$ generally contains terms in addition to those caused by the input $u(t)$, its Laplace transform is

$$y(s) = g(s) \times u(s) + d(s)$$

Thus the correlation of input and output can enhance the accuracy of the estimate for the system frequency response function $g(j\omega)$, since the correlation function then yields the following estimate of the actual process model:

$$\hat{g}(j\omega) = g(j\omega) + \frac{d(j\omega)u^*(j\omega)}{u(j\omega)u^*(j\omega)}$$

Clearly, the effect of the disturbance $d(t)$ is readily reduced if the input is chosen either to be large in amplitude, compared to the disturbance, or to be pseudo-random so that it does not correlate with the disturbance and the second numerator becomes zero, by definition.

(2) the temporal or spatial function or sequence resulting from integrating lagged products of two signals, i.e., the products of a signal with the time-inverted version of a second signal at various relative delays with respect to each other. If the two signals are identical, a maximum correlation output amplitude results at full overlap. *See also* convolution.

correlation bandwidth the frequency for which the autocorrelation of the transfer function reaches a given threshold, for example x% of the central value.

correlation coefficient a measure of the ability to predict one random variable x as the linear function of another y. The correlation coefficient

$$\rho = \frac{E[xy] - E[x]E[y]}{\sigma_x \sigma_y}$$

satisfies $-1 \leq \rho \leq 1$, where $|\rho| = 1$ implies a deterministic linear relationship between x and y, and $\rho = 0$ implies lack of correlation. *See also* correlation.

correlation detector the optimum structure for detecting coherent signals in the presence of additive white Gaussian noise.

correlation function a mathematical description that describes the common relationship between two processes. For a single time dependent quantity, the autocorrelation function describes the loss of information in the process description of the quantity. *See* autocorrelation function.

correlation peak detector a photodetector array that detects and outputs only the peak in a spatial correlation function.

correlation receiver a receiver utilizing the autocorrelation or cross-correlation properties of the transmitted signal to detect the desired information from the received signal. A correlation receiver is theoretically equivalent to a matched filter receiver. Correlation receivers are often used in spread spectrum systems and channel measurement systems.

correlation sidelobes the correlation function other than the peak; particularly where signals are designed to give a sharply peaked correlation function.

correlation similarity the (unnormalized) correlation of two real vectors $x = (x_0, \ldots, x_n)$ and $(y_0, \ldots, y_n)$ is defined as their inner product:

$$C = \sum_{i=1}^{n} x_i y_i .$$

correlator a circuit that calculates the correlation function. *See also* correlation function.

correspondence problem the problem of matching points in one image with their corresponding points in a second image.

corresponding point a point, in a set of images representing a different view of the same scene, onto which the same physical point in the real world is projected.

corrugated horn a horn with grooves on its inner walls. The grooves create the same boundary conditions on all four walls of the horn. This results in the elimination of spurious diffraction at the edges of the horn aperture.

coset leader each possible error pattern of the code word representing the left-most column of the standard array.

cosine modulated filter bank a filter bank with each of its analysis filters and synthesis filters being the modulation of a low-pass prototype filter by a cosine function. In the frequency domain, it is equivalent to shifting the low-pass prototype filter by different frequencies to form a bank of bandpass filters covering the entire frequency band.

cosine roll-off filter a filter that has an impulse response which satisfies the Nyquist I criterion for zero intersymbol interference. The filter has the following transfer function.

$$H(\omega) = \begin{cases} 1, & |\omega| \leq \frac{\pi(1-\alpha)}{T} \\ \cos^2 \frac{T}{4\alpha} \left(|\omega| - \frac{\pi(1-\alpha)}{T}\right), & \frac{\pi(1-\alpha)}{T} < |\omega| < \frac{\pi(1+\alpha)}{T} \\ 0, & |\omega| \geq \frac{\pi(1+\alpha)}{T} \end{cases}$$

where T is the transmitted symbol period and α is a parameter that is known as the excess bandwidth ($0 \leq \alpha \leq 1$). The case $\alpha = 0$ yields the ideal low-pass filter, and the case $\alpha = 1$ yields a filter referred to as the raised cosine filter.

cosine transform a transform that consists of a set of basis functions, which are cosine functions. Usually referred to as discrete cosine transform. *See also* discrete cosine transform.

cost function a nonnegative scalar function that represents the cost incurred by an inaccurate value of the estimate. Also called penalty function.

Costas loop a carrier synchronization loop in a digital communications receiver that uses a quadrature phase detector in place of a conventional square-law device.

cotree the complement of a tree in a network.

Cotton–Mouton effect second-order anisotropic reciprocal magnetooptic effect that causes a linearly polarized incident light to transmit through as an elliptically polarized output light wave when the propagation direction of the incident light is perpendicular to the direction of the applied magnetization of the magnetooptic medium. It is also known as magnetic linear birefringence.

Coulomb blockade the situation in which a particle has insufficient thermal energy to allow the necessary energy exchange during a tunneling process. Hence, the bias supply must supply energy to the electron to account for the stored energy change in tunneling, which requires $V > e/2C$, where C is the capacitance ($eV << kBT$).

Coulomb force electric force exerted on an electrically charged body, which is proportional to the amount of the charge and the electric field strength in which the charged body is placed.

Coulomb's Law the force of repulsion/attraction between two like/unlike charges of electricity concentrated at two points in an isotropic medium is proportional to the product of their magnitudes and inversely proportional to the square of the distance between them and to the dielectric constant of the medium.

Coulomb, Charles (1763–1806) Born: Angouleme, France

Coulomb is best known for his study of electric charge and magnetism resulting in Coulomb's Law, as well as his studies in friction. Coulomb also invented the torsion balance in 1777. He used this device in many experiments. Coulomb began his career in the military, but resigned when the French Revolution began. His experience as a military engineer involved him in a wide variety of different projects. It also gave him time to continue his own experimental work. Coulomb's law states that the force between two charges is proportional to the product of the charges and inversely proportional to the square of the distance between the two charges. Coulomb is honored by having his name used as the unit of electric charge, the coulomb.

counter (1) a variable or hardware register that contains a value that is always incremented or decremented by a fixed amount, and always in the same direction (usually incremented by one, but not always).

(2) a simple Moore finite state machine that counts input clock pulses. It can be wired or enabled to count up and/or down, and in various codes.

counter-EMF a voltage developed in an electrical winding by Faraday's Law that opposes the source voltage, thus limiting the current in the winding.

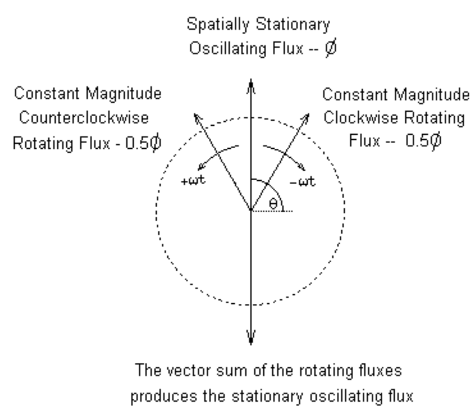
counter-EMF starter a type of DC-motor starter that reduces the resistance in the starting circuit as the voltage across the armature rises.

counter-propagation learning *See* hierarchical feature map.

counter-rotating field theory mathematical theory in which a magnetic field with stationary spatial direction but sinusoidally varying magnitude is decomposed into two constant-magnitude fluxes rotating in opposite directions. The angular velocity, ω, of the rotating fluxes equals the time-domain angular frequency of the stationary flux, and the magnitude of the rotating fluxes is half the magnitude of the stationary flux. Mathematically, this is described by the following equation:

$$B \cos\theta \sin\omega t = 0.5B \sin\omega t - \theta + 0.5B \sin\omega t + \theta$$

where the left-hand term represents the time-varying flux magnitude along the spatial direction θ, and the right-hand terms represent forward and backward rotating fields of constant magnitude rotating about θ. The following diagram illustrates this relationship. Resolution of the stationary flux into two rotating fluxes allows induction machine performance to be analyzed using standard rotating field theories. The total machine performance is determined from the net result of both rotating fluxes. Also called double revolving-field theory.



Counter-rotating field concept.

counter-torque torque developed in opposition to the rotation of a machine. It is produced as load current flows in the presence of and perpendicular to magnetic flux in a machine that is generating electric power.

counterpoise a ground wire buried beneath an overhead line to lower footing impedance.

counterpoise ground buried conductor routed under transmission lines designed to achieve low earth electrode resistance.

coupled inductor two inductors within a switching converter, which have similar voltage waveforms, are wound on the same magnetic core to steer the ripple from one winding to another. A typical example is a Ćuk converter with an isolation transformer where the input and output inductors are coupled with the transformer to provide zero ripple at the input and the output. *See also* Ćuk converter.

coupled line filter a type of microstrip or stripline filter that is composed of parallel transmission lines. Bandwidth is controlled by adjusting the transmission line spacing. Wider bandwidths are obtained by tighter coupling. A two-port circuit is formed by terminating two of the four ports in either open or short circuits, which leaves ten possible combinations. Different combinations are used to synthesize low-pass, bandpass, all pass, and all stop frequency responses.

coupled lines the electromagnetic field of two unshielded transmission lines in proximity can interact with each other to form coupled lines. Usually three conductors are needed. Examples of coupled lines are coupled microstrip lines and coupled striplines.

coupled Riccati equations a set of differential or algebraic matrix equations of the Riccati type arising in the jump linear quadratic problem which should be solved simultaneously. The set of coupled differential Riccati equations has a form

$$\dot{K}(i,t) + A(i)'K(i,t) + K(i,t)A(i)$$
$$\sum_{j=1}^{s} q_{ij}K(j,t) + Q(i)$$
$$- K(i,t)B(i)R(i)^{-1}B(i)'K(i,t) = 0$$

for $i \in \mathbf{S} = \{1, 2, \ldots, s\}$, $t \in [0, T]$ and terminal condition $K(i,T) = 0$ where

$A(i)$, $B(i)$, $Q(i)$, $R(i)$ are, respectively, system and weighting, state and input matrices in the mode i, and q_{ij} is the transition rate from mode i to j. If the system is stochastically stabilizable and the pairs $(A(i), \sqrt{Q(i)})$ are observable for all i where $\sqrt{Q(i)} = C(i)$ such that $C(i)'C(i) = Q(i)$, then the solution $K(i, t)$ is finite for each i and

$$\lim_{T-t\to\infty} K(i, t) = \hat{K}(i)$$

where $\hat{K}(i)$ is the set of solutions to the coupled algebraic Riccati equations:

$$A(i)'\hat{K}(i) + \hat{K}(i)A(i) + \sum_{j=1}^{s} q_{ij}\hat{K}(j) + Q(i) - \hat{K}(i)B(i)R(i)^{-1}B(i)'\hat{K}(i) = 0$$

Coupled Riccati equations are also used in N-person linear quadratic games. In this case $i = 1, 2, \ldots, N$ is the number of the player and the set of coupled differential matrix equations has the following form:

$$\dot{K}(i, t) + A'K(i, t) + K(i, t)A + Q(i) - K(i, t)\sum_{j=1}^{j=N} BR(j)^{-1}B'K(j, t) = 0$$

for $i \in \{1, 2, \ldots, N\}$, $t \in [0, T]$ and terminal condition $K(i, T) = 0$ where A, B are, respectively, state and input matrices in the state equation, $Q(i)$, $R(i)$ are weighting state and input matrices for the i-th player, and its solution defines the gain in a Nash equilibrium in the game.

coupled wave equations a special case of Maxwell's equations describing the propagation of two interacting electromagnetic fields in a nonlinear material. For example, in four wave mixing or optical phase conjugation, the probe and conjugate fields often obey coupled wave equations.

coupler (1) a passive, wavelength-insensitive, fiber optic component that combines all inputs and distributes them to the outputs with a defined splitting ratio. The most common types are termed fused taper and dichroic.

(2) a device inserted into an optical fiber communications link that is used to insert additional optical energy or signals onto the link and/or tap off some of the energy or signal on the link to another optical fiber. A coupler may also be used to combine power from two or more input fibers into one output fiber or to distribute the combined input power to a number of output fibers. Couplers are made in $1\times N$, $N\times N$, and $N\times M$ (input) $\times$(output) configurations where N and M are the number of fibers. The power combining and/or splitting ratios can vary from 50%/50% (a 3 dB coupler) in a symmetric 2×2 coupler to $> 99\%/ < 1\%$ in an asymmetric coupler.

coupling capacitor voltage transformer (CCVT) a potential transformer that uses the impedance of a small capacitance to reduce the power line voltage to measureable levels.

coupling factor in a coupler, the ratio of power in the coupled port to that applied at the input port.

coupling efficiency the efficiency to which a signal can be coupled from one transmission line or resonator to another.

coupling field a region of interaction where energy is transferred between systems. The energy may be transferred between systems of a similar nature (i.e., electrical–electrical) or between systems of a different nature (i.e., electrical–mechanical).

coupling loss measure of the power dissipated as a result of coupling a signal from one transmission line or resonator to another.

covariance The expectation of the product of two mean-removed random quantities:

$$C_{fg}(t_1, t_2) = E\left[f(t_1)g(t_2)^T\right] - E[f(t_1)]E[g(t_2)^T].$$

See also autocovariance, correlation, variance.

covert channel a mechanism by means of which information can be communicated indirectly despite design features that prevent direct communication. Many covert channels utilize side effects of operations, such as effects on timing or scheduling that can be seen from programs or processes that are not supposed to be direct destinations of any communications from a sender that in fact performs operations that emit signals by affecting timing or scheduling within the system.

COVQ *See* channel optimized vector quantization.

cow magnet a long, pill-shaped alnico magnet that is placed in the second stomach of a cow to capture ferrous debris and prevent it from passing through the digestive system.

CPA acronym for compensated pulsed alternator. *See* compulsator.

CPI *See* color preference index or cycles per instruction.

CPM laser *See* colliding-pulse-modelocked laser.

CPU *See* central processing unit.

CPU time the time that is required to complete a sequence of instructions. It equals to the (cycle time) $\times$ (number of instructions) $\times$ (cycles per instruction).

CR *See* cavity ratio.

Cramer-Rao bound a lower bound on the estimation error covariance for unbiased estimators. In particular, the estimation error covariance $\Lambda_e(\boldsymbol{x})$, which is a function of the unknown quantity $\boldsymbol{x}$ to be estimated, must satisfy $\Lambda_e(\boldsymbol{x}) \geq I(\boldsymbol{x})$, where I is the Fisher information matrix. If an estimator achieves the Cramer-Rao bound with equality for all $\boldsymbol{x}$, it is efficient; if an efficient estimator exists, it is the maximum likelihood estimator. *See also* bias, maximum likelihood estimation.

crash an incorrect operation of computer software or hardware leading to temporary or permanent loss of part of the data.

CRC *See* cyclic redundancy check.

CRC character a type of error detection code commonly used on disk and tape storage devices. Data stored on a device using CRC has an additional character added to the end of the data that makes it possible to detect and correct some types of errors that occur when reading the data back.

CRC-code code that employs cyclic redundancy checking. *See* cyclic redundancy check.

CRCW *See* concurrent read and concurrent write.

credit assignment problem during neural network learning, the problem of determining how to apportion credit (blame) to individual components for network behavior that is appropriate (inappropriate) to the task being learned.

crest factor the ratio of the peak value of a signal to its RMS value.

CREW *See* concurrent read and exclusive write.

CRF *See* contrast rendition factor.

crisp set in fuzzy logic and approximate reasoning, this term applies to classical (non-fuzzy Boolean) sets that have distinct and sharply defined membership boundaries. *See also* fuzzy set.

critical refers to the state of a chain reaction which is self-sustaining but which produces just enough free neutrons to compensate for those lost to the moderator and leakage.

critical angle the incidence angle, defined by Snell's law, where the incident wave is totally reflected at the interface of two different dielectric media.

critical band broadly used to refer to psychoacoustic phenomena of limited frequency resolution in the cochlea. More specifically, the concept of critical bands evolved in experiments on the audibility of a tone in noise of varying bandwidth, centered around the frequency of the tone. Increasing the noise bandwidth beyond a certain critical value has little effect on the audibility of the tone.

critical clearing angle (1) following a balanced three-phase fault at the stator terminals of a synchronous machine, the maximum value of the angular position of the rotor prior to the removal (clearing) of the fault such that the rotor will obtain synchronous speed without slipping poles following the removal (clearing) of the fault. The corresponding time for the rotor to achieve this angle is specified as the critical clearing time.

(2) the largest allowable angular deviation from synchronism that may be borne by a power system such that the system remains stable: the edge of instability.

critical damping the least amount of damping such that the system does not freely oscillate. For a characteristic equation of the form:

$$s^2 + 2\zeta\omega_n s + \omega_n^2,$$

the system is critically damped if $\zeta = 1.0$; the roots of the characteristic equation are repeated and real.

critical dimension (CD) the size (width) of a feature printed in resist, measured at a specific height above the substrate.

critical frequency the rate of picture presentation, as in a video system or motion picture display, above which the presented image ceases to give the appearance of flickering. The critical frequency changes as a function of luminance, being higher for higher luminance.

critical path a signal path from a primary input pin to a primary output pin with the longest delay time in a logic block.

critical point *See* equilibrium point.

critical race a change in two input variables that results in an unpredictable output value for a bistable device.

critical region a set of instructions for a process that access data shared with other processes. Only one process may execute the critical region at a time.

critical section *See* critical region.

critically sampled sampling that at the Nyquist frequency.

Crosby direct FM transmitter after its inventor, Murray Crosby. Also known as the "serrasoid modulator." Direct frequency modulation (FM) of an inductor/capacitor (LC) oscillator is essentially straightforward: One of the frequency determining elements value is varied in accordance with the baseband information.

cross chrominance NTSC video artifact that causes luminance information to be present in the decoded chroma signal (luminance crosses into chrominance). Cross chrominance is a result of mixing high frequency luminance information with the chrominance information in the composite video signal. An example of cross luminance is the rainbow pattern observed when tweed or a herringbone pattern appears in a TV scene.

cross color *See* cross chrominance.

cross luma *See* cross luminance.

cross luminance NTSC video artifact that causes chrominance information present in the decoded luma signal (chrominance crossed into luminance). Cross luminance has the appearance similar to a zipper caused by the color subcarrier. Television receivers that use a line comb filter to separate luma and chroma signals have cross-luminance components appearing on sharp horizontal edges. Television receivers that use a band-pass filter for luma–chroma separation have cross-chrominance components appearing on sharp vertical edges.

cross modulation an undesired intermodulation of an electromagnetic carrier wave by another electromagnetic carrier wave that is either physically adjacent to it or near it in terms of its radio frequency.

cross polar discrimination the ratio of co-polar to cross-polar received field strengths in a depolarizing medium. Usually expressed in decibels.

cross polar isolation the ratio between the field received by an antenna with one polarization from co-polar and cross-polar transmissions. This expresses the receiver's ability to detect one signal when dual-polarized signals are transmitted through a depolarizing medium.

cross power spectrum for two jointly wide sense stationary random processes the Fourier transform of their cross-correlation.

cross spectra computation of the energy in the frequency distribution of two different electrical signals.

cross-assembler a computer program that translates assembly language into machine code for a target machine different from the one on which the cross-assembler runs.

cross-compiler a computer program that translates a source code into machine or assembly code for a target machine different from the one on which the cross-compiler runs.

cross-correlation a measure of the correlation or similarity of two signals. For random processes $x(t)$ and $y(t)$, the cross-correlation is given by: $R_{xy}(t_1, t_2) = Ex(t_1)y(t_2)$. *See* wide sense stationary uncorrelated scattering channel.

cross-correlation function a function describing the degree of similarity between two signals, as a function of time-shift between the signals. *See also* correlation function.

cross-field theory a conceptual way to envision the operation of a single-phase induction motor. The rotor current is assumed to produce a magnetic field electrically and spatially orthogonal to the field produced by the main stator winding, thus contributing to a rotating magnetic field.

cross-polarization the field component orthogonal to the desired radiated field component (co-polar component).

cross-quad the simplest form of the common centroid concept, in which two matched transistors are formed by connecting diagonally opposite devices in a two-by-two array of transistors.

crossarm a transverse, generally insulated member mounted horizontally on a utility pole. It carries insulators and allows wide spacing of overhead conductors.

crossarm brace a brace, often insulated, which keeps a crossarm from rotating on its attachment bolts.

crossbar switch a structure that allows N units to communicate directly with each other, point to point. Which pairs are connected depends on how the switch is configured at that point in time. Crossbars are usually implemented for small (8 or less) numbers of nodes, but not always.

crossed field devices (CFD) radial or linear forward traveling wave amplifier or backward wave oscillator where radial or transverse DC accelerating electric fields are perpendicular to axial or longitudinal DC magnetic fields, respectively.

crossing number the even number obtained by adding the number of changes in binary value on going once around a particular pixel location; crossing number is useful for finding skeletons of shapes and for helping with their analysis: it is a measure of the number of 'spokes' of an object emanating from a specified location.

crossmodulation modulation of a desired carrier by an undesired interfering signal due to interaction of the two signals in one or more nonlinear elements.

crossover frequency the frequency where the magnitude of the open-loop gain is 1.

crossover point a crossover point of a fuzzy set A is the point in the universe of discourse whose membership in A is 0.5.

crosspoint a point at which two overlap neighboring fuzzy sets have the same membership grade.

crosspoint level the membership grade of a fuzzy set at a crosspoint.

crosstalk (1) undesired coupling (resistive, capacitive, or inductive) from one signal wire or transmission line to a colocated signal wire or transmission line.

(2) capacitative interference between two parallel transmission lines, in which a signal on one line affects a signal on the other line.

crowbar a triggered, shunt device that diverts the stored energy of the beam power supply.

CRR *See* cochannel reuse ratio.

CRT *See* cathode ray tube.

crystal filter reference amplifier a generic phrase that refers to a cascade of amplifying stages coupled together with the aid of crystal filter networks. Various topologies are available for the connection of these crystals (lattice, bridged, hybrid, and ladder). The outstanding feature of such an arrangement is that the amplitude versus frequency and phase versus frequency characteristics are essentially determined by the crystal arrangements.

crystal oscillator an electronic circuit used for generating a sinusoidal waveform whose frequency is determined by a piezoelectric crystal device.

crystalline phase in crystalline materials the constituent atoms are arranged in regular geometric ways; for instance in the cubic phase the atoms occupy the corners of a cube (edge dimensions $\approx$ 2–15 Å for typical oxides).

CSI *See* current-source inverter.

CSIM *See* capacitor-start induction motor.

CSMA *See* carrier-sense multiple access.

CSMA-CA CSMA with collision avoidance, a modification of the CSMA multiple access protocol to make it suitable for use in a radio environment. Prior to the transmission of a message, a source and destination node undertake an exchange of short messages to ensure that the destination node is idle and capable of receiving a transmission from the source node. *See also* carrier-sense multiple access.

CSMA/CD CSMA with collision detection. A modification of the CSMA protocol, where a user continues to monitor (sense) the channel after it initiates its transmission to determine if other terminals have also initiated transmissions. The terminal aborts the transmission if it detects a collision. This protocol is used in the local area network specified in the standard IEEE 802.3, which defines a local area computer network commonly referred to as the Ethernet. *See also* carrier-sense multiple access.

CSO *See* composite second order.

CSR *See* control and status register.

CT *See* current transformer.

CT2 (cordless telephone, 2nd generation). A digital cordless communication system developed in the United Kingdom, which operates in the 864-868 MHz band and can provide both private and public cordless telephony services. CT2-based public telephony services are often described as Telepoint services (q.v.). CT2 systems have 40 radio channels, each 100 kHz wide. Each radio channel provides a duplex traffic channel using simple "ping-pong" TDD. The carrier bit rate is 72 Kb/s, and CT2 terminals have a peak transmit power of 10 mW.

CTB *See* composite triple beat.

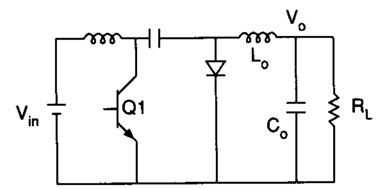
CTE *See* coefficient of thermal expansion mismatch.

CU *See* coefficient of utilization.

cubic voxel *See* voxel.

cubical quad antenna a parasitic array antenna in which the elements are made of square loops of wire with a perimeter of one wavelength. These antennas are typically used in the HF or VHF range and usually have only two or three elements, resulting in a structure that fills a roughly cubical volume.

Ćuk converter named after its inventor, Slobodan Ćuk, this device can be viewed as a boost converter followed by a buck converter with topologic simplification. A capacitor is used to transfer energy from the input to the output. The output voltage v_o is related to the input voltage v_i by $v_o = v_i d/(1-d)$ and it can be controlled by varying the duty ratio d. Note that the output voltage is opposite polarity to the input.



Ćuk converter.

cumulative distribution function (CDF) for a random variable **x**, the probability that **x** is less than or equal to some value x, denoted $F_{\mathbf{x}}(x)$. $F_{\mathbf{x}}(-\infty)$ is zero and increases monotonically to $F_{\mathbf{x}}(+\infty) = 1$. For a continuous probability density function $p(x)$, the CDF is

$$F_{\mathbf{x}}(x) = \int_{-\infty}^{x} p(t)dt .$$

The CDF is used in image processing to carry out histogram equalization. *See also* histogram equalization, probability density function.

cumulatively compounded a compound-wound DC machine in which the flux produced by the MMF of the shunt field winding and the flux produced by the MMF of the series field winding are in the same direction.

Curie temperature the temperature above which a material ceases to be magnetic; at this temperature a ferromagnetic material becomes paramagnetic.

current the flow of charge, measured in amperes (1 ampere = 1 coulomb/s).

current density vector field the field (commonly denoted J) that is related to the electric field intensity vector field by the conductivity of the medium that the fields are located in. One of the quantities found on the right side of Ampere's Law. The units are (amperes/square meter).

current distribution factor in economic dispatch studies, the proportion of a power line's total current which is contributed by a particular generating plant.

current fed inverter an inverter in which the current is switched instead of the voltage to create AC current from a DC source. A large inductor is used to maintain a nearly constant current on the DC side which is then directed to the load in an alternating fashion by the use of switching elements.

current feedback op-amp an op-amp in which the output voltage is controlled by the current in the input stage, rather than the voltage. The advantage of the current feedback op-amp is that (to first order) its closed-loop performance is not subject to the gain-bandwidth tradeoff that affects voltage feedback op-amps.

current gain short-circuit current gain that helps describe the physical operation of the transistor. The current gain is the dimensionless ratio of the peak RF output current ($I_{out.pk}$) to the peak incident RF current ($I_{incident.pk}$). Hence, current gain, G_I is

$$G_I = \frac{I_{out.pk}}{I_{incident.pk}}$$

current limiting the output current is limited to a preset level even under a shorted output condition. This can be accomplished by reducing the output voltage to prevent the current limit from being exceeded.

current limiting fuse a fuse that limits the level of fault current from that which is available. It operates by developing a substantial voltage across the fuse following the melting of the fuse element.

current mirror a configuration of two matched transistors in which the output is a current that is ideally equal to the input current. In the case of a BJT current mirror, the collector of the first transistor is forced to carry the input current. This establishes a corresponding base-emitter voltage, which is applied to the second transistor. If the two devices are matched, then the collector current of the second transistor will equal that of the first transistor, thus "mirroring" the input current. This is a commonly used configuration in integrated circuits, which can take advantage of the inherent matching available by fabricating the two transistors in close proximity to each other.

current regulator a device used to control the magnitude and phase of the current in DC, AC or other electrical variable speed drives. May use different control strategies like hysteresis current control or ramp comparison current control.

current source amplifier the most common group of amplifiers is made up of current sourcing amplifiers, in which the active device acts as a modulated current source. All class A, B, A-B, and C amplifiers fit into this general group. Parameters such as device characteristics, quiescent bias point, RF load line, and amplitude and waveform of the applied signal should be included with the class definition, thus defining the major contributors to the physical actions taking place in one of these amplifiers.

current source inverter *See* current fed inverter.

current source region region of the I-V curve(s) of a device in which the output current is relatively constant (slope near zero) for changing output voltage.

current transducer a device used to measure current in a variety of applications including variable speed drives. May give out a current proportional to the measured current or a voltage proportional to the measured current. Electrical isolation may be obtained by using a current transformer (cannot be used at DC) or a hall effect transducer that can be used down to DC.

current transformer (CT) (1) a transformer that is employed to provide a secondary current proportional to primary current flowing. The primary "winding" is often created by passing the system conductor or bus bar through an opening in the device and the secondary is typically rated at a standard value to match common meters and display units. Current transformers are used in current measurement, protective relays, and power metering applications. The load (meter) on a CT should never be removed without first shorting the secondary of the CT, otherwise dangerous voltage levels may result when the load is removed.

(2) a device which measures the instantaneous current through a conductor of an electric power line and transmits a signal proportional to this current to the power system's instrumentation.

current unit a protective relay that monitors the magnitude of a power transmission line's current flow.

current withstand rating the current withstand rating of a device is the maximum short term current that can flow in the device without causing damage. *See* ampacity.

current-controlled multivibrator a multivibrator with oscillation period controlled by the current that is charging and discharging a timing capacitor. Most of the circuits are based on two symmetric controlled current sources connected by a timing capacitor, and a steering circuit (connected between power supply voltage and this capacitor), which includes two switches. The switches take turns providing the conducting path for the current sources, and the current in the timing capacitor changes direction each half of the period. If the current sources are controlled by an external voltage, the circuit becomes a voltage-controlled multivibrator. Current- and voltage controlled multivibrators are a vital part of phase-locked loops and frequency synthesizers.

current-limiting device when operating within its current-limiting range, a current-limiting device is open in 0.25 cycle or less and limits the maximum short-circuit current to a magnitude substantially less than the short-circuit current available at the fault point.

current-mode control the inductor current is sensed to control the pulse width. The switch is turned on by a constant frequency clock and turned off when the inductor current reaches the control reference. This method produces subharmonic oscillations if the steady-state duty ratio is greater than or equal to 0.5. An artificial stabilizing ramp is necessary to achieve stable control over the full range of duty ratios. When the slope of the ramp is equal to the falling slope of the inductor current, one cycle response is achieved. (i.e., the input perturbations are rejected, and the current reference is followed within one cycle).

current-source inverter (CSI) an inverter with a DC current input. Current-source inverters are most commonly used in very high power AC motor drives.

cursor (1) the symbol on a computer screen that indicates the location on the screen that subsequent input will affect.

(2) a movable, visible mark used to indicate a position of interest on a display surface. (ANSI).

curvature a geometric property that describes the degree that a surface or a curve is bent. The curvature of a curve is the magnitude of the rate of change of the unit tangent vector with respect to arc length. The curvature of a surface is given in terms of a metric tensor which embodies two principal (planar) curvatures, κ_1 and κ_2. The curvature of a surface is sometimes characterized by the so-called Gaussian curvature $\kappa = \kappa_1 \kappa_2$.

curvature function a function that gives curvature values at different locations of a curve or surface.

cut-off frequency the minimum frequency at which a waveguide mode will propagate energy with little or no attenuation.

cut-off rate a measure of reliability of a channel. At information rates below the cut-off rate, the probability of error averaged over the ensemble of randomly selected codes can be forced to zero exponentially with the block length (for block codes), or constraint length (trellis codes). The cut-off rate is less than or equal to the channel capacity. Also known as the computational cut-off rate, since for trellis codes, it is at this rate that the expected number of computations required to perform sequential decoding becomes unbounded.

cut-off wavelength the wavelength above which a fiber exhibits single mode operation (and below which exhibits multimode operation).

cutoff frequency *See* cut-off frequency.

cutoff rate *See* cut-off rate.

cut-out a pole-mounted device which contains a high-voltage fuse integral with a disconnect switch. It is used to protect and disconnect primary circuits in distribution work.

cutset a minimal subnetwork, the removal of which cuts the original network into two connected pieces.

CVD *See* chemical vapor deposition.

CVQ *See* classified vector quantization.

CW *See* continuous wave.

cybernetics (1) the field of control and communication theory in general, without specific restriction to any area of application or investigation.

(2) the behavior and design of mechanisms, organisms, and/or organizations that receive and generate information and respond to it in order to obtain a desired result.

cycle *See* clock cycle.

cycle stealing an arrangement in which a DMA controller or I/O channel, in order to use the I/O bus, causes the CPU to temporarily suspend its use of the bus. The CPU is said to hesitate. *See also* direct memory access.

cycle time time required to complete one clock cycle (usually measured in nanoseconds).

cycles per instruction (CPI) a performance measurement used to judge the efficiency of a particular design.

cyclic access in devices such as magnetic and optical disks (and older bubble memories) that store data on rotating media, the property that any individual piece of data can be accessed once during each cycle of the media.

cyclic code a linear block code where every cyclic shift of a codeword is another codeword in the same code. This property is an outcome of the significant algebraic structure that underlies these codes.

cyclic redundancy check (CRC) (1) is used to detect transmission errors over communication channels in digital systems. When using the CRC technique, the modulo-

2 sum of the message bits is calculated after grouping them in a special way and then appended to the transmitted message and used by the receiver to determine if the message was received correctly. The number of bits used in the CRC-sum is typically 8 or 16, depending on the length of the message and the desired error-detection capability.

A value calculated from a block of data to be stored or transmitted with the data block as a check item. CRCs are generated using a shift register with feedback and are described by the length of the register and the feedback terms used.

(2) a coding scheme for detecting errors in messages. Given a polynomial $C(x)$ of order $c-1$, and an m-bit message $M(x)$ represented as a polynomial of order $m-1$, calculate $R(x) = (x^c M(x))/C(x)$, then construct the transmitted message $T(x) = (x^c M(x)) \oplus R(x)$ which is exactly divisible by $C(x)$. Supposing $E(x)$ represents any errors introduced during transmission, the receiver calculates $(T(x) + E(x))/C(x)$. If this is not zero, $E(x)$ is non-zero and the received message is erroneous. If this is zero, either no errors were introduced or $E(x)$ is such that the CRC is not strong enough to detect the error. A suitable choice of $C(x)$ will make this unlikely.

cycloconverter a frequency changing converter that synthesizes lower frequency sine waves from portions of a polyphase set of higher frequency sine waves. For example, a three-phase, 400 Hz input could be used to create a 60 Hz supply of any desired phase order.

cyclotron frequency a frequency of electron oscillation in a cyclotron. A frequency of circular motion of an electron under magnetic fields applied perpendicularly to the plane of the circular motion.

cylinder a stack of tracks where these tracks are at a constant radial position (the same track number) on a disk or disk pack.

cylindrical extension of a fuzzy set let A be a fuzzy set in a Cartesian product space X^i, and X^n be another Cartesian product space including X^i, then the cylindrical extension of A in X^n is a fuzzy set in X^n, denoted as $cext(A; X^n)$, with membership function defined equal to membership in X^i. *See also* fuzzy set, membership function, projection of a fuzzy set.

cylindrical lens a lens that has curvature, or optical focusing power, in one direction only.

cylindrical microstrip line structure that consists of an angular strip on a cylindrical ground plane separated by a dielectric substrate. The cylindrical conductor acts as a ground plane, the angular strip guides the electromagnetic wave along the longitudinal direction.

cylindrical stripline the angular strip in the homogeneous media between the two cylindrical conductors. The inner and outer conductors act as ground planes, the angular strip guides the electromagnetic wave along the longitudinal direction.

cylindrical wave an electromagnetic wave in which each wavefront (surface of constant phase) forms a cylinder of infinite length and propagates in toward or away from the axis of the cylinder. A uniform cylindrical wave has the same amplitude over an entire wavefront; a nonuniform cylindrical wave has varying amplitude.

cylndrical-rotor machine a synchronous machine with a cylindrical rotor containing a distributed field winding and an essentially uniform air-gap. This design is limited to two and four pole machines (3600 and 1800 rpm at 60 Hz) and is usually used in large generators. *See also* salient-pole rotor machine.

D

d axis *See* direct axis.

D flip-flop a basic sequential logic circuit, also known as bistable, whose output assumes the value (0 or 1) at its D input when the device is clocked. Hence it can be used as a single bit memory device, or a unit delay.

D'Arsenval meter a permanent-magnet moving-coil instrument with a horseshoe form magnet. It measures direct current only.

D-TDMA *See* dynamic time division multiple access.

D/A *See* digital-to-analog converter.

DAC *See* digital-to-analog converter.

Dahlin's method a synthesis procedure for finding a digital control law that will produce a defined closed loop behavior for a given process, when it is controlled in a feedback configuration. The synthesis equation is

$$k(z) = \frac{\left(1 - e^{-T/\lambda}\right) z^{-N-1}}{1 - e^{-T/\lambda} z^{-1} - \left(1 - e^{-T/\lambda}\right) z^{-N-1}} \times \frac{1}{g(z)}$$

where $k(z)$ is the pulse transfer function for the synthesized controller, T is the sampling time of the digital control loop, λ is the time constant specified for the closed loop system, NT is the process deadtime, and $g(z)$ is the pulse transfer function for the process.

daisy chain (1) a type of connection when devices are connected in series.

(2) a hardware configuration where a signal passes through several devices. A signal will be passed through a device if that device is not requesting service, or not passed through if the device is requesting service.

(3) an interrupt-prioritizing scheme in which the interrupt acknowledge signal from the CPU is connected in series through all devices. A shared interrupt-request line connects all devices to the CPU with a single common line. When one (or several) devices activates its request line, the CPU will (after some delay) respond with an acknowledge to the first device. If this device did request an interrupt, it will be serviced by the CPU. However, if the device did not request an interrupt, the acknowledge is just passed through to the next device in the daisy chain. This process is repeated until the acknowledge signal has passed through all the connected devices on this chain. The scheme implements prioritized service of interrupts by the way the devices are electrically connected in the daisy chain: the closer a device is to the CPU, the higher its priority.

A more general case exists where several daisy chains are used to form priority groups, where each chain has a unique priority. The CPU will service interrupts starting with the daisy chain having the highest priority. In this scheme, any device may be connected to more than one priority group (chain), using the interrupt priority level appropriate for the particular service needed at this moment.

DAMA protocol *See* demand assign multiple access protocol.

damage the failure pattern of an electronic or mechanical product.

damped sinusoid a sinusoidal signal multiplied by a decaying. An example is $x(t) = 10e^{-3t} cos(10t)$.

damper winding an uninsulated winding, embedded in the pole shoes of a synchronous machine, that includes several copper bars short-circuited by conducting rings at the ends, used to reduce speed fluctuation in the machine by developing an induction-type torque that opposes any change in speed.

damping a characteristic built into electrical circuits and mechanical systems that prevents rapid or excessive corrections that may lead to instability or oscillatory conditions.

damping coefficient electrical torque component in phase with the rotor speed.

damping factor a measure of the ability of the PLL to track an input signal step. Usually used to indicate the amount of overshoot present in the output to a step perturbation in the input.

damping ratio the ratio of the real part of the resonant frequency to the undamped resonant frequency, in a second-order system.

dark current a noise source in photodetectors, corresponding to undesired output signals in the absence of light. The main source of dark currents are ohmic leakage due to imperfect insulation and thermionic emission.

darkfield performance the amount of light that is blocked in a light valve projector when a totally dark scene is being displayed. This parameter is critical to good contrast ratio.

Darlington bipolar junction transistor a combination of two bipolar junction transistors (BJT) where the emitter current of one transistor drives the base of the second transistor. The arrangement reduces the current required from the base driver circuit, and the effective current gain of the combination is approximately the product of individual gains. The configuration can be made from two discrete transistors or can be obtained as a single integrated device.

dart leader in lightning, a continuously moving leader lowering charge preceding a return stroke subsequent to the first. A dart leader typically propagates down the residual channel of the previous stroke.

dashpot timer a fluid time-on timer that can be used in definite time DC motor acceleration starters and controllers. The dashpot timer functions where a magnetic field forces a piston to move within a cylinder when the coil is energized. The movement of the piston is limited by fluid passing through an orifice on the piston. The amount of fluid passing through the orifice is controlled by a throttle value, which in turn determines the amount of time delay. After the fluid pressure equalizes across the piston, movement stops and contacts change state. The fluid can either be air (pneumatic dashpot) or oil (hydraulic dashpot). When the timer is deenergized, a check valve allows the pressure to equalize across the piston rapidly, thereby causing the contacts to change state "immediately."

data any information, represented in binary, that a computer receives, processes, or outputs.

data access fault a fault, signaled in the processor, related to an abnormal condition detected during data operand fetch or store.

data acquisition (1) method used for capturing information and converting it to a form suitable for computer use.

(2) process of measuring real-world quantities and bringing the information into a computer for storage or processing.

data bottleneck a computer calculation in which the speed of calculation is limited by the rate at which data is presented to the processor rather than by the intrinsic speed of the processor itself. Ultra high speed parallel processors are very frequently limited in this way.

data buffer *See* buffer.

data bus set of wires or tracks on a printed circuit or integrated circuit that carry binary data, normally one byte at a time.

data cache a small, fast memory that holds data operands (not instructions) that may be reused by the processor. Typical data cache sizes currently range from 8 kilobytes to 8 megabytes. *See* cache.

data communications equipment (DCE) a device (such as a modem) that establishes, maintains, and terminates a session on a network.

data compression theorem Claude Shannon's theorem, presenting a bound to the optimally achievable compression in (lossless) source coding. *See also* Shannon's source coding theorem.

data dependency the normal situation in which the data that an instruction uses or produces depends upon the data used or produced by other instructions such that the instructions must be executed in a specific order to obtain the desired results.

data detection in communications, a method to extract the transmitted bits from the received signal.

data flow architecture a computer architecture that operates by having source operands trigger the issue and execution of each operation, without relying on the traditional, sequential von Neumann style of fetching and issuing instructions.

data fusion analysis of data from multiple sources — a process for which neural networks are particularly suited.

data logger a special-purpose processor that gathers and stores information for later transfer to another machine for further processing.

data path the internal bus via which the processor ships data, for example, from the functional units to the register file, and vice versa.

data pipeline a mechanism for feeding a stream of data to a processing unit. Data is pipelined so that the unit processing the data does not have to wait for the individual data elements.

data preprocessing the processing of data before it is employed in network training. The usual aim is to reduce the dimensionality of the data by feature extraction.

data processing inequality information theoretic inequality, a consequence of which is that no amount of signal processing on a signal can increase the amount of information obtained from that signal. Formally stated, for a Markov chain $X \rightarrow Y \rightarrow Z$,

$$I(X;Z) \leq I(X;Y)$$

The condition for equality is that $I(X;Y|Z) = 0$, i.e., $X \rightarrow Z \rightarrow Y$ is a Markov chain.

data reduction coding system any algorithm or process that reduces the amount of digital information required to represent a digital signal.

data register a CPU register that may be used as an accumulator or a buffer register or as index registers in some processors. In processors of the Motorola M68000 family, data registers are separate from address registers in the CPU.

data segment the portion of a process' virtual address space allocated to storing and accessing the program data (BSS and heap, and may include the stack, depending on the definition).

data stripe storage methodology where data is spread over several disks in a disk array. This is done in order to increase the throughput in disk accesses. However, latency is not necessarily improved. *See also* disk array.

data structure a particular way of organizing a group of data, usually optimized for efficient storage, fast search, fast retrieval, and/or fast modification.

data tablet a device consisting of a surface, usually flat, and incorporating means for selecting a specific location on the surface of the device and transmitting the coordinates of this location to a computer or other data processing unit that can use this information for moving a cursor on the screen of the display unit.

data terminal equipment (DTE) a device, such as a subscriber's computer, Exchange workstation, or Exchange central system, that controls data flow to and from a computing system. It serves as a data source, data sink, or both, and provides for the data communication control function according to protocols. Each DTE has an address that is a 12-digit number uniquely identifying the subscriber's connection to the network. DTE term is usually used when referring to the RS-232C serial communications standard, which defines the two end devices of the communications channel: the DTE and the DCE (data communications equipment). The DCE is usually a modem and the DTE is a UART chip of the computer.

data-oriented methodology an application development methodology that considers data the focus of activities because data are more stable than processes.

database computer a special hardware and software configuration aimed primarily at handling large databases and answering complex queries.

dataflow computer a form of computer in which instructions are executed when the operands that the instructions require become available rather than being selected in sequence by a program counter as in a traditional von Neumann computer. More than one processor is present to execute the instructions simultaneously when possible.

Daubechies wavelets a class of compactly supported orthogonal and biorthogonal wavelets, first proposed by Ingrid Daubechies, that can be obtained by imposing sufficient conditions on wavelet filters.

daughter board a computer board that provides auxiliary functions, but is not the main board (motherboard) of a computer system (and is usually attached to the motherboard).

dB *See* decibel.

dBc ratio of the signal power (p) to a reference signal power (p_{ref}), usually the modulation carrier signal, expressed in decibels referenced to a carrier (dBc). Thus a harmonic signal that is 1/100th of the power in a desired fundamental signal is at -20 dBc.

$$P_{dBd} = 10\log_{10}\left(\frac{p}{p_{ref}}\right)$$

dBm Power ratio in decibels referenced to 1 milliwatt.

DBS *See* direct broadcast satellite.

DBS receiver electronic assembly that accepts as input a microwave signal from a satellite, containing transmitted TV signals "modulated" onto the signal. The receiver first amplifies the low-level signal, then processes the signal by first converting it to a lower "IF" frequency and then demodulating the signal to separate the TV signals from the microwave carrier signal. A basic way of looking at the relationship of the microwave carrier to the TV signal is to think of the carrier signal as an envelope with a message letter inside. The message letter is the TV signal. Demodulation is the process of carefully removing the message from the envelope (carrier). The noise figure of receiver is a measure of the amount of noise that will be added to the signal (carrier and TV signal) by the receiver. If the receiver adds too much noise, the result will be a snowy picture on the TV screen.

dBW ratio of the signal power in watts (p_{watts}) to a 1 W reference power, expressed in decibels referenced to 1 W (dBW). Thus 1 watt signal power is equal to 0 dBW, and −30 dBW is equal to 0 dBm.

$$P_{dBW} = 10 \log_{10} \left(\frac{p_{watts}}{1 \cdot Watt} \right)$$

DC direct current. *See* DC current, DC voltage.

DC block A circuit simulation component that behaves like a capacitor of infinite value.

DC chopper a DC to DC converter that reduces the voltage level by delivering pulses of constant voltage to the load. The average output is equal to the input times the duty cycle of the switching element.

DC circuit electrical networks in which the voltage polarity and directions of current flow remain fixed. Thus such networks contain direct currents as opposed to alternating currents, thereby giving rise to the term.

DC current constant current with no variation over time. This can be considered in general terms as an alternating current (AC) with a frequency of variation of zero, or a zero frequency signal. For microwave systems, DC currents are provided by batteries or AC/DC converters required to "bias" transistors to a region of operation where they will either amplify, mix or frequency translate, or generate (oscillators) microwave energy.

DC drain conductance for an FET device under DC bias, the slope of the output drain to source current (I_{DS}) versus output drain to source voltage (V_{DS}) for a fixed gate to source voltage (V_{GS}), expressed in siemens.

$$g_d = \left. \frac{\partial I_{DS}}{\partial V_{DS}} \right|_{V_{GS} = \text{constant}}$$

DC generator commutator exciter a source of energy for the field winding of a synchronous machine derived from a direct current generator. The direct current generator may be driven by an external motor, a prime mover, or by the shaft of the synchronous machine.

DC input power the total DC or bias power dissipated in a circuit, which is usually dependent on signal amplitudes, expressed in watts. This may include input bias, bias filtering, regulators, control circuits, switching power supplies and any other circuitry required by the actual circuit. These considerations should be explicitly specified, as they will affect how efficiency calculations are performed.

DC link the coupling between the rectifier and inverter in a variable speed AC drive.

DC link capacitor a device used on the output of a rectifier to create an approximately constant DC voltage for the input to the inverter of a variable speed AC drive.

DC link inductor an inductor used on the output of a controlled rectifier in AC current source drives to provide filtering of the input current to the current source inverter. If used in conjunction with a capacitor, then it is used as a filter in voltage source drives.

DC load flow a fast method of estimating power flows in an electric power system in which the problem is reduced to a DC circuit, with line impedances modeled as resistances and all generator bus voltages presumed to remain at their nominal values.

DC machine an electromechanical (rotating) machine in which the field winding is on the stator and carries DC current, and the armature winding is on the rotor. The current and voltage in the armature winding is actually AC, but it is rectified by the commutator and brushes.

DC motor a motor that operates from a DC power supply. Most DC motors have a field winding on the stator of the machine that creates a DC magnetic field in the airgap. The armature winding is located on the rotor of the machine and the DC supply is inverted by the commutator and brushes to provide an alternating current in the armature windings.

DC motor drive a converter designed to control the speed of DC motors. Controlled rectifiers are generally used and provide a variable DC voltage from a fixed AC voltage. Alternatively, a chopper, or DC–DC converter, can be employed to provide a variable DC voltage from a fixed DC voltage.

DC offset current the exponentially decaying current component that flows immediately following a fault inception. DC offset is the result of circuit inductance, and is a function of the point in the voltage wave where the fault begins. The offset for a given fault can range from no offset to fully offset (where the instantaneous current peak equals the full peak–peak value of the AC current).

DC restoration reinsertion of lost DC level information into a signal after using AC signal coupling; in television applications, the DC component of a composite video signal represents the average brightness of the picture. After AC coupling of the composite video, the DC level includes the average luminance signal plus the fixed average of the sync and lanking signals, causing picture level racking errors. For a positive video signal, the average value of mostly white scenes will be slightly lower than it should be; for mostly dark scenes, the DC average could become negative (due to the sync and blanking signals) when it should be slightly positive. Clamping circuits restore the DC average of the video by establishing the DC level of the sync tips.

DC servo drive a feedback, speed control drive system used for position control. Servos are used for applications such as robotic actuators, disk drives, and machine tools.

DC test tests that measure a static parameter, for example, leakage current.

DC to RF conversion efficiency dimensionless ratio of RF power delivered to the load (p_{out}) versus total DC input power dissipated in the amplifier (p_{DC}). With the DC to RF conversion efficiency given my η_{DC} we have

$$\eta_{DC} = \frac{p_{out}}{p_{DC}}$$

DC transconductance for an FET device under DC bias, the slope of the output drain to source current (I_{DS}) versus input gate to source voltage (V_{GS}) for a fixed drain to source voltage (V_{DS}), expressed in siemens. Given by g_m we have

$$g_m = \left.\frac{\partial I_{DS}}{\partial V_{GS}}\right|_{V_{DS} = \text{constant}}$$

DC voltage constant voltage with no variation over time. This can be considered in general terms as an alternating current (AC) with a frequency of variation of zero, or a zero frequency signal. For microwave systems, DC voltages are provided by batteries or AC/DC converters required to "bias" transistors to a region of operation where they will either amplify, mix or frequency translate, or generate (oscillators) microwave energy.

DC–AC inverter *See* inverter.

DC–DC converter a switching circuit that converts direct current (DC) of one voltage level to direct current (DC) of another voltage level. A typical DC–DC converter includes switches, a low pass filter (to attenuate the switching frequency ripple), and a load. The size of magnetic components and capacitors can be reduced and bandwidth can be increased when operating at high frequency. Most DC–DC converters are pulse-width modulated (PWM), while resonant or quasi-resonant types are found in some applications. Commonly used topologies include the buck converter, boost converter, buck-boost converter, and Ćuk converter. Isolation can be achieved by insertion of a high frequency transformer.

DC-free code *See* balanced code.

DCA *See* dynamic channel assignment.

DCE *See* data communications equipment or distributed computing environment.

DCS-1800 digital communication system–1800 MHz. A micro-cell version of GSM that operates at a lower transmitter power, higher frequency band, and has a larger spectrum allocation than GSM, but in most other respects is identical to GSM. The DCS-1800 spectrum allocation is 1710–1785 MHz for the up-link and 1805–1880 MHz for the down-link (i.e., 2×75 MHz). The peak transmit power for portable DCS-1800 terminals is 1 W.

DCT *See* discrete cosine transform.

de Haas–Shubnikov oscillation *See* Shubnikov–de Haas oscillation.

de-assert to return an enabling signal to its inactive state.

de-emphasis refers to the receiving process of correcting the amplitude of certain signal components that have been "pre-emphasized" prior to transmission in order to improve signal-to-noise (S/N) ratio. In commercial FM broadcast receivers, de-emphasis is accomplished with a simple resistor capacitor lowpass filter that represents the inverse transfer function characteristic of the pre-emphasis network situated at the transmitter. See the figure for a de-emphasis network. *See* pre-emphasis.

de-regulation the removal of some government controls on public utilities, generally including the unbundling of certain services, the dismantling of vertically-integrated utilities, and the introduction of competition among various utility companies for customer services.

dead band (1) the portion of the operating range of a control device or transducer over which there is no change in output.

(2) referring to an automatic controller behavior, a range of values of the controlled variable in which no corrective action occurs. This type of controller behavior is responsible for the time lag, called dead zone lag, which can cause instability of the controlled system if other conditions are present.

Also known as dead zone.

dead end an installation in which an electric power line terminates at a pole or tower, typically for purposes of structural stabilty.

dead man (1) a stand on which to rest a utility pole when setting the pole by hand.

(2) a buried log used as a guy anchor.

dead-end shoe a fixture for securing a wire or strain insulator to a utility pole.

dead tank breaker a power circuit breaker where the tank holding the interrupting chamber is at ground potential. Oil circuit breakers, for example, are typically dead tank breakers.

dead zone *See* dead band.

deadbeat 2-D observer a system described by the equations

$$z_{i+1,j+1} = F_1 z_{i+1,j} + F_2 z_{i,j+1} + G_1 u_{i+1,j} + G_2 u_{i,j+1} + H_1 y_{i+1,j} + H_2 y_{i,j+1}$$

$$\hat{x}_{i,j} = Lz_{i,j} + Ky_{i,j}$$

$i, j \in Z_+$ (the set of nonnegative integers) is called a full-order deadbeat observer of the second generalized Fornasini–Marchesini 2-D model

$$\begin{aligned} Ex_{i+1,j+1} &= A_1 x_{i+1,j} + A_2 x_{i,j+1} \\ &\quad + B_1 u_{i+1,j} + B_2 u_{i,j+1} \\ y_{i,j} &= Cx_{i,j} + Du_{i,j} \end{aligned}$$

$i, j \in Z_+$ if there exists finite integers M, N such that $\hat{x}_{i,j} = x_{i,j}$ for $i > M$, $j > N$, and any u_{ij}, y_{ij} and boundary conditions x_{i0} for $i \in Z_+$ and x_{0j} for $j \in Z_+$ where $z_{ij} \in R^n$ is the local state vector of the observer at the point (i, j), $u_{ij} \in R^m$ is the input, $y_{i,j} \in R^p$ is the output, and $x_{i,j} \in R^n$ is the local semistate vector of the model, F_1, F_2, G_1, G_2, H_1, H_2, L, K, E, A_1, A_2, B_1, B_2, C, D are real matrices of appropriate dimensions with E possibly singular or rectangular, Z_+ is the set of nonnegative integers. In a similar way, a full-order asymptotic observer can be defined for other types of the generalized 2-D models.

deadbeat control of 2-D linear systems given the 2-D Roesser model

$$\begin{bmatrix} x^h_{i+1,j} \\ x^v_{i,j+1} \end{bmatrix} = \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} u_{ij}$$

$i, j \in Z_+$ (the set of nonnegative integers)

$$y_{ij} = \begin{bmatrix} C_1 & C_2 \end{bmatrix} \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix}$$

with boundary conditions $x^h_{0j} = 0$ for $j \geq N_2$ and $x^v_{i0} = 0$ for $i \geq N_1$, find an input vector sequence

$$u_{ij} = \begin{cases} \neq 0 & \text{for } 0 \leq i \leq N_1, 0 \leq j \leq N_2 \\ = 0 & \text{for } i > N_1 \text{ and } j > N_2 \end{cases}$$

such that the output vector $y_{ij} = 0$ for all $i > N_1$ and $j > N_2$ where $x^h_{ij} \in R^n_1$ and $x^v_{ij} \in R^n_2$ are the horizontal and vertical state vectors, respectively, and A_1, A_2, A_3, A_4, C_1, C_2 are real matrices.

deadlock a condition when a set of processes using shared resources or communicating with each other are permanently blocked.

deadtime the time that elapses between the instant that a system input is perturbed and the time that its output starts to respond to that input.

debug to remove errors from hardware or software. *See also* bug.

debug port the facility to switch the processor from run mode into probe mode to access its debug and general registers.

debugger (1) a program that allows interactive analysis of a running program, by allowing the user to pause execution of the running program and examine its variables and path of execution at any point.

(2) program that aids in debugging.

debugging (1) locating and correcting errors in a circuit or a computer program.

(2) determining the exact nature and location of a program error, and fixing the error.

debuncher a radio frequency cavity phased so that particles at the leading edge of a bunch of beam particles (higher momentum particles) are decelerated while the trailing particles are accelerated, thereby reducing the range of momenta in the beam.

Debye material a dispersive dielectric medium characterized by a complex-valued frequency domain susceptibility function with one or more real poles. Water is an example of such a material.

Debye media *See* Debye material.

decade synonymous with power of ten. In context, a tenfold change in frequency.

decade bandwidth 10:1 bandwidth ratio (the high-end frequency is ten times the low-end frequency). The band edges are usually defined as the highest and lowest frequencies within a contiguous band of interest at which the loss equals L_{Amax}, the maximum attenuation loss across the band.

decay a transformation in which an atom, nucleus, or subatomic particle changes into two or more objects whose total rest energy is less than the rest energy of the original object.

decay heat the fraction of the total energy obtained from a nuclear fission reaction which is produced by delayed neutrons and by the secondary decay of fission daughters.

decay length the average distance a species of a particle at a given energy travels before decaying.

decay time in the absence of any pump or other excitation mechanisms, the time after which the number of atoms in a particular state falls to $1/E$ of its initial value.

decentralized control a structure of large-scale control systems based on system decomposition onto interconnected subsystems in order to simplify control design. Decentralized control systems are usually designed in the form of local feedback controllers and are chosen to fit information structure constraints imposed by the decomposition.To ensure robustness with respect to interconnections between subsystems, the local controllers should be robust and/or coordination should ensure robustness of the overall system. *See also* decomposition.

decibel (dB) a unit of measure that describes the ratio between two quantities in terms of a base 10 logarithm. For example, the ratio between the power level at the input and output of an amplifier is called the power gain and may be expressed in decibels as follows:

$$G(dB) = 10\log_{10}\left(P_{out}/P_{in}\right)$$

Terms such as dBm, dBuV, dBW indicate that the decibel measurement was made relative to an established standard. A common power measure reference is 0 dBm, which is defined to be 1 mW (milliwatt, 0.001W). A common voltage reference is 1 μV (1 microvolt).

decimal from the number system that has base 10 and employs 10 digits.

decimation an operation that removes samples with certain indexes from a discrete-time signal and then re-indexes the remaining samples. Most frequently, decimation refers to keeping every nth sample of a signal. Also know as down-sampling.

decision boundary a boundary in feature space which separates regions with different interpretations or classes, e.g., the boundary separating two adjacent regions characterizing the handwritten characters 'E' and 'F'. In practice, the regions associated with neighboring classes overlap; consequently most decision boundaries lead to some erroneous classifications, so an error criterion is used to select the "best" boundary. *See also* classifier, Bayesian classifier.

decision directed the use of previously detected information bits in an estimator, detector, or adaption algorithm in an adaptive filter. Usually improves performance compared to non-decision directed counterparts, but introduces potential problems with error propagation (erroneous bit feed back).

decision level the boundary between ranges in a scalar quantizer. On one side of the decision level, input values are quantized to one representative level; on the other side, input values are quantized to a different representative level.

decision mechanism rules and principles by which the information available to a given decision unit (control unit) is processed and transformed into a decision; typical decision mechanisms within control systems are fixed decision rule and optimization-based mechanism. Decision mechanisms can assume a hierarchical form — one may then talk about a hierarchical decision structure.

decision support system a system whose purpose is to seek to identity and solve problems.

decision tree analysis decomposing a problem into alternatives represented by branches where nodes (branch intersections) represent a decision point or chance event having probabilistic outcome. Analysis consists of calculating expected values associated with the chain of events leading to the various outcomes.

decision-directed adaptation a method for adapting a digital equalizer in which decisions at the output of the equalizer are used to guide the adaptive algorithm. *See also* adaptive algorithm, LMS.

declaration phase or statement in which a new variable is requested; the declaration of a variable is based on the definition of its type or class. This phase leads to a instantiation of the variable.

decode cycle the period of time during which the processor examines an instruction to determine how the instruction should be processed. This is the part of the fetch-decode-execute cycle for all machine instruction.

decode history table a form of branch history table accessed after the instruction is decoded and when the branch address is available so that the table need only store a Boolean bit for each branch instruction to indicate whether this address should be used.

decoder (1) a logic circuit with N inputs and 2^N outputs, one and only one of which is asserted to indicate the numerical value of the N input lines read as a binary number.

(2) a device for converting coded information to a form that can be understood by a person or machine.

decoder source the coded signal input to the decoder. In information theory the decoder source is modeled as a random process.

decoding (1) the act of retrieving the original information from an encrypted (coded) data transmission.

(2) the process of producing a single output signal from each input of a group of input signals.

(3) the operation of the decoder. The inverse mapping from coded symbols to reconstructed data samples. Decoding is the inverse of encoding, insofar as this is possible.

decomposition (1) an operation performed on a complex system whose purpose is to separate its constituent parts or subsystems in order to simplify the analysis or design procedures.

1. For large-scale systems, decomposition is performed by neglecting links interconnecting subsystems. It is followed by design of local control systems on the base of local objectives and coordination, which enables reaching global goals. *See also* decentralized control.

2. For optimization algorithms, decomposition is reached by resolving the objective function or constraints into smaller parts, for example, by partitioning the matrix of constrains in linear programs followed by the solution of a number of low dimensional linear programs and coordination by Lagrange multipliers.

3. For uncertainties, decomposition is performed to make their model trackable, for example, by dividing them into matched and mismatched parts. *See also* matching conditions.

4. For linear time-invariant systems in state form, Kalman's decomposition is a transformation of state matrix in a way that indicates its controllable and observable, controllable and unobservable, uncontrollable and observable, and uncontrollable and unobservable parts. *See also* controllability.

5. For matrix transfer functions, decomposition transforms it to the form composed of specific blocks used in chosen design procedure. *See also* H infinity design.

(2) in fuzzy systems, if the fuzzy relation R is a composition of the fuzzy relations A and B, then the determination of A given B and R is referred to as a decomposition of R with respect to B.

decorrelation the act of removing or reducing correlation between random variables. For random vectors a discrete linear transform is often used to reduce the correlation between the vector components.

decorrelator a linear code-division multiple-access receiver, which takes the data vector output from a bank of filters matched to the desired users' spreading sequences, and multiplies by a matrix which is the inverse of the spreading-sequence correlation matrix.

decoupled load flow a load-flow study in which certain simplifying assumptions permit an accelerated solution.

decoupling problem for 2-D linear systems given the 2-D Roesser model

$$\begin{bmatrix} x^h_{i+1,j} \\ x^v_{i,j+1} \end{bmatrix} = \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} u_{ij}$$

$$y_{ij} = \begin{bmatrix} C_1 & C_2 \end{bmatrix} \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix}$$

$i, j \in Z_+$ (the set of nonnegative integers), find matrices $K = [K_1, K_2]$ and $H(\det H \neq 0)$ of the control law

$$u_{ij} = K \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} + H v_{ij} \quad i, j \in Z_+$$

such that the transfer function matrix of the closed-loop system

$$T_c(z_1, z_2) = \begin{bmatrix} C_1 & C_2 \end{bmatrix} \times \begin{bmatrix} I_{n_1} z_1 - A_1 - B_1 - K_1 & -A_2 - B_1 K_2 \\ -A_3 - B_2 - K_1 & I_{n_2} z_2 - A_4 - B_2 K_2 \end{bmatrix} \times \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} H$$

is diagonal and nonsingular, where $x^h_{ij} \in R^{n_1}$ and $x^v_{ij} \in R^{n_2}$ are horizontal and vertical state vectors, respectively, and $u_{ij} \in R^m$ is the input vector, $v_{ij} \in R^m$ is a new input vector, $y_{ij} \in R^p$ is the output vector, and A_1, A_2, A_3, A_4, B_1, B_2, C_1, C_2, are given real matrices.

decrement to reduce the value of a variable or content of a register by a fixed amount, normally one.

decryption a process, implemented in hardware or software, for reconstructing data previously coded by using a cryptography algorithm, that is encrypted data. These algorithms are typically based on keywords or codes.

DECT *See* digital European cordless telephone.

deep-bar rotor a squirrel-cage induction motor rotor in which the rotor bars are deep and narrow, to make the effective resistance, and therefore the torque, higher at starting.

deep-UV lithography lithography using light of a wavelength in the range of about 150 nm to 300 nm, with about 250 nm being the most common.

default the value or status that is assumed unless otherwise specified.

deferred addressing *See* indirect addressing.

deferred evaluation a scheduling policy under which a task is not scheduled until it has been determined that the results of that task are required by another task that is in execution and cannot proceed without these results.

definite time DC motor acceleration when DC motors accelerate during their starting sequence, starting resistors are removed from the armature circuit in steps. In definite time DC motor acceleration (also referred to as open loop DC motor acceleration), the starting resistors are removed in definite time increments, whether the motor is actually accelerating or not.

definite-purpose motor any motor design, listed and offered in standard ratings with standard operating characteristics, with special mechanical features for use under service conditions other than usual or for use on a particular type of application.

definition phase or statement in which a new type, or a class, or a frame for variables is defined. The definition of typed constant is also typically allowed.

deflector any of a number of optical devices that change the direction of an optical beam, using mechanisms such as diffraction, mechanical mirror motion, and refraction.

defocus the distance, measured along the optical axis (i.e., perpendicular to the plane of the best focus) between the position of a resist-coated wafer and the position if the wafer were at best focus.

defocusing quadrupole magnet a quadrupole magnet that focuses beam in the vertical plane and defocuses in the horizontal plane.

DeForest, Lee (1873–1961) Born: Council Bluffs, Iowa, U.S.A.

DeForest is best known for his contributions to the development of radio communications. DeForest's greatest invention was called the audion triode. This vacuum tube was based on an earlier patented tube developed by John A. Fleming. This tube, which was both an amplifier and a rectifier, allowed the development of radios, radar, television, and some early computers. DeForest's life was noted for controversial, and often poor, business decisions.

deformable mirror device a type of device for light modulation, especially spatial light modulation, employing micromechanical structures, such as cantilevered mirrors or mirrors with torsional motions, to deflect incident light rays.

defuzzification the process of transforming a fuzzy set into a crisp set or a real-valued number.

defuzzifier a fuzzy system that produces a crisp (non fuzzy) output from the results of the fuzzy inference engine. The most used defuzzifiers are

1. maximum defuzzifier that selects as its output the value of y for which the membership of the output membership function $\mu_B(y)$ is maximum;

2. centroid defuzzifier determines the center of gravity (centroid), $\overline{y}$ of B, and uses this value as the output of the fuzzy inference system.

See also fuzzy inference engine, fuzzy inference system.

degenerate common emitter a combination of the common-emitter and emitter-follower stages with a very well-defined gain.

degenerate four-wave mixing a four-wave mixing process in which all of the interacting waves have the same frequency. In certain geometrical arrangements, this process leads to optical phase conjugation and in addition can be for certain types of optical information processing.

degenerate modes two modes with different field structures having the same cutoff frequency in a waveguide or the same resonant frequency in a cavity.

degenerate two-wave mixing a special case of two wave mixing in which the two beams are of exactly the same frequency. In two-wave mixing, if the two laser beams are of the same frequency, a stationary interference intensity pattern is formed. This leads to a stationary volume refractive index grating. Such a kind of two-wave mixing is referred to as degenerate two-wave mixing.

degradation situation in which a signal has been corrupted by noise, blurred by some point-spread function or distorted in some other fashion.

degree of membership the degree to which a variable's value belongs in a fuzzy set. The degree of membership varies from 0 (no membership) to 1 (complete membership).

degree of mobility each prismatic or revolute joint has one degree of freedom and provides the mechanical structure with a single degree of mobility.

degrees of freedom the number of independent position variables that have to be specified in order to locate all parts of the mechanism is defined as a number of degrees of freedom. Therefore, the degrees of freedom is defined as the minimal number of position variables necessary for completely specifying the configuration of the mechanism.

degree of visual angle the angle subtended by an object of a given width a given distance away from the viewer.

delay (1) the time required for a signal to propagate along a wire.

(2) the difference in the absolute angles between a point on a wavefront at the device output and the corresponding point on the incident input wavefront, expressed in seconds or degrees. Delay can exceed 360 degrees. Given by t_d, we have

$$t_d = \theta_{out} - \theta_{in}$$

delay angle *See* firing angle.

delay locked loop *See* delay-locked loop.

delay power spectrum a function characterizing the spread of average received power as a function of delay. Can be obtained from the scattering function by integrating over the Doppler shift variable. *See also* scattering function, multipath propagation.

delay profile *See* delay power spectrum.

delay range the difference in arrival times between the first and last significant component of the impulse response of a wideband communication channel. Also known as the total excess delay.

delay resolution the capability, measured in units of delay (seconds), of a signal used for channel measurement to resolve received signal components which arrive with different delays. If two signal components arrive at the receiver with a delay separation less than the delay resolution, they will be observed as one signal, superimposed on each other. The actual value of the delay resolution depends on the criterion by which two signal components are defined to be resolved. An approximate measure is given by the inverse of the channel (or signal) bandwidth. *See also* multipath propagation.

delay slot in a pipelined processor, a time slot following a branch instruction. An instruction issued within this slot is executed regardless of whether the branch condition is met, so it may appear that the program is executing instructions out of order. Delay slots can be filled (by compilers) by rearranging the program steps, but when this is not possible, they are filled with "no-operation" instructions.

delay spread a measure of the time through which the duration of a transmitted signal is extended by dispersion in a wideband communication channel. Usually measured as the RMS delay spread, i.e., the second moment of the time-averaged channel impulse response.

delay-line a transmission line of the appropriate length to result in a specific time delay. As an example, a line at 100 MHz that is 90 degrees long (one-quarter wavelength) will exhibit a time delay of 2 ns.

delay-locked loop (DLL) (1) a pseudonoise (PN) sequence tracking loop typically used in receivers for spread spectrum signals. The tracking loop has two branches that correlate the received signal with two shifts of a locally generated PN sequence: an advanced and a retarded time shift of the phase of the signal being tracked.

(2) a technique for symbol synchronization based on time-shifted and reversed correlation functions of the desired symbol waveform, which results in a control function with an s-shape (termed an s-curve). The control function is used in a feedback loop similar to a PLL to adjust the timing of receiver clock used in sampling the received signal. DLLs are used, e.g., in spread-spectrum receivers to maintain chip synchronization.

delayed AGC *See* delayed automatic gain control.

delayed automatic gain control automatic gain control in which the control mechanism becomes effective only when the input signal is larger than a predetermined level.

delayed branch instruction a form of conditional branch instruction in which one (or executed irrespective of the outcome of the branch). Then the branch takes effect. Used to reduce the branch penalty.

delayed neutrons neutrons emitted by fission daughters after some time delay.

delectric resonator an unmetallized dielectric object of high dielectric constant and high quality factor that can function as an energy storage device.

delta connection a three-phase power source or load in which the elements are connected in series and are thus represented on a schematic diagram as a triangular configuration.

delta function in discrete-time, the function given by

$$\delta[n] = \begin{cases} 0 & n \neq 0 \\ 1 & n = 0. \end{cases}$$

In continuous-time, the (Dirac) delta "function" is not a function at all and, although an abuse of mathematical rigor, is a tremendously important concept throughout signal and system theory. The Dirac delta "function" is defined as

$$\delta(t) = \begin{cases} 0 & t \neq 0 \\ \infty & t = 0 \end{cases}$$

such that

$$\int f(t)\delta(t - t_o)dt = f(t_o)$$

delta gun cathode ray tube (CRT) electron gun structure has the red, green, and blue electron gun components configured in the shape of an equilateral triangle; the structure provides the smallest CRT neck size and has the smallest deflection yoke diameter, but requires color registration (color convergence) correction in both the horizontal and the vertical CRT face. *See* cathode ray tube.

delta modulation a special case of differential pulse code modulation (DPCM) where the digital code-out represents the change, or slope, of the analog input signal, rather than the absolute value of the analog input signal. A "1" indicates a rising slope of the input signal. A "0" indicates a falling slope of the input signal. The sampling rate is dependent on the derivative of the signal, since a rapidly changing signal would require a rapid sampling rate for acceptable performance.

delta modulation control a pulse-time modulation method transplanted from the delta modulation in signal processing. The difference between the control reference and the switched signal is integrated and fed to a Schmitt trigger. When the integrated value reaches a predefined upper bound the switch is turned off. When the integrated value reaches a predefined lower bound the switch is turned on.

delta rule a supervised learning algorithm, based upon gradient descent, that was developed for application to single-layer networks of linear threshold units. For each input pattern x, the weight wij connecting input xj to unit i is adjusted according to $Dwij = h(ti - wi \cdot x)xj$, where wi is the vector of weights wij, ti is the target output for unit i, and h is a positive constant. This rule is also known as the Widrow–Hoff rule and the LMS algorithm.

delta–delta transformer a three-phase transformer connection formed by connecting three single-phase transformers in which the windings on both the primary and the secondary sides are connected in series to form a closed path.

delta-wye transform a transformation between delta and wye connections.

delta–wye transformer a three-phase transformer connection formed by connecting three single-phase transformers in which the primary windings are connected in series to form a closed path while one end of each of the secondary windings is connected to a common point (the neutral).

demagnetization the act of removing a device from being in a magnetic state, i.e., rearranging the atomic magnetic domains in a disoriented fashion.

demagnetizing field the magnetic field produced by divergences in the magnetization of a magnetic sample.

demand assign multiple access protocol telephone signalling mechanism in which the access is established for the duration of a call.

demand fetch in a cache memory, the name given to fetching a line from the memory into the cache on a cache miss when it is requested and not before.

demand meter an electric meter which shows both the energy used and the peak power demand in a given period.

demand paging condition where each page in virtual memory is loaded into main memory, after first being referenced by the processor (i.e., not in advanced). The first reference to each page will thus always cause a "page fault" (page not in main memory). After these initial page faults, most of the pages needed by the program are in main memory.

demodulation the process by which a modulated signal is recovered back to its original form. It is the general process of extracting the information-bearing signal from another signal. Modulation is the general process of embedding an information-bearing signal into a second carrier signal. An important objective in modulation is to produce a signal whose frequency range is suitable for transmission over the communication channel to be used. *See also* modulation.

DeMorgan's theorem a formula for finding the complement of a Boolean expression. It has two forms:

1. $\overline{A \vee B} = \overline{A} \wedge \overline{B}$
2. $\overline{A \wedge B} = \overline{A} \vee \overline{B}$

where A and B are Boolean variables and $\wedge$ represents logical AND and $\vee$ represents logical OR and the overbar represents the logical complement.

demultiplexer a logic circuit with K inputs and I controls which steers the K inputs to one set of 2^I sets of output lines. *Compare with* multiplexer.

demultiplexing the inverse operation of multiplexing that enables the transmission of two or more signals on the same circuit or communication channel.

Denavit–Hartenberg notation a system that describes the translational and rotational relationships between adjacent links. The D-H representation results in 4×4 homogeneous transformation matrix representing each link's coordinate system at the joint with respect to the previous link's coordinate system. The D-H representation of a rigid link depends on four geometric parameters associated with each link. Every coordinate frame is assigned according to the three rules:

1. The z_{i-1} axis lies along the axis of motion of the ith joint.

2. The z_i axis is normal to the z_{i-1} axis, and pointing away from it.

3. The y_i axis completes the right-handed coordinate system as required.

Referring to the figure, the four D-H parameters are defined as follows:

• q_i is the joint angle from the x_{i-1} axis to the x_i axis about the z_{i-1} axis (using the right-hand rule),

• d_i is the distance from the origin of the $(i-1)$-th coordinate frame to the intersection of the z_{i-1} axis with the x_i axis along z_{i-1} axis,

• a_i is the offset distance from the intersection of the z_{i-1} axis with the x_i axis to the origin of the ith frame along the x_i axis (in another words it is the shortest distance between the z_{i-1} and z_i axes),

• α_i is the offset angle from the z_{i-1} to the z_i axis about the x_i axis (using the right-hand rule).

For a revolute joint d_i, a_i, and α_i are called the *link parameters* or *joint parameters* and remain constant. q_i is called the *joint variable.* For a prismatic joint, q_i, a_i, and α_i are the link parameters and remain constant, while d_i is the joint variable. The D-H transformation matrix for adjacent coordinate frames has the following form:

$$^{i-1}A_i = \begin{bmatrix} \cos q_i & -\cos\alpha_i \sin q_i & \sin\alpha_i \sin q_i & a_i \cos q_i \\ \sin q_i & \cos\alpha_i \cos q_i & -\sin\alpha_i \cos q_i & a_i \sin q_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

denormalized number nonzero number whose leading significand bit is zero and whose exponent has a fixed value. These numbers lie in the range between the smallest normalized number and zero.

density estimation statistical methods for estimating the probability density from a given set of examples.

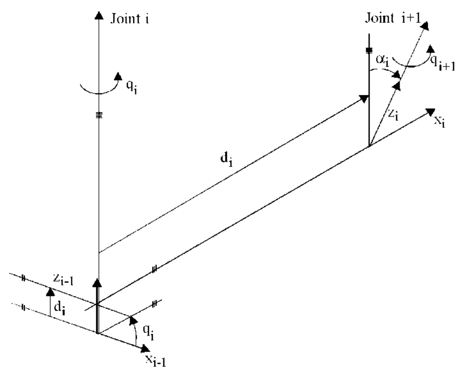
density function (DF) an alternative name for probability density function (PDF).

density matrix representation for the wave functions of quantum mechanics in terms of binary products of eigenfunction expansion amplitudes; with ensemble averaging the density matrix representation is convenient for phenomenological inclusion of relaxation processes.

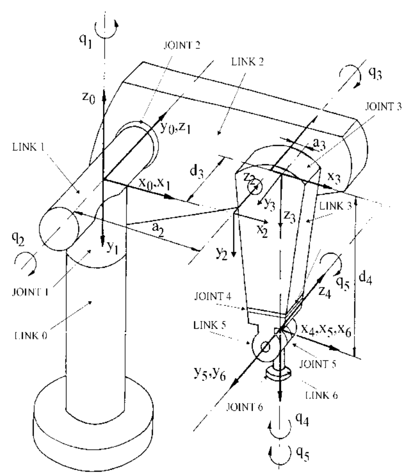
density matrix formalism of quantum mechanics a mathematical formulation of the theory of quantum mechanics more general than those based on a description in terms of a wavefunction or a state vector, because it can treat situations in which the state of the system is not precisely known. The density matrix formalism is often used in laser physics and in nonlinear optics, for example, under situations in which collisional dephasing effects are important.

dependability system feature that combines such concepts as reliability, safety, maintainability, performance, and testability.

dependency a logical constraint between two operations based on information flowing among their source and/or destination operands; the constraint imposes an ordering on the order of execution of (at least) portions of the operations. For example, if the first operation in a sequential program produces a result that is an operand of the second operation of the program, that second operation cannot be performed until the first operation has been completed, since its operand value will not be available earlier.



The Denavit–Hartenberg parameters.



A PUMA 560 robot arm illustrating joints, links, and the D-H parameters.

dependent source *See* controlled source.

depleted uranium uranium in which the proportion of fissile U-235 has been reduced below useful levels.

depletion layer space charge region or layer adjacent to a semiconductor junction where the majority carrier concentration has been depleted or reduced below the thermal equilibrium value.

depletion mode an FET that is on when zero volts bias is applied from gate to source.

depolarization (1) the change of the polarization state of a wave propagating through an anisotropic medium.

(2) phenomenon that occurs when a wave becomes partially or completely unpolarized.

(3) changing the original polarization of a propagating wave into a different type.

depolarizing scattering change in the polarization of the light due to strong scattering.

deposited multi-chip module (MCM-D) a multi-chip module built using the deposition and thin-film lithography techniques that are similar to those used in integrated circuit manufacturing.

depth in computer vision, the distance to a surface, as perceived subjectively by the observer. Also, the number of bits with which each pixel is represented in a digital image.

depth map a map of depth in a scene corresponding to each pair of coordinates in an image of the scene.

depth of field the range of depths over which objects in the field of vision are in acceptable focus.

depth of focus (DOF) the total range of focus that can be tolerated; that is, the range of focus that keeps the resulting printed feature within a variety of specifications (such as critical dimension, photoresist profile shape, and exposure latitude).

depth of penetration distance inside a material interface that an impinging wave has attenuated by $1/e$ where $e = 2.7183$ (Euler's constant).

depth-first search a search strategy for tree or trellis search where processing is performed depth first, i.e., a particular path is processed through the depth of the tree/trellis as long as it fulfills a certain threshold criterion (e.g., based on the Fano metric). If a path fails the threshold test, a new path is considered. Also known as sequential search.

derating factor the fraction (or percent) of nominal rating to which a specified quantity must be reduced due to unusual operating conditions. Examples of conditions that may require application of a derating factor are high altitude, high ambient temperature, frequent motor starting, and "plugging" operation of a motor.

derivative control control scheme whereby the actuator drive signal is proportional to the time derivative of the difference between the input (desired output) and the measured actual output.

descrambling the process of restoring a transmitted signal to its original form commonly used in CATV systems. The positive-trap, negative-trap, and baseband are common methods of scrambling requiring such a means to restore the signal to its original form.

descriptor an object describing an area of space within memory. A descriptor contains information about the origin and length of the area.

desensitization a reduction in a device output signal power due to one or more additional signals that compress the device output, expressed as a negative ratio of the desensed signal output power to the output power without the additional signals, in decibels.

$$D = -10 \log_{10} \left(\frac{p_{desensed}}{p_{undesensed}} \right)$$

design for testability designing a semiconductor component such that it is easier to feed it a set of test vectors that guarantees, or provides sufficient reassurance, that the component was manufactured (and designed) correctly.

design model a mathematical model that is used to design a controller. The design model may be obtained by simplifying the truth model of the process. The truth model is also called the simulation model. The truth model is usually too complicated for controller design purposes. The controller performance is tested using the truth model. *See also* truth model.

designed distance the guaranteed minimum distance of a BCH forward error control code that is designed to correct up to t errors.

destination operand where the results of an instruction are stored, e.g., the instruction MOV AL,7 uses AL as the destination operand (7 is the source operand).

destructive physical analysis (DPA) devices are opened and analyzed for process integrity and workmanship.

destructive read reading process in which the information is lost from memory after being read out.

detectability the property of a system concerning the existence of a stabilizing output injection. For linear time-invariant systems, it is characterized by the observability (see the definition) of the unstable modes.

detective quantum efficiency (DQE) of a photodetector, the ratio of its quantum efficiency (Q_e) to its power noise factor (k), i.e., $DQE = 3DQ_e/k$. This is a general relationship that applies to electrical, photographic, and biological (e.g., the eye) types of photodetectors.

detector (1) a device that converts RF input signals to a corresponding DC output signal.

(2) in optics, a circuit, usually containing a diode that converts the intensity of light into an electrical signal. Used in a variety of applications including power sensing, leveling, and modulation envelope reproduction. *See also* photodetector.

deterministic control of uncertain systems an approach to the control of uncertain systems that is effective over a specified range of the system parameter variations. These methods do not require on-line identification of the values of the system parameters to yield the desired robust performance. No statistical information about uncertain parameters is required. The two main approaches are variable structure sliding mode control and Lyapunov theory approach.

deuteron the nucleus of the deuterium atom (an isotope of the hydrogen) consisting of a proton and a neutron.

developed power the power converted from electrical to mechanical form in an electric motor. The developed power of a motor can be calculated from the developed torque and motor speed.

developed torque the torque created by an electric motor including torque required to overcome the friction and windage losses of the motor. This value will be higher than the shaft torque, which is actually delivered to the load.

development the process by which a liquid, called the developer, selectively dissolves a resist as a function of the exposure energy that the resist has received.

deviation a measure of the dispersion among the elements in a set of data. Sometimes, a deviation is defined as failure to meet the specified critical limits.

deviation ratio the allowable frequency deviation for an FM signal divided by the highest modulating frequency.

device a hardware entity that exists outside of the motherboard, and is accessed through device drivers. Devices often relate to I/O (floppy drives, keyboards, etc.).

device controller (1) a device used to connect a peripheral device to the main computer; sometimes called a peripheral controller.

(2) software subroutine used to communicate with an I/O device.

device driver program that controls an input/output device, usually providing a standard form of interface to the programs that utilize the device. Device drivers perform the basic functions of device operation.

device register register in an I/O device that may be read or written by the processor to determine status, effect control, or transfer data.

device scaling to increase device speed and circuit density as well as reduce power consumption, all three dimensions of transistors are reduced and the impurity concentrations increased by interrelated scale factors.

dewar a vacuum insulated, cryogenic radiation insulated, low conduction heat loss vessel for cryogenic fluids. A dewar is used for keeping material, chiefly liquids, cold or hot. The common thermos bottle is an example of a dewar. In the accelerator business dewars are often used to store large quantities of cryogenic liquids.

DF *See* dissipation factor.

DFB laser *See* distributed feedback laser.

DFD *See* displaced frame difference.

DFT *See* discrete Fourier transform.

Dhrystone *See* Dhrystone benchmark.

Dhrystone benchmark synthetic benchmark program consisting of a representative instruction mix used to test the performance of a computer. Does not compute anything in particular. Another synthetic benchmark is the Whetstone benchmark.

DIAC a two-terminal AC device that, once gated on by sufficient forward voltage, permits the flow of current until reverse biased. It is often used as a trigger device to drive the gate of other power electronic devices.

Diac's delta function *See* delta function.

diagnostic (1) one of a set of tests to run through a system that determines whether the system is functioning correctly.

(2) pertaining to the detection and isolation of faults or failures. For example, a diagnostic message, a diagnostic manual.

diagonal clipping distortion that occurs in an AM demodulator (usually associated with diode detection), where the capacitor discharge time constant is set too long for the detector to accurately follow fast changes in the AM signal envelope. Sometimes referred to as "failure to follow distortion," diagonal clipping can also occur in AM modulators when the intelligence bandwidth exceeds that of the modulator.

diagonal dominance a measure of the amount of interaction that exists between variables in a multi-input–multi-output
(MIMO) system. It is quantified by Gershgorin circles or bands that are often plotted on an inverse Nyquist array (or INA) diagram that shows the frequency response matrix of the system in a graphical form. Its practical significance relates to the fact that a diagonally dominant system can be controlled by multiple single variable controllers, whereas a nondominant process might require sophisticated and costly multivariable techniques for effective control. *See also* inverse Nyquist array.

diamagnetic materials with magnetization directed opposite to the magnetizing field, so that the permeability is less than one; metallic bismuth is an example.

die an individual MMIC circuit or subsystem that is one of several identical chips that are produced after dicing up an MMIC wafer.

dielectric (1) a medium that exhibits negligible or no electrical conductivity and thus acts as a good electrical insulator.

(2) a medium characterized by zero conductivity, unity relative permeability, and a relative permittivity greater than one. Also known as an insulator.

Dielectries are usually used to separate two conducting bodies such as to form a capacitor.

dielectric constant (1) a quantity that describes how a material stores and dissipates electrical energy.

(2) ratio of the electrical capacity of a condenser, which has a given material as the dielectric, to the capacity of an identical condenser, but with air as the dielectric.

(3) permittivity of a medium normalized to the permittivity of free space; a measure

of the response of a dielectric to an applied electric field.

(4) an electric property of an insulator or semi-conducting material, which describes how differently electric fields will behave inside of the material as compared to air. As an example, $e_r = 12.9$ for GaAs as compared to $e_r = 1$ for air. In integrated circuits, an effective dielectric constant (e_{eff}) is used, since the electric fields supported by the signals traveling through the conductors on the circuit flow through both air and the insulator or semiconductor simultaneously.

dielectric discontinuity interface between two media with different dielectric permittivity properties.

dielectric medium medium that is polarizable but relatively nonconducting.

dielectric resonator an unmetallized dielectric object of high dielectric constant and high quality factor that can function as an energy storage device.

dielectric resonator [stabled] oscillator (DRO) a dielectric resonator is a cylindrically shaped piece of material, or "puck," that has the properties of having low-loss resonant frequencies that are determined primarily by the size of the cylinder. Placing a dielectric resonator near a microstrip line can form a resonant circuit that will frequency stabilize a voltage-controlled oscillator.

dielectric resonator antenna (DRA) an antenna where a dielectric resonator is used as the radiation element.

dielectric slug tuner system of two movable dielectric pieces of material placed on a transmission line for the purpose of matching a wide range of load impedances by means of placing the dielectrics in proper positions.

dielectric step discontinuity the junction between different dielectric waveguides.

dielectric waveguide a waveguide that relies on differences in permittivity among two or more materials to guide electromagnetic energy without the need for ground planes or metallic strips. Such guides of rectangular, circular, elliptical, and other cross sections are made of dielectric materials and used for transmitting signals. Transmission is accomplished by the total internal reflection mechanism inside the waveguide.

difference amplifier *See* differential amplifier.

difference engine a mechanical calculator developed by Babbage in 1823.

difference equation the mathematical model of a LTIL discrete time system. *See also* discrete time system, LTIL system.

difference of Gaussian filter a bandpass filter whose point spread function is the difference of two isotropic Gaussians with different variances. The result is a "Mexican hat" shape similar to the Laplacian of a Gaussian (*See* Marr-Hildreth operator). Various physiological sensors, including some filters in early vision, appear to have DOG point spread functions.

difference-frequency generation a second-order nonlinear optical process in which two input beams are applied to a nonlinear optical material and an output is produced at the difference of the frequencies of the two input beams.

difference-mode signal if two arbitrary signals v_1 and v_2 are applied to the inputs of a differential amplifier, then the common-mode signal is the arithmetic average of the two signals. That is,

$$(v_1 + v_2)/2$$

differential amplifier an amplifier intended to respond only to the difference between its input voltages, while rejecting any signal common to both inputs.

The differential amplifier is designed such that the difference between the two inputs is amplified (high differential gain), while the signals appearing at either individual input (referenced to ground potential) sees a very low gain (low common-mode gain, usually loss). The differential amplifier is usually used as the first component at the receiving end of a communications link using twisted pair cable (either shielded or unshielded) as the transmission medium. This provides a method to reject any common-mode noise induced onto the twisted pair transmission line, including common-mode noise falling within the useful bandwidth of the communications link. The figure of merit for the differential amplifier is its common mode rejection ratio (CMRR), computed by dividing the differential-mode gain by the common-mode gain.

differential coding a coding scheme that codes the differences between samples. *See* predictive coding.

differential entropy the entropy of a continuous random variable. For a random variable X, with probability density function $f(x)$ on the support set $\mathcal{S}$, the differential entropy $h(X)$ is defined as

$$h(X) = -\int_{\mathcal{S}} f(x) \log f(x)$$

provided the integral exists. Also written $h(f)$, emphasizing the sole dependence upon the density. *See also* entropy, relative entropy, mutual information.

differential gain the amplification factor of a circuit that is proportional to the difference of two input signals. The differential gain may be expressed in percentage form by multiplying the above amplification factor by 100, or in decibels by multiplying the common logarithm of the differential gain by 20.

differential inclusion a multivalued differential equation,

$$\dot{\mathbf{x}} \in \mathbf{F}(t, \mathbf{x}) \ ,$$

where $\mathbf{F}(t, \mathbf{x})$ is a nonempty set of velocity vectors at $\mathbf{x} \in \mathbb{R}^n$ for each time t on some time interval. The set $\mathbf{F}(t, \mathbf{x})$ can be viewed as the set of all possible "velocities" $\dot{\mathbf{x}}(t)$ of a dynamical system modeled by the multivalued, or multifunction, differential equation. A solution $\mathbf{x}(t)$ is an absolutely continuous function on some time interval whose velocity vector $\dot{\mathbf{x}}$ lies in the set $\mathbf{F}(t, \mathbf{x})$ for almost all t. *See also* Filippov method.

differential kinematics equation $v = J(q)\dot{q}$ can be interpreted as the differential kinematics mapping relating the n components of the joint velocity vector to the $r \leq m$ components of the velocity vector v of concern for the specific task. Here n denotes number of degrees of mobility of the structure, m is the number of operational space variables, and r is the number of operational space variables necessary to specify a given task. *See also* geometric Jacobian.

differential length vector the vector sum of the differential length changes in each of the three coordinate directions along a given curve.

differential mode gain for a differential amplifier, the ratio of the output signal amplitude to the amplitude of the difference signal between the amplifier input terminals.

differential pair a two-transistor BJT (FET) amplifier in which a differential input signal is applied to the base (gate) terminals of the two transistors, the output is taken differentially from the collector (drain) terminals, and the emitter (source) terminals are connected together to a constant current source. Also known as an emitter-coupled pair (BJT) or source-coupled pair (FET). This configuration is often used as the basis of the differential input stage in voltage feedback op-amps.

differential pair oscillator a device used instead of a transistor in any LC-oscillator. Two distinct advantages result from employing the differential pair as the active element. The first is that the output signal may be taken at the collector of transistor that is external to the oscillator feedback loop, and second is that, if a tuned circuit is used as a load, the distortion of the output signal is much less than it would be for a single transistor oscillator. The second advantage follows from the fact that the differential pair collector currents do not include even harmonic components and, in addition, the amplitudes of existing high-order harmonics are smaller than they are for a single transistor.

differential peak detector a circuit commonly used for the demodulation of FM signals; it utilizes two peak detectors, a differential amplifier and a frequency selective circuit. Also known as a balanced peak detector.

differential protection a protective relaying scheme in which the currents entering and leaving the protected line or device are compared.

differential protection unit a protective unit based on the difference of currents flowing in and out of a protected zone.

differential pulse code modulation (DPCM) (1) a class of methods for pulse code modulation (or scalar quantization) where (linear) prediction is used in order to utilize the temporal redundancy in the source signal to enhance performance. Also referred to as predictive PCM or predictive SQ. *See also* pulse-code modulation, scalar quantization, adaptive differential pulse code modulation.

(2) in image processing, a lossy predictive coding scheme. In this scheme *m* pixels in a causal neighborhood of the current pixel is used to estimate (predict) the current pixel's value. The basic components of the predictive coder comprises predictor, quantizer, and code assigner.

differential relay a differential relay is a protective relay that measures current going into a device from all sources by means of a network of paralleled current transformers. Ideally, the operational current is zero for normal conditions, and rises to a high value (proportional to fault current) when a fault comes on inside the differential zone. Differential relays are commonly applied in bus protection, transformer protection, generator protection, and large motor protection.

differential volume element in a given coordinate system, the product of the differential length changes in each of the three coordinate directions.

differential-mode coupling pick-up from an electromagnetic field that induces a change in potential on both signal leads of equal magnitude but opposite phase relative to the ground reference potential.

differentially compounded a compound machine in which the flux produced by the MMF of the shunt field winding and the flux produced by the MMF of the series field winding oppose each other. Most often obtained by incorrectly connecting the machine, the differentially compounded machine may demonstrate very erratic behavior.

differentiator a filter that performs a differentiation of the signal. Since convolution and differentiation are both linear operations, they can be performed in either order.

$$(f * g)'(x) = f'(x) * g(x) = f(x) * g'(x).$$

Thus, instead of filtering a signal and then differentiating the result, differentiating the filter and applying it to the signal has the same effect. This filter is called a differentiator. A low-pass filter is commonly differentiated and used as a differentiator.

diffracted beam diffraction that takes place when the wavelength of an incident beam is short compared to the interaction distance. Particles exhibit wave-like characteristics in their passage through matter. In striking a target the incident beam scatters off nucleons. The scattered waves then combine according to the superposition principle, and the peak of this scattered wave is called the diffracted beam.

diffraction (1) distortion of an electromagnetic wave due to the proximity of a boundary or aperture.

(2) a bending or scattering of electromagnetic waves. Basically a redistribution within a wavefront when it passes near the edge of an opaque object.

(3) the propagation of light in the presence of boundaries. It is the property of light that causes the wavefront to bend as it passes an edge.

diffraction angle angle corresponding approximately to the rate of spreading of an electromagnetic wave that has been transmitted through an aperture; with Gaussian beams the far field half angle for a radius equal to the spot size.

diffraction coefficient in the Geometric Theory of Diffraction, the coefficient that is proportional to the contribution to the scattered field due to the fringe currents near an edge or corner of a scattering target.

diffraction efficiency of Bragg cell ratio of the intensity of the principal diffracted beam to the intensity of the undiffracted beam.

diffraction grating an array of reflecting or transmitting lines that mutually enhance the effects of diffraction.

diffraction loss loss from an electromagnetic beam due to finite aperture effects.

diffraction tomography generalization of computerized tomography incorporating scattering effects.

diffuse density signal that has uniform energy density, meaning that the energy flux is equal in all parts of a given region.

diffuse intensity the energy scattered in all directions out of the forward or specular directions. Sometimes also called incoherent component of the intensity.

diffuse multipath the result of multipath propagation observed as overlapping signal components, due to delay differences of multipath components being less than the delay resolution of the signal. Observable in the delay power spectrum as a continuous distribution of power over delay. *See also* multipath propagation, delay power spectrum.

diffuse scattering the component of the scattering from a rough surface that is not in the specular direction. It is caused by reflections from local surfaces oriented in planes different from that of the mean surface. *See also* specular scattering.

diffuse transmittance a transmitted signal that has uniform energy density.

diffusion a region of a semiconductor into which a very high concentration of impurity has been diffused in order to substantially increase the majority carrier concentration in that region.

diffusion pump second stage of the vacuum system. Hot oil showers the particles in a vacuum and creates a better vacuum. After a mechanical (roughing) pump is used to remove about 99.99% of the air in the beam tube, the remaining air can then be removed by a diffusion pump, down to about $1E^{-9}$ torr.

diffusion under field (DUF) a local thin layer of semiconductor with a very high carrier concentration located under and in contact with the collector of a vertical bipolar transistor to provide a low-resistivity connection to it.

diffusive scattering when the photon mean free path is much smaller than the scatterer dimensions and then the energy is scattered uniformly in all directions.

DigiCipher HDTV system a high-definition television (HDTV) digital transmission television system proposed to the FCC by the American Television Alliance composed of General Instruments and Massachusetts Institute of Technology. The DigiCipher HDTV proposal submitted to the FCC in August of 1991 was the first system to provide an all digital television system that promised spectrum compatibility with the existing television channel allocation. The system used quadrature amplitude modulation (16-QAM) digital transmission at a 4.88 MHz symbol rate.

digital circuits or systems that employ two valued (binary) signals denoted by the digits 0 and 1. Normally binary 1 is used to indicate high/true and binary 0 to indicate low/false (Positive Logic).

digital cellular radio cellular radio product designed to transmit its signals digitally.

digital communications communication techniques that employs binary bits to encode information.

digital European cordless telephone (DECT) a digital microcell system operating in the 1.88–1.90 GHz band designed to provide high-capacity wireless voice and data services indoors and outdoors in small local networks. DECT systems use a TDMA/FDMA multiple access scheme, with 10 radio frequency carriers, each 1728 kHz wide, divided into 2×12 time slots. This provides a total of 120 duplex traffic channels, with duplexing via TDD. The carrier bit rate is 1152 kb/s. DECT portable terminals have a peak transmit power of 250 mW.

digital filter the computational process or algorithm by which a sampled signal or sequence of numbers (acting as an input) is transformed into a second sequence of numbers termed the output signal. The computational process may be that of low-pass filtering (smoothing), bandpass filtering, high-pass filtering, interpolation, the generation of derivatives, etc.

digital halftone halftone technique based on patterns of same size dots designed to simulate a shade of gray between white paper and full colorant coverage.

digital image (1) an array of numbers representing the spatial distribution of energy in a scene obtained by a process of sampling and quantization.

(2) a discrete-value function $\hat{I}(k, l) = I(k\Delta x, l\Delta y)$ obtained by sampling, at equispaced positions, the continuous function $I(x, y)$ which measures image intensity at position x, y of the image plane. I can be single-valued for monochrome images or m-valued (usually $m = 3$) for color images.

digital modulation signal generator an RF signal generator capable of providing signals with digital modulation formats such as Gaussian minimum shift keying (GMSK), Pi/4 differential quadrature phase shift keying (DQPSK), and code division multiple access (CDMA).

digital optical computing optical computing that deals with binary number operations, logic gates, and other efforts to eventually build a general-purpose digital optical computer. In digital optical computing, new optical devices are sought to replace elements in an electronic computer. The digital optical computer may be primarily based on already known computer architectures and algorithms.

digital optics optical systems that handle digital data.

digital relay a relay in which decisions are made by a digital computer, typically a microprocessor system.

digital serial processing processing of more than one but not all bits in one clock cycle. If the digit size is W_1 and the word length is W, then the word is processed in W/W_1 clock cycles. If $W_1 = 1$, then the system is referred to as a bit-serial, and if $W_1 = W$, then the system is referred to as a bit-parallel system. In general, the digit size W_1 need not be a divisor of the word length W, since the least and most significant bits of consecutive words can be overlapped and processed in the same clock cycle.

digital signal processor (DSP) microprocessor specifically designed for processing digital signals. DSPs are typically well suited to perform multiplications and additions in chain, even in floating point. They are less suitable for managing interrupts and large amounts of memory. For reaching high performance, a neat division between memory for data and memory for programs is adopted, with the constraint of having a high number of pins.

digital simulator a simulator that allows the user to check the function and perform a timing analysis of a digital system.

digital subscriber line (DSL) in telephony, a digital connection between a customer premise and a central switching office (CO) using twisted-pair (copper) as the transmission medium. Although DSLs were originally introduced for narrowband ISDN applications (144 kbps), recent enhancements of DSLs (definitions follow) now support a broader range of higher-rate services.

digital sum variation a measure of the maximum possible imbalance in a line coded sequence. Definitions vary; a common definition is the total number of running digital sum values that can arise in the encoded sequence.

digital tachometer a device with a sensor that senses pulses from a rotating axis and converts them to digital output calibrated in rotations per minute (rpm).

digital voltmeter (DVM) a modern solid-state device capable of measuring voltage and displaying the value in digitized form. The term is also used loosely for the digital multimeter, which can also measure current and resistance.

digital–optical computing that branch of optical computing that involves the development of optical techniques to perform digital computations.

digital-to-analog converter (DAC, D/A) a device that changes a digital signal to an analog signal of corresponding magnitude.

digital-video effects application of digital technology to manipulate video information for production, to compress video data, to transmit video signals, and to process or transform video signals for various display systems.

The original analog video is digitized for application to computer-type circuits that can produce effects such as video mixing or overlay; editing of video signals; compression of video data; synchronizing video systems; signal transformation and timebase correction for various display formats and signal conversion back to analog form. The primary video artifacts observed from the digital-video effects result from either digitizing to an insufficient number of bits per picture element (pixel) or from too few samples for the video block processing algorithms. Using fewer than 8 bits/pixel for each color component will cause poor signal-to-noise ratios and produce scenes that have the appearance of a poster or cartoon. The poster appearance results from contours that are too abrupt and from colors that are not smoothly blended. Similarly, algorithms that process large blocks of pixels tend to reduce resolution and produce blocks with color shifts.

digitization a process applied to a continuous quantity that samples the quantity first, say, in time or spatial domain, and then quantizes the sampled value. For instance, a continuous-time signal can be first sampled and then quantized to form a digital signal, which has been discretized in both time and magnitude.

digitize the action of converting information from analog to digital form.

digitizer *See* data tablet.

dilation a fundamental operation in mathematical morphology. Given a structuring element B, the dilation by B is the operator transforming X into the Minkowski sum $X \oplus B$, which is defined as follows:
1. If both X and B are subsets of a space E,

$$X \oplus B = \{x + b \mid x \in X, b \in B\}$$

2. If X is a gray-level image on a space E and B is a subset of E, for every $p \in E$ we have

$$(X \oplus B)(p) = \sup_{b \in B} X(p - b)$$

3. If both X and B are gray-level images on a space E, for every $p \in E$ we have

$$(X \oplus B)(p) = \sup_{h \in E} [X(p - h) + B(h)]$$

with the convention $\infty - \infty = -\infty$ when $X(p - h), B(h) = \pm\infty$. (In the two items above, $X(q)$ designates the gray-level of the point $q \in E$ in the gray-level image X.) *See* erosion, structuring element.

dilation equation the equation

$$\pi(t) = \sum_{n=-infty}^{infty} a(n)\pi(2t - n)$$

with $\pi(t)$ being scaling function and $a(n)$ being the coefficients. It states the fact that, in multiresolution analysis, a scaling space is contained in a scaling space with finer scale.

Dill parameters three parameters, named A, B, and C, that are used in the Dill exposure model for photoresists. A and B represent the bleachable and nonbleachable absorption coefficients of the resist, respectively, and C represents the first-order kinetic rate constant of the exposure reaction. (Named for Frederick Dill, the first to publish this model.) Also called the ABC parameters.

dilution transformer one of several hedges, (e.g., somewhat, quite, rather, and sort of) that dilute the characteristics of a fuzzy set.

diminished radix complement form of the complement representation of negative numbers. In the binary system, the radix complement is called the 2s complement and the diminished radix complement is called the 1s complement.

diode a two-terminal device that permits the flow of electric current in only one direction.

Diodes are most often constructed by abutting n-type and p-type regions of a semiconductor, that has significantly higher electrical conductivity in one direction (forward-biased) than the other (reverse-biased).

Diode devices may be specially designed for low-power, high switching speed applications (signal diodes) or higher-power applications (rectifier diodes).

diode detector a device that by use of rectification and the use of inherent nonlinearity separates a modulating signal from its carrier.

diode gun Plumbicon a Plumbicon tube with an electron gun that operates with positive voltage applied to G_1 with respect to the cathode. The diode gun principle provides a finer beam spot size and lower beam temperature. This results in higher resolution and improved lag performance compared to triode gun tubes. The diode gun also provides a much higher current reserve for highlight handling when used in conjunction with a dynamic beam control circuit.

diode laser laser in which the amplification takes place in an electrically pumped semiconducting medium. Also known as a semiconductor laser or a heterojunction laser.

diode rectifier a circuit in which the output voltage is fixed by the circuit parameters and the load. The direction of power flow is not reversible. An example of a single-phase diode-bridge rectifier with a capacitor filter is shown. Note that the diodes are on only for a short duration, while the rectified line voltage is greater than the capacitor voltage.

dioptric an optical system made up of only refractive elements (lenses).

dip *See* sag.

DIP *See* dual in-line package.

DIP switch set of micro-switches (on/off or deviators) that are compliant with the DIP for the position of their pin (connections); thus, they can be installed in standard sockets for integrated circuits.

dipole *See* magnetic dipole.

dipole antenna a straight wire, with two arms, of oppositely pulsating charges, typically $\lambda/2$ or $\lambda/4$.

Dirac's delta function not actually a function, Dirac's delta function is defined functionally by its property of "choosing" a single value of the integrand when integrated:

$$f(r_0) = \int f(r)\delta(r - r_0)dr$$

when the volume of integration includes the point r_0. *See* delta function.

direct addressing address of the operand (data upon which the instruction operates) of the instruction is included as part of the instruction.

direct axis (d axis) the magnetic axis of the rotor field winding of a synchronous machine. The axis between the poles of a DC machine.

direct axis magnetizing (armature) reactance a reactance that represents all the inductive effects of the d-axis stator current of a synchronous machine, except for that due to the stator winding leakage reactance. In Park's d-axis equivalent circuit of the synchronous machine, this reactance is the only element through which both the stator and rotor currents flow. Its value may be determined by subtracting the stator winding leakage reactance from the steady-state value of the d-axis operational impedance or from the geometric and material data of the machine.

direct axis synchronous reactance the sum of the stator winding leakage reactance and the direct-axis magnetizing (armature) reactance of a synchronous machine. This represents the balanced steady-state value of the direct-axis operational impedance of the synchronous machine, and thus characterizes the equivalent reactance of the machine during steady-state operation.

direct axis transient reactance a value that characterizes the equivalent reactance of the d-axis windings of the synchronous machine between the initial time following a system disturbance (subtransient interval) and the steady state. This reactance cannot be directly mathematically related to the d-axis operational impedance. However, in models in which the rotor windings are represented as lumped parameter circuits, the d-axis transient reactance is expressed in closed form as the sum of the stator winding leakage reactance, and the parallel combination of the d-axis magnetizing reactance and the field winding leakage reactance.

direct broadcast satellite (DBS) refers to TV signal transmission and distribution from a base station up to a satellite, and then down to consumers who have suitable satellite receiving antennas and down-converter receivers.

$$F(dB) = 10\log_{10}(SNR_{in}/SNR_{out})$$

direct burial (1) the practice of burying a specially-armored power or communications cable in a ditch without the use of a surrounding conduit.

(2) a term applied to any cable which is meant for direct burial.

direct control bottom, first, control layer of a multilayer controller, directly responsible for adjusting the manipulated inputs to the controlled process; typical example of direct control is the regulation layer of an industrial control system, where the manipulated inputs are used to make the controlled variables follow the desired set point values.

direct control layer *See* direct control.

direct converter a frequency converter that converts an RF signal to a baseband signal directly in receivers. It converts a baseband signal to an RF signal directly in transmitters.

direct current machine a DC machine is an electromechanical dynamo that either converts direct current electrical power into mechanical power (DC motor), or converts mechanical power into direct current electrical power (DC generator). Some DC machines are designed to perform either of these functions, depending on the energy source to the dynamo.

direct current motor a rotation machine energized by DC electrical energy and used to convert electrical energy to mechanical energy.

direct digital synthesizer an oscillator that generates sinusoidal wave by digital calculation and digital to analog conversion. It can generate an arbitrary frequency signal in a fine channel step.

direct drive a drive in which no gear reducer is used.

direct drive robot a mechanical arm where all or part of the active arm joints are actuated with the direct drive. Due to the fact that many actuators are best suited to relatively high speeds and low torques, a speed reduction system is required. Gears are the most common elements used for reduction. A robot with a gear mechanism is called a geared robot. Gears are located at different joints; therefore, usually geared robots have a transmission system, which is needed to transfer the motion from the actuator to the joint.

direct dynamics the direct dynamics problem consists of determining the joint generalized accelerations $\ddot{q}(t)$ assuming that joint generalized forces $\tau(k)$, joint positions $q(t)$, and joint velocities $\dot{q}(t)$ are known. Solution of the direct dynamics leads to the dynamic simulation which is defined as follows: for a given set of joint generalized forces and initial values of the joint positions and velocities integrate the equations of motion in order to find a set of joint accelerations, velocities, and positions. The dynamics simulation is very useful for manipulator simulation.

direct fuzzy control the use of fuzzy control directly in the inner control loop of a feedback control system.

direct kinematics direct kinematics (or forward kinematics) for an arbitrary manipulator and given the joint variables vector $q(t) = [q_1(t), q_2(t), \ldots, q_n(t)]^T$ and the geometric link parameters finds the position and orientation of the end-effector of the manipulator with respect to a reference coordinate frame. The direct kinematics problem can be solved by successive multiplication of the D-H transformation matrices from the base of the manipulator towards its end-effector. More precisely the kinematics can be represented mathematically as a continuous map assigning to every joint position (configuration of the manipulator) a corresponding position and orientation of the end-effector. $k : Q \to E$ where Q and E are called, respectively, the inertial (joint) space and the external space of the manipulator. Suppose that a manipulator has r-revolute and $(n - r)$ prismatic joints. Then the internal space is defined as $Q = T^r \times R^{n-r}$, where T^r denotes the r dimensional torus, and R^{n-r} $(n - r)$ dimensional space of real numbers.

direct mapped *See* direct mapped cache.

direct mapped cache a cache where each main memory (MM) block is mapped directly to a specific cache block. Since the cache is much smaller than the MM, several MM blocks map to the same cache block.

If, for example, the cache can hold 128 blocks, MM block k will map onto cache block k modulo 128. Because several MM blocks map onto the same cache block, contention may arise for that position. This is resolved by allowing the new block to overwrite the old one, making the replacement algorithm very trivial in this case.

In its implementation, a high-speed random access memory is used in which each cache line and the most significant bits of its main memory address (the tag) are held together in the cache at a location given by the least significant bits of the memory address (the index). After the cache line is selected by its index, the tag is compared with the most significant bits of the required memory address to find whether the line is the required line and to access the line.

direct memory access (DMA) used in a computer system when transferring blocks of information between I/O devices (e.g., disk memory) to/from the main memory with minimal intervention from the CPU. A "DMA controller" is used and can, after initiation by the CPU, take control of the address, control, and data busses. The CPU initiates the DMA controller with parameters such as the start address of the block in main memory, number of bytes to be transferred, and the type of transfer requested (read or write). The transfer is then completely handled by the DMA controller, and the CPU is typically notified by an interrupt when the transfer service is completed. While the DMA transfer is in progress, the CPU can continue executing the program doing other things. However, as this may cause access conflicts of the busses between the CPU and the DMA controller, a "memory bus controller" handles prioritized bus requests from these units. The highest priority is given to the DMA transfer, since this normally involves synchronous data transfer that cannot wait (e.g., a disk or tape drive). Since the CPU normally originates the majority of memory access cycles, the DMA control is considered as "stealing" bus cycles from the CPU. For this reason, this technique is normally referred to as "cycle stealing."

direct method Lyapunov's second method of investigating the stability of dynamical systems. The method is called a direct method because no knowledge of the solution of the differential equations modeling a dynamical system is required when investigating the stability of an equilibrium solution. *See also* equilibrium solution and stability.

direct method coordination coordination by the direct method amounts to iterating the coordination variables (direct coordination instruments) defined as the interaction inputs and outputs and, if needed, any other variables that, when fixed, provide for independence of the local decision problems. The results of these problems are used by the coordinator to check whether its objectives are satisfied — if not, then the direct coordinating instruments are changed (iterated), etc.

direct modulation modulation of the optical intensity output from a semiconductor diode laser by direct modulation of the bias current.

direct scattering theory predicts the distribution of scattered intensity from knowledge of the structure of the inhomogeneous medium.

direct semiconductor a semiconductor whose band gaps are between electronic states with the same momentum, thus allowing optical transitions to occur between them.

direct sequence refers to a technique for digital spread spectrum modulation. The data symbol is modulated by a higher-rate pseudo-random sequence. The resulting signal is thus at a higher rate, or equivalently, occupies a larger bandwidth. This is denoted direct sequence spreading.

direct stroke (1) a lightning strike which terminates on a piece of equipment

(2) an approach to the design of overhead electric transmission lines which assumes that only direct strokes to the line will be disruptive to a power system.

direct write lithography a lithography method whereby the pattern is written directly on the wafer without the use of a mask.

direct-access storage storage in which an item can be accessed without having to first access all other items that precede it in the storage; however, sequential access may be required to a few preceding systems. An example is a disk, in which blocks may be accessed independently, but access to a location within a block is preceded by access to earlier locations in the block. *See also* sequential-access storage.

direct-axis subtransient open-circuit time constant a constant that characterizes the initial decay of transients in the d-axis variables of the synchronous machine with the stator windings open-circuited. The interval characterized is that immediately following a disturbance, during which the effects of all amortisseur windings are considered. A detailed (derived) closed-form expression for the subtransient open-circuit time constant of a machine with a single d-axis amortisseur windings is obtained by taking the reciprocal of the smallest root of the denominator of the d-axis operational impedance. An approximate (standard) value is often used, in which it is assumed the field winding resistance is very small and the detailed expression simplified.

direct-axis subtransient reactance the high-frequency asymptote of the d-axis operational impedance of a synchronous machine. This value characterizes the equivalent reactance of the d axis of the machine during the initial time following a system disturbance. In models in which the rotor windings are represented as lumped parameter circuits, the d-axis subtransient reactance is expressed in closed form as the sum of the stator winding leakage reactance, and the parallel combination of the d-axis magnetizing reactance and the d-axis rotor leakage reactances.

direct-axis subtransient short-circuit time constant a constant that characterizes the initial decay of transients in the d-axis variables of the synchronous machine with the stator windings short-circuited. The interval characterized is that immediately following a disturbance, during which the effects of amortisseur windings are considered. A detailed (derived) closed-form expression for the subtransient short-circuit time constant of a machine with a single d-axis amortisseur winding is obtained by taking the reciprocal of the largest root of the numerator of the d-axis operational impedance. An approximate (standard) value is often used, in which it is assumed the field winding resistance is small and the detailed expression simplified.

direct-axis transient open-circuit time constant a constant that characterizes the decay of transients in the d-axis variables of the synchronous machine with the stator windings open-circuited. The interval characterized is that following the subtransient interval, but prior to steady-state, during which the effects of the amortisseur windings are small (possibly negligible). A detailed (derived) closed-form expression for the transient open-circuit time constant of a machine with a single d-axis amortisseur winding is obtained by taking the reciprocal of the smallest root of the denominator of the d-axis operational impedance. An approximate (standard) value is often used, in which it is assumed the amortisseur winding resistance is infinite and the detailed expression simplified.

direct-axis transient short-circuit time constant a constant that characterizes the decay of transients in the d-axis variables of the synchronous machine with the stator windings short-circuited. The interval characterized is that following the subtransient interval, but prior to steady-state, in which the effects of the amortisseur windings are small (possibly negligible). A detailed (derived) closed-form expression for the short-circuit transient time constant is obtained by taking the reciprocal of the smallest root of the numerator of the d-axis operational impedance. An approximate (standard) value is often used, in which it is assumed the amortisseur winding resistance is infinite and the detailed expression simplified.

direction cosine similarity between two variables $x = (x_0, ..., x_n)$ and $y = (y_0, ..., y_n)$, it is defined as

$$\cos\theta = \frac{(x, y)}{\| x \| \| y \|}$$

where (x, y) is the inner product of x and y and $\| x \|$ is the Euclidean norm of x.

direction line a curve to which the given field is tangential at every point on the curve. Also called stream line or flux line.

direction of arrival *See* angle of arrival.

directional coupler a passive, 3 or 4 port device used to sample a portion of the forward (incident) signal or the reverse (reflected) signal, or both (dual directional coupler) in an RF, microwave, or mmW circuit. Directional couplers are usually described in terms of coupling factor and directivity. The coupling factor describes what fraction of the incident (or reflected) power appears at the desired coupled port. Directivity describes the fraction of power coupled to the same port due to reverse power in the main arm of the coupler.

directional overcurrent relay an overcurrent relay that operates only for overcurrents flowing in the tripping direction. Direction sensing is typically done with respect to a voltage or current signal, which is not affected by fault location.

directional power relay a protective relay that operates for power flow in a given direction. Applications are in cases where normal power flow is in one direction, including anti-motoring protection on a turbine-generator and fault backfeed protection on parallel step-down transformers.

directivity the maximum ratio of an antenna's ability to focus or receive power in a given direction relative to a standard; the standard is usually an isotropic radiator or a dipole. Only depends on the radiation pattern shape and does not include the efficiency of the antenna.

directory a table used in the directory method to maintain cache coherence in multiprocessors. Contains entries identifying the caches that hold copies of memory locations.

directory look-aside table (DLT) *See* translation lookaside buffer.

Dirichlet conditions a set of conditions guaranteeing that a signal $x(t)$ will be equal to the N-term Fourier approximation of $x(t)$ as $N \to \infty$ except at isolated values of t for which $x(t)$ is discontinuous. The conditions are that

(1) the signal $x(t)$ must be absolutely integrable,

(2) $x(t)$ must have a finite number of maxima and minima during a period, and (3) $x(t)$ must have a finite number of (finite) discontinuities in any finite interval of time.

dirty bit a status bit used to indicate if a block (e.g., cache block, page, etc.) at some level of the memory hierarchy has been modified (written) since it was first loaded in. When the block is to be replaced with another block, the dirty bit is first checked to see whether the block has been modified. If it has, the block is written back to the next lower level. Otherwise, the block is not written back.

dirty page a page in memory that has been altered since last loaded into main memory. *See also* dirty bit.

disable action that renders a device incapable of performing its function; the opposite of enable.

disagreement of interests situation in which there are several decision units with conflicting goals. *Compare with* consistency of interests.

disassembler a computer program that can take an executable image and convert it back into assembly code.

disc *See* magnetic disk. Also spelled "disk."

DISC Cerenkov counter stands for differential isochronous self-collimating Cerenkov counter. This device is used to identify particles over a wide range of masses and can also be used to give an independent calibration of the average momentum of a beam line.

disco contraction of "distribution company," a firm which owns the electric distribution network in a service area but neither generates nor transmits electric power.

disconnect switch a manually operated switching device used to disconnect circuit conductors and their associated load(s) their source of electrical power.

discontinuity effect an appropriate equivalent circuit model for discontinuities that have a tendency to disturb the electric and magnetic fields in their vicinity.

discontinuity manifold *See* sliding surface.

discontinuous control the control law that is allowed to vary discontinuously to account for sudden switching. An example of a discontinuous controller is

$$u = -U \operatorname{sign}(s(e)) ,$$

where e is a control error and s is a function of e, where

$$\operatorname{sign}(s) = \begin{cases} -1 \text{ if } s < 0 \\ \ \ 1 \text{ if } s > 0. \end{cases}$$

discrete cosine transform (DCT) a popular format for video compression. The spatial signal is expanded in a cosine series, where the higher frequencies represent increased video resolution.

The forward 2-D DCT of an $n \times n$ block is defined as

$$F(u,v) = \frac{4C(u)C(v)}{n^2} \sum_{j=0}^{n-1} \sum_{k=0}^{n-1} f(j,k)$$

$$\cos\left(\frac{(2j+1)u\pi}{2n}\right) \cos\left(\frac{(2k+1)v\pi}{2n}\right)$$

and the inverse is defined as

$$f(j,k) = \sum_{j=0}^{n-1} \sum_{k=0}^{n-1} C(u)C(v)F(u,v)$$

$$\cos\left(\frac{(2j+1)u\pi}{2n}\right) \cos\left(\frac{(2k+1)v\pi}{2n}\right)$$

where $C(w) = \frac{1}{\sqrt{2}}$ for $w = 0$ and 1 for $w = 1, 2, \ldots, n-1$.

For images that exhibit high pixel to pixel correlation, the DCT is indistinguishable from the Karhunen–Loeve transform (KLT).

There is a family of DCTs, of which the DCT-II described above is the one commonly used. These other types of DCT, specifically the DCT-IV, are sometimes used in calculating fast transforms. The $N = 8$ element DCT is particularly important for image data compression and is central to the JPEG and MPEG standards. As a matrix, the 8-element DCT is as in the figure for DCT .

discrete data channel the concatenation of all communication system elements between and including the modulator and demodulator.

discrete Fourier transform (DFT) the sum of complex exponentials representing a sampled sequence. This transform is obtained to represent a reasonable approximation of a signal for which only a finite sample exists. Defined as

$$X(x) = \sum_{n=0}^{N-1} x(n) e^{-j(2\pi/N)nk}$$

where $x(n)$ represents a sequence of finite samples of a signal; N is the number of samples in the sequence.

discrete fuzzy set a fuzzy set that includes only those sample points of a continuous variable.

discrete Hadamard transform *See* Hadamard transform.

discrete Hopfield network a single layer, fully connected network that stores (usually bipolar) patterns by setting its weight values w_{ij} equal to the (i, j) entry in the sum of the outer products of the patterns. The network can be used as an associative memory so long as the number of stored patterns is less than about 14% of the number of neural elements. *Compare with* continuous Hopfield network.

discrete multipath the result of multipath propagation observed as clearly separable, discrete signal components, seen in the delay power spectrum as a set of discrete peaks at various delays. *See also* multipath propagation, delay power spectrum, specular reflection.

discrete network an electronic network composed of separate, i.e., individual, components.

discrete sine transform (DST) a unitary transform mapping N samples $g(n)$ to N coefficients $G(k)$ according to:

$$G(k) = \sqrt{\frac{2}{N+1}} \sum_{n=0}^{N-1} g(n) \sin \frac{nk\pi}{N+1}$$

with inverse

$$g(n) = \sqrt{\frac{2}{N+1}} \sum_{k=0}^{N-1} G(k) \sin \frac{nk\pi}{N+1}$$

As with the discrete cosine transform there is a family of DSTs, the other members of which are rarely used. While the DST is closely related to the DCT, the latter is the form which has attained supremacy for image data compression.

discrete spectrum the eigenvalues of a differential equation with real coefficients and finite boundary conditions form a discrete spectrum. By extension, also the modes of closed waveguides originate a discrete spectrum.

discrete time Fourier series representation of a periodic sequence x_n with period N by the sum of a series of harmonically related complex exponential sequences:

$$x_n = \frac{1}{N} \sum_{k=0}^{N-1} X_k e^{\frac{j2\pi kn}{N}}.$$

The X_k are the Fourier series coefficients, obtained by

$$X_k = \sum_{n=0}^{N-1} x_n e^{-\frac{j2\pi kn}{N}}.$$

$$\begin{pmatrix}
0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 \\
0.4904 & 0.4157 & 0.2778 & 0.0975 & -0.0975 & -0.2778 & -0.4157 & -0.4904 \\
0.4619 & 0.1913 & -0.1913 & -0.4619 & -0.4619 & -0.1913 & 0.1913 & 0.4619 \\
0.4517 & -0.0975 & -0.4904 & -0.2778 & 0.2778 & 0.4904 & 0.0975 & -0.4517 \\
0.3536 & -0.3536 & -0.3536 & 0.3536 & 0.3536 & -0.3536 & -0.3536 & 0.3536 \\
0.2778 & -0.4904 & 0.0975 & 0.4157 & -0.4157 & -0.0975 & 0.4904 & -0.2778 \\
0.1913 & -0.4619 & 0.4619 & -0.1913 & -0.1913 & 0.4619 & -0.4619 & 0.1913 \\
0.0975 & -0.2778 & 0.4157 & -0.4904 & 0.4904 & -0.4157 & 0.2778 & -0.0975
\end{pmatrix}$$

Discrete cosine transform (DCT).

discrete time signal a signal represented by samples at discrete moments of time (usually regularly spaced). The samples may take values from a continuous range, so the term is usually used to differentiate a sampled analog signal from a digital signal which is quantized. *See* signal.

discrete time system a process that transforms discrete time input signals to discrete time output signals.

discrete time white Gaussian noise noise samples modeled as independent and identically distributed Gaussian random variables.

discrete Walsh-Hadamard transform *See* Hadamard transform.

discrete wavelet transform (DWT) a computation procedure that calculates the coefficients of the wavelet series expansion for a given finite discrete signal.

discriminator a circuit whose output voltage varies in magnitude and polarity in direct proportion to the difference between the input voltage and a standard signal. A discriminator that converts phase deviations at the input to a linearly proportionate variation in output voltage is called a phase discriminator and is used in FM detection.

disk *See* magnetic disk. Also spelled "disc."

disk actuator a mechanical device that moves the disk arms over the disk surface(s) in order to position the read/write head(s) over the correct disk track.

disk arm a mechanical assembly that positions the head over the correct track for reading or writing a disk device. The arm is not movable on a fixed-head disk, but is on a moving-head disk.

disk array a number of disks grouped together, acting together as a single logical disk. By this, multiple I/O requests can be serviced in parallel, or that the bandwidth of several disks can be harnessed together to service a single logical I/O request.

disk cache a buffer memory area in main memory used to hold blocks of data from disk storage. The cache can hide much of the rotational and seek latencies in disk accesses because a complete data block (disk sector) is read or written together. Disk caches are normally managed by the machine's operating system, unlike a processor cache, which is managed by hardware.

disk capacitor a small single-layer ceramic capacitor with a dielectric insulator consisting of conductively silvered opposing surfaces.

disk controller unit that carries out the actions required for the proper operations of a disk unit.

disk drive assembly consisting of electronics and mechanical components, to control disk and disk-head movement and to exchange data, control, and status signals with an input/output module, as required for the proper reading or writing of data to or from a disk. The head disk assembly plus all the associated electronics.

disk format the (system-dependent) manner in which a track of a disk is partitioned so as to indicate for each sector: the identity, the start and end, synchronization information, error-checking information, etc. A disk must be formatted before any initial writing can take place.

disk head read/write head used in a disk drive. Such a head may be fixed-gap, in which the head is positioned at a fixed distance from the disk surface; contact-head, in which the head is always in contact with the surface; and aerodynamic, in which the head rests lightly on the surface when the disk is motionless but floats a small distance above when the tape is rotating. Typically, contact heads are used in floppy disks, and aerodynamic head are used in Winchester disks.

In earlier systems, "fixed-head disks" having one read/write head per track were used in some disk systems, so the seek time was eliminated. However, since modern disks have hundreds of tracks per surface, placing a head at every track is no longer considered an economical solution.

disk latency time between positioning a read/write head over a track of data and when the beginning of the track of data passes under the head.

disk operating system (DOS) a set of procedures, services, and commands that can be used by the computer user for managing its resources with a special attention to disks managing. The most famous DOS for personal computers is the MS-DOS (Microsoft-DOS). It is a mono-task and mono-user operating system.

disk pack a stack of disk platters that can be removed for off-line storage.

disk platter metal disks covered with a magnetic material for recording information.

disk scheduling algorithms used to reduce the total mechanical delays in disk accesses, as seen by a queue of simultaneous I/O requests. E.g., if a "shortest-seek-time-first" scheduling algorithm is used, seek times can be reduced. That is, among the queue of pending I/O requests, the one next serviced is the one requiring the shortest seek time from the current location of the read/write head. The disk scheduling algorithm is run by the computer operating system.

disk sector the smallest unit that can be read or written on a track; adjacent sectors are separated by a gap. A typical track has 10–100 sectors.

disk spindle a stack of disk platters.

disk striping the notion of interleaving data across multiple disks at a fine grain, so that needed data can be accessed from all the disks simultaneously, thus providing much higher effective bandwidth.

disk track connectric circle over which a read/write head moves; adjacent tracks are separated by a gap. A typical disk has hundreds to thousands of tracks.

diskette a floppy disk is a flexible plastic diskette coated with magnetic material. It is a smaller, simpler, and cheaper form of disk storage media than the hard disk, and also easily removed for transportation.

disocclusion the uncovering of an object. *See* occlusion.

disparity in binocular vision, the relative difference of position of an object with respect to a background between the left and right images. It is usually measured in minutes of arc.

dispatch the determination of the power output of each plant in an electric power system.

dispersed generation problem in economic dispatch calculations, the task of accounting for the production capacity of cogeneration or dispersed sources such as photovoltaic or wind generation plants.

dispersion (1) a characteristic of a medium in which the propagation velocity of a wave varies as a function of signal frequency.

As a pulse propagates through an optical fiber, its chromatic components will spread out or "disperse" in time. This phenomenon limits the distance between optical regenerators in fiber communication systems. There are four sources of dispersion: modal dispersion, material dispersion, waveguide dispersion, and nonlinear dispersion.

(2) the variation of the index of refraction of a material as a function of wavelength.

dispersion compensator a device that compensates for the accumulated chromatic dispersion in a fiber optic transmission system. Three main schemes exist: fiber grating dispersion compensators, dispersion compensating fiber, and phase conjugation or mid-span spectral inversion.

dispersion diagram a plot of propagation constant versus frequency.

dispersion of authority a situation in which the decisions, for example, decisions concerned with the manipulated inputs to the controlled process, are distributed between several (control) decision units; dispersion of authority may result either from natural, legislative, or other reasons, or may appear due to design of the controller; decentralized control, in particular, is based on the dispersion of authority between the local decision units. Also known as dispersion of control.

dispersion of control *See* dispersion of authority.

dispersion shifted fiber single mode optical fibers with zero dispersion in the 1550 nm telecommunications window. Prior to 1985, single mode optical fibers were designed to have zero dispersion in the 1310 nm telecommunications window.

dispersive medium (1) a medium for which the permittivity or the permeability (or both) are frequency dependent.

(2) in optics, medium in which the index of refraction varies significantly with frequency.

displaced frame difference (DFD) the difference between a given digital image frame and its estimate obtained by using the motion compensation technique. It is useful in image (sequence) data compression and motion estimation.

displacement current a field quantity that describes the completion of a circuit when a conducting path is not present.

displacement parameter complex parameter representing the displacement of the amplitude and phase centers of a Gaussian beam from the axis of an optical system.

display a device that provides a visual non-permanent display of system input and or output. Common display technology includes CRT (cathode ray tube), LED (light emitting diode), PDP (plasma display panel), EL (electroluminescense) and LCD (liquid crystal display).

dissipated power the power dissipated as a heat, which is defined by subtracting an RF output power from a DC input power.

dissipation the phenomenon associated with the attenuation of a propagating wave in a medium with material losses.

dissipation factor (DF) the ratio of the effective series resistance of a capacitor to its reactance at a specified frequency measured in percentage. Also known as loss tangent.

dissipation power (1) ratio of real power (in phase power) to reaction power (shifted 90° out of phase).

(2) the ratio of the imaginary to real parts of the complex permittivity, expressed as a dimensionless ratio.

dissipative half-space used for analysis of complex systems, it is constructed by dividing the infinite space in two by some convenient fashion. The resulting two half-spaces can both be infinite, or one finite and one infinite. The resulting half-space is then filled with a dissipative material (other than a perfect insulator or conductor).

dissipator a form of air terminal which is meant to prevent lightning strikes to a structure by reducing the surface charge on the earths's surface in the immediate region of the structure.

distance *See* chamfer distance, chessboard distance, Euclidean distance, Hamming distance, Hausdorff distance, inter-feature distance, Mahalanobis distance, Manhattan distance.

distance between symbol strings a measure of the difference between two symbol strings. The most frequently used distance measures between two strings include Hamming distance, edit or Levenshtein distance, and maximum posterior probability distance. *See also* Hamming distance, edit distance, maximum posterior probability distance.

distance measure a function $d(x, y)$ defined on a metric space, such that

$d(x, y) \geq 0$, where = holds iff $x = y$,

$d(x, y) = d(y, x)$, and

$d(x, y) \leq d(s, z) + d(z, y)$.

See also similarity measure.

distance profile for convolutional codes, the minimum Hamming weight of all sequences of a specific length emerging from the zero state. A distance profile for one code is superior to that of another if

1. all values of the distance profiles of the two codes up to a certain depth p (lower than the constraint length) are equal; and

2. the superior distance profile code has higher values of the distance profile for all depths above the given depth p.

distance protection relaying principle based upon estimating fault location (distance) and providing a response based upon the distance to the fault.

distance relay *See* impedance relay.

distance resolution delay resolution mapped into the spatial domain, measured in units of distance (meters). Each unit of time delay corresponds to a unit of distance d traveled by the radio wave through the equation

$$d = c\tau,$$

where τ is the delay and c is the speed of light. Distance resolution gives the smallest difference in path length resolved by a signal. Is also a measure of the spatial resolution capability of a signal (or measurement system).

distance transform a map of all the pixels in a shape showing the closest distance of each point in the shape from the background; also, an image in which the distance maps of all the shapes in the image are indicated. *See also* distance.

distortion (1) addition of an unwanted component to an electronic signal.

(2) undesired change in a signal's amplitude and/or phase as the result of it passing through an active nonlinear circuit. Numerous figures of merit have been adopted to describe various aspects of signal distortion.

distortion cross modulation nonlinear distortion of a system or carrier signal characterized by the appearance in the output of frequencies equal to the sum and difference of the desired carrier's frequency and the unwanted cross modulating carrier's frequency. Although harmonic components are also caused to be present, they are not usually a part of measurements of this effect.

distortion factor *See* total harmonic distortion.

distortion-rate theory *See* rate-distortion theory.

distributed amplifier (1) composed of two main artificial transmission-line sections consisting of series inductors and shunt capacitors, which are usually supplied by the FET transistor. Excellent bandwidth performers are obtainable and the amplifier can be designed as wideband low-noise amplifiers and are relatively easy to simulate and fabricate.

(2) the input and output capacitance of the active devices can be absorbed into distributed circuits (i.e., transmission lines) to obtain a very broad bandwidth.

distributed antenna typically consists of a set of discrete radiators fed by a common cable from a single signal source.

distributed arbitration a scheme used for bus arbitration where multiple bus masters can access the bus. Arbitration is not done centrally (by a bus arbiter), but instead done in a distributed fashion. A mechanism to detect when more than one master tries to transmit on the bus is included. When this happens, one (or all) stops transmitting and will reattempt the transmission after a short (e.g., random) time delay.

Compare with centralized arbitration.

distributed computing an environment in which multiple computers are networked together and the resources from more than one computer are available to a user. *See also* distributed computing environment.

distributed computing environment (DCE) an industry-standard, comprehensive, and integrated set of services that supports the development, use, and maintenance of distributed computing technologies. DCE is independent of the operating systems and network types. It provides interoperability and portability across heterogeneous platforms, and provides security services to protect and control access to data. DCE also provides services that make it easy to find distributed resources; for instance, directory service, a DCE component, is a central repository for information about resources in a distributed system. Distributed time service (DTS), another DCE component, provides a way to synchronize the times on different hosts in a distributed system. DCE gives a model for organizing widely scattered users, services, and data. It runs on all major computing platforms and is designed to support distributed applications in heterogeneous hardware and software environments. Particularly important for the World Wide Web and security of distributed objects.

distributed computing system a system whose different parts can run on different processors.

distributed control a control technique whereby portions of a single control process are located in two or more places.

distributed element a circuit element in which dimension is not negligible relative to the wavelength. The characteristics of a distributed element depend upon a dimension such as a length.

distributed feedback laser (DFB) a laser source where the optical feedback is distributed throughout the length of the gain medium. Feedback then occurs through Bragg diffraction, and the laser operates in only one optical mode.

distributed generation small power plants at or near loads and scattered throughout the service area.

distributed memory denotes a multiprocessor system where main memory is distributed across the processors, as opposed to being equally accessible to all. Each processor has its own local main memory (positioned physically "close"), and access to other processors' memory takes place through passing of messages over a bus. The term "loosely coupled" could also be used to describe this type of multiprocessor architecture to contrast it from shared-memory architectures, which could be denoted as "strongly coupled."

distributed memory architecture a multiprocessor architecture in which physical memory is distributed among the processing nodes, as opposed to being in a central location, equidistant from all processors.

distributed refresh in a DRAM, carrying out refresh operations one at a time, at regular intervals. Requires that all rows be refreshed in a time less that the time before which any given row needs to be refreshed. *See also* burst refresh.

distributed sample scrambling a modification of the reset scrambling technique in which information regarding the state of the scrambling sequence generator is embedded into the encoded sequence in a distributed fashion for purposes of synchronizing the descrambling sequence generator.

distribution (1) the possibility to execute different parts of a system on different processors.

(2) that class of electric power system work which is concerned with the distribution of electric power within a load area such as a residential or commercial area, or within an industrial installation. The distribution circuit extends from the local substation and terminates at the customer's meter.

distribution function *See* cumulative distribution function.

distribution management system (DMS) a system that helps manage the status of the distribution network, crews and their work flow, system safety, and abnormal conditions.

distribution switchboard a switchboard used in the distribution system, typically within a building.

distribution transformer a transformer designed for use on a power distribution system (typically 2.4 kV to 34.5 kV) to supply electrical power to a load at the proper utilization voltage.

disturbance a sudden change or a sequence of changes in the components or the formation of a power system. Also called fault.

disturbance decoupling of generalized 2-D linear systems given the second generalized 2-D Fornasini–Marchesini model with disturbances

$$\begin{aligned} Ex_{i+1,j+1} &= A_1 x_{i+1,j} + A_2 x_{i,j+1} \\ &\quad + B_1 u_{i+1,j} + B_2 u_{i,j+1} \\ &\quad + H_1 z_{i+1,j} + H_2 z_{i,j+1} \\ y_{ij} &= C x_{ij} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers), find a state-feedback $u_{ij} = K x_{ij}$ such that the output y_{ij} is not affected by the disturbances for $i, j \in Z_+$ where $x_{ij} \in R^n$, $u_{ij} \in R^m$, $y_{ij} \in R^p$, $z_{ij} \in R^q$ are semistate vector, input vector, output vector, and disturbance vector, respectively, and E, A_k, B_k, H_k $(k = 1, 2,)$ are real matrices with E possibly singular or rectangular.

dithering computer technique allowing the display and printing of gray-level images on devices having a small number of available colors (generally two, as in black-and-white CRTs and printers). The two main approaches are matrix dithering, where a matrix of black and white dots is associated with each gray-level, and error-diffusion dithering, where each gray-level pixel in turn is assigned an available color, and the error is spread to its unprocessed neighbors (as in the Floyd-Steinberg) method. *See* halftone.

divergence the angle that the trajectory of each particle makes with the beam axis. Accelerator systems always try to reduce beam divergence.

divergence theorem let us consider a volume V bounded by a surface S and an outer normal n. Let also $\mathbf{F}$ be a vector function which, together with its partial derivatives, is continuous at all points of V and S. The divergence theorem states that

$$\int_V div \mathbf{F} d\mathbf{x} = \int_S \mathbf{F} \cdot \mathbf{n} dS .$$

The above equation may also be used to define the divergence.

diversity combining a communication technique that combines the signals received through different, possibly independent channels. The most common methods of combining are maximum-ratio combining, equal gain combining, selection combining, and switched combining.

diversity frequency a method for increasing the reliability of digital communications in which multiple copies of the signal, or other types of redundant information, are transmitted. Frequency diversity implies that the received signal occupies a much wider bandwidth than the minimum bandwidth needed to carry the information.

diversity path a form of diversity in which multiple copies of the signal are created via different paths from the transmitter to receiver.

diversity selection a form of diversity reception in which the receiver selects the strongest signal among the copies received. The weaker signals are simply ignored.

divide by zero error occurring when a division per zero is operated. This case is mathematically undefined. In many cases, this problem is detected directly at level of microprocessor that activates an exception and leaving true a status flag. The exception can be managed for recovering the error and avoiding the interruption of the program execution. Also known as divide per zero.

divide per zero *See* divide by zero.

divider functional unit consisting of circuits that implement either integer or floating-point division.

DLL *See* delay-locked loop.

DLT directory look-aside table. *See also* translation lookaside buffer.

DMA *See* direct memory access.

DMS *See* distribution management system.

DOA direction of arrival. *See also* angle of arrival.

DOF *See* depth of focus.

domain module or area of execution that is to be kept isolated from other domains; a domain may have special properties that define the nature of the isolation and the limits on communication to and from the domain. In the context of secure system design, a domain may be an execution of a process that has specific security attributes.

dominant mode the mode of a waveguide having the lowest cutoff frequency or of a cavity having the lowest resonant frequency.

don't care a function that can be taken either as a minterm or a maxterm at the convenience of the user.

donor an impurity in a semiconductor that donates a free electron to the conduction band.

door *See* lid.

dopant an impurity substance (such as phosphorus or boron) added in very small controlled quantities to a semiconductor base material (such as silicon or gallium arsenide), thereby changing the material conduction characteristics by modifying electron and/or hole concentration. A donor dopant is one that gives rise to electrons and an acceptor dopant is one that gives rise to holes.

doping the process of introducing impurity atoms into pure silicon to change its electrical properties. The impurities may be either n-type (introducing an additional conducting electron) or p-type (introducing the absence of a conducting electron, also called a "hole").

Doppler broadened lineshape function spectral function that results from Doppler shifts caused by the velocity distribution of atoms or molecules in a gas; a Gaussian function for a Maxwellian velocity distribution.

Doppler broadening broadening of a spectral line due to Doppler shifts caused by the random motion of atoms or molecules in a vapor.

Doppler effect *See* Doppler shift.

Doppler filter a filter used to resolve targets from each other and from extraneous returns from other objects (called clutter) by filtering in the velocity or Doppler domain. So-called because the Doppler effect causes frequency shifts proportional to velocity variations in tracked objects.

Doppler frequency a shift in frequency of the returned power from a target as a result of the target's motion relative to the illuminating source.

Doppler linewidth characteristic width of a Doppler-broadened spectral line; usually the full width at half maximum when the line is Gaussian.

Doppler power spectrum a function characterizing the spread of average received power as a function of Doppler shift. Can be obtained from the scattering function by integrating over the delay variable. *See also* scattering function, multipath propagation.

Doppler radar radar-based technique used in measuring the velocity of a moving target or wind by measuring the Doppler shift (Doppler effect).

Doppler shift a frequency shift in a received signal caused by time-variant transmission delay, or equivalently time-variant propagation path length. This in turn is caused by movement of terminals with respect to each other, or by movement of reflecting objects. In optics, frequency shifts imposed on laser beams such as when used in laser radar or when diffracted by an acoustic wave.

The Doppler shift depends on the frequency of the signal and the angle of arrival of the signal relative to the direction of movement of the receiver. For a signal consisting of a range of frequencies, each frequency component will experience a different shift. Hence the received signal will have a different bandwidth than the transmitted signal (Doppler dispersion).

For a tone (continuous-wave) signal of frequency f, the Doppler shift f_D observed on a single propagation path of changing length is given by

$$f_D = \frac{fv}{c} ,$$

where v is the rate (in m/s) of path length change, and c is the speed of light.

Also known as Doppler effect.

Doppler spread the increase of bandwidth of a signal due to doppler shifting of multipath energy arriving at a mobile receiver from differing directions.

Doppler-free spectroscopy a spectroscopic technique in which two or more light fields are used to produce a spectral line that is not Doppler shifted or Doppler broadened. For example, in the case of lambda systems or vee systems, this requires that the electromagnetic fields co-propagate, whereas for cascade systems, the fields must counter-propagate.

DOS *See* disk operating system.

dose to clear the amount of exposure energy required to just clear the resist in a large clear area for a given process.

dosimeter an instrument used for measuring or evaluating the absorbed dose of radiation. It may depend on the measurement of ionization for its operation or may simply involve the darkening of a piece of photographic film ("film badge").

dot pitch the center-to-center distance between adjacent green phosphor dots of the red, green, blue triad in a color display.

dot-matrix printer a printer that produces readable characters by imprinting a large number of very small dots.

dots per inch (DPI) a measure of the density of line-printer plots in dots per inch.

double bridge a Wheatstone bridge modification designed to increase the precision of measurements for low-value resistors. To avoid the error due to resistance of the connection (called yoke) between the unknown resistor and the standard resistor, the ends of the unknown resistor and the standard resistor are connected to the balance detector (usually a galvanometer for this type of bridge) via two small resistors, the ratio of which is the same as the ratio of resistors in the ratio arms. Then the yoke resistance is eliminated from the balance condition and the unknown resistor can be found using the same formula as in an ordinary Wheatstone bridge.

double buffering (1) generally, any buffering scheme where two identical memory images are used. One memory image is used to hold received data, while data is simultaneously read from the other memory image.

(2) in terminal-to-computer communication scheme where a number of remote terminals are connected to a single computer through a "multiplexer." This unit connects n low-speed bit-serial transmission lines onto a single high-speed bit-serial line (running n times faster) using STDM (synchronous time division multiplex) of the connection. In the multiplexer, each low-speed line is connected to a "one-character buffer," converting the received low-speed bitstream to a high-speed bitstream using two shift-registers (buffers). The first one receives the low-speed line character bits (8 bits), clocked by the low-speed "receive clock." When a complete character has been received, it is moved to the second shift-register, where it is stored until it can be shifted out on the high-speed line on the appropriate time slot. Meanwhile, the next character is assembled in the first shift-register. For full-duplex operation (simultaneous two-way communication), a similar structure is needed for the opposite (computer-to-terminal) connection.

double conversion the process where an incoming RF signal is mixed with a local oscillator (LO) signal to produce the first intermediate frequency (IF). This IF is then mixed with a second fixed LO to produce a second IF signal.

double conversion receiver a receiver that uses two heterodyne operations before detection generating two intermediate frequencies, first intermediate frequency (IF) and second IF, respectively. *See also* intermediate frequency.

double heterostructure dye laser laser in which the amplification takes place in a dye; a broadly tunable laser.

double lambda system a quantum mechanical system composed of two interacting lambda systems that share common lower states. A double lambda system is also a double vee system. Double lambda systems can be used to construct resonant closed loop interactions in which some linear combination of the phases of the four fields is constant in time.

double line to ground fault *See* double phase ground fault.

double phase ground fault a fault with two transmission lines being connected to the ground.

double revolving-field theory *See* counter-rotating field theory.

double sideband modulation (DSB) a modulation scheme resulting in a spectrum consisting of the carrier frequency, one signal that is the sum of the carrier and the modulating signal, and one signal that is the difference between the carrier and the modulating signal.

double tuned a circuit, amplifier, or other device having a response that is the same as two single-tuned circuits.

double word data block that contains twice the number of bits as the machine word size in a microprocessor.

double-cage rotor *See* dual-cage rotor.

double-frequency recording *See* magnetic recording code.

double-line contingency a malfunction of a power system which involves the simultaneous failure of two transmission lines.

double-sided assembly a packaging and interconnecting structure with components mounted on both the primary and secondary sides.

double-sided disk a disk in which both sides of a platter are covered with magnetic material and used for storing information.

doublet a system of two quadrupole magnets in close proximity and with opposite polarity used to simultaneously constrain the beam size in two dimensions at some point downstream. Doublet (Quadrupole) is a beam optical system consisting of two quadrupoles of opposite sign, which provides net particle focusing in all planes.

doubly-fed induction motor an induction motor with a wound-rotor. The rotor and stator windings are connected to separate sources of electric energy. The machine can be used as a generator to provide frequency conversion or precise speed control in the motor-mode.

down-sampling *See* decimation.

downconductor the cable which connects an air terminal or lightning rod to ground. *See* air terminal.

download to bring data from a remote source to local storage.

downstream in power distribution work, the direction in which power flows, i.e., towards the load.

DPA *See* destructive physical analysis.

DPCM *See* differential pulse code modulation.

DPCM encoding *See* differential pulse code modulation.

DPI *See* dots per inch.

DPLL *See* dual phase-locked loop.

DQE *See* detective quantum efficiency.

DRA *See* dielectric resonator antenna.

drain terminal of an FET (usually identical in structure to the source) to which electrons flow. Electrons in the FET channel flow down the drain, and current flow is defined as the negative direction of electron movement, since electrons are negative. In p-channel FETs, current flows from source to drain. In n-channel FETs, current flows from drain to source. The drain is usually considered to be the metal contact at the surface of the die.

drain conductance the increase in drain current when the magnitude of the applied FET drain-to-source voltage is increased. Mathematically, the derivative of drain current with respect to drain voltage.

drain saturation current the drain-to-source current flow through the JFET under the conditions that $V_{GS} = 0$ and $| V_{DS} |>| V_P |$ such that the JFET is operating in the active or saturated region.

drain-source leakage the current flowing in the channel of a MOSFET when its gate and source are shorted together. The magnitude of the leakage current is strongly influenced by the applied drain-source voltage, the gate length and substrate doping concentration.

drain-to-source voltage (VDS) potential difference between the FET drain and source terminals, this voltage determines the device operational region and limits the output power. For an n-channel device this voltage is normally positive, and negative for a p-channel device. Magnitudes usually range up to as high as 10 V for a low noise device and much higher for power devices.

DRAM *See* dynamic random access memory.

drift (1) movement of free carriers in a semiconductor due to the electric field.

(2) the relatively uninpaired fluctuation of adaptive filter coefficients in the direction of least sensitivity along the eigenvector corresponding to the minimum eigenvalue is known as coefficient drift.

Coefficient drift can be a problem if this eigenvalue gets very small, as coefficients can drift out of the allowed region. Also important as random, often temperature-induced, fluctuations in the output levels of DC amplifiers.

drift chamber a series of chambers used to detect particle trajectories. They are similar to multi-wire proportional chambers, except the wire spacing is increased. The correlation between the position of an ionized track produced by a charged particle and the time of appearance of an electric pulse at the wire is used to measure the distance of the trajectory from the wires.

drift space space where electrons move due only to their inertia.

drip-proof machine a machine with ventilating openings constructed in such a way that drops of liquid or solid particles falling on it, at an angle less than 15 degrees from the vertical, can enter the machine neither directly nor by striking on it, run along a horizontal or inwardly inclined surface.

drive circuit a circuit that produces gate trigger pulses, of desired level and timing, to turn on and off active switches (just turn on for natural-commutated switches) in switching circuits.

driving-point admittance the admittance measured at the antenna terminals when the antenna is in free space (not loaded).

DRO *See* dielectric resonator (stabled) oscillator.

dropout equipment misoperation due to an interruption, noise, or sag.

dropout compensation signal compensation provided when a loss of information from magnetic tape defects occurs during VCR tape playback. Signal dropouts result from oxide or dust interfering with the tape-head to tape contact when the VCR is in the record or the playback operational mode. A horizontal delay line stores the luminance signal of the previous line that is used to replace the lost video information. The signal dropout is detected as a loss of the tape playback. FM signal activates an electronic switch. The switch substitutes the stored delay line contents into the video path to compensate for the lost video from the tape playback.

dropout current the current at which a magnetically-operated device will revert to its de-energized position.

dropout voltage the voltage level where proper equipment operation is hindered.

Drude material a frequency-dependent dielectric whose complex permittivity is described by an equation with two poles, one of them at $w = 0$. A collisional plasma is an example of such a material duration–bandwidth reciprocity relation.

Drude media *See* Drude material.

drum memory an old form of backing memory. Similar to magnetic disks in operation, but here the magnetic film is deposited on the surface of a drum, instead of a disk.

dry-type transformer a transformer that is cooled by circulating air or gas through or around the transformer housing.

DS-CDMA direct sequence code division multiple access. *See also* direct sequence and code division multiple access.

DSB *See* double sideband modulation.

DSI *See* discrete sine transform.

DSL *See* digital subscriber line.

DSP *See* digital signal processor.

DTE *See* data terminal equipment.

DTW *See* dynamic time warping.

dual control an adaptive control that performs two different functions at the same time: one that applies probing signals to learn more about the system dynamics and the other that tries to keep the output at a desired value.

dual functions mathematical relationship between two sets used to represent a signal. If a signal $s(t)$ can be represented by a complete set $\{\pi_n(t)\}$, *i.e.*, $s(t) = \sum_n a_n \pi(t)_n$, there must exist a dual set $\{\hat{\pi}_n(t)\}$ such that the expansion coefficients $a_n =< s(t), \hat{\pi}_n(t) >$. $\pi_n(t)$ and $\hat{\pi}_n(t)$ are called dual functions. As a special case, if the set $\{\pi_n(t)\}$ is orthonormal, then it is its own dual.

dual in-line package (DIP) a standard case for packaging integrated circuits. The package terminates in two straight, parallel rows of pins or lead wires. This standard has been more recently substituted by surface-mount standards. *Compare with* single in-line packaging.

dual mode filters filters realized by using two resonances inside the same cavity, hence allowing saving of space, volume, and weight.

dual phase-locked loop (DPLL) programmable, low-jitter, low-power, and high-performance devices. DPPLs are capable of synthesizing two low-jitter clocks with user-selected, industry-standard frequencies, phased-locked to the system reference timing. They accept a wide range of popular telecom and networking input frequencies and can be programmed to generate a range of output frequencies. Used for wide area network (WAN) and ISDN applications.

dual port memory memory system that has two access paths; one path is usually used by the CPU and the other by I/O devices.

dual-cage rotor a three-phase induction motor rotor with two separate squirrel cage windings, that give the effect of varying rotor resistance. The outer cage has high resistance to obtain high starting torque, while the inner cage has low resistance to reduce losses at full load.

dual-element fuse a fuse constructed with two different types of fusible elements in series. One element is designed to melt very quickly in the presence of fault current. The other is designed to melt after a time delay when exposed to overload conditions. The fusible elements are somewhat similar in operation to the thermal and magnetic elements of an inverse-time circuit breaker. Dual-element and time-delay are often used interchangeably.

duality property of Fourier transform the property that results from the symmetry between the Fourier transform synthesis and analysis equations. To illustrate, let $f(w)$ be the Fourier transform of the time function $g(t)$ ($f(w) = F\{g(t)\}$). Substituting t for w in f gives the time function $f(t)$. Applying a Fourier transform to $f(t)$ gives the function $2\pi g(-w)$, a frequency domain function similar to the original time function $g(t)$ ($g(-w) = \frac{1}{2\pi} F\{f(t)\}$).

DUF *See* diffusion under field.

dump an area of steel and dense concrete into which unwanted particle beam can be steered so that its energy can be dissipated in a safe and controlled manner. The dump resistor is switched into the magnet/capacitor circuit in order to dissipate the stored energy in the magnets/capacitors.

duoplasmatron a type of ion-producing source that develops protons by extracting positive ions from an arc struck in hydrogen gas.

duplex a method of winding the armature of a commutated electric machine such that the number of parallel electrical paths between brushes is double that provided by a simplex winding. Duplex windings are constructed by placing consecutive coils in alternate coil slots and continuing the winding twice around the rotor, filling the empty slots on the second pass. The result is two complete, identical windings between brush positions rather than the one winding that is produced when coils are placed in adjacent slots. *See also* simplex, multiplex, reentrancy.

duplex channel two-way simultaneous (and independent) data communication, e.g., between a computer and remote terminals.

duplex ultrasound simultaneous display of speed versus time for a chosen region and the two-dimensional B-mode image.

duplication with complementary logic fault detection based on circuit duplication and comparison. One module is designed using positive logic and the other module uses negative logic. This assures detecting common mode faults.

dust cover a cover to protect the terminals of a pad-mount transformer.

dust-ignition-proof machine a machine designed with a casing or specialized enclosure to safely contain any internal ignition or flammable substances or components, and prevent them from igniting external flammables such as explosive gases, vapors, and dust particles.

DUT device under test.

duty cycle (1) the ratio of the turn-on time of a semiconductor switch to the sum of the turn-on and turn-off times;

Turn-on / (Turn-on + Turn-off)

(2) the mode of operation that an electric machine is classified, in consideration of thermal limits, e.g., continuous operation, intermittent operation.

Also known as duty ratio.

duty ratio *See* duty cycle.

DVM *See* digital voltmeter.

DWT *See* discrete wavelet transform.

DX-center stands for defect unknown(X)/ complex. Name originally given to defects that caused persistent photoconductivity (PPC) in GaAs. The term is now commonly applied to similar defects in both III-V and II-VI compound semiconductors. The presently accepted interpretation of the microscopic nature of the DX-center is a large deformation associated with a negatively charged substitutional impurity.

dyadic decomposition wavelet decomposition in which the dilation is a dyadic number, i.e., 2^j with j being the decomposition level; this corresponds to a octave frequency band division in the frequency domain.

dyadic Green's functions Green's functions that relate together vector field quantities.

dyed resist a photoresist with an added nonphotosensitive chemical that absorbs light at the exposing wavelength.

dynamic allocation allocation of memory space that is determined during program execution. Dynamic allocation can be used to designate space on the stack to store objects whose lifetimes match the execution interval of a subroutine; this allocation is performed upon entry to the subroutine.

dynamic beam control a circuit in a camera designed to instantaneously increase beam current to handle highlights in a scene.

dynamic brake the braking operation of a machine by extracting electrical energy and then dissipating it in a resistor.

dynamic braking since AC motors do not have separate field excitation, dynamic braking is accomplished by continuing to excite the motor from the drive. This causes a generative current to the drives DC intermediate bus circuit. The dynamic brake resistors are then placed across the DC bus to dissipate the power returned. The brake resistor is usually switched by a transistor or other power switch controlled by the drive.

dynamic channel assignment (DCA) a technique of assigning or reassigning radio channels in a communications system in order to respond to current interference or propagation conditions. Such assignment or reassignment may be made before or during radio transmission. DCA is typically implemented in a distributed fashion, with mobile terminals and/or fixed cell sites taking measurements to determine local interference levels, and then applying an algorithm to choose the best radio channel on which to initiate or reassign communication.

dynamic convergence the process of making the electron beam fall on a specified surface during scanning, as in the case of a CRT. This process is necessary for all three-gun CRTs that do not have in-line video displays or CRTs.

dynamic linking deferring the determination of the association between a symbol used in a program module and the object to which it refers until that object must be accessed (i.e., during program execution).

dynamic load line graphical plot showing the instantaneous relationship between voltage across and current through a transistor when driven by an input AC signal.

dynamic matching *See* variational similarity.

dynamic memory allocation the run-time assignment of small units of memory to an active program. Used typically to support growing structures such as lists.

dynamic path reconnect used in IBM's high-end computer systems to allow a "sub-channel" to change its channel path each time it cycles through a disconnect/reconnect with a given device. This enables it to be assigned to another available path, rather than just wait for the currently allocated path to become free.

dynamic programming introduced by Bellman, one of the best known methods for solving the optimal control problems. A recursive method to compute the optimal control as a function of the state, dynamic programming is used in multistage systems by working backward from the final stage.

Dynamic programming is based on The Optimality Principle. The Principle says that optimal control strategy has the feature that regardless of initial state and initial decision, decision in the next step must form an optimal control strategy with respect to the final state of the previous decisions. This principle allows us to find an optimal strategy in a numerical way. The principle serves to limit the number of potentially optimal control strategies that must be investigated. It also implies that optimal control strategies must be determined by working backward from the final stage.

dynamic random access memory (DRAM) a semiconductor memory using one capacitor and one access transistor per cell (bit). The information is stored dynamically on a small charge on the cell capacitance, and can be read or written through the "access transistor" in the cell. Since the charge will slowly leak away (through semiconductor junctions), the cells need to be "refreshed" once every few milliseconds. This is typically done using on-chip circuitry. DRAMs have very high storage density, but are slower than SRAMs (static RAMs). *See also* burst refresh, distributed refresh.

dynamic range refers to the range of input signal amplitudes over which an electronic device will operate within a set of specified parameters. Usually expressed in decibels. In a communications receiver, the upper end of the dynamic range is determined by the largest tolerable input signal, while the lower end is set by the receiver's sensitivity. The sensitivity is the minimum discernible signal for a specific signal-to-noise ratio (SNR). *See also* signal-to-noise ratio.

dynamic reconfiguration changes of optical paths from sources to detectors which are instantly controllable. Paths of optical signals are controlled and changed by an optical crossbar switch that is usually a spatial light modulator.

dynamic scattering procedure to study the change of state of atoms and molecules by analyzing the frequency shift and fluctuations of scattered light.

dynamic scheduling (1) creating the execution schedule of instructions at run-time by the hardware, which provides a different schedule than strict program order (i.e., a processor issues instructions to functional units out of program order). The processor can dynamically issue an instruction as soon as all its operands are available and the required execution unit is not busy. Thus, an instruction is not delayed by a stalled previous instruction unless it needs the results of that previous instruction.

(2) changing the software program schedule dynamically depending on data or operating conditions.

(3) automatic adjustment of the multiprocessing program at run time that reflects the actual number of CPUs available presently. For instance, a DO loop with 100 iterations is automatically scheduled as 2 blocks with 50 iterations on a two-processor system, as 10 blocks with 10 iterations on a ten-processor system, and as one block on a single-processor machine. This enables one to run multiprocessor programs on single-processor computers.

dynamic simulation *See* direct dynamics.

dynamic stability a measure of a power system to return to a pre-disturbance steady-state condition following a disturbance.

dynamic system *See* static system.

dynamic time division multiple access (D-TDMA) time division multiple access scheme in which the channels are assigned dynamically. *See also* time division multiple access.

dynamic time warping in problems of temporal pattern recognition, each exemplar can be regarded as a sequence of vectors. The process of pattern matching requires to carry out an optimal alignment of the vectors composing the sequences so as to minimize a proper distance. For example, in automatic speech recognition, the problem of isolated word recognition requires producing an optimal alignment between the incoming word to be classified and a reference template. Let

$$\mathbf{A} = [\mathbf{a_1}, \ldots, \mathbf{a_M}]$$
$$\mathbf{B} = [\mathbf{b_1}, \ldots, \mathbf{b_N}]$$

be two sequences of vectors ($\mathbf{a_i}, \mathbf{b_i} \in \mathcal{R}^{\mathbf{p}}$) that must be aligned optimally. Formally, determining the optimal alignment consists of finding a warping function

$$C = c_1, \ldots, c_K$$

where $c(k) = [i_k, j_k]$, such that the distance

$$d(\mathbf{A}, \mathbf{B}) == \doteq \sum_{k=1}^{K} (\mathbf{a_{i(k)}} - \mathbf{b_{j(k)}})^2$$

is minimum. The optimization must take place under the following conditions:
1. *monotonic condition*
$i(k) \geq i(k-1)$ and $j(k) \geq j(k-1)$
2. *boundary conditions*
$i(1) = k(1) = 1$
$i(K) = M$
$j(K) = N$
3. *non-skip condition* $i(k) - i(k-1) \leq 1$ and $j(k) - j(k-1) \leq 1$
4. *efficiency condition*
$|i(k) - j(k)| < Q$

The solution of this problem can be obtained by Belmann's dynamic programming. The algorithm that produces the optimal template alignment is referred to as dynamical time warping (DTW).

dynamic time warping (DTW) a recognition technique based on nonlinear time alignment of unknown utterances with reference templates.

dynamical linear nonstationary continuous-time finite-dimensional system a system described by the linear ordinary differential state-equation

$$x'(t) = A(t)x(t) + B(t)u(t)$$

and the linear algebraic output equation

$$y(t) = C(t)x(t) + D(t)u(t)$$

where

$$x(t) \in R^n$$

is the state vector,

$$u(t) \in R^m$$

is the input vector,

$$y(t) \in R^q$$

is the output vector.

$$u \in L^2_{loc}([t_0, \infty), R^m)$$

is an admissible control, $A(t)$ is $n \times n$ dimensional matrix, with piecewise-continuous elements, $B(t)$ is $n \times m$ dimensional matrix, with piecewise-continuous elements, $C(t)$ is $q \times n$ dimensional matrix with piecewise-continuous elements, $D(t)$ is $q \times m$ dimensional matrix with piecewise-continuous elements. The solution of the state equation has the form

$$x(t, x(t_0), u) = F(t, t_0)x(t_0) + \int_{t_0}^{t} F(t, s)B(s)u(s)ds$$

where $F(t, s)$ is $n \times n$ dimensional transition matrix for a dynamical system.

dynamical linear nonstationary discrete-time finite-dimensional system a system described by the linear difference state equation

$$x(k+1) = A(k)x(k) + B(k)u(k) \quad (1)$$

and the linear algebraic output equation

$$y(k) = C(k)x(k) + D(k)u(k)$$

where $x(k) \in R^n$ is the state vector, $u(k) \in R^m$ is a control vector, $y(k) \in R^q$ is an output vector, and $A(k)$, $B(k)$, $C(k)$, and $D(k)$ are matrices of appropriate dimensions with variable coefficients. Solution of the difference state equation (1) has the form

$$x(k, x(k_0), u) = F(k, k_0)x(k_0) + \sum_{j=k_0}^{j=k-1} F(k, j+1)B(j)u(j)$$

where $F(k, j)$ is $n \times n$ dimensional transition matrix defined for all

$$k \geq j$$

in the following manner:

$$\begin{aligned} F(k, k) &= I_{nxn} \quad \text{for} \quad k \in Z \\ F(k, j) &= F(k, j+1)A(j) \\ &= A(k-1)A(k-2)\ldots A(j+1)A(j) \end{aligned}$$

for $k > j$.

dynamical linear stationary continuous-time finite-dimensional system a system described by the linear differential state-equation

$$x'(t) = Ax(t) + Bu(t) \quad (1)$$

and the linear algebraic output equation

$$y(t) = Cx(t) + Du(t)$$

where

$$x(t) \in R^n$$

is the state vector,

$$u(t) \in R^m$$

is the input vector,

$$y(t) \in R^q$$

is the output vector, A, B, C, and D are constant matrices of appropriate dimensions. The transition matrix of (1) has the form $F(t, s) = e^{A(t-s)}$.

dynamical linear stationary discrete-time finite-dimensional system a system described by the linear difference state equation

$$x(k+1) = Ax(k) + Bu(k) \quad (1)$$

and the linear algebraic output equation

$$y(k) = Cx(k) + Du(k)$$

where $x(k) \in R^n$ is a state vector, $u(k) \in R^m$ is a control vector, $y(k) \in R^q$ is an output vector, and A, B, C, and D are constant matrices of appropriate dimensions. The transition matrix of (1) has the form $F(k, j) = A^{k-j}$.

dynamical systems with delays a system described by the linear state equation

$$x'(t) = A_0 x(t) + A_1 x(t-h) + Bu(t) \quad (1)$$

where $x(t)$ is n-dimensional vector, $u(t)$ is m-dimensional control vector, and A_0, A_1, and B are constant matrices of appropriate dimensions and $h > 0$ is a constant delay. For a given admissible control and initial data, the above differential equation (1) with deviating argument has a unique solution derived by the method of steps.

The state space for dynamical system (1), $X = W_1^{(2)}([-h, 0], R^n)$, is infinite-dimensional Sobolev space of absolutely continuous functions defined on $[-h, 0]$ with values in R^n and with square integrable derivatives.

Linear unbounded operator connected with the dynamical system (1) generates the solution in the state space X and has infinite number of eigenvalues each of finite multiplicity. The corresponding eigenfunctions may form the basis in the infinite-dimensional state space X.

It should be stressed that it is possible to consider another type of linear dynamical systems with delays, namely systems with multiple delays, systems with delays in the control or neutral dynamical systems with delayed derivative.

dynamo a term used to describe any of a variety of rotating machines that convert mechanical to electrical energy, or less commonly, electrical to mechanical energy. Dynamos typically consist of a stationary structure, called the stator, supporting a rotating element called the rotor. Energy conversion occurs via Faraday induction. A field winding (or in some smaller machines, permanent magnets) is mounted on one of the mechanical structures and produces a magnetic flux. An armature winding is mounted on the other structure, and rotation of the rotor produces relative motion between the field flux and the coils of an armature winding, inducing a Faraday voltage in the armature coil. This Faraday induced voltage is the source of electrical energy at the dynamo output.

dynamometer a rotating device used to measure the steady-state torque and power output of rotating machines. Dynamometers generally provide precise control of the load torque applied to a test machine, and power output is determined through precise speed measurements.

E

E modes the wave solutions with the zero magnetic field component along the direction of propagation. Also known as transverse magnetic (TM) modes.

E plane in measuring an antenna's radiation pattern, the plane that contains the current in the element and therefore the electric field intensity vector field. This plane is perpendicular to the H plane cut.

E-beam excitation *See* electron beam excitation.

E-plane sectoral horn a horn antenna where the aperture is formed by flaring the walls in the direction of the E plane. The H-plane dimension is left unchanged from that of the waveguide feed.

early stopping a technique applied to network training that is aimed at assuring good generalization performance. Training on a finite set of data eventually leads to overfitting, and this can be avoided by periodically assessing generalization performance on a set of test data. As training proceeds, network performance on both the training set and the test set gradually improves, but eventually performance on the test set begins to deteriorate, indicating that training should be stopped. The set of network weights that give the best performance on the test data should be employed in the trained network.

early vision the set of (mainly perceptual) processes occurring at an early stage of the vision process, typically at the retinal level.

EAROM electrically alterable programmable read-only memory. *See also* electronically erasable programmable read-only memory.

earth electrode system a network of electrically interconnected rods, plates, mats, or grids installed for the purpose of establishing a low-resistance contact with earth. The design objective for resistance to earth of this subsystem should not exceed 10 Ω.

Earth station the interface point for communications to and from a satellite. An earth station (also known as a hub) consists of an antenna and transmit and receive subsystems.

earth wire an overhead wire which is maintained at ground potential for purposes of lightning shielding and system grounding.

earthing *See* grounding.

EBCDIC *See* extended binary-coded-decimal inter-change code.

ebullient heat transfer the heat transfer process associated with the formation and release of vapor bubbles on a heated surface.

ECC *See* error-correcting code.

ECG *See* electrocardiography.

echo cancellation technique that removes the unwanted effects that result from impedance mismatch. Echo cancellation frequently makes use of adaptive filtering algorithms that can be realized by digital filters.

echo canceller in telephony, a filter that removes echoes caused by leakage of the transmitted signal through a hybrid. The hybrid is the interface between two wire (local) and four wire (long-distance) facilities, and separates inbound and outbound signals. Echo cancellers are used in analog telephony to cancel echoes from signals that traverse the entire round-trip connection, and in full-duplex voiceband modems, where the echo is due to leakage through the near-end hybrid.

echo width in a 2-D scattering problem, the width needed to capture the exact amount of incident power, that when the scattering body is replaced by a cylinder, and the cylinder radiates the captured power, the amount of power received at a specified point is the same as that received if the scattering body is not replaced. Echo width is the 2-D analog of radar cross section in 3-D. The units of echo width are meters.

Eckert, John Presper Eckert is best known as one of the designers of ENIAC (Electronic Numerical Integrator And Calculator), an early computer. Like many computer pioneers during World War II, Eckert was looking for more efficient ways of calculating trajectory tables for artillery and ranging systems for radar. Eckert graduated from the University of Pennsylvania and remained there to work with John Mauchly. Eckert and Mauchly later formed a company and continued to develop and refine their machine. Eckert eventually sold the company to what would become the Sperry Rand Corporation. Here he produced UNIVAC I (Universal Automatic Computer), one of the first commercially successful computers. The chief improvement of this machine over its predecessors was in its use of a stored memory.

ECL *See* emitter-coupled logic.

ecliptic plane of earth's orbit around the sun.

economic dispatch a generation scheme in which units are utilized such that the greatest profit is generated for the utility.

economic interchange an arrangement between interconnected electrical power systems whereby a system can meet its load demand by buying power from one or more of the other systems in the interconnection group.

ectopic beat a heart beat that originates from other than the normal site.

eddy current a circulating current in magnetic materials that is produced as a result of time-varying flux passing through a metallic magnetic material.

eddy current brake a braking device in which energy is dissipated as heat by generating eddy currents.

eddy current drive a magnetic drive coupled by eddy currents induced in an electrically conducting member by a rotating permanent magnet, resulting in a torque that is linearly proportional to the slip speed.

eddy current loss the energy wasted in sustaining undesirable eddy currents in an electrical conductor.

EDFA *See* erbium doped fiber amplifier.

edge (1) a local intensity discontinuity, often corresponding to the boundary of an object, in an image. *See also* graph.

(2) a substantial change, over a small distance, in the values of an image's pixels — typically in the gray level values. Edges can be curved or straight and are important because they are often the boundaries between objects in an image.

edge condition an electric/magnetic field perpendicular to a dielectric/metallic edge shows a singular behavior referred to as the edge condition.

edge coupled microstrip lines the microstrip lines that have the same ground plane and are on the same dielectric substrate and are parallel to each other. The coupling is mainly due to the fringing fields at the edges of the lines.

edge detection the location of edges in an image by computer. *See also* Canny operator, gradient edge detector, Marr-Hildreth operator, Sobel operator, straight edge detection.

edge elements the basis functions that are associated with the edges of the discretizing elements (such as triangles, tetrahedrals, etc.) in a numerical method such as finite element method.

edge enhancement a type of image processing operation where edges are enhanced in contrast, such as by passing only the high spatial frequencies in an image.

edge guide two conductor transmission lines in which one of the conductors is a thin sheet of width substantially larger than the gap to the second conductor. The guided wave is largest at the edge or boundary of the thin sheet conductor, standing across to the second conductor, and propagating in the direction of the thin sheet conductor edge or boundary.

edge-sensitive pertaining to a bistable device that uses the edge of a positive or negative pulse applied to the control input, to latch, capture, or store the value indicated by the data inputs.

edge-triggered *See* edge-sensitive.

Edison, Thomas Alva (1847–1931) Born: Milan, Ohio, U.S.A.

Edison is best known as the holder of 1069 patents secured during his lifetime. Among these were patents for the phonograph and the incandescent filament lamp. Edison was largely self-taught. His early interest in communication devices stemmed from his employment as a telegraph operator. He used the profits from the sale of his first invention, a "stock ticker," to set up a lab in Newark, New Jersey. Always a shrewd commercial developer, he followed the invention of the light bulb with work on developing efficient generators to power these bulbs. Edison is considered the archetypal American inventive genius.

Edison Electric Institute a trade group of investor-owned public electric utilities in the USA.

edit distance the edit distance between two string A and B is defined as

$$D_{edit} = \min\{a + b + c\}$$

where B is obtained from A with a replacements, b insertions, and c deletions. There is an infinite number of combinations $\{a, b, c\}$ to achieve this. One of the ways to find the minimum from these is dynamic programming. Edit distance is also called Levenshtein distance.

EEG *See* electroencephalography.

EEPROM *See* electronically erasable programmable read-only memory.

effective address (1) the computed address of a memory operation.

(2) the final actual address used in a program. It is usually 32 or 64 bits wide.

The effective address is created from the relative address within a segment (that is, relative to the base of a segment), which has had applied all address modification specified in the instruction word. Depending on the configuration of the memory management unit, the effective address may be different from the real address used by a program, i.e., the address in RAM, ROM, or I/O space where the operation occurs.

(3) when a memory location is referenced by a machine instruction, the actual memory address specified by the addressing mode is called the effective address. For example, if an instruction uses an indirect mode of addressing, the effective address is to be found in the register or memory location whose address appears in the instruction.

effective aperture a figure of merit for an antenna giving the equivalent aperture size required to intercept from a field of uniform power density an amount of power equal to that received by the antenna placed in the same field. At a given wavelength, the effective aperture is directly proportional to the gain.

effective dielectric constant (1) simple and single dielectric constant used to describe a complicated configuration of media with a variety of dielectric constants in an equivalent model.

(2) the resulting computational effects of having two dielectric materials in a microstrip transmission line.

effective isotropic radiated power the product of the total radiated power by the directive gain of the antenna.

effective isotropically radiated power (EIRP) in antenna theory, the amount of power needed by an isotropic radiator to produce the same radiation intensity at a receiver as the original antenna in the main beam direction. EIRP, which is expressed in decibel-meters or decibel-watts, can be calculated by multiplying power supplied to an antenna by its directive gain in the desired direction. *See also* effective radiated power.

effective length the ratio of the voltage induced across an antenna terminating impedance divided by the incident field strength.

effective mass an approach whereby a particular response is described using classical equations by defining an effective mass whose value differs from the actual mass. For example, an electron in a lattice responds differently to applied fields than would a free electron or a classical particle.

effective permittivity a simple and single permeability constant used to describe a complicated configuration of media with a variety of permeability constants in an equivalent model.

effective radiated power (ERP) the effective power output from an antenna in a specified direction, including transmitter output power, transmission line loss, and antenna power gain.

efficiency (1) the ratio of the input power to the output power. It is a figure of merit for the energy cost effectiveness of a device.

(2) in antennas, the ratio of the power radiated to the input power. This term is sometimes defined with the mismatch loss $(1-\gamma^2)$ included in the total efficiency of the antenna; other times, it is omitted from the calculation.

efficient estimator an unbiased estimator which achieves the Cramer-Rao bound. *See also* Cramer-Rao bound.

EFIE *See* electric field integral equation.

EGA *See* enhanced graphics adaptor.

EIA Electronics Industry Association.

eigenfunction the name given to an eigenvector when the eigenvectors arise as solutions of particular types of integral equation. *See also* eigensystem, eigenvector.

eigenfunction expansion a method used to expand a given field in terms of eigenfunctions. It is particularly used in modal analysis of waveguide discontinuities.

eigenstate a linear combination of quantum mechanical basis states that is constant in time. A quantum mechanical system starting in an eigenstate will remain unchanged in time except for an overall phase. The phase varies as the product of the eigenvalue and time. Quantum mechanical eigenstates are analogous to normal modes of coupled oscillator systems in classical mechanics.

eigensystem a system where the output of a system is the input function multiplied by a constant. *See also* eigenfunction, eigenvalue, eigenvector.

eigenvalue the multiplicative scalar associated with an eigenfunction or an eigenvector. For example, if $Ax = \lambda x$, then λ is the eigenvalue associated with eigenvector x. If A is a covariance matrix, then λ represents the variance of one of the principal components of A. *See also* eigensystem, eigenvector, principal component.

eigenvalue assignment a technique that, given a set of desired eigenvalues, has the objective to compute a constant state feedback gain K such that the closed-loop state equation has precisely these eigenvalues.

eigenvector for a linear system A, any vector x whose direction is unchanged when operated upon by A. *See also* eigensystem, eigenvalue.

eight connected *See* pixel adjacency.

eighteen connected *See* voxel adjacency.

Einstein coefficients coefficients introduced by Einstein to represent the spontaneous decay rate, A, and the stimulated emission or absorption coefficient, B, in the presence of an electromagnetic energy density or intensity.

EIRP *See* effective isotropically radiated power.

EISA *See* extended industry standard architecture.

elastic scattering (1) a scattering process in which energy is conserved.

(2) the state in which there is no energy transfer between the light wave and the scattering medium, and hence no frequency change.

elasto-optic effect the change in refractive index of a medium due to mechanical forces. Also known as the photoelastic effect.

elastomer a polymer material that can undergo reversible shape changes, expanding or contracting under influence of an applied electric field; often used for mechanical light modulation devices.

elbow in URD work, the termination of a buried cable where it attaches to the distribution transformer.

electret a material similar to ferroelectrics, but charges are macroscopically separated and thus are not structural. In some cases the net charge in the electrets is not zero, for instance when an implantation process was used to embed the charge.

electric charge a basic physical quantity that is a source of electromagnetic fields. The units of electric charge are coulombs.

electric charge density the fundamental, macroscopic source of the electromagnetic field that quantifies the average number of discrete electric charges per unit volume. SI units are coulombs per cubic meter.

electric current density a source vector in electromagnetics that quantifies the amount of electric charge crossing some cross–sectional area per unit time. The direction of the electric current density is in the direction of electric charge motion. SI units are amperes per square meter.

electric field in a region of space, if a test charge q experiences a force F then the region is said to be characterized by an electric field of intensity E given by

$$E = \frac{F}{q}$$

electric field integral equation (EFIE) the integral equation based on the boundary condition of the total electric field. It is often used in moment method description of microstrip circuits and metallic antennas. *See also* moment method.

electric field intensity a force field that is a measure of the magnitude and direction of the force imparted upon a discrete charge normalized to the discrete charge's value. Depends on material characteristics. The units are volts per meter.

electric flux density basic electromagnetic field quantity used to describe the effects of permeable matter to the electric field; it is expressed in SI units of coulombs per square meter.

electric furnace a method of smelting metals and applying high heat for industrial processes which makes use of the heat from an electric arc struck between (typically) carbon electrodes.

electric permittivity tensor relationship between the electric field vector and the electric displacement vector in a medium with no hysteresis; displacement divided by the electric field in scalar media.

electric polarization vector an auxiliary vector in electromagnetics that accounts for the creation of atomic dipoles in a dielectric material due to an applied electric field. Macroscopically, the electric polarization vector is equal to the average number of electric dipole moments per unit volume. Mathematically, $P = D - \epsilon_0 E$, where D is the electric flux density, E is the electric field intensity, and ϵ_0 is the free space permittivity. SI units are coulombs per square meter.

electric susceptibility tensor relationship between the electric field vector and the electric polarization vector in a medium with no hysteresis. It is the polarization divided by the permittivity of free space and the electric field in scalar media.

electric vector potential a vector function that is used to derive solutions for electric and magnetic fields.

electric vehicle a vehicle powered by an electrical energy storage device such as batteries.

electrical breakdown *See* breakdown.

electrical degrees a convenient way of representing the distance around the circumference of a machine with two poles spanning the entire 360° of the circumference,

$$\text{Electrical Degree} = \text{Pairs of poles} \times \text{Mechanical Degree}$$

electrical network a collection of interconnected electrical devices.

electrical tree a microscopic cracking pattern which forms in the insulation of electric power cables which are not exposed to water *See* tree, water tree.

electrically alterable read-only memory (EAROM) a PROM device that can be erased electronically. More costly than the EPROM (erasable PROM) device, which must be erased using ultra-violet light.

electrically erasable programmable read-only memory (EEPROM) a nonvolatile semiconductor memory, it is used at the place of PROM or EPROM. They can be programed and erased by electrical means.

electro-acoustic smart material one of several materials that have self-adaptive characteristics in their acoustic behavior (such as transmission, reflection, and absorption of acoustical energy) in response to an external stimulus applied as a function of the sensed acoustical response.

electro-optic coefficient a parameter that describes the change in refractive index in a medium with application of an electric field. The linear electro-optic coefficient describes media where the index change is linearly related to applied field; the quadratic electro-optic coefficient describes media where the index change is related to the square of the applied field, i.e., the Kerr effect.

electro-optic device any device that uses the electro-optic effect, such as for optical beam modulation and deflection.

electro-optic effect an optical phenomenon in certain types of crystals in which the application of an applied electric field results in a change in the dielectric tensor, or equivalently a change in the refractive index of the medium. In the linear electro-optic effect, the resulting change in refractive index is proportional to the electric field strength; in the quadratic electro-optic effect, the resulting change in refractive index is proportional to the square of the electric field strength. The linear electric-optic effect was first studied by F. Pockels in 1893.

electro-optic modulator a device that uses the electro-optic effect to alter the temporal and spatial character of a light beam.

electro-optic scanner a device that uses the electro-optic effect to scan a light beam across a range of angles.

electro-optic smart materials materials in which optical properties are changed self-adaptively with an external electric stimulus proportional to the sensed optical characteristics.

electro-optic switch a device that uses the electro-optic effect to switch a light beam on or off.

electro-optic wave retarder a device that will retard the phase of an optical beam by a fixed amount using the electro-optic effect; in particular, the retardation of one polarization component of the light beam using the electro-optic effect in a birefringent material.

electroacoustics science of interfacing between acoustical waves and corresponding electrical signals. This includes the engineering of transducers (e.g., loudspeakers and microphones), but also parts of the psychology of hearing, following the notion that it is not necessary to present to the ear signal components that cannot be perceived.

electrocardiography (ECG) the device (electrocardiograph) or the output (electrocardiogram) depicting the body surface recording of the electrical activity of the heart.

electroencephalography (EEG) recordings of the electrical potentials produced by the brain.

electroluminescence a general term for optical emission resulting from the passage of electric current.

electrolyte current-conducting solution between two electrodes or plates of a capacitor, at least one of which is covered by a dielectric.

electrolytic capacitor a capacitor solution between two electrodes or plates of a capacitor, at least one of which is covered by a dielectric.

electromagnet a magnet that employs an electric current in a coil to produce a magnetic field.

electromagnetic compatibility (EMC) the ability of a system or equipment to operate within design tolerances in its intended environment, with adjacent systems and equipment, and with itself, so that the effect of any electromagnetic disturbances produced by the systems or equipment is reduced.

electromagnetic energy energy contained in electromagnetic fields and associated polarizable and magnetizable media.

electromagnetic environmental effects encompasses all electromagnetic disciplines, including electromagnetic compatibility (EMC); electromagnetic interference (EMI); electromagnetic vulnerability (EMV); electromagnetic pulse (EMP); radiation hazard (RADHAZ) (hazard of electromagnetic radiation to personnel, ordnance, and fuels (HERP, HERO, HERF)); lightning, p-static; electrostatic discharge (ESD), and emission control (EMCON).

electromagnetic interference (EMI) (1) any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics/electrical equipment. It can be induced intentionally, as in some forms of electronic warfare, or unintentionally, as a result of a spurious emissions and responses, intermodulation products, and the like. Additionally, EMI may be caused by atmospheric phenomena, such as lightning and precipitation static and non-telecommunication equipment, such as vehicles and industry machinery.

(2) unwanted high-frequency electrical signals, also known as radio frequency interference (RFI), which can be generated by power electronic circuits switching at high frequencies. The signals can be transmitted by conduction along cables (450 kHz to 30 MHz) or by radiation (30 MHz to 40 GHz) and can interfere with control or other electronic equipment.

electromagnetic interference filter a filter used to reduce or eliminate the electromagnetic interference (EMI) generated by the harmonic current injected back onto the input power bus by switching circuits. The harmonic current is caused by the switch action that generates switch frequency ripple, voltage and current spikes, and high-frequency ringing. Generally called an EMI filter.

electromagnetic pulse (EMP) a large impulsive-type electromagnetic wave generated by nuclear or chemical explosions.

electromagnetic radiation an electromagnetic wave created by the acceleration or deceleration of charge.

electromagnetic smart materials materials such as shielding materials, radar-absorbing materials (RAMs), and electromagnetic surface materials, in all of which some electromagnetic properties can be adaptively controlled by means of an external stimulus dictated by the sensed electromagnetic response.

electromagnetic spectrum the frequency and wavelength of electromagnetic radiation. We have the following classification reported in the figure, while the microwave frequency band designations is reported in the table.

electromagnetic susceptibility a device's failure to perform appropriately if there is an electromagnetic disturbance.

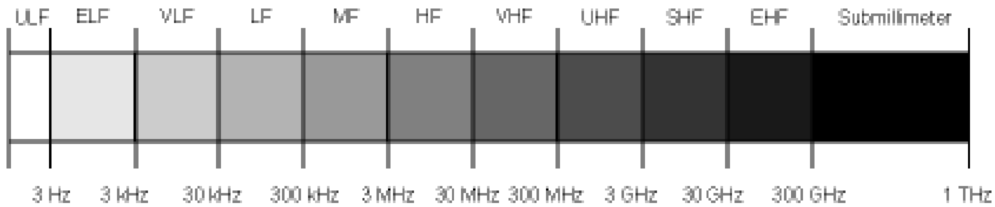
electromagnetic torque the torque produced in a machine by the interaction of the magnetic fields and/or by the varying reluctance principle where the field attempts to maximize its intensity in a machine during electromechanical energy conversion.

electromagnetic vulnerability (EMV) the inability of a device, equipment, or system to perform without degradation when subjected to electromagnetic environment of a specified power level and frequency range.

electromagnetic wave wave in which the electric and magnetic variables are solutions of the Maxwell–Heaviside equations.

electromagnetic wave propagation the phenomenon of electromagnetic energy propagating in the form of waves of the coupled electric and magnetic field intensity vectors.

electromagnetically induced transparency a technique to render optically dense media transparent by using a long-lived quantum



ULF	Ultra Low Frequency
ELF	Extremely Low Frequency
VLF	Very Low Frequency
LF	Low Frequency
MF	Medium Frequency
HF	High Frequency
VHF	Very High Frequency
UHF	Ultra High Frequency
SHF	Super High Frequency
EHF	Extremely High Frequency
Submillimeter	

Electromagnetic spectrum.

mechanical coherence. Depending on the quantum mechanical system, electromagnetically induced transparency can be viewed as a special case of effects such as Fano interference or coherent population trapping applied to optically dense media.

electromagnetics the study of the effect of electric charges at rest and in motion.

electromechanical equation a basic nonlinear equation that governs the rotational dynamics of a synchronous machine in stability studies. The equation is given by

$$2Hd^2\delta/\omega_s dt^2$$

where H is a constant defined as the ratio of the kinetic energy in megajoules at synchronous speed to the machine rating in MVA, ω_s is the synchronous speed in rads per second, and δ is the load angle expressed in electrical degrees. Various forms of the swing equation serve to determine stability of a machine within a power system. Solution of the swing equation yields the load angle δ as a function of time. Examination of all the Swing curves (plot of δ w.r. to time) shows whether the machines will remain in synchronism after a disturbance. *See also* swing equation.

electromechanical relay a protective relay that uses electrical, magnetic, and mechanical circuits to implement the operating logic.

electron band a range or band of energies in which there is a continuum (rather than a discrete set as in, for example, the hydrogen atom) of allowed quantum mechanical states partially or fully occupied by electrons. It is the continuous nature of these states that permits them to respond almost classically to an applied electric field.

electron beam excitation electron impact excitation due to a free electron beam rather than, for example, the conduction electrons in a gas discharge; permits high-pressure excitation without arcing.

Microwave frequency band designations

Frequency	Wavelength	IEEE Radar Band Designation	
		Old	New
1–2 GHz	30–15 cm	L	D
2–3 GHz	15–10 cm	S	E
3–4 GHz	10–7.5 cm	S	F
4–6 GHz	7.5–5 cm	C	G
6–8 GHz	5–3.75 cm	C	H
8–10 GHz	3.75–3 cm	X	I
10–12.4 GHz	3–2.42 cm	X	J
12.4–18 GHz	2.42–1.67 cm	Ku	J
18–20 GHz	1.67–1.5 cm	K	J
20–26.5 GHz	1.5–1.13 cm	K	K
26.5–40 GHz	1.13 cm–7.5 mm	Ka	K
40–300 GHz	7.5–1.0 mm	mm	

electron beam lithography lithography performed by exposing resist with a focused beam of electrons.

electron beam welding a welding process that produces coalescence of metals with the heat obtained from a concentrated beam composed primarily of high-velocity electrons impinging on the surfaces to be joined.

electron collision frequency the average number of collisions per second an electron has with heavy particles in a medium such as plasma.

electron impact excitation excitation of an atom or molecule resulting from collision by an electron.

electron multiplication the phenomenon where a high-energy electron strikes a surface and causes additional electrons to be emitted from the surface. Energy from the incident electron transfers to the other electrons to cause this. The result is electron gain proportional to the incident electron energy.

electron oscillator model simplified classical model for an atomic or molecular medium in which the charges are assumed to be bound together by springs rather than quantum mechanical potentials; provides good qualitative explanation for absorption and dispersion.

electron plasma a plasma medium in which electrons are the mobile charge carriers and the ions form the stationary compensating positive charge background.

electron wave the wave described by Bloch function solutions to the problem of an electron in a periodic lattice of ions.

electron-beam lithography refers to a lithographic (or photographic) process in which the exposure energy is provided by the energy carried by a beam of focused electrons rather than by photons (light).

electronic bottleneck the factor limiting the speed and capacity of a fiber optic communication network is ultimately the link between photons of light and the electronics required to transmit or receive and process them. In order to exploit the full bandwidth capacity of a single-mode optical fiber an optical network should minimize the number of optical to electrical conversions and instead process the signals in the optical domain.

electronic brake a power electronic system designed to decelerate a motor. For an induction machine, the brake supplies DC current to the stator winding, producing a stationary magnetic field, negative slip, and braking torque.

electronic motor starter starter in which solid state devices provide reduced voltage to the motor for starting, thus limiting the starting current.

electronic nonlinear response the nonlinear optical response resulting from the motion of bound electrons. It is characterized by moderately large response and very short (several fs) response times.

electronic overload device an overload device that employs an electronic circuit to sense motor voltage and current for the purpose of providing precise motor overload protection. *See also* overload heater, overload relay.

electronic switch an electronic circuit that controls analog signals with digitary (binary) signals.

electronic transition alteration in the electronic structure of a material such that one electron temporarily changes its energy level through the absorption or emission of energy.

electronic warfare contention for the control of the electromagnetic (EM) spectrum, to allow active and passive EM sensing and communications while denying the same ability to adversaries. Includes deceptive EM techniques.

electronically commutated machine a DC machine with rotor-mounted permanent magnets, and concentrated (square) stator windings. The machine fundamentally behaves like a DC machine with linear speed and torque characteristics, and hence is also called a brushless DC machine. The machine is distinguished from conventional DC machines in its substitution of a six-switch inverter for brushes and copper commutator bars and in its need for the rotor position information in real time.

electronically erasable programmable read-only memory (EEPROM) a term used to denote a programmable read-only memory where the cells are electronically both written and erased. Also known as electrically alterable read-only memory. *See also* electronically programmable read-only memory.

electronically programmable read-only memory (EPROM) Programmable read-only memory that is electronically written but requires ultraviolet light for erasure.

electroplastic effect plastic deformation of metals with the application of high-density electric current.

electroplastic smart material material with smart properties of elastic deformation changes proportional to a controlled electric current applied in proportion to the sensed deformation.

electrorheological property property exhibited by some fluids that are capable of altering their flow characteristics depending on an externally applied electric field.

electrorheological smart fluid fluid with smart flow characteristics dictated to change self-adaptively by means of an electric field applied in proportion to the sensed flow parameters.

electrorheological smart material material with smart properties of elastic deformation changes proportional to a controlled electric current applied in proportion to the sensed deformation.

electroslag welding a welding process that produces coalescence of metals with molten slag that melts the filler metal and the surfaces of the parts to be joined.

electrostatic discharge (ESD) the discharge of a body through a conducting path between two pins of an IC. Circuits located at the inputs and outputs of ICs protect the internal devices from ESD events.

electrostatic precipitator a method of extracting dust from stack gases or ventilating systems in which ions are laid on the dust particles by high-voltage electrodes and then attracted electrostatically into a trap.

electrostatic voltmeter a voltmeter, typically used for voltages in the kilovolt range, in which the pointer is moved by the electrostatic attraction of a pair of metal plates across which the voltage to be measured is applied.

electrostriction the tendency of materials to become compressed in the presence of an applied electric field. The change in density is proportion to the square of the electric field strength. This process leads to an increase in the refractive index of the material, describable by $\delta n = n_2 I$, where n_2 is the (positive) coefficient of the nonlinear refractive index and I is the intensity of the field in units of power per unit area. For condensed matter, a typical value of n_2 is 10^{-20} m^2/W.

element factor in antenna theory, that part of the radiation pattern that is governed by the geometrical shape of the antenna that constrains the current.

Elias' upper bound for any (n, k) block code, the minimum distance is bounded asymptotically as

$$\frac{d_{\min}}{n} \leq 2A(1 - A)$$

where the parameter A is related to the code rate through the equation

$$\frac{k}{n} = 1 + A \log_2 A + (1 - A) \log_2 (1 - A)$$

$$0 \leq A \leq \frac{1}{2}$$

ellipse detection the detection of ellipses in digital images, often with a view to locating elliptical objects or those containing ellipses; ellipse detection is also important for the location of circular features on real objects following orthographic projection or perspective projection.

ellipsometry measurement of the changes of light polarization produced by scattering.

elliptic *See* elliptic filter.

elliptic filter (1) filter with an equal ripple passband frequency response, but in which the stop band also exhibits an equal ripple (peaks) stopband response. Also known as a Caurer filter.

(2) member of a class of low pass, high pass, band pass and band stop filters with an equiripple characteristic, designed to achieve optimally rapid rollof rates near cutoff frequencies (*See also* Butterworth filter and Chebyshev filter) at the expense of a loss of monotonicity in both the passbands and the stopbands. For example, an elliptic low pass filter design is equiripple in the passband and stopband, and has a squared magnitude response of the form

$$|H(jw)|^2 = \frac{1}{1 + \epsilon^2 U_N^2 (w/w_c)},$$

where $U_N(w)$ is a Jacobian elliptic function.

elliptical polarization the polarization state of a radiated electromagnetic field in which the tip of the electric field vector traces an ellipse as a function of time for a fixed position. The sense of rotation of the electric field vector is either right-hand or left-hand (clockwise or counter-clockwise). Circular polarization and linear polarization are special cases of elliptical polarization.

embedded computer (1) a computing machine contained in a device whose purpose is not to be a computer. For example, the computers in automobiles and household appliances are embedded computers.

(2) a device, consisting of a microprocessor, firmware (often in EPROM), and/or FPGAs/EPLDs, which is dedicated to specific functions, and becomes an inseparable component of a device or system, in contrast to devices that are controlled by stand-alone computers. Embedded computers use embedded software, which integrates an operating system with specific drivers and application software. Their design often requires special software–hardware codesign methods for speed, low power, low cost, high testability or other special requirements.

(3) software that is part of a larger system and performs some of the requirements of that system; e.g., software used in an aircraft or rapid transit system. Such software does not provide an interface with the user. *See* firmware.

embedded computer system *See* embedded computer, embedded system.

embedded passives 3-D packaging solution, consisting of embedding passive elements into the mounting substrate, for increasing the packaging efficiency.

embedded system software that is part of a larger system and performs some of the requirements of that system; e.g., software used in an aircraft or rapid transit system. Such software does not provide an interface with the user. *See also* firmware.

EMC *See* electromagnetic compatibility.

EMI *See* electromagnetic interference.

EMI filter *See* electromagnetic interference filter.

emission credit a scheme in the USA for the control of nitrous oxide and sulfur dioxide emissions from industrial plants. A utility can purchase from the government the right to emit a certain quantity of pollutant. If it does not emit this amount, the credit can be sold on the market to another plant which may need to emit some pollutant. The resale value of the pollution credit forms a financial incentive for a facility to emit as little pollution as possible.

emissivity the fraction of the power incident on a material that is reradiated after being absorbed by the material. For a material in thermal equilibrium, the emissivity is equal to the absorptivity.

emitter follower *See* common collector amplifier.

emitter-coupled logic (ECL) a very high speed bipolar transistor logic circuit family.

emitter-coupled pair *See* differential pair.

EMP *See* electromagnetic pulse.

empirical distribution function *See* histogram.

empirical model mathematical model based on curve-fitting specific mathematical functions to measured data, rather than on device physics. Empirical models generally have a low to midrange modeling valuation coefficient.

EMTP the Electro-Magnetic Transient Program, a computer program which simulates an electric power system such that its response to disturbances may be accurately predicted.

emulate executing a program compiled to one instruction set on a microprocessor that uses an incompatible instruction set, by translating the incompatible instructions while the program is running.

emulation a model that accepts the same inputs and produces the same outputs as a given system. To imitate one system with another. *Contrast with* simulation.

emulation mode state describing the time during which a microprocessor is performing emulation.

emulator (1) the firmware that simulates a given machine architecture.

(2) a device, computer program, or system that accepts the same inputs and produces the same outputs as a given system. *Compare with* simulator.

EMV *See* electromagnetic vulnerability.

encapsulation property of a program that describes the complete integration of data with legal process relating to the data.

enclosure a box, cabinet, wall, fence, barrier, or other means designed to protect personnel from accidentally contacting energized electrical parts and to protect the electrical parts from physical damage.

encoder (1) a device that directly creates a digital signal based on an analog value.

(2) a logic circuit with 2^N inputs and N outputs, the outputs indicating the number of the one input line that is asserted.

(3) a device used to obtain positional information. The encoder uses a disk mounted on the shaft of a rotating machine and a light source. The combination provides lights pulses that can be decoded to provide the angular position of the motor. *See also* absolute encoder and incremental encoder.

encoding (1) the act of placing information to be transmitted in a form that can be transmitted over a particular medium and will be recognizable by the receiver. *See also* coding.

(2) in computing systems, to represent various pieces of information by a defined sequence of the binary digits 0 and 1, called bits. To apply the rules of a code.

encryption the transformation employed to transform information to be transmitted (plaintext) into a format that is unintelligible (ciphertext or a cryptogram). The ciphertext can then be transmitted via a communication channel without revealing the contents of the plaintext. This is achieved by means of an encryption key. A system for performing encryption is also known as a cipher. The information to be encrypted is referred to as plaintext, and the encrypted message resulting from encryption is referred to as ciphertext. The intended receiver of the ciphertext also has the encryption key, and by having both the ciphertext and the encryption key available, the original plaintext can be recovered. *See also* encryption key, block cipher, stream cipher, public key cryptography, private key cryptography.

encryption key a codeword used for decryption of ciphertext into plaintext in encryption systems. Ciphertext can then be transmitted via a communication channel without revealing the contents of the plaintext. The plaintext can only be recovered by someone in possession of the encryption key. *See also* encryption, block cipher, stream cipher.

end bell the cap that forms the end of the stator housing for an electric machine with a cylindrical frame.

end-around carry technique used in one's complement arithmetic, in which a carryover of the result of an addition or subtraction beyond the leftmost bit during addition (or subtraction) is "wrapped around" and added to the result.

end-effector a part found at the free end of the chain of the links which form a manipulator. Position and orientation of the manipulator are referred to the end-effector. The frame attached the end-effector is known as end-effector frame. The end-effector can be a gripper or it can be attached to the end-effector. The orthonormal end-effector frame consists of three unit vectors *a*-approach (it approaches the object) *o*-orientation (which is normal to the sliding plane between the fingers of the gripper), and n-normal vector to two others so that the frame (n, o, a) is right-handed.

end-fire the pattern factor is maximum in the E plane (for a dipole antenna along the z axis, this is the plane where $\theta = 0$ or 180 degrees).

end-fire array a linear phased array antenna in which the amplitudes and phases of the element excitations are adjusted such that the direction of maximum radiation is along the axis passing through the center of the array elements.

endian an adjective used with a qualifier to indicate how long values are constructed from smaller values that reside in memory. A "big-endian" machine constructs long values by placing the smaller parts from the lower addresses at the left end of the value (the "big" end).

endoscope remote imaging system used by physicians to examine a patient's internal organs. The cylindrical rod is placed either through an existing opening in the body or through a small incision. The rod contains an illuminating fiber optic bundle and an optical system to deliver the image to a video monitor. In a conventional endoscope, the image is transmitted through a series of lenses to a camera outside of the patient. In an electronic endoscope the image is collected by a CCD camera positioned inside the patient.

endpoint detection the process of isolating spoken words, typically used subsequently for word recognition.

ends a crimped-type wire connector.

energy that which does work or is capable of doing work. In electrical systems, it is generally a reference to electrical energy measured in kilo-watt hours.

energy band continuous interval of energy levels that are allowed in the periodic potential field of the crystalline lattice.

energy banking pertaining to the maintenance of a thermal unit on hot reserve.

energy compaction in a transformation, the concentration of the input signal energy into a relatively small part of the transformed signal. A linear transform of a random vector compacts the signal energy when the energy or variance of a small number of transform coefficients is large relative to the variance of the other coefficients.

energy conservation the conservation of energy between the input and output of a system; i.e., the energy of the output signal is equal to that of the input signal to within a constant factor. A unitary or orthogonal transform conserves energy in that the energy or magnitude of the output vector is equal to that of the input vector.

energy gap the width of the energy interval between the top of the valence band and the bottom of the conduction band.

energy level one of the specific values possible for the energy of an electron in an atom or molecule.

energy product the product of the magnetic flux density, B and magnetic field intensity, H at any operating point on the normal demagnetization curve, indicating the energy delivered by the magnet. The maximum energy product is commonly used to designate varying grades of materials.

energy relaxation time the characteristic time for energy loss to scattering processes.

energy signal a continuous time signal $f(t)$ is an energy signal if

$$\int_{-\infty}^{\infty} f(t)^2 dt < \infty .$$

For example, the signal $f(t) = e^{-t}, t \geq 0$ is an energy signal. The signal $f(t) = 1$ is not an energy signal. The definition has practical significance if the signal f is a voltage, or current, applied to an electric circuit, as shown in the figure. The energy dissipated by the circuit is given by

$$\frac{1}{R}\int_{-\infty}^{infty} v(t)^2 dt \; .$$

A discrete time signal is an energy signal if

$$\sum_{k=-\infty}^{\infty} f(k)^2 < \infty \; .$$

energy-density spectrum for a continuous time signal $x(t)$ the function $|X(w)|^2$, where $X(w)$ is the Fourier Transform of x. The function $|X(w)|^2$ is referred to as an energy-density spectrum because $\Delta|X(w_0)|^2$ is proportional to the energy in the signal x in a bandwidth Δ around the frequency w_0. Analogously, a discrete time signal $x[n]$ has an energy-density spectrum $|X(\Omega)|^2$.

enhanced backscattering peak of the angular distribution of scattered intensity in the retroreflection direction, due to multiple scattering of light in dense volumes or very rough boundaries.

enhanced graphics adaptor (EGA) a video adapter proposed by IBM in 1984. It is capable of emulating CGA and MDA. It can reach 43 lines with 80 columns. In graphic mode, it can reach 640×350 pixels (wide per high) with 16 colors selected from a pallet of 64.

enhanced small device interface *See* enhanced small disk interface.

enhanced small disk interface (ESDI) mass storage device interface similar to MFM and RLL except that the clock recovery circuits are in the peripheral device rather than in the controller. Originally designed by Maxtor.

enhancement improvement of signal quality without reference to a model of signal degradation. *See* restoration, image enhancement.

enhancement mode an FET that is off when zero volts bias is applied from gate to source.

ENI *See* equivalent noise current.

ENR *See* excess noise ratio.

enriched uranium uranium which contains 1.5% to 5% of fissile U-235 and is thus suitable for use in power reactors.

enrichment the process of increasing the ratio of one isotope of a chemical element, e.g. fissile uranium, to another, less desirable isotope, e.g. non-fissile uranium.

ensemble processor a parallel processor consisting of a number of processing elements, memory modules, and input/output devices under a single control unit. It has no interconnection network to provide interprocessor or processor-memory communications.

entity a software process that implements a part of a protocol in a computer communication network.

entity relationship diagram a diagram that describes the important entities in a system and the ways in which they are interrelated.

entropy information theoretic quantity representing the amount of uncertainty in guessing the value of a random variable. For a discrete random variable X, with probability mass function $p(x)$ defined on the support set $\mathcal{S}$, the entropy, $H(X)$ is defined as

$$H(X) = -\sum_{x \in \mathcal{S}} p(x) \log p(x)$$

Also written $H(p)$, emphasizing the sole dependence upon the mass function. *See also* differential entropy, relative entropy, mutual information.

entropy coding a term generally used as equivalent to lossless source coding. The name comes from the fact that lossless source coding can compress data at a rate arbitrarily close to the entropy of the source.

entropy estimation noiseless source coding theorem states that the bit rate can be made arbitrarily close to the entropy of the source that generated the image. Entropy estimation is the process of characterizing the source using a certain model and then finding the entropy with respect to that model. The major challenge here is to approximate the source structure as close as possible while keeping the complexity of the model and the number of parameters to a minimum.

entry mask bit pattern associated with a subroutine entry point to define which processor registers will be used within the subroutine and, therefore, which should be saved upon entry to the subroutine. Some processor designs perform this state saving during the execution of the instruction that calls a subroutine.

entry point instruction that is the first instruction in a subroutine.

ENV *See* equivalent noise voltage.

envelope the imaginary waveform produced by connecting the peak values of a modulated carrier wave. For AM, the amplitude of the carrier sinusoid is a function of time

$$e(t) = E(t) \sin(\omega_c + \theta)$$

where $E(t)$ is a function of the intelligence. In this case, the envelope of the resulting double sideband AM waveform, $e(t)$, is a scaled representation of the intelligence.

envelope delay the time it takes for a specific reference point on the envelope of a modulated wave to propagate between two points in a circuit or transmission system. In a time invariant system, the envelope delay is the derivative (i.e., rate of change) of phase (in radians) with respect to angular frequency (also in radians) as the envelope of the signal passes between two points in the system. Also referred to as time delay.

envelope detection a device that produces an output waveform that is proportional to the real envelope of its input, i.e., when the input is $A(t)cos(2\pi f_c t + \theta(t))$, the output is $v(t) = CA(t)$ with C a constant.

envelope detector the optimum structure for detecting a modulated sinusoid with random phase in the presence of additive white Gaussian noise.

environment a set of objects outside the system, a change in whose attributes affects, and is affected by, the behavior of the system.

environmental dispatch a generation scheme in which units are committed so as to minimize disturbance to the natural environment.

epipolar line in stereo vision, the intersection of an image plane with an epipolar plane, which is the plane identified by a point P and the centers of projection of the two cameras.

epitaxial layer a doped layer of semiconducting material grown on the surface of a prepared semiconductor substrate. Various methods are utilized, resulting in a very thin and dimensionally well controlled active layer for fabricating semiconductor devices. "Epi" parts generally are more uniform and perform better than ion implanted devices, but are also more expensive to fabricate.

EPROM *See* erasable programmable read-only memory.

equal area criterion a criterion used often in power system studies whenever the stability of a single machine system needs to be determined without actually solving the swing equation. It is a direct approach. *See also* electromechanical equation or swing equation.

equal gain combining a method of diversity combining in which the outputs of several communication channels are first co-phased and then summed. The resulting signal has increased mean power and reduced fade depth. *See also* angle diversity, antenna diversity.

equal ripple in-band power gain or power loss vs. frequency response in which the minimum dips are equal in power and maximum peaks are equal in power.

equalization a method used in communication systems to compensate for the channel distortion introduced during signal transmission.

equalizer a device used at the receiver (typically a digital filter) that attempts to suppress or cancel intersymbol interference.

equalizer adaptive an equalizer that automatically adjusts its parameters to suppress or cancel intersymbol interference. In the case of a digital filter, the parameters are the filter coefficients, which are adapted to minimize a cost criterion (e.g., mean-squared error).

equalizer decision-feedback a nonlinear digital filter that consists of a linear prefilter $P(z)$ for suppressing precursor intersymbol interference, and a feedback filter $F(z)$ for suppressing postcursor intersymbol interference.

equalizer minimum mean squared error (MMSE) a digital equalizer (filter) in which the coefficients are selected to minimize the mean-squared error between the transmitted symbols and the filter outputs.

equalizer transversal an equalizer that is implemented as a finite impulse response digital filter. Also called a "tapped-delay line."

equalizer zero-forcing an equalizer in which the parameters are adjusted to eliminate intersymbol interference (at the expense of enhancing the noise).

equalizing pulse interval series of 12 sync pulses inserted in the vertical blanking interval of each field of the NTSC composite video signal. The equalizing pulse makes a transition between the composite signal blanking level and the sync level at one-half horizontal line intervals. The duration at the sync level is 3.575 ± 0.425 percent of the horizontal line time (0.45 to 0.5 times the horizontal sync). There are three horizontal lines of equalizing pulses (6 pulses) preceding the vertical synchronization signal and 3 horizontal lines of equalizing pulses (6 pulses) following the vertical synchronization interval. The equalizing pulse interval repeats every field of 262.5 horizontal lines.

equalizing pulses in an encoded video signal, a series of $2\times$ line frequency pulses occurring during vertical blanking, before and after the vertical synchronizing pulse. Different numbers of equalizing pulses are inserted into different fields to ensure that each field begins and ends at the right time to produce proper interlace. The $2\times$ line rate also serves to maintain horizontal synchronization during vertical blanking.

equiband a complex method of chrominance signal demodulation, that does not require dissimilar filters and delay equilization; it most frequently utilizes a bandwidth of 800 KHz.

equilibrium manifold *See* sliding surface.

equilibrium point for a continuous-time system $dx/dt = f(t, x)$, a constant solution x^* such that $f(t, x^*) = 0$. For a discrete-time system $x(k+1) = f(k, x(k))$, a constant solution x^* such that $x^* = f(k, x^*)$.

equilibrium solution consider a dynamic system described by a first-order vector differential equation of the form

$$\dot{x}(t) = f(x(t), t, u(t))$$

If there exists a vector x_e such that

$$f(x_e, t, 0) = 0 \qquad \forall t$$

then whenever $x(t) = x_e$, the system is said to be in equilibrium and x_e is called an equilibrium state.

equilibrium state *See* equilibrium solution.

equipment hazard a possible source of peril, danger, risk, or difficulty.

equiripple filter a filter designed using an iterative algorithm, for example, Remez exchange algorithm, to minimize the maximal deviation from the desired magnitude frequency response in both passband and stopband for a given filter length. It has equal amplitude ripples within the passband and stopband. *See also* Chebyshev filter.

equivalence in continuous-valued logic similar to equivalence in conventional logic equivalence in continuous-valued logic between two variables x and y, which are continuous in the open interval $(0, 1)$, can be defined as

$$e(x, y) = \max\{\min(x, y), \min((1-x), (1-y))\} .$$

See equivalence in logic.

equivalence in logic for two Boolean variables x and y, defined as

$$(x \equiv y) = (\bar{x} \wedge \bar{y}) \vee (x \wedge y)$$

equivalence theorem an electromagnetic theorem: If the tangential magnetic and electric fields are known everywhere on some closed surface S, then these fields may be replaced with equivalent electric and magnetic surface currents, respectively. These equivalent currents will produce the same field structure exterior to S as the original fields and the null field internal to S.

equivalent circuit a combination of electric circuit elements chosen to represent the performance of a machine or device by establishing the same relationships for voltage, current, and power.

equivalent control an algorithm used to determine a system's dynamics when restricted to a sliding surface. The method entails combining the solution to an algebraic equation involving the time derivative of the function describing the sliding surface and the dynamical system's model. *See also* variable structure system and sliding mode control.

equivalent current a theoretical current used to obtain the scattered field from a surface or discontinuity. The equivalent current is formulated to represent the actual physical currents so as to result in an equivalent scattered field.

equivalent impedance the impedance of the windings of an electromagnetic machine reflected to one side (component) of the machine. For example, in a transformer, the equivalent impedance consists of the combined leakage reactances and resistances of the primary and secondary.

equivalent noise current (ENI) a noise current source that is effectively in parallel with either the noninverting input terminal (ENI$^+$) or the inverting input terminal (ENI$^-$) and represents the total noise contributed by the op amp if either input terminal is open circuited.

equivalent noise temperature an alternative way of describing the noise properties of two port networks.

equivalent noise voltage (ENV) a noise voltage source that is effectively in series with either the inverting or noninverting input terminal of the op amp and represents the total noise contributed by the op amp if the inputs were shorted.

equivalent reactance the reactance of the windings of an electromagnetic machine reflected to one side (component) of the machine. *See also* equivalent impedance.

equivalent resistance the resistance of the windings of an electromagnetic machine reflected to one side (component) of the machine. *See also* equivalent impedance.

equivalent source fictitious source used in the equivalence theorem.

equivalent sphere illumination (ESI) the level of sphere illumination that would produce task visibility equivalent to that produced by a specific lighting environment.

equivalent system dynamics a dynamical system model resulting from substituting the *equivalent control* into the plant's modeling equation. The equivalent system's trajectory is confined to a surface that is parallel to the sliding surface if the system's initial condition is off the sliding surface. If the initial condition is on the sliding surface, then the equivalent system's trajectory will stay on the sliding surface.

erasable optical disk a magneto-optical disk that can be both read/written and erased. A thermo-magneto process is used for recording and erasure of information. The recording process uses e.g., the "laser power modulation" or the "magnetic field modulation" technique.

erasable programmable read-only memory (EPROM) a nonvolatile chip memory, it is used in the place of PROM. EPROMs presents a glass on the case that allows one to see the chip. They can be erased by exposing the chip at the ultraviolet light for typically 20 minutes. Once erased they can be reprogrammed. The programming has to be performed by using a special algorithm and a supplementary V_{pp}. Also called UVPROM. *See also* electronically erasable programmable read-only memory.

erasure in a forward error control system, a position in the demodulated sequence where the symbol value is unknown. Depending on the quality of the received signal when no decision is made on a particular bit, the demodulator inserts an erasure in the demodulated data. Using the redundancy in the transmitted data, the decoder attempts to fill in the positions where erasures occurred. *See* binary erase channel.

erbium doped fiber amplifier (EDFA) an optical amplifier based on the rare-earth erbium that can amplify optical signals in the 1550 nm telecommunications window. The useful gain region extends from approximately 1530 nm to 1565 nm.

EREW *See* exclusive reads and exclusive writes.

ergodic process a process that has all possible ergodic properties.

For process $X(t)$ when the time average

$$\lim_{T\to\infty} (1/T) \int_{-T/2}^{T/2} X(t)dt$$

exists and equals the corresponding expected value $E[X(t)]$, it is said that $X(t)$ is ergodic in the mean. There are ergodic properties associated with the mean, autocorrelation, and power spectral density as well as all finite-order joint moments.

ergodicity stochastic processes for which ensemble averages can be replaced by temporal averages over a single realization are said to be ergodic. For a stochastic process to be ergodic, a single realization must in the course of time take on configurations closely resembling the entire ensemble of processes. Stationary filtered white noise is considered ergodic, while the sinusoidal process $A\cos(wt+\phi)$ with random variables A and ϕ is not.

Erlang B a formula (or mathematical model) used to calculate call blocking probability in a telephone network and in particular in cellular networks. This formula was initially derived by A. K. Erlang in 1917, a Danish pioneer of the mathematical modeling of telephone traffic, and is based on the assumption that blocked calls are forever lost to the network. *See also* Erlang C.

Erlang C similar to Erlang B, the formula is based on a traffic model where the call arrival process is modeled as a Poisson process, the call duration is of variable length and modeled as having an exponential distribution. The system is assumed to have a queue with infinite size that buffers arriving calls when all the channels in the switch are occupied. The model is based on the assumption that blocked calls are placed in the queue.

Erlang capacity maximum number of users in the system which leads to the maximum allowable blocking probability (for example, 2%).

erosion an important basic operation in mathematical morphology. Given a structuring element B, the erosion by B is the operator transforming X into the Minkowski difference $X \ominus B$, which is defined as follows:
1. If both X and B are subsets of a space E,

$$X \ominus B = \{z \in E \mid \forall b \in B,\ z+b \in X\}$$

2. If X is a gray-level image on a space E and B is a subset of E, for every $p \in E$ we have

$$(X \ominus B)(p) = \inf_{b\in B} X(p+b)$$

3. If both X and B are gray-level images on a space E, for every $p \in E$ we have

$$(X \ominus B)(p) = \inf_{h\in E}\big[X(p+h) - B(h)\big]$$

with the convention $\infty - \infty = +\infty$ when $X(p+h), B(h) = \pm\infty$. (In the two items above, $X(q)$ designates the gray-level of the point $q \in E$ in the gray-level image X.) *See* dilation, structuring element.

ERP *See* effective radiated power.

error (1) manifestation of a fault at logical level. For example, a physical short or break may result in logical error of stuck-at-0 or stuck-at-1 state of some signal in the considered circuit.

(2) a discrepancy between a computed, observed, or measured value or condition and the true, specified, or theoretically correct value or condition. *See* bug, exception.

error control coding *See* channel coding.

error-correcting code (ECC) code used when communication data information in and between computer systems to ensure correct data transfer. An error correcting code has enough redundancy (i.e., extra information bits) in it to allow for the reconstruction of the original data, after some of its bits have been the subject of error in the transmission. The number of erroneous bits that can be reconstructed by the receiver using this code depends on the Hamming distance between the transmitted codewords. *See also* error detecting code.

error correction capability of a code is bounded by the minimum distance and for an (n,k) block code, it is given by $t = [(d_{min} -$

1)/2], where $[x]$ denotes the largest integer contained in x.

error detecting code code used when communication data information in and between computer systems to ensure correct data transfer. An error detecting code has enough redundancy (i.e., extra information bits) in it to allow for the detection of the original data, after some of its bits have been the subject of error in the transmission. The number of erroneous bits that can be detected by the receiver using this code depends on the Hamming distance between the transmitted codewords. *See also* error-correcting code.

error detection the process of detecting if one or more errors have occurred during a transmission of information. Channel codes are suitable for this purpose. The family of CRC-codes are an example of channel codes specially designed for error detection. *See also* error detecting code.

error detection capability the capability of a code to detect error is bounded by the minimum distance, and for an (n, k) block code, it is given by $d_{\text{min}} - 1$.

error extension the multiplication of errors that might occur during the decoding of a line coded sequence, or during the decoding of a forward error control coded sequence when the number of symbol errors exceeds the error correction capability of the code.

error function mathematical function over some interval in which a calculated result is compared to a known quantity (usually data) by utilizing a difference quantity to determine how well the mathematical function replicates the known quantity over that interval. Most error functions utilize an area or least squares difference function.

error latency length of time between the occurrence of an error and the appearance of the resulting failure.

error recovery process of regaining operational status and restoring system integrity after the occurrence of an error with the use of special hardware and software facilities.

error state diagram a diagram that illustrates all possible error events with respect to an assumed reference event, e.g., an error sequence compared to a reference sequence, both produced by a finite state machine. All possible sequences that diverge and later merge with the reference sequence are accounted for in the diagram. The transfer function of the error state diagram can be used for performance evaluation of detection/decoding algorithms working on noise outputs from a finite state machine.

error-correction the mechanism by which a receiving circuit is able to correct errors that have occurred in an encoded transmission. *See also* Hamming code, error-correcting code.

ESD *See* electrostatic discharge.

ESDI *See* enhanced small disk interface.

ESI *See* equivalent sphere illumination.

ESPRIT acronym for estimation of signal parameters via rotational invariance techniques. A subspace-based estimation technique based on two identical, displaced sensor arrays.

estimation in adaptive control, a key role is played by on-line determination of process parameters. A recursive parameter estimator is present in many adaptive control schema such as self-tuning regulator (explicitly) or model-reference adaptive controller (implicitly).

Usually, parameters estimation is viewed in the broader context of system identification formed by selection of model structure, experiment design, parameters estimation, and validation. In adaptive control, the parameters vary continuously, and it is necessary to estimate them recursively. A basic technique used for parameters estimation is the Least Squares Method. This method is particularly useful if the model has the property of being linear in the parameters.

estimator any function of the sample points. Hence, an estimator is a random variable. To be useful, an estimator must have a good relationship to some unknown quality that we are trying to determine by experiment.

etching a reactive process where material is removed from a semiconductor device or printed circuit board. Usually a photosensitive material is exposed through a photomask, and either a wet chemical process or a dry plasma process is used to selectively remove material to leave a particular pattern behind after the etch process is completed.

Ethernet a standard for interconnecting devices on a local area network (LAN).

Euclidean distance a distance measure between two real valued vectors $(x_1, x_2, \ldots, x_n)$ and $(y_1, y_2, \ldots, y_n)$ defined as

$$D_{Euclidean} = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

Euclidean distance is the special case of Minkowski distance when $\lambda = 2$. *See also* Minkowski distance.

Euler number a topological invariant of an object having an orientable surface. Assuming that the surface is endowed with the structure of a graph with vertices, edges, and faces (where two neighboring faces have in common either a vertex or an edge with its two end-vertices, their interiors being disjoint): the Euler number is $V - E + F$, where V, E, and F are respectively the number of vertices, edges and faces; this number $V - E + F$ does not depend on the choice of the subdivision into vertices, edges, and faces. For a bounded 2-D object in a Euclidean or digital plane, the Euler number is equal to the number of connected components of that object, minus the number of holes in it. For 2-D binary digital figures on a bounded grid, the Euler number can easily be computed by counting the number of occurrences of some local configurations of on and off pixels. Also called genus.

eureka in a multiprocessor system, a coordination (synchronization) operation generating a completion signal that is logically ORed among all processors participating in an asynchronously parallel action. The interpretation and name come from its use in systems that delegate various portions of a search space to different processing modules. A processor executes the eureka operation when it has found the desired object or value; this can serve as a signal for the others to abort their attempts to find a solution.

eutectic alloy composition with minimum melting temperature at the intersection of two solubility curves.

eutectic alloy overload device an overload device that employs a melting alloy as the actuating element. *See also* overload heater, overload relay.

EUV lithography lithography using light of a wavelength in the range of about 5 to 50 nm, with about 13 nm being the most common. Also called soft X-ray lithography.

even function a real-valued function $x(t)$ in which $x(-t) = -x(t)$ for all values of t. *Compare with* odd function.

even mode impedance characteristic impedance of a transmission line when a single and certain even mode exists on it.

even order response a circuit gain or insertion loss versus frequency response in which there are an even number of peaks in the ripple pattern, due to an even number of paired elements in the circuit. Even order circuits exhibit a peak for each element pair and a loss equal to L_{amax} (maximum attenuation loss across the band) at DC (low pass) or at ω_0 (band pass).

even signal a signal that has even symmetry. If $x(t)$ is an even signal, it satisfies the condition $x(t) = x(-t)$. *See also* odd signal.

even-mode characteristic impedance characteristic impedance of a circuit due to an even-mode current or voltage excitation. Often applied in the context of a transmission line coupler where the even-mode excitation consists of applying equal amplitude voltages or currents of identical phase on two conductors. The resulting impedance under this excitation is defined as the even mode characteristic impedance.

even-order response circuit gain or insertion loss versus frequency response in which there are an even number of peaks in the ripple pattern, due to an even number of paired elements in the circuit. Even-order circuits exhibit a peak for each element pair and a loss equal to L_{amax} (maximum attenuation loss across the band) at DC (low pass) or at ω_o (band pass).

event (1) a nonsequential change in the sequencing of macroinstructions in a computer. Events can be caused by a variety of factors such as external or internal interrupts (traps) or branch statements.

(2) a specific instance taken from some sample space, normally with an associated probability or probability density; also commonly an idealized infinitesimal point in (x, y, z, t) space at which some occurrence is taken to happen. For example, a flash of light at time t_0 at position (x_0, y_0, z_0) — event (x_0, y_0, z_0, t_0) — will lead at a later time t_1 to a wave of light passing a point (x_1, y_1, z_1) — namely event (x_1, y_1, z_1, t_1).

event table table listing all events, and their corresponding effects as well as reactions to them. Exception conditions/responses table is a special type of event table.

exact absolute controllability a dynamical system where the attainable set K_∞ is equal to the whole state space $W_1^{(2)}([-h, 0], R^n)$.

exact coding coding methods that reproduce the picture at the receiver without any loss. This method is also called information-lossless or exact coding techniques. Four methods of exact coding are run-length coding, predictive coding, line-to-line predictive differential coding, block coding. However, several coding schemes use these in a hybrid manner.

exact controllability of infinite dimensional system an infinite dimensional system where the attainable set K_∞ is equal to the whole state space X.

exception (1) an unusual condition arising during program execution that causes the processor to signal an exception. This signal activates a special exception handler that is designed to handle only this special condition. Division by zero is one exception condition. Some vendors use the term "trap" to denote the same thing.

(2) an event that causes suspension of normal program execution. Types include addressing exception, data exception, operation exception, overflow exception, protection exception, underflow exception.

exception handler a special block of system software code that reacts when a specific type of exception occurs. If the exception is for an error that the program can recover from, the program can recover from the error and resume executing after the exception handler has executed. If the programmer does not provide a handler for a given exception, a built-in system exception handler will usually be called, which will result in terminating the process that caused the exception. Finally, the reaction to exception can be halt-ing of the system. As an example, a bus error handler is the system software responsible for handling bus error exceptions.

excess delay the arrival times of a component of the impulse response of a wideband communication channel relative to the first arriving component. Hence the total excess delay, the difference in arrival time between the first and last significant components.

excess loss the ratio of the actual propagation loss between two antennas to the free space loss for two antennas separated by the same distance in a vacuum. Usually expressed in decibels.

excess noise (1) thermal noise in excess or exceeding thermal noise at 290°K. The excess noise ratio (ENR) is the ratio of the excess noise to the noise at 290°K, expressed in decibels.

(2) Noise in excess of the thermal noise (n_e), which is a function of the device, frequency and bias current, also known as $1/f$, $1/f_a$, flicker or popcorn noise. This noise rapidly dies off such that above a few megahertz it becomes insignificant. It is a major concern in generating phase noise in oscillators.

$$ENR = 10 \log_{10} \left(\frac{T - 290^\circ K}{290^\circ K} \right)$$

$$n_e = f\left(\text{device}, 1/f^a, I_{bias} \right)$$

excess noise ratio (ENR) a noise source used in noise figure measurements. ENR is the ratio of the source's noise power when it is on to the noise power when it is off. The ENR values are entered and stored in the noise figure meter to calibrate a measurement.

excess-N representation method of representing floating point numbers, in which a positive or negative exponent is stored as a positive integer by adding the value N to it. For example, in excess-128 representation, an exponent of -40 would be stored as the value 88.

exchangeable disk *See* removable disk.

excimer a molecule formed by the excited state of one atom and one or more other atoms that remains a molecule only as long as the excited state lifetime.

excimer laser laser using a gas or gases to create an excited dimer (e.g., KrF), usually resulting in pulsed deep-UV radiation.

excitation population of excited states of a laser medium at the expense of some energy source.

excitation system the DC voltage source and its accompanying control and protection systems connected to the synchronous generator rotor.

exciter a DC source that supplies the field current to produce a magnetic flux in an electric machine. Often it may be a small DC generator, placed on the same shaft of the electrical machine.

exciting current the current drawn by a transformer primary with its secondary open circuited. It is the vector sum of the core loss current I_c and the magnetizing branch current I_m. The exciting current I_e is also the current measured in the open circuit test on a transformer. The exciting current is calculated as the ratio of the primary induced EMF and the impedance of the tank circuit. On load, it is equal to the difference between the primary and reflected secondary currents of the transformer.

exciton laser laser (or laser-like system) in which the amplified field consists of excitons rather than electromagnetic waves or photons.

exclusive OR Boolean binary operator typically used for comparing the status of two variables or signals. Sometimes written "XOR." The truth table for $\oplus \equiv X$ XOR Y

is as follows:

X	Y	$X \oplus Y$
F	F	F
F	T	T
T	F	T
T	T	F

exclusive reads and exclusive writes (EREW) shared memory model, in which only exclusive reads and exclusive writes are allowed.

execution cycle sequence of operations necessary to execute an instruction.

execution time amount of time it takes a computation (whether an instruction or an entire program) to complete, from beginning to end. Time during which an instruction or a program is executed. The portion of one machine cycle needed by a CPU's supervisory-control unit to execute an instruction.

execution unit in modern CPU implementations, the module in which actual instruction execution takes place. There may be a number of execution units of different types within a single CPU, including integer processing units, floating point processing units, load/store units, and branch processing units.

exhaustive search a search through all possibilities before deciding on what action to take. For example, for the maximum-likelihood (exhaustive search) detection of a sequence of k bits, all 2^k possible bit sequences are considered and the one with the largest likelihood is selected.

expanded memory expanded memory specification, EMS, was born for adding memory to PCs (the so-called LIM-EMS). PCs were limited in memory to 640 kb even if the 8088/8086 CPU's limit is 1 Mb. Thus, in order to overcome this limit, the additional memory was added by using a paging mechanism: up to four windows of 16 kb of memory included into the 640 kb to seen up to 8 Mb of memory divided into pages of 16 kb. To this end, special memory boards were built. Currently, the MS-DOS is still limited to 640 kb, but the new microprocessors can address even several gigabytes over the first megabyte. Thus, to maintain the compatibility with the previous version and the adoption of the MS-DOS, the presence of expanded memory is simulated by means of specific drivers.

expectation the integral of a function with respect to some probability measure. If $f(\cdot)$ is a deterministic function and $\boldsymbol{x}$ is random, governed by probability density $p(\boldsymbol{x})$, then

$$E[f(\boldsymbol{x})] = \int_{-\infty}^{\infty} f(\boldsymbol{x})p(\boldsymbol{x})d\boldsymbol{x}.$$

expected value of a random variable ensemble average value of a random variable that is given by integrating the random variable after scaling by its probability density function (weighted average) over the entire range.

expert system a computer program that emulates a human expert in a well-bounded domain of knowledge.

explicit value a value associated with the bit string according to the rule defined by the number representation system being used.

explosion-proof machine National Electrical Manufacturers Association (NEMA) classification describing an electrical machine that is totally enclosed and whose enclosure is designed to withstand an internal explosion of a specified gas or vapor that may accumulate within the enclosure. The specification also requires that the design prevent ignition of the specified gas or vapor surrounding the enclosure due to sparks, flashes, or explosions of the specified gas within the enclosure.

exponent (1) the field within a floating-point format that determines the power to which the mantissa should be raised.

(2) a shorthand notation for representing repeated multiplication of the same base. 2^4 is exponential notation to multiply two by itself four times : $2^2 = 2 \cdot 2 \cdot 2 \cdot 2 = 16$. 4 is called the exponent, indicating how many times the number 2, called the base, is used as a factor.

(3) the component of a binary floating-point number that signifies the integer power of two by which the significand is multiplied in determining the value of the represented number.

exponential distribution a probability density function having the following exponential behavior:

$$f(x) = \begin{cases} \lambda e^{-\lambda x} & x \geq 0 \\ 0 & x < 0 \end{cases}$$

where $\lambda > 0$. This distribution can describe a number of physical phenomena, such as the time for a radioactive nucleus to decay, or the time for a component to fail. *See also* probability density function, Cauchy distribution, Gaussian distribution.

exponential stability (1) the property of an asymptotically stable equilibrium solution that guarantees an exponentially decreasing (to zero) norm in time of the difference between the solution and the equilibrium point.

(2) a special case of uniform asymptotic stability of an equilibrium point of $\dot{\mathbf{x}} = \mathbf{f}(t, \mathbf{x})$.

exposure the process of subjecting a resist to light energy (or electron energy in the case of electron beam lithography) for the purpose of causing chemical change in the resist.

exposure dose *See* exposure energy.

exposure energy the amount of energy (per unit area) that the photoresist is subjected to upon exposure by a lithographic exposure system. For optical lithography, it is equal to the light intensity times the exposure time. Also called exposure dose.

exposure field the area of a wafer that is exposed at one time by the exposure tool.

express feeder a feeder to which laterals are connected only at some distance from the substation. These thus traverse areas fed by other feeders and are used to supply concentrated loads or new subdivisions. *See* feeder, lateral.

expulsion fuse a fuse used on primary distribution lines which extinguishes the arc that results when it blows by explosively ejecting the fuse wire from its enclosure.

expulsion tube arrester a gapped lightning arrester which establishes the power-follow arc in a tube lined with a substance which generates a sufficient quantity of gas when heated to blow out the arc. *See* power follow, lightning arrestor.

expurgated code a code constructed from another code by deleting one or more codewords from the original code.

extended binary-coded-decimal interchange code (EBCDIC) character code developed by IBM and used in mainframe computers. It is closely related to the Hollerith code for punched cards.

extended code a code constructed from another code by adding additional symbols to each codeword. Thus an (n, k) original code becomes an $(n + 1, k)$ code after the adding of one redundant symbol.

extended industry standard architecture (EISA) a bus architecture designed for PCs using an Intel 80386, 80486, or Pentium microprocessor. EISA buses are 32 bits wide and support multiprocessing. The EISA bus was designed by IBM competitors to compete with micro channel architecture (MCA). EISA and MCA are not compatible with each other, the principal difference between EISA and MCA is that EISA is backward compatible with the ISA bus (also called the AT bus), while MCA is not. Therefore, computers with an EISA bus can use new EISA expansion cards as well as old AT expansion cards, while computers with an MCA bus can use only MCA expansion cards.

extended Kalman filter state estimation method based on linearization (see the definition) of nonlinear system and measurement equations about the current state estimate. The forms of both the filter gain and estimation error covariance equations are similar to those in the Kalman filter (see the definition). However, due to the linearization about the current state estimate, both equations are dependent on the current state estimate and cannot be calculated off-line.

extended memory in PCs, the memory located over the first megabyte of memory. This kind of memory is seen in the PC as continuous. Operating systems such as Windows NT, LINUX, and OS/2 are capable of working in protected mode, and thus at 32 bits. When MS-DOS is adopted to allow the exploitation of this memory as EMS, special software drivers have to be used. This overcomes the limit of 640 kb imposed by the real-mode and adopted by MS-DOS.

extended source a (light) source in which rays are emitted from a large source area. *Compare with* point source.

extended space for a space of functions $\mathcal{X}$, another space of functions, denoted $\mathcal{X}_e$, defined as the space of all functions whose truncation belongs to $\mathcal{X}$. *See also* truncation.

extended storage *See* solid state disk.

extension principle a basic identity for extending the domain of nonfuzzy or crisp relations to their fuzzy counterparts.

external cavity klystron a klystron device in which the resonant cavities are located outside the vacuum envelope of the tube.

external event event occurring outside the CPU and I/O modules of a computer system that results in a CPU interrupt. Examples include power fail interrupts, interval timer interrupts, and operator intervention interrupts.

external fragmentation in segmentation, leaving small unusable areas of main memory that can occur after transferring segments into and out of the memory.

external interrupt a signal requesting attention that is generated outside of the CPU.

external memory secondary memory of a computer.

external modulation modulation of the optical intensity using an optical intensity modulator to modulate a constant power laser.

external space the space of allowable positions and orientations of the end-effector of the manipulator. In general the external space, with the special Euclidean group $SE(3) \cong SO(3) \times R^3$, consists of rotations $(SO(3))$ and translations (R^3) in R^3. The external space is called as Cartesian space, test-oriented space, or operational space by many roboticians. Some people mean by Cartesian space the space in which the position of a point is given with three numbers, and in which the orientation of a body is given by three numbers. This is because in order to position and orient a body in Cartesian space we need 6 coordinates. In general orientation is specified by 3×3 orientation matrix that forms orthonormal vectors. Orientation can be specified in terms of a minimal representation describing the rotation of the end-effector frame with respect to the reference frame, e.g., Euler angles or rotation about an arbitrary axis and equivalent angle. Then manipulator position and orientation is $m \times 1$

vector, with $m \leq n$ (n denotes number of degrees of freedom). Using minimal representation of the orientation matrix, direct kinematics equation can be written in the following form: $x = \begin{bmatrix} \phi \\ p \end{bmatrix} = k(q)$ where ϕ is a set of vectors for minimal representation and p denotes three position coordinates.

external stability stability concepts related to the input–output behavior of the system.

externally vented machine classification describing an electrical machine constructed with an open frame in which ventilation air is forced through the machine by blower(s) mounted outside the machine enclosure.

extinction angle time in electrical degrees from the instant the current in a valve reaches zero (end of conduction) to the time the valve voltage changes sign and becomes positive.

extinction cross section the sum of the scattering and the absorption cross sections.

extrapolation one of several methods to estimate the values of a sequence $r(k)$ for lags $|k| > p$ from the given values of $r(k)$ for $|k| \leq p$.

extrinsic associated with the outside or exterior. In devices and device modeling, extrinsic refers to that part of the device or model associated with the passive structures that provide interconnects and contacts to other components, but are still considered a part of the device.

extrinsic fiber optic sensor a fiber optic sensor where the fiber delivers light to and from a sensing element external to the fiber. Chemical sensors are an example where the sensing element exhibits a change in optical property such as absorption, fluorescence or phosphorescence upon detection of the species to be measured.

F

f_H common notation for higher band edge frequency in hertz.

f_L common notation for lower band edge frequency in hertz.

Fabry–Perot etalon interferometer consisting of two highly reflecting flat or spherical mirrors; only resonant frequencies are transmitted.

Fabry–Perot laser a laser source where the gain medium is placed within a Fabry–Perot cavity, which provides feedback into the laser medium. Several simultaneous lasing modes are supported in such cavities.

Fabry–Perot resonator any open (as opposed to a cavity) resonator, usually the assembly of two parallel plates resembling the optical Fabry–Perot interferometer. *See also* standing-wave resonator.

Fabry–Perot structure Fabry–Perot etalon or interferometer that has an optically nonlinear medium in its cavity.

facsimile the process of making an exact copy of a document through scanning of the subject copy, electronic transmission of the resultant signals modulated by the subject copy, and making a record copy at a remote location.

facsimile encoding a bilevel coding method applied to the encoding and transmission of documents. Facsimile systems may include support for grayscale image coding too, which is described under still image coding.

FACTS *See* flexible AC transmission system.

fading channel signal fluctuation caused by multiple propagation paths over a radio channel is called fading. May be categorized as fast fading or slow fading, depending on the rate of fading with respect to the information symbol rate. May also be categorized as frequency selective or frequency nonselective, depending on the transfer function of the radio channel. *See also* fading margin, fading Rayleigh, fading Rician.

fading margin the margin by which the average signal-to-noise ratio (SNR) in a radio communications link is over-designed, in order to compensate for variations in the short-term SNR that occur due to fading of the signal. The signal fading is typically due to multipath propagation, which arises due to the presence of multiple reflectors in the radio link. Utilizing diversity schemes and transmitter power control are typically employed in order to reduce the fading margin required in a radio system.

fading rate the rate at which the received signal level crosses the median signal level in a downward direction (i.e., with a negative slope). It is usually expressed in fades per second or fades per minute, depending on the actual rate of fading.

fading Rayleigh in mobile wireless communications, wide fluctuations in received signal strength (e.g., swings of 30 – 40 dB) and phase caused by scattering of the transmitted signal off of surrounding objects. The scattering induces a Gaussian distribution on the in-phase and quadrature signal components, so that the received signal envelope has a Rayleigh distribution. *See also* Rayleigh distribution.

fading Rician similar to Rayleigh fading, the only difference being that a direct line-of-sight component is present in the received signal in addition to the scattered signal. The received signal envelope has a Rician distribution. *See also* Rice distribution.

fail safe pertaining to a circuit, for a set of faults, if and only if for any fault in this set and for every valid input code either the output is correct or assumes some defined safe state.

fail-stop processor a processor that does not perform incorrect computation in the event of a fault. Self-checking logic is often used to approximate fail-stop processing.

failure manifestation of an error at system level. It relates to execution of wrong actions, nonexecution of correct actions, performance degradation, etc.

failure mechanism a physical or chemical defect that results in partial degradation or complete failure of a product.

fairness (1) the concept of providing equivalent or near-equivalent access to a shared resource for all requestors.

(2) a fair policy requires that tasks, threads, or processes are allowed access to a resource for which they compete.

(3) the degree to which a scheduling or allocation policy is equitable and nondiscriminatory in granting requests among processes competing for access to limited system resources such as memory, CPU, or network bandwidth.

fall time (1) in digital electronics, the period of duration of the transition of a digital signal from a stable high-voltage level to a stable low-voltage level.

(2) in optics, the time interval for the falling edge of an optical pulse to transition from 90% to 10% of the pulse amplitude. Alternatively, values of 80% and 20% may be used.

falling edge (1) the region of a waveform when the wave goes from its high state to its low state.

(2) the high-to-low transition in voltage of a time-varying digital signal.

false color the replacement of a color in a colored image by a different color, usually not present in the original image. Used to highlight regions or distinguish pixels of similar colors. *See also* pseudo color.

false sharing the situation when more than one processor accesses different parts of the same line in their caches but not the same data words within the line. This can cause significant performance degradation because cache coherence protocols consider the line as the smallest unit to be transferred or invalidated.

fan beam reconstruction reconstruction of a computed tomography image from projections created by a point source that emits a fan- or wedge-shaped beam of radiation. Fan beam reconstruction enables data to be gathered much more quickly than by using a linear beam to produce parallel projections. *See also* computed tomography, image reconstruction, projection, Radon transform.

fan-in (1) the number of inputs to a module. This is usually used in connection with logic gates.

(2) multiple inputs of a channel. If the channel is a bus, only an input is allowed at a time. When N light beams are combined with an optical element, only $1/N$ of the power of each beam finds its way into the combined beam. Large fan-in is quite impractical for VLSI, because it uses a unique discrete channel for each input and current flows are limited by transistor capacitance.

fan-out (1) the limit to the number of loading inputs that can be reliably driven by a driving device's output.

(2) multiple outputs of a bus. A signal is distributed into multiple channels. With a fan-out of N, each channel receives only $1/N$ of the light power. Large fan-out is quite impractical for VLSI, because it uses a unique discrete channel for each output and current flows are limited by transistor capacitance.

Fano algorithm a sequential decoding algorithm for decoding of trellis codes.

Fano mode a bound nonradiative surface mode that propagates along an interface and decays in a nonoscillatory manner in a direction perpendicular to the propagation. Such a mode occurs when one of the media is a plasma medium and has a negative dielectric function. A metal at optical frequency is an example of such a medium.

Fano's inequality information theoretic inequality bounding the probability of incorrectly guessing the value of one random variable based on observation of another. If P_e is the probability of incorrectly guessing a random variable $X \in \mathcal{X}$, based upon observation of the random variable Y, then

$$H\left(P_e\right) + P_e \log(|\mathcal{X} - 1) \geq H(X|Y)$$

Named after its discoverer, R. M. Fano (1952). Used in proving the weak converse to the channel coding theorem (Shannon's second theorem).

Fano's limit theoretical limit relating the achievable gain and bandwidth of a given passive lossless matching network when terminated in an arbitrary load impedance.

far field (1) that region of space in which the electric field and magnetic field components of an electromagnetic wave are related by the impedance of free space. The far field is generally considered to begin no closer to the NIER source than a distance of several wavelengths or several times the antenna aperture.

(2) that region of the field of a certain source where the angular field distribution depends in a known way from the distance of the source. Generally, in free space, if we consider as a source an antenna with maximum overall dimension D, assumed large compared to the wavelength, the far-field region is commonly taken to exist at distances greater than $2D^2/\lambda$ from the antenna, λ being the wavelength. Also called the Fraunhofer region.

far pointer a pointer to a far segment. In 80×86 architecture, a far pointer specifies the segment address and the offset.

far-field pattern graph or chart representing the absolute or normalized antenna gain as a function of angle (typically azimuth or elevation) and used to describe the directional properties of an antenna in the far field (Fraunhofer region).

far-infrared (FIR) spectral region often considered to range from about 10 to 100 micrometers.

farad the basic unit of measure in capacitors. A capacitor charged to 1 volt with a charge of 1 coulomb (1 ampere flowing for 1 second) has a capacitance of 1 farad.

Faraday effect the rotation of the plane of polarization of a high-frequency signal (microwave RF, optical field) in the presence of a magnetic field.

Faraday rotation (1) rotation in the direction of polarization experienced by a wave traveling through an anisotropic medium. Important examples of media in which the phenomenon occurs include the earth's ionosphere and ferrites biased by a static magnetic field.

(2) depolarization caused in a plasma (e.g., the ionosphere) resulting from interaction between the ions of the plasma and the magnetic field of the wave.

(3) rotation in the polarization vector experienced by a wave after it propagates through a gyromagnetic medium.

Faraday rotator a magneto-optical device that changes the orientation plane of polarized light when it passes parallel to a magnetic field through a substance with pronounced absorption lines.

Faraday shield an electrostatic (E field) shield made up of a conductive or partially conductive material or grid. A Faraday cage or screen room is effective for protecting inside equipment from outside radiated RF energies.

Faraday's law one of Maxwell's equations that describes the fundamental relationship between induced voltage and a time-varying magnetic field. For a conducting coil, the induced voltage is proportional to the time rate of change in the magnetic flux linking the coil. This change may be produced either by actual variation of field strength or by relative motion between coil and field. *See also* Maxwell's equations.

Faraday, Michael (1791–1867) Born: Newington, Surrey, England

Faraday is best known as the greatest experimental physicist of the 19th century. It was Faraday who invented the electric motor, generator, and transformer, and first described electromagnetic induction and the laws of electrolysis. Faraday had no formal schooling, although he attended many lectures. The most inspirational of these lectures were by the famed chemist Sir Humphry Davy. Faraday became Davy's assistant and thus began an extraordinary career as an experimentalist. Faraday's contributions are recognized by the use of his name as the unit of electrical capacitance, the farad in the SI system, and the Faraday constant in electrolysis.

farm *See* processor farm.

fast Fourier transform (FFT) a computational technique that reduces the number of mathematical operations in the evaluation of the discrete Fourier transform (DFT) to $N \log_2 N$.

fast neutrons neutrons emitted from fission reactions which travel at velocities higher than the average velocity of atoms under random thermal motion.

fast packet networks networks in which packets are transferred by switching at the frame layer rather than the packet layer. Such networks are sometimes called frame relay networks. Current thinking views frame relay as a service, rather than transmission, technology.

fast reactor a reactor which maintains a critical chain reaction with fast neutrons and which does not require a moderator.

father wavelet the scaling function in the coarsest resolution in wavelet analysis.

fault (1) in hardware, a physical defect or imperfection of hardware. Typical circuit faults are shorts opens in conductor, defects in silicon, etc. *See also* disturbance.

(2) in software, the manifestation of an error.

fault avoidance a technique used to prevent or limit fault occurrence (for example, with signal shielding, fan-out limitation, and power dissipation decrease).

fault confinement technique that limits the spread of fault effects to some area of the system and prevents propagation of these effects to other areas.

fault coverage the measure of test quality expressed as the percentage of detected faults.

fault detection the process of locating distortions or other deviations from the ideal, typically during the process of automated visual inspection, e.g., in products undergoing manufacture.

fault indicator a small indicating unit equipped with a permanent magnet and pivoting pointer which is hung on a transmission line suffering intermittent faults of unknown origin. After a fault occurs, fault indicators are inspected. Each shows the presence and direction of a fault, thus allowing the defect to be located.

fault kva fault kilovolt-amps (kva) is the fault level expressed in terms of volt-amps rather than amps. One advantage of using volt-amps rather than amps is that the same flow is experienced on both sides of a transformer when expressed in volt-amps, while the flow changes due to the transformer turns ratio when it is expressed in amps. Volt-amps for a three-phase fault are expressed as 1.73 $\times$ rms line-line voltage $\times$ rms symmetrical fault current. Volt-amps for a single phase fault are defined as 1.73 $\times$ rms line-line voltage $\times$ rms symmetrical current in the faulted phase.

fault latency the length of time between the occurrence of a fault and the appearance of an error.

fault masking a technique that hides the effects of faults with the use of redundant circuitry or information.

fault mva fault megavolt-amps (mva) is the fault level expressed in terms of volt-amps rather than amps. One advantage of using volt-amps rather than amps is the same flow is experienced on both sides of a transformer when expressed in volt-amps, while the flow changes due to the transformer turns ratio when it is expressed in amps. Volt-amps for a three-phase fault are expressed as 1.73 $\times$ rms line-line voltage $\times$ rms symmetrical fault current. Volt-amps for a single phase fault are defined as 1.73 $\times$ rms line-line voltage $\times$ rms symmetrical current in the faulted phase.

fault prevention any technique or process that attempts to eliminate the possibility of having a failure occur in a hardware device or software routine.

fault resistance the resistance that occurs at the point of fault due to voltage drop across an arc or due to other resistance in the fault path.

fault secure pertaining to a circuit, with respect to a set of faults, if and only if for any fault in this set, and any valid input code the output is a non-code or correct code (the output is never an invalid code). The circuit is considered to operate properly if the output is a code word.

fault simulation an empirical method used to determine how faults affect the operation of the circuit and how much testing is required to obtain the desired fault coverage.

fault tolerance correct execution of a specified function in a circuit (system), provided by redundancy despite faults. The redundancy provides the information needed to negate the effects of faults.

fault tree the identification and analysis of conditions and factors that cause or contribute to the occurrence of a defined undesirable event, usually one that significantly affects system performance, economy, safety, or other required characteristics.

fault-tolerant control system a system that exhibits stability and acceptable performance in the presence of component faults (failures) or large changes in the system that resemble failures.

fax abbreviation for a machine that makes and transmits facsimiles. *See* facsimile.

FCA *See* fixed channel assignment.

FCM *See* fuzzy cognitive map or fuzzy c-means.

FCT *See* field controlled thyristor.

FDD *See* frequency division duplex.

FDDI *See* fiber distributed data interface.

FDM *See* frequency division multiplexing.

FDMA *See* frequency division multiple access.

FDTD *See* finite difference time domain.

feature a measurable characteristic of an object in an image. Simple examples would be area, perimeter, and convexity. More complex features use vectors; examples include moments, Fourier descriptors, projections, and histogram based features. Features are frequently used to recognize classes of object, and sets of simple features can be collected into a vector for this purpose. Using both area and perimeter, for instance, one can quickly distinguish between a circle and a triangle. May also refer to a characteristic of a whole image: such a feature could then be used in image database analysis.

feature detection the detection of smaller features within an image with a view to inferring the presence of objects. This type of process is cognate to pattern recognition. Typically, it is used to locate products ready for inspection or to locate faults during inspection. A feature can be detected by finding points having optimal response to a given combination of local operations such as convolutions or morphological operators. *See also* object detection.

feature extraction a method of transforming raw data, which can have very high dimensionality, into a lower dimensional representation that still contains the important features of the data.

feature map a fixed geometrical structure (often two dimensional) for unsupervised learning that maps the input patterns to different output units in the structure so that similar input patterns always trigger nearby output units topographically. *See also* self-organizing system, self-organizing algorithm.

feature measurement the measurement of features, with the aim of recognition or inspection to determine whether products are within acceptable tolerances.

feature orientation measurement of the orientation of features, either as part of the recognition process or as part of an inspection or image measurement process.

feature recognition the process of locating features and determining what types of features they are, either directly or indirectly through the location of sub-features followed by suitable inference procedures. Typically, inference is carried out by application of Hough transforms or association graphs.

feature size the characteristic size of electronic components on a die.

FEC *See* forward error correction.

feedback (1) signal or data that is sent back to a commanding unit from a control process output for use as input in subsequent operations. In a closed-loop system, it is the part of the system that brings back information on the process condition under control.

(2) the provision of a path from the output to the input of a system, such that the output may be made a function of both the input and the previous outputs of the system.

(3) the technique of sampling the output of an amplifier and using that information to modify the amplifier input signal. A portion of the output is "fed back" to the input. Positive feedback occurs when the output is added to the input; negative feedback occurs when the output is subtracted from the input. Negative feedback, invented by communications engineer Harold Black in 1928, usually results in a gain–bandwidth tradeoff: decreasing and stabilizing the amplifier gain, while increasing the bandwidth. According to Norbert Wiener, feedback is a method of controlling a system by reinserting into it the results of its past performance.

feedback amplifier a circuit configuration of amplifiers that has a feedback path. A negative feedback configuration is commonly used in amplifiers for its stable performance, where a portion of the output signal is added to the input signal at 180 degrees out of phase. There are two types of basic feedback configurations: parallel feedback and a series feedback.

feedback control the regulation of a response variable of a system in a desired manner using measurements of that variable in the generation of the strategy of manipulation of the controlling variable.

feedback decoding a majority-logic decoding method for decoding of convolutional codes.

feedback linearization a method of using feedback to cancel out nonlinearities in a dynamical system model so that the resulting closed-loop system model is linear. The method uses tools from differential geometry. *See also* Lie derivative.

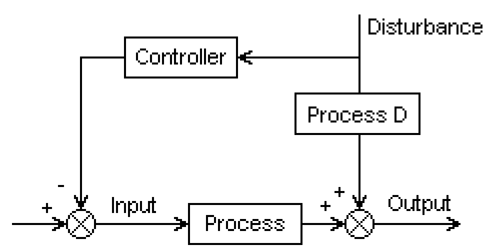
feedback oscillator electronic circuits designed to provide specific signals of desired waveshape. The feedback oscillator should be envisioned as two basic network subsystems: the active portion (amplifier) and the passive (or feedback, FB) portion. The output of one subsystem is connected to the input of the other and vice versa. The passive network is lossy but provides the important function of establishing the necessary electrical phase shift to establish oscillation at the desired frequency. *See also* Barkhausen criterion.

feeder overhead lines or cables that are used to distribute the load to the customers. They interconnect the distribution substations with the loads.

feeder circuit an electrical circuit designed to deliver power from the service equipment or separately derived system to the branch circuit panelboard(s) on a facility. For large systems, there may be more than one level of feeder circuits. *See also* branch circuit.

feedforward amplifier a circuit configuration of low distortion amplifiers where a distorted voltage extracted from the output signal is fed again to the output port so as to cancel the distorted voltage included in the output signal.

feedforward control a form of compensation in which the measurement of a disturbance is used to take preventative control action before the effect of the disturbance is noted at the system output (and then only compensated by feedback control action). A typical feedforward control configuration is shown in the figure. The controller is designed to have the same effect as the cascade combination of the process and process D.



A typical feedforward control configuration.

feedforward network *See* feedforward neural network.

feedforward neural network one of two primary classifications of neural networks (the other is recurrent). In a feedforward neural network the **x**-vector input to the single functional layer of processing elements (this input typically occurs via a layer of input units) leads to the **y**-vector output in a single feedforward pass. An example of the feedforward neural network is a multilayer perceptron.

female connector a connector presenting receptacles for the insertion of the corresponding male connector that presents pins.

fenestration any opening or arrangement of opening (normally filled with media for control) for the admission of daylight.

Ferranti, Sebastian Ziani de (1864–1930) Born: Liverpool, Lancashire, England

Ferranti is best known for developing systems of high-voltage AC power systems. The generating and transmission systems he designed still form the basis for most modern power systems. As a principal in the London Electric Supply Corporation, Ltd., Ferranti demonstrated that high-voltage AC current could be distributed and then stepped down for use in a more efficient and economical system than the smaller DC current systems then operating. Ferranti invented a number of other devices and systems as a consultant and in his own company. He was named president of the Institute of Electrical Engineers in 1911.

ferrite a term applied to a large group of ceramic ferromagnetic materials usually consisting of oxides of magnesium, iron, and manganese. Ferrites are characterized by permeability values in the thousands and are used for RF transformers and high Q coils.

ferrite beads small toroids made of ferrites which are slipped over a conductor in order to suppress RF currents. The beads act as RF chokes at high frequencies.

ferrite core a magnetic core made up of ferrite (compressed powdered ferrromagnetic) material, having high resistivity and low eddy current loss.

ferrite core memory *See* magnetic core memory.

ferrite material a material that has very low conductivity (σ) and very large permeability (μ). Its properties can be altered when an external magnetic field is applied. It is used in ferrite loaded loop antennas, for example, to increase the flux through the loop antenna.

ferroelectric material a polar dielectric in which the crystallographic orientation of the internal dipole moment can be changed by the application of an electric field.

ferrofluid iron based solution employed in voice coil/pole piece gap improving magnetic flux and power handling capacity.

ferromagnetic materials in which internal magnetic moments spontaneously line up parallel to each other to form domains, resulting in permeabilities considerably higher than unity (in practice, 1.1 or more); examples include iron, nickel, and cobalt.

ferroresonance a resonant phenomenon involving inductance that varies with saturation. It can occur in a system through the interaction of the system capacitance with the inductance of, for example, that of an open-circuited transformer. Ferroresonance resembles, to some extent, the normal resonance that occurs wherever L-C circuits are encountered. If the capacitance is appreciable, ferroresonance can be sustaining or result in a limited over voltage enough to damage the cable or the transformer itself.

ferroresonant transformer a transformer that is designed to operate as a tuned circuit by resonating at a particular frequency.

Fessenden, Reginald Aubrey (1866–1932) Born: East Bolton, Quebec, Canada

Fessenden is best known as a radio pioneer who described the principle of amplitude modulation and the heterodyne effect. Fessenden became the chief scientist at Edison's laboratory and then spent two years with Westinghouse. He later held teaching posts at Purdue University and Western University of Pennsylvania (now the U. of Pittsburgh.) During his career, Fessenden was the holder of over 500 patents — only Edison had more.

FET *See* field-effect transistor.

fetch cycle the period of time during which an instruction is retrieved from memory and sent to the CPU. This is the part of the fetch–decode–execute cycle for all machine instruction.

fetch on demand *See* fetch policy.

fetch on miss *See* fetch policy.

fetch policy policy to determine when a block should be moved from one level of a hierarchical memory into the next level closer to the CPU.

There are two main types of fetch policies: "fetch on miss" or "demand fetch policy" brings in an object when the object is not found in the top-level memory and is required; "prefetch" or "anticipatory fetch policy" brings in an object before it is required, using the principle of locality. With a "fetch on miss" policy, the process requiring the objects must wait frequently when the objects it requires are not in the top-level memory. A "prefetch" policy may minimize the wait time, but it has the possibility of bringing in objects that are never going to be used. It also can replace useful objects in the top-level memory with objects that are not going to be used. *See also* cache and virtual memory. The prefetching may bring data directly into the relevant memory level, or it may bring it into an intermediate buffer.

fetch-and-add instruction for a multiprocessor, an instruction that reads the content of a shared memory location and then adds a constant specified in the instruction, all in one indivisible operation. Can be used to handle multiprocessor synchronizations.

fetch–execute cycle the sequence of steps that implement each instruction in a computer instruction set. A particular instruction is executed by executing the steps of its specific fetch–execute cycle. The fetch part of the cycle retrieves the instruction to be executed from memory. The execution part of the cycle performs the actual task specified by the instruction. Typically, the steps in a fetch–execute cycle are made up of various combinations of only three operations:

1. the movement of data between various registers in the machine,

2. the addition of the contents of two registers or the contents of a register plus a constant with the results stored in a register, and, less frequently,

3. shift or rotate operations upon the data in a register.

fetching the process of reading instructions from a stored program for execution.

FFT *See* fast Fourier transform.

FH-CDMA frequency hopping code division multiple access. *See* frequency hopping and code division multiple access.

FIB *See* focused ion beam.

fiber Bragg grating a distributed Bragg reflector written by ultraviolet light in the core of a photosensitive optical fiber. Multiple weak Fresnel reflections coherently add in phase to produce a strong reflection over a well defined narrow band of wavelengths.

fiber cladding the region of an optical fiber having a lower index of refraction than the core region, to allow confinement of light in the core.

fiber distributed data interface (FDDI) an American National Standards Institute standard for 100 megabits per second fiber-optic local-area networks. Incorporates token processing and supports circuit-switched voice and packetized data. For its physical medium, it uses fiber optic cable, in a dual counter-rotating ring architecture.

fiber optic bundle an optical system to deliver the image to a video monitor. In a conventional endoscope, the image is transmitted through a series of lenses to a camera outside of the patient. In an electronic endoscope the image is collected by a CCD camera positioned inside the patient.

fiber optic sensor a sensor employing an optical fiber to measure chemical composition or a physical parameter, such as temperature, pressure, strain, vibration, rotation or electromagnetic fields. Light is launched down a fiber to a transducer or sensing element that alters the properties of the light in response to the parameter being measured. The altered light is returned back down a fiber to a detector.

fiber Raman amplifier provides amplification of signals through stimulated Raman scattering in silica fibers. Raman amplification differs from stimulated emission in that in stimulated emission, a photon of the same frequency as the incident photon is emitted where as in the case of Raman amplification, the incident pump photon looses energy to create another photon at a lower frequency.

fiber-optic cable a glass fiber cable that conducts light signals and can be used in token ring local area networks and metropolitan area networks. Fiber optics can provide higher data rates than coaxial cable. They are also immune to electrical interference.

fiber-optic interconnect interconnect that uses an optical fiber to connect a source to a detector. An optical fiber is used for implementing a bus. The merits are large bandwidth and high speed of propagation.

fidelity a qualitative term used to describe how closely the output amplitude of a device faithfully reproduces that of its input. Faithful reproduction here refers to the preservation of those characteristics of the input signal (e.g., amplitude, frequency, and/or phase shift) essential to proper operation of the device under question. Waveform fidelity degradation is most often characterized by a change in signal shape (time domain), or a change in the relative scaling of its frequency components as the signal propagates through the circuit or system (frequency domain). *See also* amplitude linearity.

field (1) the member of an electrical machine that provides the main magnetic flux, which then interacts with the armature causing the desired machine operation (i.e., motor or generator).

(2) a description of how a physical quantity varies as a function of position and possibly time.

See also electric field, finite field.

field circuit a set of windings that produces a magnetic field so that the electromagnetics induction can take place in electric machines.

field controlled thyristor (FCT) a thyristor controlled by change in the magnitude of the field current.

field current control a method of controlling the speed of a DC motor by varying the field resistance, thus producing a change in the field current.

field discharge resistor a resistor used to dissipate the energy stored in the inductance of a field winding. It may be a standard power resistor that is connected across the winding just prior to opening the supply switch, or a permanent non-linear resistive device that has high resistance at normal voltage but low resistance when voltage rises at switching.

field loss protection a fault-tolerant scheme used in electric motors. Some DC motor control circuits provide field loss protection in the event the motor loses its shunt field. Under a loss of field, DC motors may overspeed causing equipment damage and/or personal injury. In a motor controller that has field loss protection, a sensor determines when the shunt field has lost current flow, then secures the motor before an overspeed condition occurs.

field memory video memory required to store the number of picture elements for one vertical scan (field) of video information of an interlaced scanned system.

The memory storage in bits is computed by multiplying the number of video samples made per horizontal line times the number of horizontal lines per field (vertical scan) times the number bits per sample. A sample consists of the information necessary to reproduce the color information.

Storage requirements can be minimized by sampling the color video information consisting of the luminance (Y) and the two color difference signals, (R - Y) and (B - Y). The color signal bandwidth is less than the luminance bandwidth that can be used to reduce the field memory storage requirements. Four samples of the luminance (Y) signal is combined with two samples of the (R - Y) signal and two samples of the (B - Y) signal. The preceding video sampling technique is designated as 4:2:2 sampling and reduces the field memory size by one-third. Field memory for NTSC video sampled at 4 times the color subcarrier frequency at 8 bits/pixel would require 3.822 megabits of RAM when 4:2:2 sampling is used.

field mill a measuring instrument for electric fields consisting of a rotary array of blades which revolves near a capacitive pickup. The AC variation of the pickup's output is proportional to the electric field in the region near the instrument in the direction of the rotor axis.

field orientation a term related to the vector control of currents and voltages that enables direct control of machine torque in AC machines. Vector control refers to the control of both the amplitude and phase angle, and the control results in a desired spatial orientation of the electromagnetic fields in the machine.

field oxide an insulating silicon oxide layer used in integrated circuits to electrically isolate components.

field propagator the analytical description of how electromagnetic fields are related to the sources that cause them. Common field propagators in electromagnetics are the defining Maxwell equations that lead to differential equation models, Green's functions that produce integral equation models, optical propagators that lead to optics models, and multipole expansions that lead to modal models.

field rate the rate at which a field of video is generated. The field rate for NTSC television is 59.94 fields per second consisting of alternating even and odd fields. Each field consists of 262.5 lines of video, generating the even or odd numbered lines of video.

field reversing a method of achieving a reversal of rotation of a DC motor by reserving the field flux.

field singularity *See* edge condition.

field strength in general terms the magnitude of the electric field vector (in volts per meter) or the magnitude of the magnetic field vector (in ampere-turns per meter). As used in the field of EMC/EMI, the term is applied only to measurements made in the far field and is abbreviated as FS. For measurements made in the near field, the term electric field strength (EFS) or magnetic field strength (MFS) is used, according to whether the resultant electric or magnetic field, respectively, is measured.

field weakening a method of achieving speed increase in DC motors by reducing the field flux (increasing field circuit resistance).

field-by-field alignment a method of alignment whereby the mask is aligned to the wafer for each exposure field (as opposed to global alignment).

field-effect transistor (FET) a majority-carrier device that behaves like a bipolar transistor with the important difference that the gate has a very high input impedance and therefore draws no current.

An active device with three terminals — gate, source, and drain — in the active (amplifier) mode of operation, the drain current is related to the gate-source voltage. The relationship is usually approximated by a square law, but there are significant deviations from the square law depending on factors such as device geometry. The FET can also be used as a switch, with the gate-source voltage controlling the "on/off" state of the conducting channel between source and drain terminals. The input resistance at the gate is extremely high (usually of order tens of megaohms) and the gate current is negligibly small (usually of order picoamperes or less).

There are various families of FETs, including MOSFETs and JFETs. Within each family, there are two types of FET, n-channel and p-channel (named for the sign of the majority carriers that form the current conducting path between source and drain).

Some FETs also have a fourth terminal, the "substrate" or "body" terminal. The p-n junctions between the substrate and the drain and source terminals should be reverse-biased to insure proper device operation.

field-oriented control speed control of an induction motor obtained by varying the magnitude and orientation of the airgap magnetic field. This is also referred to as vector control and requires sensing of the rotor position. Vector controllers allow the induction motor to operate very much like a DC motor, including development of rated torque at zero speed.

field-programmable gate array (FPGA) (1) a programmable logic device that consists of a matrix of programmable cells embedded in a programmable routing mesh. The combined programming of the cell functions and routing network define the function of the device.

(2) a gate array with a programmable multi-level logic network. Reprogrammability of FPGAs make them generic hardware and allow them to be reprogrammed to serve many different applications. FPGAs consist of SRAMS, gates, latches, and programmable interconnects.

FIFO *See* first-in-first-out.

FIFO memory commonly known as a queue. It is a structure where objects are taken out of the structure in the order they were put in. Compare this with a LIFO memory or stack. A FIFO is useful for buffering data in an asynchronous transmission where the sender and receiver are not synchronized: the sender places data objects in the FIFO memory, while the receiver collects the objects from it.

figure of merit performance evaluation measure for the various target and equipment parameters of a sonar system. It is a subset of the broader sonar performance given by the sonar equations, which includes reverberation effects.

file format the structure of the computer file in which an image is stored. Often the format consists of a fixed-size header followed by the pixel values written from the top to the bottom row and within a row from the left to the right column. However, it is also common to compress the image. *See also* Graphics Interchange Format, header, image compression, tagged image file format (TIFF).

Filippov method a definition of a solution to a system of first-order differential equations with discontinuous right-hand side,

$$\dot{\mathbf{x}} = \mathbf{f}(t, \mathbf{x}) \ ,$$

proposed by A. F. Filippov. A vector function $\mathbf{x}(t)$ defined on the interval $[t_1, t_2]$ is a solution to the above system of differential equations in the sense of Filippov, if it is absolutely continuous and for almost all

$t \in [t_1, t_2]$,

$$\dot{\mathbf{x}}(t) \in \mathbf{F}(t, \mathbf{x}) \ ,$$

where $\mathbf{F}(t, \mathbf{x})$ is an appropriately constructed convex set. *See also* differential inclusion.

fill-in when solving a set of sparse linear equations using Gaussian elimination, it is possible for a zero location to become nonzero. This new nonzero is termed a fill-in.

FILO *See* first-in-last-out.

filter (1) a network, usually composed of inductors and capacitors (for lumped circuit), or transmission lines of varying length and characteristic impedance (for distributed circuit), that passes AC signals over a certain frequency range while blocking signals at other frequencies. A bandpass filter passes signals over a specified range (flow to fhi), and rejects frequencies outside this range. For example, for a DBS receiver that is to receive satellite transmitted microwave signals in a frequency range of 11 GHz to 12 GHz, a band-pass filter (BPF) would allow signals in this frequency range to pass through with minimum signal loss, while blocking all other frequencies. A low-pass filter (LPF) would allow signals to pass with minimum signal loss as long as their frequency was less than a certain "cutoff frequency" above which significant signal blocking occurs.

(2) an operator that transforms image intensity $I\mathbf{x}$ of pixel $\mathbf{x}$ into a different intensity $\hat{I}\mathbf{x}$, depending on the values of a set of (usually neighboring) pixels (which may or may not include $\mathbf{x}$). Filtering is performed to enhance significant features of an image or to remove nonsignificant ones or noise.

filter bank a set of filters consisting of a bank of analysis filters and a bank of synthesis filters. The analysis filters decompose input signal spectra into a number of directly adjacent frequency bands for further processing, and the synthesis filters recombine the signal spectra from different frequency bands.

filtered backprojection an algorithm for image reconstruction from projections. In the filtering part of the algorithm, the projections are measured, their Fourier transforms computed, and the transforms are multiplied (filtered) by a weighting function. In the backprojection part, the inverse Fourier transforms of the weighted projections are computed and summed to yield the reconstructed image. Filtered backprojection is the reconstruction algorithm currently used by almost all commercial computed tomography scanners. *See also* Fourier transform, image reconstruction, projection, Radon transform, reconstruction, tomography.

filtering (1) an estimation procedure in which the present value of the state vector (see the definition) is estimated based on the data available up to the present time.

(2) the process of eliminating object, signal or image components which do not match up to some pre-specified criterion, as in the case of removing specific types of noise from signals. More generally, the application of an operator (typically a linear convolution) to a signal.

fin efficiency a thermal characteristic of an extended surface that relates the heat transfer ability of the additional area to that of the base area.

final test electrical test performed after assembly to separate "good" devices from "bad."

finesse measure of the quality of a Fabry-Perot interferometer; free spectral range divided by linewidth (full width at half maximum).

finger stick an insulated stick like a hotstick used to actuate a disconnect-switch atop a pole.

finite difference method a numerical technique for solving a differential equation wherein the differential equation is replaced by a finite difference equation that relates the value of the solution at a point to the values at neighboring points.

finite difference time domain (FDTD) a numerical technique for the solution of electromagnetic wave problems that involves the mapping of the Maxwell equations onto a finite difference mesh and then following the time evolution of an initial value problem. This technique is widely used to investigate the performance of a complex RF structures.

finite differences a method used to numerically solve partial differential equations by replacing the derivatives with finite increments.

finite element a numerical technique for the solution of boundary value problems that involves the replacement of the set of differential equations describing the problem under consideration with a corresponding set of integral equations. The area or volume of the problem is then subdivided with simple shapes such as triangles and an approximation to the desired solution with free parameters is written for each subregion and the resulting set of equations is minimized to find the final solution. This approach is useful for solving a variety of problems on complex geometries.

finite field a finite set of elements and two operations, usually addition and multiplication, that satisfy a number of specific algebraic properties. In honor of the pioneering work by Evariste Galois, finite fields are often called Galois fields and denoted $GF(q)$, where q is the number of elements in the field. Finite fields exist for all q which are prime or the power of a prime.

finite impulse response (FIR) filter any filter having an impulse response that is nonzero for only a finite period of time (therefore having a frequency response consisting only of zeros, no poles). For example, every moving average process can be written as the output of a FIR filter driven by white noise. *See also* impulse function, moving average, infinite impulse response (IIR) filter. *See* recursive filter.

finite state machine (FSM) a mathematical model that is defined in discrete time and has a finite number of possible states it can reside in. At each time instance, an input, x, is accepted and an output, y, and a transition from the current state, S_c, to a new state, S_n, are generated based on separate functions of the input and the current state. A finite state machine can be uniquely defined by a set of possible states, S, an output function, $y = f(x, S_c)$, and a transition function, $S_n = g(x, S_c)$. An FSM describes many different concepts in communications such as convolutional coding/decoding, CPM modulation, ISI channels, CDMA transmission, shift-register sequence generation, data transmission and computer protocols. Also known as finite state automata (FSA), state machine.

finite state VQ (FSVQ) a vector quantizer with memory. FSVQ form a subset of the general class of recursive vector quantization. The next state is determined by the current state S_n together with the previous channel symbol u_n by some mapping function.

$$S_{n+1} = f\left(u_n, S_n\right), n = 0, 1, \ldots$$

This also obeys the minimum distortion property

$$\alpha(\mathbf{x}, s) = \overset{-1}{\min}\, d(\mathbf{x}, \beta(u, s))$$

with a finite state $\mathbf{S} = [\alpha_1, \alpha_2, \ldots, \alpha_k$, such that the state S_n can only take on values in S. The states can be called by names in generality.

finite wordlength effect any perturbation of a digital filter output due to the use of finite precision arithmetic in implementing the filter calculations. Also called quantization effects.

finite-extent sequence the discrete-time signals with finite duration. The finite-extent sequence $\{x(n)\}$ is zero for all values of n outside a finite interval.

FIR *See* far-infrared, finite impulse response filter.

firing angle time in electrical degrees from the instant the valve voltage is positive to the application of firing pulse to the valve (start of conduction). Also called delay angle.

firm power an amount of electric power intended to be available at all times to a commercial customer, regardless of system conditions.

firm real-time *See* firm real-time system.

firm real-time system a real-time system that can fail to meet one or more deadlines without system failure. *Compare with* soft real-time, hard real-time.

firmware software that cannot be modified by the end user.

first difference for a sequence $\{x(n)\}$ the sequence obtained by simply subtracting its $(n-1)$th element from its nth element, i.e.,

$$y(n) = x(n) - x(n-1)$$

first order hold (FOH) for a signal $f(k)$, the sequence of straight lines connecting the sample points of $f(k)$. It interpolates the values between two adjacent samples $f(k)$ and $f(k+1)$ using a linear approximation given by

$$x(t) = x(kT_s) + \frac{t - kT_s}{T_s} (x((k+1)T_s) - x(kT_s)).$$

first order system the system that can be described by a linear first-order difference equation. The output of the first-order system $y(n)$ is equal to a linear combination of the past output value $y(n-1)$ and the input value $x(n)$, i.e.,

$$y(n) = \alpha x(n) + \beta y(n-1).$$

first-fit memory allocation a memory allocation algorithm used for variable-size units (e.g., segments). The "hole" selected is the first one that will fit the unit to be loaded. This hole is then broken up into two pieces: one for the process and one for the unused memory, except in the unlikely case of an exact fit, there is no unused memory.

first-in-first-out (FIFO) a queuing discipline whereby the entries in a queue are removed in the same order as that in which they joined the queue.

first-in-last-out (FILO) a queuing rule whereby the first entries are removed in the opposite order as that in which they joined the queue. This is typical of Stack structures and equivalent to last-in-first-out (LIFO).

first-swing stability criterion to determine transient stability by use of the swing equation. The rotor angle immediately following a severe disturbance usually increases. The criterion states that if the rotor angle swings back and decreases a short time after the disturbance, then the system is first-swing stable.

Fisher information a quantitative measurement of the ability to estimate a specific set of parameters. The Fisher information $J(\theta)$ is defined by

$$\begin{aligned} J(\theta) &= E_\theta \left(\frac{\partial \ln f_\theta(y)}{\partial \theta} \right)^2 \\ &= -E_\theta \left(\frac{\partial^2 \ln f_\theta(y)}{\partial^2 \theta} \right) \end{aligned}$$

where Y is a N-dimensional vector indexed by a vector of parameters θ. *See also* Cramer-Rao bound.

fissile material an isotope which has a significant probability of undergoing nuclear fission, e.g., U235, plutonium-239, thorium-232, and enriched uranium.

fission the nuclear reaction in which a single heavy nucleus is split into two or more lighter nucleii called "daughter" products and emit highly energetic sub-atomic particles plus energy in the process.

fixed channel assignment (FCA) a technique of assigning radio channels in a communications system in a fixed and predetermined way in accordance with predicted rather than actual interference and propagation conditions. Such assignments are not changed during radio transmission.

fixed losses that component of the copper losses in DC shunt, short-shunt, and long-shunt machines' field circuit, that does not vary with change in the load current. With a fixed field power supply, it is an accepted industry agreement to not consider the losses in the field circuit rheostat in computing the efficiency and hence consider the field losses as fixed losses.

fixed point *See* equilibrium point.

fixed reference D/A converter the analog output is proportional to a fixed (nonvarying) reference signal.

fixed resolution hierarchy an image processing scheme in which the original and reconstructed image are of the same size. Pixel values are refined as one moves from level to level. This is primarily used for progressive transmission. Tree-structured VQ and transform-based hierarchical coding are two of the fixed resolution hierarchies.

fixed shunt *See* shunt capacitor.

fixed station (FS) that part of a radio communications system that is permanently located in a given geographical location. Another name for the base station in a cellular radio telephone network.

fixed termination a broadband termination of a specific nominal impedance, usually 50 ohms, used to terminate the signal path of a transmission line. Fixed terminations are used in the calibration of network analyzers and general microwave measurements.

fixed-gap head *See* disk head.

fixed-head disk a disk in which one read/write head unit is placed at every track position. This eliminates the need for positioning the head radially over the correct track, thus eliminating the "seek" delay time. Rarely used today because modern disks consist of hundreds of tracks per disk surface, making it economically infeasible to place a head unit at every track.

fixed-length instruction the machine language instructions for a computer all have the same number of bits.

fixed-point processor a processor capable of operating on scaled integer and fractional data values.

fixed-point register a digital storage element used to manipulate data in a fixed-point representation system whereby each bit indicates an unscaled or unshifted binary value. Common encoding schemes utilized in fixed-point registers include Unsigned Binary, Sign-Magnitude, and Binary Coded Decimal representations.

fixed-point representation (1) a number representation in which the radix point is assumed to be located in a fixed position, yielding either an integer or a fraction as the interpretation of the internal machine representation. *Contrast with* floating-point representation.

(2) a method of representing numbers as integers with an understood slope and origin. To convert a fixed-point representation to its value, multiply the representation by the slope (called the DELTA in Ada) and add the origin value. Fixed-point representation provides fast computations for data items that can be adequately represented by this method.

FLA *See* full load amperage.

flag (1) a bit used to set or reset some condition or state in assembly language or machine language. For instance, the inheritance flag, and the interrupt flag. As an example, each maskable interrupt is enabled and disabled by a local mask bit. An interrupt is enabled when its local mask bit is set. When an interrupt's trigger event occurs, the processor sets the interrupt's flag bit.

(2) a variable that is set to a prescribed state, often "true" or "false," based on the results of a process or the occurrence of a specified condition. Same as indicator.

flag register (1) a register that holds a special type of flag.

(2) a CPU register that holds the control and status bits for the processor. Typically, bits in the flag register indicate whether a numeric carry or overflow has occurred, as well as the masking of interrupts and other exception conditions.

flash EEPROM *See* flash memory.

flash memory a family of single-transistor cell EPPROMs. Cell sizes are about half that of a two-transistor EEPROM, an important economic consideration. Bulk erasure of a large portion of the memory array is required.

The mechanism for erasing the memory is easier and faster that needed for EEPROM. This allowed their adoption for making memory banks on PCMCIA for replacing hard disks into portable computers. Recently, also used for storing BIOS on PC main boards. In this way, the upgrading of BIOS can be made by software without opening the computer by non-specifically skilled people.

flashover arcing between segments of the commutator of a DC machine. Flashover may occur due to distortion of the airgap flux as a result of heavy overloads, rapidly changing loads, or operation with a weak main field.

flat address a continuous address specification by means of a unique number. Operating systems such as Windows NT, OS/2 and Mac OS use such a type of address. MS-DOS adopts the real-mode that adopts a segmented memory.

flat fading *See* frequency nonselective channel.

flat pack a component with two straight rows of leads (normally on 0.050-in centers) that are parallel to the component body.

flat panel display a very thin display screen used in portable computers. Nearly all modern flat-panel displays use liquid crystal display technologies. Most LCD screens are backlit to make them easier to read in bright environments.

flat topping a distortion mechanism in an amplifying stage in which the stage is unable to faithfully reproduce the positive peaks of the output signal. Reasons for such problems include poor regulation of the plate voltage supply.

flat voltage start the usual initial assumption made when beginning a power-flow study. All voltages are assumed to be 1.0 p.u., and all angles are assumed to be zero.

flat-compounded characteristic of certain compound-wound DC generator designs in which the output voltage is maintained essentially constant over the entire range of load currents.

Fleming, John Ambrose (1849–1945) Born: Lancaster, Lancashire, England

Fleming is best known as the inventor of the thermionic diode valve, also known as the Fleming valve. This valve was later adapted by Lee DeForest into a form of vacuum tube he called the Audion Triode. Fleming was an avid experimentalist as well as a solid theoretician. He began his studies under James Clerk Maxwell and ended up consulting for Edison, Swan, and Ferranti, as well as Marconi. Thus Fleming can be considered one of the earliest pioneers in the field of radio and television electronics.

Fletcher-Powell algorithm an iterative algorithm of Fletcher and Powell (1963) for finding a local minimum of the approximation error. In its original form, the Fletcher-Powell algorithm performs an unconstrained minimization.

flexible AC transmission system a transmission scheme in which each power line is maintained at its optimal impedance, generally by means of thyristor-controlled series compensators.

flexible link opposite to rigid link, is subject to elastic deformations of its structure. Basic assumption is that its model is described by the so-called Euler–Bernoulli beam equations of motion in which of second or higher order in the deformation variables are neglected.

flexible manipulator member of a class of robot manipulators with flexible links. *See* flexible link.

flexible manufacturing systems (FMS) manufacturing systems that deal with high-level distributed data processing and automated material flow using computer-controlled machine tools, robots, assembly robots and automated material handling, etc., with the aim of combining the benefits of a highly productive transfer line, and a highly flexible job shop.

flexure node standing wave pattern in loudspeaker membrane caused by applied energy.

flicker the apparent variation of lighting luminance over time to an observer.

(2) the apparent visual interruptions produced in a TV picture when the field (one half of a TV frame) frequency is insufficient to completely synchronize the visual images. Occurs when the field rate is too low and the biologic characteristic of the human eye known as the persistence of vision does not give the illusion of continuous motion. Flicker is eliminated if the field rate exceeds 50 to 60 Hz.

(3) repetitive sags and swells in the electric service voltage, often accompanied by periodic harmonic distortion.

flicker fusion the perception by the human visual system of rapidly varying lights (flicker) as being steady (fused). Flicker fusion is why fluorescent lights and scenes in movies and television appear to have constant illumination.

flicker noise occurs in solid-state devices and vacuum tubes. Its power varies inversely with frequency; therefore, it is also called $1/f$ noise.

flip-chip for microwave a packaging interconnection, in which the chips are bonded with contact pads, face down by solder bump connection. The solder bumps support the weight of the chip and control the height of the joint. It is a very good approach for high-frequency packages.

flip-flop a basic digital device capable of storing one bit of information (1 or 0). In an “edge-triggered” flip/flop, information is stored in the device at the transition (positive or negative) of a clock-signal. A flip/flop is typically constructed using two “latches” in series. The first one (the “master”) opens and closes by one clock-phase, and the second (the “slave”) opens and closes using another (non-overlapping) phase. A flip/flop may be implemented using a static or dynamic logic style. In the latter case, the size is only half of the static version, but the information is lost (due to leakage) after some time, needing “refresh” (or storing new data) for proper operation.

float switch a switch that is operated by a fluid level in a tank or process channel.

floating point characteristic part of a number that represents the exponent.

floating point operation arithmetic operation (e.g., add or multiply) involving floating point numbers (i.e., numbers with decimal points).

floating-point operations per second (FLOP) a measure of processing speed, as in megaFLOPs or gigaFLOPs.

floating-point register a register that holds a value that is interpreted as being in floating-point format.

floating-point representation in floating-point notation, a number is represented as a fractional part times a selected base (radix) raised to a power. This is the counterpart of scientific notation used in digital systems. The decimal equivalent of the floating-point value can be written $N.n = f \times r^e$ where f is the fraction or mantissa and e is a positive or negative integer called the exponent. *Contrast with* fixed-point representation.

floating-point unit a circuit that performs floating point computations, which is generally addition, subtraction, multiplication, or division.

FLOP *See* floating-point operations per second.

floppy disk a flexible plastic disk coated with magnetic material. Enclosed in a cardboard jacket having an opening where the read/write head comes into contact with the diskette. A hole in the center of the floppy allows a spindle mechanism in the disk drive to position and rotate the diskette. A floppy disk is a smaller, simpler, and cheaper form of disk storage media, and is also easily removed for transportation.

Floquet mode a solution to Maxwell’s equations that can be supported by an infinite, periodic structure.

Floquet’s theorem a basic theorem underlying the theory of wave propagation in periodic structures.

flow dependency *See* true data dependency.

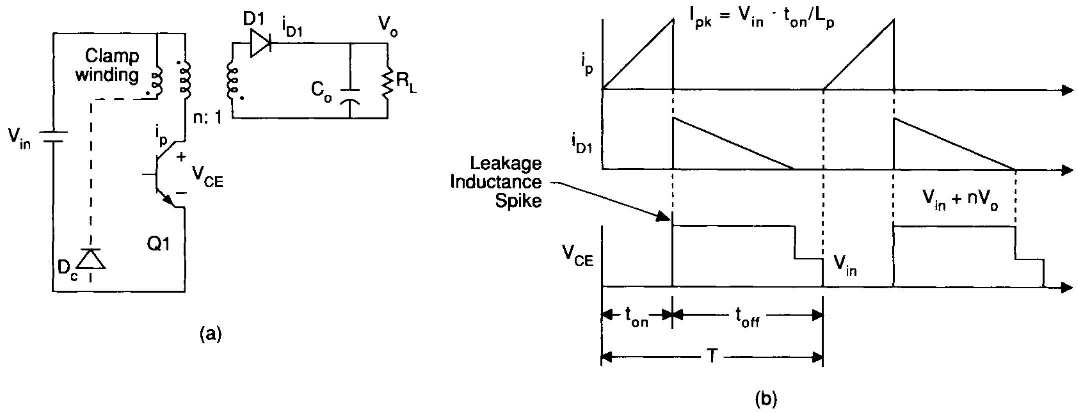
flow diagram *See* flowchart.

flowchart a traditional graphic representation of an algorithm or a program, in using named functional blocks (rectangles), decision evaluators (diamonds), and I/O symbols (paper, disk) interconnected by directional arrows which indicate the flow of processing. Also called flow diagram.

flower pot a cover for the bushing of a pad-mount transformer.

fluidized bed combustion a method of solid-fuel combustion in which the fuel, usually coal, is pulverized and mixed with a ballasting substance and burned on a bed of pressurized air. If the ballasting agent is crushed limestone, sulfur from the coal is absorbed and carried out as solid ash.

fluorescence emission of light from an electronically excited state that was produced by absorption of radiation with a wavelength shorter than the emitted light. Fluorescence emission is a quantum mechanically allowed transition between electronic levels of the



Flyback converter.

same spin state, resulting in emission of light with a very short lifetime, typically nanoseconds.

fluorescent lamp typically a lamp made by exciting a low pressure discharge in mercury vapor and other gases; mercury, when excited in the discharge, predominantly emits 257 nm radiation (ultraviolet) which is absorbed by a phosphor on the inside wall of the lamp tube; the phosphor fluoresces, emitting a white light spectrum in the visible.

fluoroscopy a mounted fluorescent screen on which the internal structure or parts of an optically opaque object may be viewed as shadows formed by the transmission of X-rays through the object.

flush the act of clearing out all actions being processed in a pipeline structure. This may be achieved by aborting all of those actions, or by refusing to issue new actions to the pipeline until those present in the pipeline have left the pipeline because their processing has been completed.

flux (1) lines that indicate the intensity and direction of a field. Intensity is usually represented by the density of the lines.

(2) a measure of the intensity of free neutron activity in a fission reaction, closely related to power, the product of neutron density and neutron velocity, e.g., neutrons per square cm per second.

flux density lines of magnetic flux per unit area, measured in tesla; $1T = 1Wb/m^2$.

flux line *See* direction line.

flux linkage quantity that indicates the amount of flux associated with a coil. Flux linkage is denoted by the symbol λ and expressed in Webers (Wb) or Weber-Turns (Wb-t). For a single turn coil, flux linkage is the same as the flux. Flux linkages of an N turn coil are $N\phi$ Wb-t.

fluxmeter an instrument that measures the change in magnetic flux within a coil by integrating the induced voltage with respect to time.

flyback converter the isolated version of the buck-boost converter. In this case, the transformer is also an inductor that stores energy when the transistor is on and releases energy to the output when the transistor is off. The primary and the secondary of the transformer conduct alternately. The advantage of this topology is that through the addition of a second winding on the input inductor, i.e., to form a transformer, electrical isolation is achieved. This type of transformer is called a flyback transformer or flyback inductor. *See also* buck-boost transformer.

Flynn's Taxonomy

	Single-Data Stream	Multiple-Data Stream
Single-Instruction Stream	von Neumann architecture/uniprocessors RISC	Systolic processors Wavefront processors
Multiple-Instruction Stream	Pipelined architectures Very long instruction word processors	Dataflow processors Transputers

flyback inductor *See* flyback converter.

flyback transformer *See* flyback converter.

flying head disk a disk storage device that uses a read/write head unit "flying" over (i.e., very closely above) the disk surface on a thin air bearing. Used e.g., in "Winchester" disks (a sealed "hard disk"). This is in contrast to, e.g., floppy disks, where the head unit is actually in physical contact with the disk when reading or writing. *See also* disk head.

Flynn's taxonomy a classification system that organizes computer processor types as either single-instruction stream or multiple-instruction stream and either single-data stream or multiple-data stream. The four resultant types of computer processors are known as SISD, MISD, SIMD, and MIMD (see table below). Due to Michael J. Flynn (1966).

flywheel a heavy wheel placed on the shaft of an electrical machine for storing kinetic energy. A flywheel may be used to help damp speed transients or, to help deliver energy to impact loads such as a punch press.

FM *See* frequency modulation.

FMS *See* flexible manufacturing systems.

FM sound a carrier wave whose instantaneous frequency is varied by an amount proportional to the instantaneous amplitude of the sound input modulating signal.

focal length distance from a lens or mirror at which an input family of parallel light rays will be brought to a focus.

focus the position of the plane of best focus of the optical system relative to some reference plane, such as the top surface of the resist, measured along the optical axis (i.e., perpendicular to the plane of best focus).

focus of attention the center of the region detected by a visual attention mechanism, which is the first stage of a pattern recognition system that is aimed to detect regions where a target object is likely to be found.

focus of expansion (1) in optical flow computation, the point into which the velocity field lines of a translating object converge.

(2) the point in an image from which feature points appear to be diverging when the camera is moving forward or objects are moving toward the camera.

focus-exposure matrix the variation of linewidth (and possibly other parameters) as a function of both focus and exposure energy. The data is typically plotted as linewidth versus focus for different exposure energies, called the Bossung plot.

focused ion beam (FIB) a lithography technique similar to electron beam lithography in which a stream of charged ions is raster-scanned to produce an image in a resist.

focuser a focusing electrode for an electron steam in a vacuum tube.

FOH *See* first order hold.

fold-over distortion the names given to the phenomena associated with the generation of an erroneously created signal in the sampling process are called "fold-over" distortion or aliasing. Sampling a signal exhibits many of the same properties that a "mixer" circuit in RF communications possesses. The mathematical relationship for a mixer circuit and a sampling circuit is expressed by the trigonometric identity

$$\sin A \cdot \sin B = .5\cos(A-B) - .5\cos(A+B)$$

From the equation it is evident that if the A radian frequency is not twice the B radian frequency, then the $A - B$ term will produce a signal whose radian frequency is less than B's. This created signal will appear within the original frequency bandwidth. These error signals can be minimized by incorporating an anti-aliasing filter (i.e., a low-pass filter) on the input to the sample-and-hold circuit. The anti-aliasing filter bandlimits the input frequencies so that fold-over distortion or aliasing is minimized.

folded sideband an FM method used frequently in video tape recording (VTR) systems. The term refers to the fact that there is no corresponding upper sideband to the one existing sideband.

folding the technique of mapping many tasks to a single processor.

foldover a form of distortion in a digital communications system which occurs when the minimum sampling rate is less that two times the analog input signal frequency.

footing impedance the electrical impedance between a steel tower and distant earth.

foot-candle the unit of illuminance when the foot is taken as the unit of length. It is the illuminance on a surface one square foot in area on which there is a uniformly distributed flux of one lumen.

force manipulability ellipsoid a model that characterizes the end-effector forces and/or torques, F, that can be generated with the given set of joint forces and/or torques, τ, with the manipulator in a given posture. Mathematically assuming that the joint forces and/or torques, satisfy the equation $\tau^T\tau = 1$, the ellipsoid (taking into account kineto-static duality) can be written as follows: $F^T(JJ^T)F = 1$. Here, J denote geometric Jacobian of the manipulator. *See also* kineto-static duality.

forced commutation the use of external circuitry to artificially force a current zero, thus allowing a diode or thryistor to turn off.

forced interruption an interruption in electric supply caused by human error, inappropriate equipment operation, or resulting from situations in which a device is quickly taken out of service by automatic or manual switching operations.

forced outage the unscheduled interruption of electric power to a portion of a power system due to equipment failure, weather conditions, or other mishaps.

forced outage rate a measure of performance usually applied to generation units. It is the ratio of equipment down-time vs. the total time that the unit is available for operation.

forced system a dynamic system is said to be forced if it is excited by a nonzero external source.

foreground (1) a process that is currently the process interacting with the user in a shell, as opposed to background processes, which get suspended when they require input from the user.

(2) a term describing a Unix command that is using your terminal for input and output, so that you will not get another Unix prompt until it is finished.

(3) the foreground of a window is a single color or a pattern. The foreground text or graphics is displayed against the background of the window.

fork (1) the action of a process creating another (child) process without ending itself.

(2) in Unix, fork is a process that can create a new copy of itself (a child) that has its own existence until either it terminates (or is killed) or its parent terminates. The prepare handler is called before the processing of the fork subroutine commences. The parent handler is called after the processing of the fork subroutine completes in the parent process. The child handler is called after the processing of the fork subroutine completes in the child process.

form term used to indicate the structure and dimensions of a multiterm equation without details within component terms.

formants the main frequencies that result from typical short-time spectral analysis of vowels. Depending on the application, two or three formants are commonly extracted.

forming gas a mixture of hydrogen and nitrogen (typically 5% hydrogen and 95% nitrogen), typically used in the post-metal annealing process in wafer fabrication.

forward channel also referred to as forward link, it is the radio link (channel) in a cellular or microcellular network where the base station is the transmitter and the mobile terminal is the receiver. In the case of cellular networks, the term is synonymous with down-link. The mobile to base station link is known as the reverse link or up-link.

forward converter an isolated version of a buck converter. The primary and the secondary of the transformer conduct at the same time. The transformer does not store energy. An additional winding with a diode is often used to reset the magnetizing energy when the transistor is off.

forward error correction (FEC) an error control system used for simplex channels (only a forward channel) where the channel code is used to determine the most likely transmitted sequence of information symbols. *Compare with* automatic repeat request.

forward error recovery a technique (also called roll-forward) of continuing processing by skipping faulty states (applicable to some real-time systems in which occasional missed or wrong responses are tolerable).

forward voltage the voltage across the device when the anode is positive with respect to the cathode.

forward wave in a traveling wave tube, microwaves propagate in the same direction with electrons in the electron beam. Electromagnetic waves travel in the positive direction of the coordinate system.

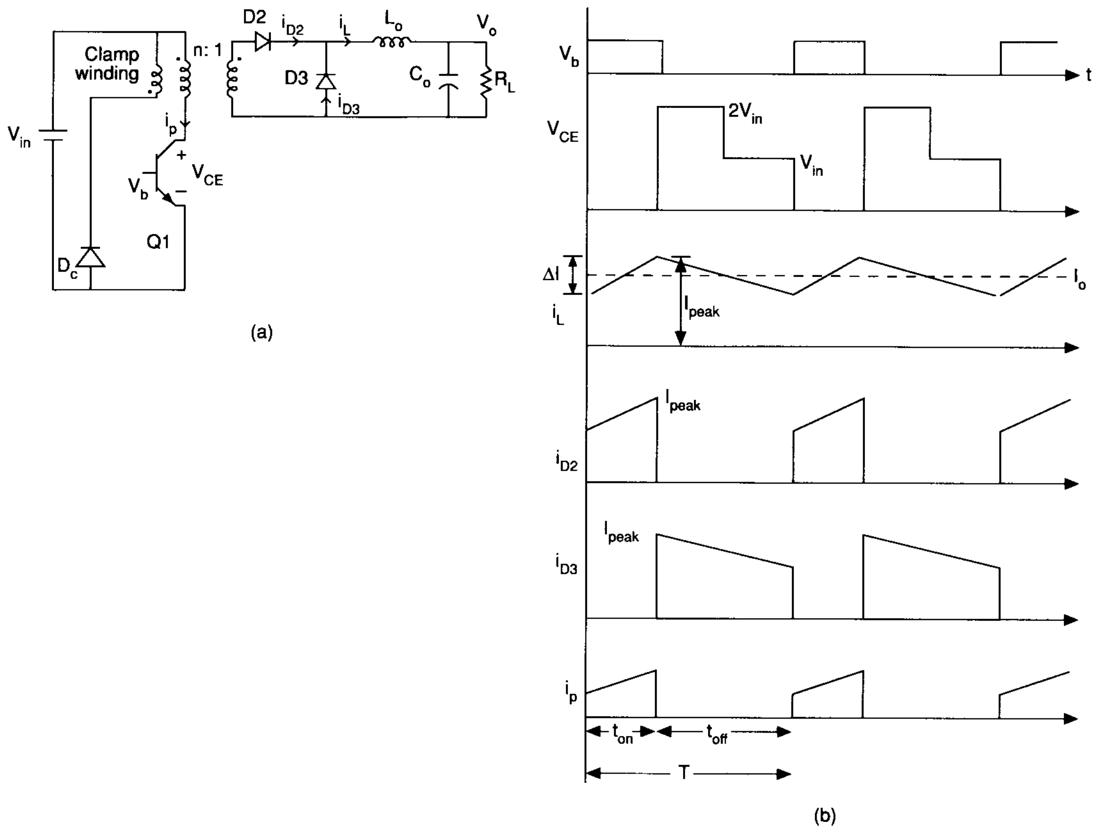
forward–backward procedure an efficient algorithm for computing the probability of an observation sequence from a hidden Markov model.

forwarding (1) sending a just-computed value to potential consumers directly, without requiring a write followed by a read.

(2) to immediately provide the result of the previous instruction to the current instruction, at the same time that the result is written to the register file. Also called bypass.

Foster's reactance theorem states that the driving-point impedance of a network composed of purely capacitive and inductive reactances is an odd rational function of frequency.

Foster–Seeley discriminator similar to the balanced slope detector. A circuit used to convert an incoming FM signal to a related AM signal to provide a demodulation process.



Forward converter.

foundry for semiconductor manufacturing, a vendor providing wafer processing.

four connected *See* pixel adjacency.

four-level laser laser in which the most important transitions involve only four energy states; usually refers to a laser in which the lower level of the laser transition is separated from the ground state by much more than the thermal energy kT (contrast with three-level laser).

four-point starter a manual motor starter that requires a fourth terminal for the holding coil. Because of its independent holding coil circuit, it is possible to vary the current in the field circuit independently of the holding coil circuit. The disadvantage is that the motor starter holding relay will not drop out with loss of the field; however, proper overcurrent protection should shut down the motor in the event of field loss.

four-quadrant operation (1) a signed representation of electrical or mechanical variables in the phase plane in order to situate the different modes for energy transfer. This term can be used both for power electronics and electrical machines. For electrical variables, the four-quadrant operation is defined by the voltage–current (or current–voltage) characteristic with the two variables expressed as instantaneous or mean values. For mechanical variables, the term is defined by the torque–speed (or speed–torque) characteristic with the same time-domain representation as previously explained. The energy transfer is defined with electrical power in the voltage–current curve and with mechanical power in the torque–speed curve. The four-quadrant operation is related to reversible power in electromechanical systems. For example, in the case of power electronics, the four-quadrant operation is defined only with electrical variables to visualize the way of energy transfer in a static converter. For electrical machines, the same operation can be defined with electrical variables at the input (motor) or at the output (generator) and also with mechanical variables at the output (motor) or at the input (generator).

(2) the four combinations of forward/ reverse rotation and forward/reverse torque of which a regenerative drive is capable. These are: motoring: forward rotation/forward torque; regeneration: forward rotation/reverse torque; motor: reverse rotation/reverse torque; and regeneration: reverse rotation/forward torque.

four-wave mixing a nonlinear optical phenomenon in which four optical beams interact inside nonlinear media or photorefractive crystals. When four beams of coherent electromagnetic radiation intersect inside a nonlinear or photorefractive medium, they will, in general, form six interference patterns and induce six volume refractive index gratings in the medium. The presence of the index gratings will affect the propagation of these four beams. This may lead to energy coupling. The coupling of the four optical beams is referred to as four-wave mixing. In one of the most useful four-wave mixing configurations, the four beams form two pairs of counterpropagating beams. In this particular configuration, some of the refractive index gratings are identical in their grating wavevectors. This leads to the generation of phase conjugate waves. Four-wave mixing is a convenient method for the generation of phase conjugated waves.

four-way interleaved splitting a resource into four separate units that may be accessed in parallel for the same request (usually in the context of memory banks).

Fourier amplitude the amplitude angle (modulo 2π) taken by the Fourier transform. Specifically, given the Fourier transform $\mathcal{F}(f) = \mathcal{A}(f)(u)\exp(i\,\Phi(f)(u))$, then $\mathcal{A}(f)$ represents the amplitude. *See* Fourier transform.

Fourier filter a filter, or mask, placed in the Fourier transform plane.

Fourier binary filter a filter placed in the Fourier plane of an optical system constructed with only two amplitude or two phase values.

Fourier integral the integral that yields the Fourier transform of an absolutely integrable function f over n-dimensional Euclidean space:

$$\mathcal{F}(f)(\mathbf{u}) = \int f(\mathbf{x})\,\exp[-i\,\mathbf{u}\cdot\mathbf{x}]\,d\mathbf{x}$$

where the frequency $\mathbf{u}$ is expressed in radians. *See also* Fourier transform.

Fourier optics optical systems that utilize the exact Fourier transforming properties of a lens.

Fourier optics relay lens a lens system that produces the exact Fourier transform of an image. Two such relay lens will reproduce an image without any phase curvature.

Fourier phase the phase angle (modulo 2π) taken by the Fourier transform. Specifically, given the Fourier transform $\mathcal{F}(f) = \mathcal{A}(f)(u)\exp(i\,\Phi(f)(u))$, then $\Phi(f)$ represents the phase. *See* Fourier transform.

Fourier phase congruence for a 1-D real-valued signal f and a point p, the Fourier phase that the signal f would have if the origin were shifted to p; in other words, it is the Fourier phase of f translated by $-p$. The congruence between the phases at p for the various frequencies — in other words the degree by which those phases at p are close to each other — can be measured by

$$f(p)^2 + \mathcal{H}(f)(p)^2,$$

where $\mathcal{H}(f)$ is the *Hilbert transform* of f. *See* Fourier amplitude, Fourier phase, Hilbert transform.

Fourier plane a plane in an optical system where the exact Fourier transform of an input image is generated.

Fourier series Let $f(t)$ be a continuous time periodic signal with fundamental period T such that

$$f(t) = \sum_{n=-\infty}^{\infty} c_n e^{j\omega_0 t}, -\infty < t < \infty$$

where ω_0 is the fundamental frequency, c_0 is a real number, and $c_n, n \neq 0$ are complex numbers. This representation of $f(t)$ is called the *exponential Fourier series* of $f(t)$. The coefficients c_n are called the Fourier coefficients and are given by

$$c_n = \frac{1}{T}\int_T f(t)e^{-j\omega_0 t}dt, n = 0, \pm 1, \pm 2, \ldots$$

The function $f(t)$ can also be expressed as

$$f(t) = c_0 + \sum_{n=1}^{\infty}(a_n \cos(n\omega_0 t) + b_n \sin(n\omega_0 t))$$

with Fourier coefficients a_n and b_n determined from

$$a_n = \frac{2}{T}\int_T f(t)\cos(n\omega_0 t dt), n = 1, 2, 3, \ldots$$

$$b_n = \frac{2}{T}\int_T f(t)\sin(n\omega_0 t dt), n = 1, 2, 3, \ldots$$

This representation of $f(t)$ is called the *trigonometric Fourier series* of $f(t)$. A signal $f(t)$ has a Fourier series if it satisfies Dirichlet conditions, given by (i) $f(t)$ is absolutely integrable over any period, (ii) $f(t)$ is piecewise continuous over any period, and (iii) $\frac{d}{dt}f(t)$ is piecewise continuous over any period. Virtually all periodic signals used in engineering applications have a Fourier series.

Fourier transform a linear mathematical transform from the domain of time or space functions to the frequency domain. The discrete version of the transform (DFT) can be implemented with a particularly efficient algorithm (fast Fourier transform or FFT). The discrete Fourier transform of a digital image represents the image as a linear combination of complex exponentials.

The Fourier transform of a continuous time period signal $f(t)$ is given by

$$F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt, -\infty < \omega < \infty .$$

If the signal $f(t)$ is absolutely integrable and is well behaved, then its Fourier transform exists. For example, the rectangular pulse signal

$$f(t) = \begin{cases} 1, -\frac{T}{2} \leq t < \frac{T}{2} \\ 0, \text{otherwise} \end{cases}$$

has Fourier transform $F(w) = \frac{2}{\omega}\sin\frac{\omega T}{2}$.

The inverse Fourier transform of a signal is given by

$$f(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} F(\omega)e^{j\omega t}d\omega$$

See also optical Fourier transform, two-dimensional Fourier transform.

Fourier, Jean Baptiste Joseph (1768–1830) Born: Auxerre, France

Fourier is best known for the development of new mathematical tools. The Fourier series, which describes complex periodic functions, and the Fourier integral theorem, which allows complex equations to be broken into simpler trigonometric equations for easier solution, are named in honor of their discoverer. Fourier was an assistant lecturer under the great mathematicians Joseph Lagrange and Gaspard Monge at the Ecole Polytechnique in Paris. He also served in a number of positions in Napoleon's government, eventually resigning in protest. His contributions to the field of electrical engineering are well recognized.

Fowler–Nordheim oscillation oscillations in internal field emission tunneling current due to quantum interference.

Fox and Li method iterative diffraction integral method for calculating the electromagnetic modes of a laser resonator.

FPC coefficients the parameters of the linear system that performs the linear prediction of a given stochastic process.

FPGA *See* field-programmable gate array.

FQO *See* four-quadrant operation.

fractal from the Latin *fractus*, meaning broken or irregular, a fractal is a rough geometric shape that is self-similar over multiple scales, i.e., its parts are approximate copies of larger parts, or ultimately of the whole. Magnifying a fractal produces more detail. Fractals are good models of many natural phenomena such as coast lines, clouds, plant growth, and lightning as well as artificial items such as commodity prices and local-area network traffic. *See also* fractal coding.

fractal coding the use of fractals to compress images. Regions of the image are represented by fractals, which can then be encoded very compactly. Fractal coding provides lossy compression that is independent of resolution and can have extremely high compression ratios, but it is not yet practical for general images. Some of the methods are covered by patents. *See also* compression, compression ratio, fractal, image compression, image resolution, lossy compression, model based image coding, spatial resolution, vector image.

fractional arithmetic mean radian bandwidth dimensionless ratio of the bandwidth ($bw = \omega_H - \omega_L$) to the arithmetic radian center frequency (ω_{oa}). The band edges are usually defined as the highest (ω_H) and lowest (ω_L) frequencies within a contiguous band of interest at which the loss equals L_{Amax}, the maximum attenuation loss across the band.

$$bw_a = \frac{\omega_H - \omega_L}{\omega_{oa}} = \frac{2\left(\omega_H - \omega_L\right)}{\omega_H + \omega_L}$$

fractional Brownian motion a nonstationary generalization of Brownian motion; it is a zero-mean Gaussian process having the following covariance:

$$E\left[B_H(t)B_H(s)\right] = \frac{\sigma^2}{2}\left(|t|^{2H} + |s|^{2H} - |t-s|^{2H}\right).$$

This process has interesting self-similarity and spectral properties; it is a fractal with dimension $D = 2 - H$. *See also* Brownian motion.

fractional discrimination coding a preprocessing scheme where the images are processed with fractional discrimination functions and then coded. This method of coding enables efficient local feature based encoding of pictures while preserving global features. This is a type of contextual coding scheme.

fractional geometric mean radian bandwidth dimensionless ratio of the bandwidth ($bw = \omega_H - \omega_L$) to the geometric radian center frequency (ω_{oa}). The band edges are usually defined as the highest (ω_H) and lowest (ω_L) frequencies within a contiguous band of interest at which the loss equals L_{Amax}, the maximum attenuation loss across the band.

$$bw_a = \frac{\omega_H - \omega_L}{\omega_{oa}} = \frac{\left(\omega_H - \omega_L\right)}{\sqrt{\omega_H + \omega_L}}$$

fractional horsepower National Electrical Manufacturers Association (NEMA) classification describing any "motor built in a frame smaller than that having a continuous rating of 1 horsepower, open type, at 1700 to 1800 rpm."

fractional rate loss for frame-by-frame transmitted convolutionally encoded data, the fraction of overhead (compared to the size of the frame) needed to put the encoder into a known state.

fragmentation waste of memory space when allocating memory segments for processes. Internal fragmentation occurs when memory blocks are rounded up to fix block sizes, e.g., allocated in sizes of power of 2 only. E.g., if 35 K of data is allocated a 64 K block, the difference $(64 - 35 = 29K)$ is wasted. External fragmentation occurs between allocated segments, as a result of allocating different sized segments for processes entering and leaving memory. This latter fragmentation is also called checkerboarding.

frame (1) a set of four vectors giving position and orientation information.

(2) the basic element of a video sequence. The standard frame rate for TV standards is 25 frames/s (European standards, e.g., PAL and SECAM) or 30 frames/s (U.S. and Japanese standards, e.g., NTSC).

(3) in paging systems, a memory block whose size equals the size of a page. Frames are allocated space according to aligned boundaries, meaning that the last bits of the address of the first location in the frame will end with n zeros (binary), where n is the exponent in the page size. Allocating frames for pages makes it easy to translate addresses and to choose a frame for an incoming page (since all frames are equivalent).

(4) time interval in a communication system over which the system performs some periodic function. Such functions can be multiple access functions (e.g., TDMA multiple access frame) or speech-processing functions (e.g., speech coding frame, interleaving frame, or error control coding frame).

(5) single image; component of a sequence of images which, displayed rapidly in succession, give the illusion of a moving picture. In video a frame represents a single complete scan of the image; it often consists of two interlaced fields.

frame grabber a device that is attached to an electronic camera and which freezes and stores images digitally, often in gray-scale or color format, typically in one or three 8-bit bytes per pixel respectively.

frame memory video memory required to store the number of picture elements for one complete frame of electronically scanned video information. The memory storage in bits can be computed by multiplying the number of video samples made per horizontal line, times the number of horizontal lines per field (vertical scan), times the number bits per sample, times the number of fields/frame. A sample consists of the information necessary to reproduce the color information.

The NTSC television system consists of two interlaced fields per frame. Storage requirements are usually minimized by sampling the color video information consisting of the luminance (Y) and the two color difference signals, $(R - Y)$ and $(B - Y)$. The color signal bandwidth is less than the luminance bandwidth that can be used to reduce the field memory storage requirements. Four samples of the luminance (Y) signal is combined with two samples of the $(R - Y)$ signal and two samples of the $(B - Y)$ signal. The preceding video sampling techniques is designated as 4:2:2 sampling and reduces the field memory size by one third.

The number of memory bits that are required to store one NTSC frame is two times the number of bits required to store one NTSC field. Field memory for NTSC video sampled at 4 times the color subcarrier frequency at 8 bits/pixel would require 7.644 megabits of RAM when 4:2:2 sampling is used.

frame processing image processing applied to frames or sequences of frames.

frame rate in analog and digital video, the rate per second at which each frame or image is refreshed. The NTSC (National Television Systems Committee) rate for analog television is 30 frames per second.

frame store a device that stores images digitally, often in gray-scale or color format, typically in one or three 8-bit bytes per pixel respectively; a frame store often incorporates, or is used in conjunction with, a frame grabber.

frame synchronization a method to obtain rough timing synchronization between transmitted and received frames. The degree of synchronization obtained depends on the level of frame synchronization (super-frame, hyper-frame). The level of frame synchronism also determines the actual method and the place where the synchronism takes place.

frame synchronizer (1) a time-base corrector effective over one frame time. Video data may be discarded or repeated in one-frame increments; in the absence of an input, the last received frame is repeated, thus producing a freeze-frame display.

(2) a device that stores video information (perhaps digitally) to reduce the undesirable visual effect caused by switching nonsynchronous sources.

Franklin, Benjamin (1706–1790) Born: Boston, Massachusetts, U.S.A.

Franklin was best known as the greatest American statesman, scientist, and entrepreneur of his day. He was the person who described electric charge, introduced the terms "positive" and "negative" as descriptive of charges, and described the fundamental nature of lightening. Franklin received no formal training in the sciences. His printing business gave him the financial security necessary to carry out numerous fundamental experiments on the nature of electricity. The results of these experiments were later given theoretical validation by Michael Faraday. Franklin's political contributions to the United States were also extraordinary. Amazingly, this additional responsibility did not deter Franklin from numerous other experiments and inventions in a variety of fields.

Fraunhofer region *See* far field.

free distance the minimum Hamming distance between two convolutionally encoded sequences that represent different valid paths through the same code trellis. The free distance equals the maximum column distance and the limiting value of the distance profile.

free electron laser laser in which the active medium consists of electrons that are subject to electric and magnetic fields but are not associated with atoms or molecules.

free input a quantity influencing the controlled process from outside, generated within the process environment, and being beyond direct or indirect influence of the controller; a free input is defined by a continuous trajectory over given time interval or by a sequence of values at given time instants.

free input forecasting process of predicting — at a given time — future values of the free input; these future values can be predicted in different forms: single future free input trajectory (scenario) over a specified time interval (forecasting interval); bunch of possible scenarios over specified time interval, (or intervals) — eventually with attached weights; stochastic model valid at the considered forecasting time and other. Free input forecasting can be essential for making most of the decisions concerning current values of the manipulated inputs.

free input model model, usually stated in form of a set of differential or difference equations, describing the behavior of the free inputs; for example, ARMA process is often used as the free input model. Usually free input model is driven by a white noise stochastic process or by a sequence of set bounded — but otherwise time-independent — quantities.

free running frequency the frequency at which an oscillator operates in the absence of any synchronizing input signal. The frequency is usually determined by a time constant from externally connected resistance and capacitance.

free space loss the propagation loss experienced between two isotropic antennas in a vacuum resulting from spreading of power over spherical wavefronts centered at the transmitting antenna and from the finite aperture of the receiving antenna. The free space loss increases proportional to the square of the distance from the antenna and the square of the frequency.

free system *See* unforced system.

free-page list a linked-list of information records pointing to "holes" (i.e., free page frames) in main memory.

free-space interconnect interconnect using optical elements such as lenses, gratings, and holograms, in which optical signals may cross each other in the space. The main advantages are high interconnection density and parallelism, and dynamic reconfiguration.

free-wheeling diode a diode connected in parallel with the load of a half-wave rectifier to prevent the return of energy from the load to the source. Due to the stored energy in the inductive load, the current must continue after the source voltage becomes negative. The free-wheeling diode provides a path for the current to circulate and allows the diode or SCR in the rectifier to turn off.

Fremdhold integral equation a linear integral equation wherein the limits of integration are fixed.

frequency the repetition rate of a periodic signal used to represent or process a communication signal. Frequency is expressed in units of hertz (Hz). 1 Hz represents one cycle per second, 1 MHz represents one million cycles per second, and 1 GHz represents one billion cycles per second.

frequency chirp a monotonic change in optical frequency with time; often used for laser radar ranging in analogy with conventional radar and for ultrashort pulse generation via pulse compression or autocorrelation. *See also* chirp signal.

frequency compensation the modification of the amplitude–frequency response of an amplifier to broaden the bandwidth or to make the response more nearly uniform over the existing bandwidth.

frequency converter an equipment or circuit that converts an RF signal to an intermediate (IF) signal in receivers. It converts an IF signal to an RF signal in transmitters.

frequency correlation function a function characterizing the similarity of a received signal with respect to a shift in frequency.

frequency deviation in a frequency modulated system, the number of hertz the carrier is varied during the modulation process.

frequency domain representation of a signal by frequency components, such as its Fourier transform.

frequency domain sampling a procedure that is a dual of the time-domain sampling theorem, whereby a time-limited signal can be reconstructed from frequency-domain samples.

frequency distortion caused by the presence of energy storage elements in an amplifier circuit. Different frequency components have different amplifications, resulting in frequency distortion, and the distortion is specified by a frequency response curve.

frequency division duplex (FDD) a technique based on the allocation of two separate frequency bands for the transmission in both directions in a link. FDD typically requires a guard band between the two frequency bands in order to eliminate interference between the transmitter and receiver at a terminal. In a full duplex communication system, information flows simultaneously in both directions between two points.

frequency division multiple access (FDMA) a multiple-access technique based on assigning each user a unique frequency band upon which transmission takes place. *See also* time division multiple access, code division multiple access.

frequency division multiplexing (FDM) refers to the multiplexing of signals by shifting each signal to a different frequency band. *See also* frequency division multiple access.

frequency domain storage an optical data storage technique in which individual bits are stored by saturating or bleaching spectral holes into an inhomogeneously broadened absorption spectrum. Usually, this hole burning is accomplished using electromagnetic fields of discrete frequencies. The maximum frequency domain storage density is given by the ratio of inhomogeneous width to homogeneous width of the absorption spectrum.

frequency hopping a system where the carrier frequency used for modulation is changed according to some predetermined hopping pattern. The receiver hops according to the same pattern in order to retrieve the information. If the rate of change is lower or equal to the data rate, the process is known as slow frequency hopping, otherwise as fast. Frequency hopping is used for counteracting intentional interference, frequency selective fading, and as a multiple access technique (FH-CDMA).

frequency independent antenna antenna with very large bandwidths. Upper frequency can be about 40 times higher than the lower frequency. Examples: spiral and log periodic antennas.

frequency modulation (FM) angle modulation in which the instantaneous frequency of a sine-wave carrier is caused to depart from the carrier frequency by an amount proportional to the instantaneous value of the modulating wave.

frequency nonselective channel a radio channel that has a uniform transfer function over the bandwidth of information signal. In such a channel, fading leads to reduced SNR at the receiver, but does not lead to distortion of the symbol shape and hence intersymbol interference.

frequency pulling shift of the frequency of a laser oscillation mode from the empty cavity or nondispersed cavity frequency toward the center frequency of the amplifying transition.

frequency regulation the change in the frequency of an unloaded generator with respect to its frequency in a fully-loaded state. Typically applied to small, isolated power systems such as emergency power units.

frequency relay a protective relay which monitors the frequency of the electric power system.

frequency resolution a measure of the ability of a system to resolve different frequencies in a signal. As the frequency resolution increases, more finely-spaced frequency components can be resolved. The time resolution of a system is roughly inversely proportional to the frequency resolution; the uncertainty principle places a lower bound on the time-frequency resolution product.

frequency response consider a system with transfer function given by

$$H(s) = \frac{Y(s)}{F(s)} .$$

The term *frequency response* is used to denote $H(j\omega)$, (commonly written $H(\omega)$). The frequency response is often used in describing the steady-state (stable) system response to a sinusoidal input. For example, in the case of a stable continuous-time system with input signal $f(t) = A\cos(\omega t)$, the steady-state output signal is given by

$$y_{ss}(t) = A|H(j\omega)|\cos(\omega t + \angle H(j\omega) .$$

The term $|H(j\omega)|, -\infty < \omega < \infty$, is called the *magnitude response*. The term $\angle H(j\omega), -\infty < \omega < \infty$, is called the *phase response*. The magnitude and phase responses are typically represented in the form of a *Bode plot*. *See also* Bode plot, transfer function.

frequency reuse a way to increase the effective bandwidth of a satellite system when available spectrum is limited. Dual polarizations and multiple beams pointing to different earth regions may utilize the same frequencies as long as, for example, the gain of one beam or polarization in the directions of the other beams or polarization (and vice versa) is low enough. Isolations of 27–35 dB are typical for reuse systems.

frequency reuse cluster a group of cells in a cellular communications network wherein each frequency channel allocated to the network is used precisely once (i.e., in one cell of the group). The size of the frequency reuse cluster is one of the major factors that determines the spectral efficiency and ultimately the capacity of a cellular network. For a given channel bandwidth, the smaller the cluster size, the higher the network capacity.

frequency selective filter a filter that passes signals undistorted in one or a set of frequency bands and attenuate or totally eliminate signals in the remaining frequency bands.

frequency selective surface (FSS) filter made of two-dimensional periodic arrays of apertures or metallic patches of various shapes. Several layers can be used to obtain a structure with a set of desired spectral properties.

frequency shift keying (FSK) (1) an encoding method where different bits of information are represented by various frequencies; used for spread-spectrum signal encoding for security and reduced interchannel interference.

(2) a digital modulation technique in which each group of successive source bits determines the frequency of a transmitted sinusoid.

frequency space the transformed space of the Fourier transform.

frequency synchronization the process of adjusting the frequency of one source so that it exactly matches that of another source: more specifically, so that n periods of one frequency are exactly equal to m periods of the other frequency, for integral n and m. *See also* phase-locked loop.

frequency synthesizer an oscillator that produces sinusoidal wave with arbitrary frequency. In common cases, generated frequencies are allocated with a frequency spacing called the channel step.

frequency variation a change in the electric supply frequency.

frequency-modulation recording *See* magnetic recording code.

fresh fuel nuclear fuel which has never participated in a nuclear reaction and is thus only slightly radioactive.

Fresnel region the region in space around an antenna at which the fields have both transverse and radial components and the antenna pattern is dependent on the distance from the antenna. The Fresnel, or near-field, region is typically taken to be $r < 2D^2/\lambda$, where r is the distance from the antenna, D is the maximum dimension of the antenna, and λ is the wavelength.

Fresnel zone an indicator of the significant volume of space occupied by a radio wave propagating along a line-of-sight path between the transmitter and receiver. At an arbitrary point which is at distance d_1 from the transmitter and at distance d_2 from the receiver, along the axis joining the transmitter and the receiver, a radio wave with wavelength λ occupies a volume, which at that point between the transmitter and the receiver, has a radius which is given by the radius of the first Fresnel zone. The radius of the first Fresnel zone is given by

$$R = \sqrt{\frac{\lambda d_1 d_2}{d_1 + d_2}}$$

From this equation one can see that the significant volume occupied by a radio wave is essentially ellipsoidal. In order for a transmitter and receiver to communicate successfully, it is important for this volume to be kept free from any obstruction, especially at microwave frequencies.

fricative a phoneme pronounced when constricting the vocal tract so as the air flow becomes turbulent and the corresponding frequency spectrum looks like a broadband noise. The utterances with frication can occur with or without phonation. When phonation also occurs, the presence of formants can be detected in the spectrum.

Friis transmission formula a formula used to compute the received signal power in a radio communication link given the amount of power transmitted, the effective apertures or gains of the transmit and receive antennas, the distance between the antennas, and the wavelength.

fringing the portion of the flux at the air gap in a magnetic circuit that does not follow the shortest path between the poles.

frit a relatively low softening point material of glass composition.

Fritchman model N-state Markoff model describing N error states of a channel.

frog the top of a tower.

front end (1) an initial processing unit that provides a user interface and/or reformats input data for subsequent computations on a special-purpose or high-performance back end processor.

(2) the portion of the compiler that does machine-independent analysis.

front of a motor the end of a motor that is opposite to the major coupling or driving pulley.

front porch video blanking level duration of approximately 1.27 microseconds contained within the horizontal blanking interval of the composite NTSC signal. The front porch duration is 2% of the total horizontal line time, starting at the end of a horizontal line of video signals and ending at the beginning of the horizontal line sync signal.

frontside bus the term used to describe the main bus connecting the processor to the main memory (cf. backside bus).

frustrated total reflection *See* attenuated total reflection.

FS *See* fixed station.

FSA finite state automata. *See* finite state machine.

FSK *See* frequency shift keying.

FSM *See* finite state machine.

FSS *See* frequency selective surface.

FSVQ *See* finite state vector quantizer.

fuel cell an electrochemical device in which the chemical energy of a conventional fuel converted directly and efficiently into low voltage, direct current electrical energy.

fuel cycle (1) the operating time of a nuclear reactor between shutdowns for refueling.

(2) the life cycle of nuclear fuel, e.g., raw materials, to fresh fuel, to irradiated fuel, to spent fuel, to recycling, and finally to residual waste.

fuel pool a large vat of water used to store both fresh and spent nuclear fuel at the reactor site.

fuel rod long, thin canister, typically made of zirconium or other metal, which contains the radioactive fuel in a nuclear reactor core.

fulgurite a vitrified tube of fused sand created by power fault arcs or lightning strikes to sandy soil.

full adder a combinational logic circuit that produces a two-bit sum of three one-bit binary numbers.

full bridge amplifier a class-D amplifier based on a full-bridge inverter configuration.

full load amperage (FLA) a value, found on the nameplate of an induction motor, indicating the expected current drawn by the motor when operating at rated voltage and load.

full permutation symmetry *See* nonlinear susceptibility.

full rank Jacobian a Jacobian matrix where $\dim(R(J)) = r$, $\dim(N(J)) = n - r$. At a singular configuration of the Jacobian, one has $\dim(R(J)) + \dim(N(J)) = n$ independently of the rank of the matrix J. *See* null space of the Jacobian and range of Jacobian.

full-load amperage the current measured at the input of an electrical apparatus which has a rated variable at the output. The full-load amperage is also defined as a value that permits the system to operate in a safe condition if it is equal to the rated value. The full-load amperage is equal to the rated value if and only if the voltage is at its rated value. The full load is defined with the electrical power in the case of transformers, generators, or power electronics converters and it is defined with the mechanical power for electrical motors.

full-load speed the speed of a motor that produces rated power when operating at rated voltage and, for AC motors, frequency.

full-load torque the torque of a motor that is producing rated power at rated speed.

full-wave analysis the rigorous computation of electromagnetic fields without approximations (apart for numerical discretization) is often referred to as full-wave analysis.

full-wave control both the positive and negative half cycle of the waveforms are controlled.

full-wave rectifier a device that passes positive polarity portions of a signal and reverses negative polarity portions of an AC signal. Ideally, for a sinusoidal input $v_i(t) = V_m \cos(\omega t)$, the output of an ideal full-wave rectifier is $v_o(t) = |V_m \cos(\omega t)|$.

full width at half max (FWHM) the width of a distribution function (i.e., the horizontal distance between two points having the same vertical coordinate) defined at a vertical position halfway between the maximum and minimum. This value exists for certain functions that are of interest as possible point spread functions (e.g., Gaussian, Moffat function) and gives a rough idea of the amount of blur to be expected.

fully associative cache a cache block mapping technique where a main memory block can reside in any cache block position. A number of bits from the address received from the CPU is compared in parallel with the cache tags to see if the block is present in the cache. Although costly to implement, and impractical for large cache sizes, it is the most flexible mapping method. *See also* cache, direct mapped cache, and associativity.

function a programming construct that creates its own frame on a stack, accepting arguments, performing some computation, and returning a result.

function sensitivity in a circuit described by the function $F(s, x)$ where s is a complex variable, and x is a passive or active element in the circuit realization of the function, the equation

$$\mathbf{S}_x^{F(s,x)} = \frac{\partial F(s,x)}{\partial x} \frac{x}{F(s,x)}$$

Under conditions of sinusoidal steady state, when $s = j\omega$, the function $F(j\omega, x)$ is described by the sensitivity

$$\begin{aligned}\mathbf{S}_x^{F(j\omega,x)} &= \mathrm{Re}\, \mathbf{S}_x^{F(j\omega,x)} + j\ \mathrm{Im}\, \mathbf{S}_x^{F(j\omega,x)} \\ &= \mathbf{S}_x^{|F(j\omega,x)|} + j\ \frac{\partial \arg F(j\omega,x)}{\partial x/x}\end{aligned}$$

Thus, the real part of the function sensitivity gives the relative change in the magnitude response, and the imaginary part gives the change in the phase response, both with respect to a normalized element change.

function test a check for correct device operation generally by truth table verification.

function-oriented design a design methodology based on a functional viewpoint of a system starting with a high-level view and progressively refining it into a more detailed design.

functional block ASICs designed using this methodology are more compact than either gate arrays or standard cells because the blocks can perform much more complex functions than do simple logic gates.

functional decomposition the division of processes into modules.

functional redundancy checking an error detection technique based on checking bus activity generated by a processor (master) with the use of another slave processor which monitors this activity.

functional unit a module, typically within a processor, that performs a specific limited set of functions. The adder is a functional unit.

fundamental component the first order component of a Fourier series of a periodic waveform.

fundamental frequency for a continuous time periodic signal, $f(t)$ with fundamental period T (seconds), $\omega_0 = 2\pi/T$ (rad/sec). *See also* periodic signal.

fundamental mode (1) operating mode of a circuit that allows only one input to change at a time.

(2) lowest order mode of a laser cavity; usually refers to a Gaussian transverse field distribution without regard to the longitudinal mode order.

fuse an overcurrent device that employs one or more fusible elements in series. The fusible element(s) are designed to melt and interrupt the circuit when current above a threshold value flows in the circuit.

fuse coordination the process of matching the fuse or circuit breaker interruption capability to overload current and short-circuit current and insuring that the protective device closest to a fault opens first so as to minimize the service interruption.

fuse cutout a primary distribution voltage level fuse that employs a replaceable fusible link and provides a means of disconnect. The interrupting rating of a fuse cutout can be somewhat lower than that of a power fuse, however.

fuse link used in nonerasable programmable memory devices. Each bit in the memory device is represented by a separate fuse link. During programming, the link is either "blown" or left intact to reflect the value of the bit. *See also* fusible link ROM.

fuse reducer an adapter that allows fuses to be installed in fuseclips designed for larger fuses.

fuse saving the practice of tripping distribution line reclosers or circuit breakers on a fast trip to beat sectionalizing fuses that are protecting laterals. The following reclose will restore all load. If the fault remains following the fast trip(s), subsequent slow trip(s) will allow the fuse to operate on a permanent fault on the lateral. Fuse saving decreases the customer outage rate but causes more sags to customers in a fault situation.

fused disconnect a disconnect switch that also employs fuse(s) for the purpose of overcurrent protection.

fusible link ROM read-only memory using fuse links to represent binary data. *See also* fuse link.

fusion a nuclear reaction in which two light nuclei are combined into a heavier nucleus with a release of energy. Fusion power reactors have been proposed but as yet never successfully constructed.

Futurebus a bus specification standardized by the IEEE, originally defined for CPU-memory data transfers.

fuzz stick a short hot-stick.

fuzzification a procedure of transforming a crisp set or a real-valued number into a fuzzy set.

fuzzifier a fuzzy system that transforms a crisp (nonfuzzy) input value in a fuzzy set. The most used fuzzifier is the *singleton fuzzifier,* which interprets a crisp point as a fuzzy singleton. It is normally used in fuzzy control systems. *See also* fuzzy inference system, fuzzy singleton.

fuzziness the degree or extent of imprecision that is naturally associated with a property, process or concept.

fuzzy adaptive control adaptive control involving fuzzy logic concepts or fuzzy control involving adaptation. Examples of such control are self-organizing fuzzy control, model reference fuzzy adaptive control, and fuzzy self-tuning control.

fuzzy aggregation network artificial neural network that can be trained to produce a compact set of fuzzy rules with conjunctive and disjunctive antecedents. An aggregation operator is used in each node.

fuzzy algorithm an ordered set of fuzzy instructions which upon execution yield an approximate solution to a specified problem. Examples of fuzzy algorithms include fuzzy c-mean clustering, fuzzy-rule-based classification, etc.

fuzzy AND *See* triangular norm.

fuzzy approximation an action or process of using a fuzzy system to approximate a nonlinear function or mapping.

fuzzy associative memory a look-up table constructed from a fuzzy IF-THEN rule base and inference mechanism to define a relationship between the input and output of a fuzzy controller, or a fuzzy system. *See also* fuzzy inference system.

fuzzy automata based on the concept of fuzzy sets, a class of fuzzy automata is formulated similar to Mealy's formulation of finite automata.

fuzzy basis functions a set of fuzzy membership functions or their combinations in a fuzzy system that form a basis of a function space, normally for function approximation.

fuzzy behavioral algorithm a relational algorithm that is used for the specific purpose of approximate description of the behavior of a system.

fuzzy C the C programming language incorporating fuzzy quantities and fuzzy logic operations.

fuzzy c-means (FCM) a fuzzy version of the commonly used K-means clustering algorithm. The main feature of FCM is that a type of membership function is utilized in computing a distance measure. Also called fuzzy ISODATA.

fuzzy clustering a method used to cluster data into subsets based on a distance or similarity measure that incorporates fuzzy membership functions.

fuzzy cognitive map (FCM) nonlinear dynamical systems whose state trajectories are constrained to reside in the unit hypercube $[0, 1]^n$. The components of the state vector of an FCM stand for fuzzy sets or events that occur to some degree and may model events, actions, goals, etc. The trajectory of an FCM can be viewed as an inference process. For example, if an FCM's trajectory starting from an initial condition $\mathbf{x}(0)$ converges to an equilibrium state $\mathbf{A}$, then this can be interpreted as the FCM providing an answer to a question "What if $\mathbf{x}(0)$ happens?" In this sense it can be interpreted that the FCM stores the rule "IF $\mathbf{x}(0)$ THEN the equilibrium $\mathbf{A}$." FCMs were introduced by B. Kosko.

fuzzy complement the complement of a fuzzy set A is understood as NOT (A).

fuzzy concentration the concentration of a fuzzy set produces a reduction by squaring the membership function of that fuzzy set.

fuzzy conditional statement an IF-THEN statement of which either the antecedents or consequent(s) or both may be labels of fuzzy sets. Also know as fuzzy rule, linguistic fuzzy model, linguistic rules. *See* fuzzy IF-THEN rule.

fuzzy control the application of fuzzy logic and fuzzy inference rules utilizing knowledge elicited from human experts in generating control decisions for the control of processes. More specifically, a means of expressing an operator's knowledge of controlling a process with a set of fuzzy IF-THEN rules and linguistic variables.

fuzzy control system stability stability of a fuzzy control system that normally includes a plant to be controlled and a fuzzy controller.

fuzzy controller devices for implementing fuzzy control, normally including the following components: a fuzzifier to transform a crisp real-valued number to a fuzzy set; a fuzzy rule base to define IF-THEN control rules; a fuzzy inference engine to combine the IF-THEN rules; and a defuzzifier to transform a fuzzy set to a crisp real-valued number.

fuzzy controller design a process of determining a fuzzy controller including a fuzzifier, a fuzzy rule base, a fuzzy inference engine, and a defuzzifier.

fuzzy decision rule a decision rule with fuzzified antecedents.

fuzzy decision tree a decision tree with fuzzy decision functions.

fuzzy decision tree algorithm an algorithm to generate a fuzzy decision tree, such as the branch-bound-backtrack algorithm.

fuzzy decisional algorithm a fuzzy algorithm that serves to provide an approximate description of a strategy or decision rule.

fuzzy definitional algorithm a finite set of possible fuzzy instructions that define a fuzzy set in terms of other fuzzy sets (and possibly itself, i.e., recursively).

fuzzy digital topology an extension of the topological concepts of connectedness and surroundness in a digital picture using fuzzy subsets.

fuzzy dilation an operator that increases the degree of belief in each object of a fuzzy set by taking the square root of the membership function.

fuzzy dynamic model model involving fuzzy logic concepts and system dynamics. A typical example is a hierarchical model with a higher level of fuzzy inference rules and a lower level of analytical linear dynamic equations.

fuzzy dynamic system system involving fuzzy logic concepts and system dynamics. A typical example is a fuzzy control system with a dynamic plant and a fuzzy controller.

fuzzy entropy the entropy of a fuzzy set is a functional to measure the degree of fuzziness of a fuzzy set based on Shannon's function. It has been applied to provide a quantitative measure of ambiguity to the problems of gray-tone image enhancement.

fuzzy estimation an action or process of deducing state variables from given input and output measurements in a fuzzy dynamic state space model.

fuzzy expert system a rule-based system for approximate reasoning in which rules have fuzzy conditions and their triggering are driven by fuzzy matching with fuzzy facts. *See also* fuzzy inference system.

fuzzy filter a filter involving fuzzy logic concepts. A typical example is a filter constructed from a number of local filters through fuzzy membership functions.

fuzzy gain scheduling gain scheduling involving fuzzy logic concepts. A typical example is the use of a number of fuzzy IF-THEN rules to adjust a controller gain.

fuzzy generational algorithm a fuzzy algorithm serves to generate rather than define a fuzzy set. Possible applications of generational algorithms include generation of handwritten characters and generation of speech.

fuzzy geometry a way to describe an image by fuzzy subsets.

fuzzy global control a fuzzy control for an overall plant or a control based on a fuzzy global model that consists of a number of local models smoothly connected through a set of membership functions.

fuzzy global model a fuzzy dynamic model consisting of a number of local linear models or simple nonlinear models smoothly connected through a set of nonlinear membership functions.

fuzzy grammar an attributed grammar that uses fuzzy primitives as the syntactic units of a language.

fuzzy H-infinity control H-infinity control involving fuzzy logic concepts or fuzzy control to achieve an H-infinity controller performance index.

fuzzy H-infinity filter an H-infinity filter involving fuzzy logic concepts or a fuzzy filter to achieve an H-infinity filter performance index.

fuzzy hierarchical systems fuzzy systems of hierarchical structures. A typical example is a two-level fuzzy system with a higher level of fuzzy inference rules and lower level of analytical linear models.

fuzzy identification a process of determining a fuzzy system or a fuzzy model. A typical example is identification of fuzzy dynamic models consisting of determination of the number of fuzzy space partitions, determination of membership functions, and determination of parameters of local dynamic models.

fuzzy IF-THEN rule rule of the form

$$\text{IF } x \text{ is } A \text{ THEN } y \text{ is } B$$

where A and B are linguistic values defined by fuzzy sets on universe of discourse X and Y respectively (abbreviated as $A \longrightarrow B$). The statement "x *is* A" is called the *antecedent* or *premise,* while "y *is* B" is called the *consequence* or *conclusion.* A fuzzy IF-THEN rule can be defined as a binary *fuzzy relation.* The most common definition of a fuzzy rule $A \longrightarrow B$ is as A *coupled with* B, i.e.,

$$R = A \longrightarrow B = A \times B \ ,$$

or

$$\mu_{A\times B}(x, y) = \mu_A(x) \star \mu_B(y) \ ,$$

where $\star$ is a triangular norm.

See also fuzzy relation, fuzzy set, linguistic variable, triangular norm.

fuzzy implication *See* fuzzy IF-THEN rule.

fuzzy inference a fuzzy logic principle of combining fuzzy IF-THEN rules in a fuzzy rule base into a mapping from a fuzzy set in the input universe of discourse to a fuzzy set in the output universe of discourse. A typical example is a composition inference.

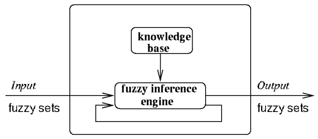
fuzzy inference engine a device or component carrying out the operation of fuzzy inference, that is, combining fuzzy IF-THEN rules in a fuzzy rule base into a mapping from a fuzzy set in the input universe of discourse to a fuzzy set in the output universe of discourse. *See also* approximate reasoning, fuzzy inference system, fuzzy rule.

fuzzy inference system a computing framework based on fuzzy set theory, fuzzy IF-THEN rules, and approximate reasoning. There are two principal types of fuzzy inference systems:

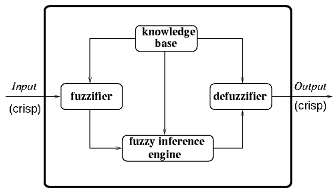
1. Fuzzy inference systems mapping fuzzy sets into fuzzy sets (pure fuzzy inference systems) that are composed of a knowledge base containing the definitions of the fuzzy sets and the database of fuzzy rules provided by experts; and a fuzzy inference engine that performs the fuzzy inferences.

2. Fuzzy inference systems performing non-linear mapping from crisp (nonfuzzy) input data to crisp (nonfuzzy) output data. In the case of a Mamdani fuzzy system, in addition to a knowledge base and a fuzzy inference engine, there is a fuzzifier that represents real-valued inputs as fuzzy sets, and a defuzzifier that transforms the output set to a real value. In the case of a Sugeno fuzzy system, special fuzzy rules are used, giving a crisp (nonfuzzy) conclusion, and the output of the system is given by the sum of those crisp conclusions, weighted on the activation of the premises of rules. Some fuzzy systems of this type hold the universal function approximation property.

See also defuzzifier, fuzzifier, fuzzy set, fuzzy IF-THEN rule, fuzzy reasoning, Sugeno fuzzy rule, universal function approximation property.



Pure fuzzy inference system.



Mamdani fuzzy system.

fuzzy input–output model input–output models involving fuzzy logic concepts. A typical example is a fuzzy dynamic model consisting of a number of local linear transfer functions connected by a set of nonlinear membership functions.

fuzzy integral an aggregation operator used to integrate multiattribute fuzzy information. It is a functional defined by using fuzzy measures, which corresponds to probability expectations. Two commonly used fuzzy integrals are Sugeno integral and Choquet integral.

fuzzy intensification an operator that increases the membership function of a fuzzy set above the crossover point and decreases that of a fuzzy set below the crossover point.

fuzzy intersection the fuzzy intersection is interpreted as "A AND B," which takes the minimum value of the two membership functions.

fuzzy ISODATA *See* fuzzy c-means.

fuzzy local control fuzzy control in a sense of local region of plant operation range, which is a key feature of fuzzy control. A typical example is a local control based on a local fuzzy dynamic model.

fuzzy local model a fuzzy model in a sense of local region of plant operation range. A typical example is a fuzzy model of Takagi–Sugeno–Kang type.

fuzzy local system fuzzy system in a sense of local region of plant operation range. A typical example is a fuzzy system of Takagi–Sugeno–Kang type.

fuzzy logic introduced by Zadeh (1973), gives us a system of logic that deals with fuzzy quantities, the kind of information humans manipulate that is generally imprecise and uncertain. Fuzzy logic's main characteristics is the robustness of its interpolative reasoning mechanism. *See also* approximate reasoning, linguistic variable, modifier, generalized modus ponens.

fuzzy logic controller controller based on a fuzzy logic system. *See also* fuzzy logic system.

fuzzy logic system a system of logic that deals with fuzzy quantities, that are unprecise and uncertain.

fuzzy measure a subjective scale used to express the grade of fuzziness similar to the way probability measure is used to express the degree of randomness. An example of fuzzy measure is g_λ-fuzzy measure proposed by Sugeno.

fuzzy membership function function of characterizing fuzzy sets in a universe of discourse which takes values in the interval $[0, 1]$. Typical membership functions include triangular, trapezoid, pseudo-trapezoid, and Gaussian functions.

fuzzy minus the minus operation applied to a fuzzy set to give an intermediate effect of dilation. *See also* fuzzy plus.

fuzzy model *See also* fuzzy inference system.

fuzzy model-based control fuzzy control based on various kinds of mathematical or linguistic models. A typical example is control of dynamic systems based on dynamic fuzzy models, which consist of a number of local linear models smoothly connected through a set of nonlinear membership functions.

fuzzy modeling combination of available mathematical description of the system dynamics with its linguistic description in terms of IF-THEN rules. In the early stages of fuzzy logic control, fuzzy modeling meant just a linguistic description in terms of IF-THEN rules of the dynamics of the plant and the control objective. Typical examples of fuzzy models in control application includes Mamdani model, Takagi–Sugeno–Kang model, and fuzzy dynamic model.

fuzzy neural control a control system that incorporates fuzzy logic and fuzzy inference rules together with artificial neural networks.

fuzzy neural network artificial neural network for processing fuzzy quantities or variables with some or all of the following features: inputs are fuzzy quantities; outputs are fuzzy quantities; weights are fuzzy quantities; or the neurons perform their functions using fuzzy arithmetic.

fuzzy neuron a McCulloch–Pitts neuron with excitatory and inhibitory inputs represented as degrees between 0 and 1; output is a degree to which it is fired.

fuzzy nonlinear control nonlinear control involving fuzzy logic concepts or fuzzy control with application to nonlinear systems.

fuzzy number a convex fuzzy set of the real line such that

1. it exists exactly one point of the real line with membership 1 to the fuzzy set;

2. its membership function is piecewise continuous.

In fuzzy set theory, crisp (nonfuzzy) numbers are modeled as fuzzy singletons.

See also convex fuzzy set, fuzzy singleton.

fuzzy observer a device to estimate the states of a dynamic system, involving fuzzy logic concepts. A typical example is an observer constructed from a number of local observers through fuzzy membership functions.

fuzzy operator logical operator used on fuzzy sets for fuzzy reasoning. Examples are the complement (NOT), union (OR), and the intersection (AND).

fuzzy optimal control optimal control involving fuzzy logic concepts or fuzzy control to achieve an optimal control performance index.

fuzzy optimal filter optimal filter involving fuzzy logic concepts or fuzzy filter to achieve an optimal filter performance index.

fuzzy OR *See* triangular co-norm.

fuzzy output feedback fuzzy control based on feedback of a plant output. This is closely related to fuzzy dynamic models.

fuzzy parameter estimation a method that uses fuzzy interpolation and fuzzy extrapolation to estimate fuzzy grades in a fuzzy search domain based on a few cluster center-grade pairs. An application of this method is to estimate mining deposits.

fuzzy partition partition of a plant operating space based on fuzzy logic concepts. A typical example is a partition of a state space by overlapping subspaces which are characterized by a set of fuzzy membership functions.

fuzzy pattern matching a pattern matching technique that applies fuzzy logic to deal with ambiguous or fuzzy features of noisy point or line patterns.

fuzzy plus the operation of plus applied to a fuzzy set to give an intermediate effect of concentration. *See also* fuzzy minus.

fuzzy PROLOG the PROLOG programming language incorporating fuzzy quantities and fuzzy logic operations.

fuzzy proposition a proposition in which the truth or falsity is a matter of degree.

fuzzy reasoning approximate reasoning based on fuzzy quantities and fuzzy rules. *See also* approximate reasoning.

fuzzy relation a fuzzy set representing the degree of association between the elements of two or more universes of discourse. *See also* fuzzy set.

fuzzy relational algorithm a fuzzy algorithm that serves to describe a relation or relations between fuzzy variables.

fuzzy relational matrix a matrix whose elements are membership values of the corresponding pairs belonging to a fuzzy relation.

fuzzy relaxation a relaxation technique with fuzzy membership functions applied.

fuzzy restriction a fuzzy relation that places an elastic constraint on the values that a variable may take.

fuzzy rule *See* fuzzy IF-THEN rule.

fuzzy rule bank a collection of all fuzzy rules that are arranged in N-dimensional maps.

fuzzy rule base a set of fuzzy IF-THEN rules. It is a central component of a fuzzy system and defines major functions of a fuzzy system.

fuzzy rule minimization a technique to simplify the antecedent and consequent parts of rules and to reduce the total number of rules.

fuzzy rule-based system system based on fuzzy IF-THEN rules, or another name for fuzzy systems. *See also* fuzzy inference system.

fuzzy rules of operation a system of relational assignment equations for the representation of the meaning of a fuzzy proposition.

fuzzy self-tuning self-tuning based on fuzzy logic concepts or fuzzy systems with some kind of self-tuning strategy or adaptation.

fuzzy set introduced by L. Zadeh (1965). A fuzzy set A in a universe of discourse X is characterized by a *membership function* μ_A which maps each element of X to the interval $[0, 1]$. A fuzzy set may be viewed as a generalization of a classical (crisp) set whose membership function only takes two values, zero or unity. *See also* crisp set, membership function.

fuzzy singleton a fuzzy set of membership value equal to 1 at a single real-valued point and 0 at all other points in the universe of discourse. *See also* membership function, fuzzy set.

fuzzy sliding mode control a combination of available mathematical description of the system dynamics with its linguistic description in terms of IF-THEN rules. In the early stages of fuzzy logic control, fuzzy modeling meant just a linguistic description in terms of IF-THEN rules of the dynamics of the plant and the control objective. *See also* TSK fuzzy model and fuzzy system.

fuzzy space the region containing the fuzzy sets created by set theoretic operations, as well as the consequent sets produced by approximate reasoning mechanisms.

fuzzy state feedback fuzzy control based on feedback of plant states.

fuzzy state space model fuzzy dynamic models in state space format. A typical example is a set of local linear state space models smoothly connected through a set of nonlinear membership functions.

fuzzy system a fuzzy system is a set of IF-THEN rules that maps the input space, say X, into the output space Y. Thus, the fuzzy system approximates a given function $F : X \to Y$ by covering the function's graph with patches, where each patch corresponds to an IF-THEN rule. The patches that overlap are averaged. *See also* fuzzy inference system.

fuzzy thresholding algorithm a thresholding algorithm with a threshold selected based on fuzzy measure.

fuzzy tuning the tuning of a control system using fuzzy logic and fuzzy rules.

fuzzy union an operator that take the maximum value of the membership grades.

FWHM *See* full width at half max.

G

G (giga) a prefix indicating a quantity of 10^9. For instance, a gigabyte (GB) of storage is 1,000,000,000 (typically implemented as 2^30) bytes.

G$_{CR}$ common notation for compression. *See* compression.

g$_d$ common notation for DC drain conductance.

G$_I$ common notation for current gain. G_I is dimensionless.

g$_m$ common notation for DC transconductance.

G$_P$ common notation for power gain in decibels.

G$_T$ common notation for transducer gain in amperes/volt.

G$_V$ common notation for voltage gain. G_V is dimensionless.

G-line a line of the mercury spectrum corresponding to a wavelength of about 436 nm.

GaAlSb/InGaAlAsSb nearly lattice matched semiconductor heterostructure system capable of "staggered" band lineups in which the electrons and holes congregate in separate layers. Unique transport properties are utilized in optical devices and tunnel structures.

GaAs periodic table symbol for gallium arsenide. *See* gallium arsenide.

GaAs laser a semiconductor laser for wavelengths in the near infrared. The active medium is a gallium-arsenide semiconductor alloy.

GaAs/AlGaAs most commonly grown semiconductor epitaxial heterostructure due to its lattice match, common anion, and existing technology base of GaAs devices.

Gabor transform a short-time Fourier transform in which the window function is the Gaussian function.

gain (1) the ratio of the output variable of a device to its input variable. For calculation purposes, the dimensionality of the gain is simply the unit of the output variable divided by the unit of the input variable. The gain of a device is a dimensionless value only when the electrical units of both the input and output variables are the same (e.g., voltage gain, current gain, power gain, etc.). In this case, a gain greater than one indicates an increase from input to output, while a value for gain less than one is indicative of a decrease (or attenuation). The overall gain of several cascaded components is found by multiplying the individual gains of each component in the system. Gain is often expressed in decibels to facilitate calculation of cascaded gains in a system. *See also* decibel.

(2) the ratio of the radiation intensity of a particular antenna to that of an isotropic radiator, in the same direction and at the same distance.

gain circles circles of constant gain plotted on the Smith chart that can be used to graphically impedance match a device to achieve a desired gain. The circles are generated by plotting on the Smith chart the solution for the source reflection coefficient, Γ_s, or load reflection coefficient, Γ_L, in the transducer gain equation for a fixed value of

$$G = \frac{|S_{21}|^2(1-|\Gamma_S|^2)(1-|\Gamma_L|^2)}{|(1-S_{11}\Gamma_S)(1-S_{22}\Gamma_L)-S_{12}S_{21}\Gamma_L\Gamma_S|^2}$$

for a fixed value of G_t, where S_{11}, S_{22}, S_{12}, and S_{21} are the scattering parameters for the device.

gain coefficient factor multiplying distance in a formula for the exponential amplitude or intensity growth of a wave in an unsaturated amplifying medium.

gain compensation this deals with the assumption in motion estimation in interframe coding that illumination is spatially and temporally uniform. Under these assumptions, the monochrome intensities $b(\mathbf{z}t)$ and $b(\mathbf{z}t-\tau)$ of two consecutive frames are related by $b(\mathbf{z}t)$ and $b(\mathbf{z}-\mathbf{D}, t-\tau)$ where τ is the time between two frames, $\mathbf{D}$ is the two-dimensional translation vector. Often this assumption about uniform illumination is not correct. In some situations, a multiplicative factor called *gain* is used to change the intensity. This is called gain compensation. This results in estimating $\mathbf{D}$ using gradient-type algorithms to minimize the square of the prediction error.

gain focusing focusing or collimation of an electromagnetic beam by the profile of the gain; gain guiding.

gain guided laser diode electrically pumped semiconductor laser in which the mode fields are confined in the transverse direction by the profile of the gain.

gain medium medium for which an output electromagnetic wave has more power than the corresponding input, essential for laser operation.

gain ripple difference between the maximum gain ($G_{max} = 10\log_{10}[p_{outmax}/p_{incident}]$) and the minimum gain across the band ($G_{min} = 10\log_{10}[p_{outmin}/p_{incident}]$), expressed in decibels. The band edges are usually defined as the highest and lowest frequencies within a contiguous band of interest at which the gain equals the minimum required passband gain.

$$\begin{aligned} G_{ripple} &= G_{max} - G_{min} \\ &= 10\log_{10}\left(\frac{p_{outmax}}{p_{incident}}\right) \\ &\quad - 10\log_{10}\left(\frac{p_{outmin}}{p_{incident}}\right) \end{aligned}$$

gain saturation reduction in gain that occurs when the intensity of a laser field depletes the population inversion.

gain switching rapid turn-on of the gain in a laser oscillator for the purpose of producing a large output pulse.

gain–bandwidth product for amplifiers based on a voltage-feedback op-amp, increasing the closed-loop gain causes a proportional decrease to the closed-loop bandwidth; thus the product of the two is a constant. This constant is called the gain–bandwidth product, and is a useful figure-of-merit for the performance of the op-amp.

gain-guided laser laser in which the mode fields are confined in the transverse direction by the profile of the gain.

gain-shape vector quantization (GSVQ) *See* shape-gain vector quantization.

gain-transfer measurement method common antenna gain measurement scheme in which the absolute gain of the antenna under test is determined by measuring its gain relative to a gain standard (i.e., antenna with accurately known gain).

GaInN/AlInN rapidly evolving semiconductor heterostructure system with ability to emit light in the green and blue regions of the spectrum for long-lifetime LEDs and lasers.

Galerkin's method in an integral equation technique used to solve a numerical electromagnetic problem, the method in which the expansion and testing functions are the same.

gallium arsenide (GaAs) a composite widely used in the fabrication of active elements.

gallium phosphide (GaP) (1) a semiconductor for high-speed electronics and that is part of the family of III-V compounds for semiconductor lasers.

(2) an acousto-optic material with good acousto-optic figure of merit and with low acoustic attenuation for high-bandwidth acousto-optic cells.

galloping a low-frequency vibration of electric power lines caused by wind.

Galois field a finite field with q elements denoted as $\mathrm{GF}(q)$, important in the study of cyclic codes. *See also* finite field.

Galvani, Luigi (1737–1798)
Born: Bologna, Italy

Galvani is best known for the use of his name in the description of zinc plating, or "galvanizing" metals. Galvani was an anatomist who studied the flow of electricity in frog's legs when metal contacts were applied. Many of Galvani's ideas were later proved incorrect by Alessandro Volta. However, his pioneering work was honored by the reference to Galvanic current as an early name for electric current. Andre Ampere also honored him by naming his current measurement apparatus a galvanometer.

gamma camera a device that uses a scintillation crystal to detect gamma photons for radionuclide imaging. Also known as a scintillation camera.

gamma correction inside a CRT, the luminance of a pixel is represented by a voltage V; however, the luminance of the ray produced by that voltage is not proportional to V, but rather to V^{γ}, where γ is a device-dependent constant between 2 and 2.5. It is thus necessary to compensate for this effect by transforming the luminance L into $L^{1/\gamma}$; this is called gamma correction. Some CCD cameras implement gamma correction directly on the signal that they generate. Some computer monitors allow modification of the factor γ or gamma correction through software.

gamma rays electromagnetic radiation of very high energy (greater than 30 keV) emitted after nuclear reactions or by a radioactive atom when its nucleus is left in an excited state after emission of alpha or beta particles.

gamma-ray laser laser producing its output in the gamma-ray region of the spectrum, often considered to be any wavelength below about 0.1 angstrom; graser, not yet demonstrated.

ganged operation of a multiple phase device with all phases operated simultaneously.

GaP *See* gallium phosphide.

gap filler a low-power transmitter that boosts the strength of transmitted DAB RF signals in areas that normally would be shadowed due to terrain obstruction. Gap fillers can operate on the same frequency as DAB transmissions or on alternate channels that can be located by DAB receivers using automatic switching.

gapless arrester a lightning arrester which is distinguished from a gapped arrester by having a continuous conductive path between the conductor and ground.

gapped arrester a lightning arrester whose conducting path contains a gas- or air-filled spark gap which must be broken down by the lightning impulse voltage.

garbage an object or a set of objects that can no longer be accessed, typically because all pointers that direct accesses to the object or set have been eliminated.

garbage collection the process by which the memory, a program no longer uses, is automatically reclaimed and reused. Relying on garbage collection to manage memory simplifies the interfaces between program components. Two main methods used to implement garbage collection are reference counting and mark-and-sweep.

garbage collector a software run-time system component that periodically scans dynamically allocated storage and reclaims allocated storage that is no longer in use (garbage).

gas cable an electric power cable which is pressurized with an insulating gas, typically sulfur hexaflouride, for its primary insulation.

gas capacitor a capacitor whose dielectric is composed of a high-pressure gas, often nitrogen or an electronegative gas such as sulfur hexaflouride.

gas circuit breaker a circuit breaker in which the arc between the contacts is extinguished by immersion in or a blast of an electronegative gas.

gas discharge excitation electron impact excitation or pumping of a laser medium occurring as a result of collisions between the lasing atoms or molecules and the discharge electrons.

gas dynamic excitation excitation or pumping of a laser medium occurring as a result of heating followed by rapid expansion and cooling of a gaseous laser medium.

gas insulated switchgear circuit breakers and switches whose primary insulation is compressed gas.

gas laser laser in which the amplifying medium is a gas.

gas metal arc welding (GMAW) a welding process that produces coalescence of metals by heating them with an arc between a consumable filler metal electrode and the parts to be joined. The process is used with shielding gas and without the application of pressure.

gas substation an electric power substation in which the conductors are insulated from each other and the ground by a high-pressure gas, generally sulfur hexaflouride.

gas tungsten arc welding (GTAW) a welding process that produces coalescence of metals by heating them with an arc between a nonconsumable tungsten electrode and the parts to be joined. The process is used with shielding gas and without the application of pressure. Filler may or may not be used.

gate (1) a logical or physical entity that performs one logical operation, such as AND, NOT, or OR.

(2) the terminal of a FET to which controls the flow of electrons from source to drain. It is usually considered to be the metal contact at the surface of the die. The gate is usually so thin and narrow that if any appreciable current is allowed to flow, it will rapidly heat up and self-destruct due to I-R loss. This same resistance is a continuing problem in low noise devices, and has resulted in the creation of numerous methods to alter the gate structure and reduce this effect.

gate array a semicustom integrated circuit (IC) consisting of a regular arrangement of gates that are interconnected through one or more layers of metal to provide custom functions. Generally, gate arrays are preprocessed up to the first interconnect level so they can be quickly processed with final metal to meet customer's specified function.

gate length the length in microns of that portion of the FET channel, as measured in the direction of channel current flow, that can be pinched off by application of the proper control bias. Gate lengths are usually on the order of 0.1 to 2 microns. The $f_{\max}$ of a FET is inversely proportional to the gate length.

If the length is very short (less than 0.05 microns for GaAs), then quantum effects play a role in device operation.

gate turn off device (1) any power semiconductor switching device which can turned off with a signal to its gate.

(2) a thyristor capable of gate-turn-off operation.

gate turnoff thyristor a thyristor that can be turned off with a negative gate current while conducting current in the forward direction.

gate width the width in microns of that portion of a FET channel associated with a single gate, as measured in the direction orthogonal to channel current flow, that can be pinched off by application of the proper control bias. A single FET structure may include many subcells placed in parallel with each other, resulting in a much higher gate periphery for more power (i.e., 4 individual FETs, each with a gate of 100 microns, may be paralleled together to form a 4×100 micron FET with a gate periphery of 400 microns).

gate-to-drain breakdown voltage the breakdown voltage of the reverse biased gate-to-drain junction of an FET. Usually it is specified at a predetermined value of current per millimeter of gate periphery.

gate-to-drain capacitance the capacitance between the gate and drain terminals of a FET. It is formed primarily by the capacitance of the FET's physical interconnect structure (extrinsic fixed capacitance) and by the depleted region capacitance (intrinsic capacitance), which is a function of voltage and temperature.

gate-to-source breakdown voltage the breakdown voltage of the reverse-biased gate-to-source junction of an FET. Usually it is specified at a predetermined value of current per millimeter of gate periphery.

gate-to-source capacitance the capacitance between the gate and source terminals of a FET. It is formed primarily by the capacitance of the FET's physical interconnect structure (extrinsic fixed capacitance) and by the depleted region capacitance (intrinsic capacitance), which is a function of voltage and temperature.

gate-to-source voltage the potential difference between the FET gate and source terminals, this voltage controls the channel from saturation to pinchoff. This voltage is normally negative for an n-channel FET, and positive for a p-channel FET. However, either of these devices can be operated in a slightly enhanced mode, allowing low-level excursions of the opposite polarity.

gateway *See* router.

Gauss' law fundamental law of electromagnetic field that states that the total electric/magnetic flux through a closed surface is equal to the total electric/magnetic charge enclosed.

Gauss' theorem *See* divergence theorem.

Gaussian aperture aperture in which the transmission profile is a Gaussian function of radius.

Gaussian approximation an approximation used in statistics where the distribution of a sum of random variables is approximated by the Gaussian distribution. Such an approximation is based on the central limit theorem of probability.

Gaussian beam electromagnetic beam solution of the paraxial wave equation in which the field has spherical phase fronts and is a Gaussian function of distance from the beam axis.

Gaussian distribution a probability density function characterized by a mean μ and covariance Σ:

$$f(x) = (2\pi)^{-N/2}|\Sigma|^{-1/2} \exp\left(-(x-\mu)^T \Sigma^{-1}(x-\mu)/2\right),$$

where $|\Sigma|$ represents the determinant of Σ and N represents the dimensionality of x. If x is scalar then the above function simplifies considerably to its more familiar form:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{1}{2}\frac{(x-\mu)^2}{\sigma^2}\right).$$

The Gaussian distribution is tremendously important in modeling signals, images, and noise, due to its convenient analytic properties and due to the central limit theorem. *See also* probability density function, mean, covariance. *See also* Cauchy distribution, exponential distribution.

Gaussian elimination the standard direct method for solving a set of linear equations. It is termed direct because it does not involve iterative solutions. Variations of this scheme are used in most circuit simulators.

Gaussian mirror mirror in which the reflection profile is a Gaussian function of radius.

Gaussian noise a noise process that has a Gaussian distribution for the measured value at any time instant.

Gaussian process (1) a random process where the joint distribution of a set of random variables $X_1, X_2, \ldots, X_n$ determined as values of the process at the points $t_1, t_2, \ldots, t_n$ is an n-variate Gaussian distribution for all sets of points $t_1, t_2, \ldots, t_n$, and all values of the integer n.

(2) a random (stochastic) process $x(t)$ is Gaussian if the random variables $x(t_1), x(t_2), \ldots, x(t_n)$ are jointly Gaussian for any n.

Gaussian pulse pulse in which the field is a Gaussian function of time from the pulse maximum.

Gaussian sphere unit sphere, with an associated spherical coordinate system, normally used to represent orientations.

gaussmeter an instrument to measure the flux density due to a magnetic field.

Ge *See* germanium.

geared robot an arbitrary robot equipped with gears is called a geared robot. *See* direct drive robot.

genco a contraction of "generating company," which is a company which generates electric power but does not engage in transmission or distribution activities.

gender an adapter presenting two male or two female connectors for reversing the type of cable connector. Connectors can be of the same type or not.

general response formula for 2-D Roesser model the solution to the 2-D Roesser model

$$\begin{bmatrix} x^h_{i+1,j} \\ x^v_{i,j+1} \end{bmatrix} = \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} u_{ij} \quad \text{(1a)}$$

$i, j \in Z_+$ (the set of nonnegative integers)

$$y_{ij} = [C_1, C_2] \begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} + Du_{ij} \qquad \text{(1b)}$$

with boundary conditions x^h_{0j}, $j \in Z_+$ and x^v_{i0}, $i \in Z_+$ is given by

$$\begin{bmatrix} x^h_{ij} \\ x^v_{ij} \end{bmatrix} = \sum_{p=1}^{i} T_{i-p,j} \begin{bmatrix} 0 \\ x^v_{p0} \end{bmatrix} + \sum_{q=1}^{j} T_{i,j-q} \begin{bmatrix} x^h_{0q} \\ 0 \end{bmatrix} \qquad \text{(2)}$$
$$+ \sum_{p=0}^{i} \sum_{q=0}^{j} \left(T_{i-p-1,j-q} \begin{bmatrix} B_1 \\ 0 \end{bmatrix} \right.$$

$$+ T_{i-p,j-q-1} \begin{bmatrix} 0 \\ B_2 \end{bmatrix} \Big) u_{pq}$$

where $x^h_{ij} \in R^{n_1}$ and $x^v_{ij} \in R^{n_2}$ are the horizontal and vertical state vectors, $u_{ij} \in R^m$ is the input vector, $y_{ij} \in R^p$ is the output vector, A_1, A_2, A_3, A_4, B_1, B_2, C_1, C_2, D are given real matrices, and the transition matrix T_{pq} is defined by

$$T_{pq} = \begin{cases} I_n \ \text{ for } \ p = q = 0 \\ \begin{bmatrix} A_1 & A_2 \\ 0 & 0 \end{bmatrix} \ \text{ for } \ p = 1, q = 0 \\ \begin{bmatrix} 0 & 0 \\ A_3 & A_4 \end{bmatrix} \ \text{ for } \ p = 0, q = 1 \ \text{ and } \\ T_{10}T_{i-1,j} + T_{01}T_{i,j-1} \ \text{ for } \\ i, j \in Z_+ \ \ (i + j > 0) \\ 0 \ \text{ for } \ p < 0 \ \text{ or/and } \ q < 0 \end{cases}$$

Substitution of (2) into (1b) yields the response formula.

general response formula for generalized 2-D model the solution x_{ij} to the generalized 2-D model

$$\begin{aligned} Ex_{i+1,j+1} &= A_0 x_{ij} + A_1 x_{i+1,j} + A_2 x_{i,j+1} \\ &\quad + B_0 u_{ij} + B_1 u_{i+1,j} \\ &\quad + B_2 u_{i,j+1} \qquad (1a) \\ y_{ij} &= C x_{ij} + D u_{ij} \qquad (1b) \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) with admissible boundary conditions $x_{i0}, i \in Z_+$ and $x_{0j}, j \in Z_+$ is given by

$$\begin{aligned} x_{ij} &= \sum_{p=1}^{i+n_1} \sum_{q=1}^{j+n_2} \big(T_{i-p-1,j-q-1} B_0 \\ &\quad + T_{i-p,j-q-1} B_1 \\ &\quad + T_{i-p-1,j-q} B_2 \big) u_{pq} \\ &\quad + \sum_{p=1}^{i+n_1} \big(T_{i-p,j-1} [A_1, B_1] \\ &\quad + T_{i-p-1,j-1} [A_0, B_0] \big) \begin{bmatrix} x_{p0} \\ u_{p0} \end{bmatrix} \\ &\quad + \sum_{q=1}^{i+n_2} \big(T_{i-1,j-q} [A_2, B_2] \\ &\quad + T_{i-1,j-q-1} [A_0, B_0] \big) \begin{bmatrix} x_{0q} \\ u_{0q} \end{bmatrix} \\ &\quad + T_{i-1,j-1} [A_0, B_0] + \begin{bmatrix} x_{00} \\ u_{00} \end{bmatrix} \qquad (2) \end{aligned}$$

where $x_{i,j} \in R^n$ is the semistate local vector, $u_{i,j} \in R^m$ is the input vector, E, A_k, B_k $(k = 0, 1, 2)$ C, D are given real matrices with E possibly singular and the transition matrices T_pq are defined by

$$ET_{pq} = \begin{cases} A_0 T_{-1,-1} + A_1 T_{0,-1} \\ +A_2 T_{-1,0} + I \ \text{ for } \ p = q = 0 \\ A_0 T_{p-1,q-1} + A_1 T_{p,q-1} \\ +A_2 T_{p-1,q} \\ \text{for } \ p \neq 0 \ \text{ and/or } \ q \neq 0 \end{cases}$$

and

$$\begin{aligned} &[Ez_1 z_2 - A_0 - A_1 z_1 - A_2 z_2]^{-1} \\ &= \sum_{p=-n_1}^{\infty} \sum_{q=-n_2}^{\infty} T_{pq} z_1^{-(p+1)} z_2^{-(q+1)} \end{aligned}$$

pair (n_1, n_2) of positive integers n_1, n_2 such that $T_{pq} = 0$ for $p < -n_1$ and/or $q < -n_2$ is called the index of the model. Substitution of (2) into (1b) yields the response formula.

general-purpose motor term often used to describe National Electrical Manufacturers Association (NEMA) class B, and less often class B, induction motors. General-purpose motors are those typically used when relatively low starting currents, low slip, good speed regulation, moderate starting torque, and high efficiency are the predominant concerns.

general-purpose register a register that is not assigned to a specific purpose, such as holding condition codes or a stack pointer, but that may be used to hold any sort of value. General-purpose registers are typically not equipped with any dedicated logic to operate on the data stored in the register.

general-use switch a manually operated switching device designed for general use. It is designed to interrupt rated current at rated voltage.

generalization the process of inferring rules and taking decisions after a learning phase has taken place. The process is supposed to take place on data not used during learning.

generalized cone data structure for volumetric representations, generated by sweeping an arbitrarily-shaped cross section along a 3-D line called the "generalized cone axis."

generalized delta rule the weight update rule employed in the backpropagation algorithm.

generalized Lloyd algorithm (GLA) a generalization of the Lloyd (or Lloyd–Max) algorithm for scalar quantizer design to optimal design of vector quantizers. *See also* K-means algorithm.

generalized modus ponens generalization of the classical *modus ponens* based on the compositional rule of inference.

Let be a fuzzy rule $A \longrightarrow B$, that can be interpreted as a fuzzy relation R, and a fuzzy set A', then the compositional rule of inference maps a fuzzy set

$$B' = A' \circ R = A' \circ (A \longrightarrow B)$$

that can be interpreted as

premise1: *(fact)*	x is A'
premise2 : *(fuzzy rule)*	if x is A then y is B
consequence : *(conclusion)*	y is B'

For example, if we have the fuzzy rule *"If the tomato is red then it is ripe,"* and we know *"The tomato is more or less red"* (fact), the generalized modus ponens can infer *"The tomato is more or less ripe."*

See also compositional rule of inference, fuzzy inference, fuzzy relation, linguistic variable, modifier.

generator in electrical systems, any of a variety of electromechanical devices that convert mechanical power into electrical power, typically via Faraday induction effects between moving and stationary current-carrying coils and/or magnets. Electrostatic generators use mechanical motion to physically separate stationary charges to produce a large electrostatic potential between two electrodes.

generator coherency a group of generators where the rotor angles swing in synchronism with one another following a disturbance. Usually, generators in close electrical proximity and at some distance from the fault tend to be coherent.

generator differential relay a generator differential relay is a differential relay specifically designed for protection of electric power generators. Variations include allowances for split-phase winding machines.

generator inertia constant a term proportional to the combined moment of inertia of the turbine-generator mass.

generator matrix a matrix used to describe the mapping from source word to code word in a linear forward error control code. The mapping is described through multiplication of the source word by this matrix using element-wise finite field arithmetic. A linear code is completely specified by its generator matrix.

generator polynomial uniquely specifies a cyclic code and has degree equal to the number of the parity bits in the code. For an (n, k) cyclic code, it is the only code word polynomial of minimum degree $(n - k)$.

genetic algorithm an optimization technique that searches for parameter values by mimicking natural selection and the laws of genetics. A genetic algorithm takes a set of solutions to a problem and measures the "goodness" of those solutions. It then discards the "bad" solutions and keeps the "good" solutions. Next, one or more genetic operators, such as mutation and crossover, are applied to the set of solutions. The "goodness" metric is applied again and the algorithm iterates until all solutions meet certain criteria or a specific number of iterations has been completed. *See also* optimization.

genlock a shortened term for "generator lock," meaning that one sync generator system is locked to another. When video systems are genlocked, sync and burst information is the same for both systems.

geodesic lens a lens composed of circularity symmetric spherical depression (or dimples) in the surface of a thin-film waveguide. In this type of lens, light waves are confined in the waveguide and follow the longer curved path through the lens region. Waves propagating near the center of the lens travel a longer path than waves near the edge, modifying the wave front so that focusing can occur.

geometric distribution a discrete probability density function of a random variable **x** that has the form

$$p\{\mathbf{x} = k\} = p(1-p)^k k = 0, 1, 2, \ldots.$$

This is the probability that k independent trials, each with probability of success p and failure $1 - p$, fail before one succeeds. *See also* probability density function.

geometric Jacobian the Jacobian (or more precisely the Jacobian matrix, but roboticists usually shorten it to simply Jacobian) is a mapping from velocities in joint space (generalized velocities) to velocities in Cartesian space. This mapping is written in the form $v = J(q)\dot{q}$ where v is a six-dimensional vector of linear and angular velocities of the end-effector and $\dot{q}$ is a vector of generalized velocities $\dot{q}(t) = [\dot{q}_1(t), \dot{q}_2(t), \ldots, \dot{q}_n(t)]^T$. The Jacobian has dimensions $6 \times n$. All points in which the Jacobian is not invertible are called singularities of the mechanism or singularities. The Jacobian is defined for an arbitrary manipulator and depends on its geometric parameters (more precisely, Denavit–Hartenberg parameters). *See also* analytical Jacobian.

geometric radian center frequency the logarithmic radian center frequency, it is the logarithmic mid-point between the higher (ω_H) and lower (ω_H) band edges, expressed in radians/second. The band edges are usually defined as the highest and lowest frequencies within a contiguous band of interest at which the loss equals L_{Amax}, the maximum attenuation loss across the band.

$$\omega_{OG} = \sqrt{\omega_H \cdot \omega_L}$$

or

$$\log_{10}(\omega_{OG}) = \frac{\log_{10}(\omega_H) + \log_{10}(\omega_L)}{2}$$

geometric theory of diffraction a correction to geometrical optics that includes diffracted fields due to corners or edges and accounts for energy diffracted into the shadow region.

geometric transformation transforms the pixel co-ordinates of an image to effect a change in the spatial relationships of elements in the image. The change often takes the form of a stretching or warping of the image.

geometrical optics a high-frequency technique using ray tracing for tubes of rays to determine incident, reflected, and refracted fields. Most useful in real media when the wave amplitude varies slowly compared to the wavelength.

geosynchronous orbit an orbit 22,753 miles above the earth in which an object will orbit the earth once every 24 hours above the equator and will appear to be stationary from the earth's surface.

geothermal energy thermal energy in the form of hot water and steam in the earth's crust.

germanium (Ge) an optical material for construction of components and systems at infrared wavelengths, especially in the 8 to 14 micron region. Also, an acousto-optic material for infrared wavelengths.

Gershgorin circle measures the relative size of the off-diagonal elements in a transfer function matrix at a given frequency. When evaluated over a range of frequencies, these circles sweep out a band, centered on the diagonal elements, that is used in the prediction of closed loop stability for multi-input–multi-output systems. This theory is based on Gerhsgorin's theory on the bounds of matrix eigenvalues. *See also* diagonal dominance and inverse Nyquist array.

GFCI *See* ground-fault circuit interrupter.

GFI *See* ground fault interrupter.

GFLOP *See* gigaflop.

ghosting the formation of an image in which a ghost image (i.e., a similar, fainter, slightly displaced image) appears superimposed on the intended image; ghosts result from a form of crosstalk, and typically arise by radio transmission via an alternative path occurring as a result of random reflection.

giant magnetoresistance effect huge change in electrical resistance with relatively small change in magnetic field exhibited by multilayers of many combinations of metallic materials. Used in the next generation of hard disk memory.

giant pulse large output pulse from a laser oscillator that results when the cavity losses are quickly raised from a high value holding a pumped laser below threshold to low value bringing the laser above threshold (Q-switching or loss-switching) or when the gain occurs in the form of a short pulse (gain switching).

Gibbs phenomenon the rippling phenomenon in the reconstruction of a function around a discontinuity based on the Fourier series of the function. Specifically, given a discontinuous periodic function f which is square-integrable on its period, the Fourier series of f converges to f in the square mean sense. When the periodic function corresponding to the n first terms of that Fourier series is built, then ripples appear at the vicinity of each discontinuity of f. When n tends to infinity, these ripples tend to zero in the square mean sense, but their maximum amplitude does not tend to zero; this produces an overshoot by a factor of 1.1789797 and an undershoot by a factor of 0.9028233. A similar effect arises for a square-integrable nonperiodic function reconstructed from its Fourier transform. The phenomenon causes ringing around edges in low bit rate image coding. *See* Fourier integral, Fourier series, norm.

Gibbs random field a class of random fields described by normalized exponentials of potential functions over cliques. Let $S = s_1, s_2, \ldots$ be points on a lattice, and let $\omega \in \Omega$ be a sample of a random field on this lattice. Points on the lattice interact with other lattice points in a local, predefined manner; that is, the energy of the lattice is given by the sum of the energies of locally-interacting sets of points in the lattice: each such set of points is known as a clique $C \in \mathcal{C}$. Specifically, the energy of clique C in sample ω is $V_C(\omega)$, where V is a potential function depending only upon the points in C. Then the total energy of a sample ω is given by

$$E(\omega) = \sum_{C \in \mathcal{C}} V_C(\omega).$$

With this definition, a probability measure π is a Gibbs random field if

$$\pi(omega) = \frac{1}{Z} e^{-E(\omega)/T}$$

where $Z = \sum_\omega e^{-E(\omega)/T}$ is a normalization constant.

Gibson mix an analysis of computer machine language instructions that concluded that approximately 1/4 of the instructions accounted for 3/4 of the instructions executed on a computer.

GIF *See* Graphics Interchange Format.

gigaflop (GFLOP) 1000 million floating point operations per second.

Gilbert cell a four-transistor configuration combining the differential pair and current mirror concepts. With appropriate signal conditioning at the input and output terminals, the cell can be used for many analog signal processing applications such as analog multiplication.

Gilbert, William (1544–1603) Born: Colchester, Essex, England

Gilbert is best remembered as an early investigator into electric charge and magnetism. He is also considered by many to be the inventor of the modern scientific method. This is due to his rigorous experimental methodology, and the detailed records he kept on his investigations. Isaac Newton and Francis Bacon both acknowledged his contributions in this regard. Gilbert was, by training, a physician and held the post of royal physician in the courts of Elizabeth I and James I.

Givens transformation a transformation, proposed by Givens, that transforms a general matrix to a triangular form. The Givens transformations $G_{ij\theta}$ are functions of three parameters. Transforming a vector b, $a = G_{ij\theta}b$; then $a_n = b_n$ for all $n \neq i, n \neq j$, and the two-vector $[a_i a_j]$ is equal to the rotation of vector $[b_i b_j]$ by an angle θ in the plane. Givens rotations can be used to successively set elements of a matrix to zero by an appropriate selection of $ij\theta$.

GKS *See* graphical kernel system.

GLA *See* generalized Lloyd algorithm.

glass laser laser in which the host medium for doping with laser atoms is a glass.

glitch (1) an incorrect state of a signal that lasts a short time compared to the clock period of the circuit. The use of "glitch" in describing power systems is generally avoided. *See also* hazard.

(2) slang for a transient that causes equipment crashes, loss of data, or data errors.

global alignment a method of alignment where the mask is aligned globally to the whole wafer (as opposed to field-by-field alignment).

global interconnection interconnection in which every source is connected to all detectors and every detector is connected to all sources. Global interconnection is easily implementable using optics because, unlike electrons, photons do not interact with each other, and an optical system is inherently a parallel processor.

global memory in a multiprocessor system, memory that is accessible to all processors. *See also* local memory, distributed memory.

global minimum a point at which a function attains its lowest value over the domain of its arguments.

global observability of generalized 2-D model the generalized 2-D model

$$\begin{aligned} Ex_{i+1,j+1} &= A_1 x_{i+1,j} + A_2 x_{i,j+1} \\ &\quad + B_1 u_{i+1,j} + B_2 u_{i,j+1} \\ y_{ij} &= C x_{ij} \end{aligned}$$

is called globally observable if any of its global semistates

$$X(q) := \{x_{i-q,-i}\ , i = \ldots, -1, 0, 1, \ldots; \\ q = 0, 1, \ldots\}$$

can be calculated using future outputs and inputs of the model, i.e.,

$$U(k) := \{u_{i+k,-i}, i = \dots, -1, 0, 1, \dots;$$
$$k = 0, 1, \dots\}$$
$$Y(k) := \{y_{i+k,-i}, i = \dots, -1, 0, 1, \dots;$$
$$k = 0, 1, \dots\} \text{ for } k \geq q$$

global positioning system (GPS) system of 18 primary satellites in medium earth orbit, distributed so that at least four are simultaneously visible from each point on the globe; typically used in timing and positioning applications.

global reconstructibility of generalized 2-D model the generalized 2-D model

$$E x_{i+1,j+1} = A_1 x_{i+1,j} + A_2 x_{i,j+1} + B_1 u_{i+1,j} + B_2 u_{i,j+1}$$
$$y_{ij} = C x_{ij}$$

is called globally reconstructible if any of its global semistates

$$X(q) := \{x_{i-q,-i}, i = \dots, -1, 0, 1, \dots;$$
$$q = 0, 1, \dots\}$$

may be calculated using past outputs and inputs of the model, i.e.,

$$U(k) := \{u_{i+k,-i}, i = \dots, -1, 0, 1, \dots;$$
$$k = 0, 1, \dots\}$$
$$Y(k) := \{y_{i+k,-i}, i = \dots, -1, 0, 1, \dots;$$
$$k = 0, 1, \dots\} \text{ for } k \leq q$$

Global System for Mobile Communications (GSM) a set of systems specifications that describe the Pan European digital mobile cellular radio system. This set of 13 recommendations describe service, synchronization, hardware, operating and maintenance characteristics for the system.

globally asymptotically stable equilibrium an asymptotically stable equilibrium (see the definition) with a region of attraction (see the definition) equal to $\Re^n$ (n-dimensional real Euclidean space).

globally asymptotically stable state *See* asymptotically stable in the large.

glove in power line work, this refers to conductors which are energized with voltages low enough to be safely contacted by workers wearing suitable rubber gloves, to the range of voltages at which the practice is allowed, and to the gloves themselves.

GMAW *See* gas metal arc welding.

GMSK *See* minimum-shift keying Gaussian.

goat head the top of a tower.

Gold book *See* IEEE Color Books.

Gold sequences a set of spreading sequences developed by the coding theorist R. Gold in 1966 that are typically used in a multiple access system utilizing direct sequence spread spectrum. The set of Gold sequences is the solution of a problem in sequence design, where the criteria is the minimization of the maximum cross-correlation between any two sequences in the set under all possible cyclic shifts of one sequence relative to the other. *See also* cross-correlation.

Gompertz dynamics the simplest nonlinear, with sigmoidal growth function, model of population dynamics. The unperturbed growth of population is described by the first-order differential equation

$$\dot{x} = gxln\left(\frac{x_{\max}}{x}\right)$$

where x is an average number of individuals in the population with maximal value (the so-called plateau population) x_{max} and g is a positive growth parameter. The Gompertz equation may be simplified using the dimensionless scaling

$$y = ln\left(\frac{x_{\max}}{x}\right)$$

which leads to a linear equation of the form

$$\dot{y} = -gy$$

The simplest way to introduce perturbations to the dynamics represented by affine control actions is to add a bilinear term into the Gompertz equation

$$\dot{x} = gln\left(\frac{x_{\max}}{x}\right) - kux$$

where u is a control variable and k represents a perturbed population loss (or growth) parameter. By applying the dimensionless scaling, the equation could be once more transformed into the linear one with respect to variable y. The unperturbed Gompertz dynamics could also be represented by two first-order differential linear equations

$$\dot{x} = q(t)x; \dot{q} = -gq; x(0) = x_0; q(0) = q_0$$

with $x_0 e^{-\frac{q_0}{g}} = x_{\max}$.

Gordon–Haus limit expresses the maximum performance of a soliton-based communication system as a bitrate-length product.

GOS *See* grade of service.

governor a device connected to a rotating machine by which the speed-regulating system is automatically adjusted to maintain constant speed under various load conditions.

governor power flow the inherent response of prime movers or governors to a change in the operating condition of the power system in an attempt to balance the power equation. All generators participate at some level in the change, with larger generators picking up relatively larger amounts.

GPS *See* global positioning system.

grade of service (GOS) a probabilistic measure of service or equipment availability in a telecommunications network, expressed as the probability of a particular service (e.g., a completed telephone connection) being denied at request time.

graded index medium in which the index of refraction varies as a function of position; usually refers to variations transverse to the direction of propagation, and quadratic transverse variations are especially important.

graded index fiber an optical fiber where the core refractive index varies from a maximum at its center to a minimum value at the core-cladding interface. The profile is typically designed so that all modes of a multimode fiber propagate at approximately the same velocity. *See also* step index fiber.

graded index lens cylindrical optical elements with a refractive-index profile across the cross section of the element to provide the transfer; lens in which the transmitted waves are focused or defocused by transverse variations of the index of refraction rather than by transverse variations of the thickness.

graded index optical fiber an optical fiber with a refractive index in the core that decreases monotonically from the fiber axis to the interface between the core and cladding. The index usually goes from a higher value in the center of the core to a lower value of refractive index at the core/cladding interface. *See also* graded index profile.

graded index optics optical elements that use a refractive-index profile across the cross-section of the element, typically a cylinder, to provide particular transfer functions as for lenses; the profile is generally produced by ion implantation. Also called GRIN optics.

graded index profile an index of refraction in an optical fiber core that decreases with distance from the core axis out to the core/cladding boundary. The variation of the index of refraction with the radial distance from the fiber axis can be given approximately as a power law.

gradient a vector function denoted by ∇f or **grad** f, where f is a continuous, differentiable scalar function. For a 2-D function

$f(x, y)$, the gradient is

$$\nabla f = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

The magnitude of this gradient is

$$|\nabla f| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}.$$

In image processing, the term gradient often refers to the magnitude of the gradient. *See also* Sobel operator.

gradient descent a method for finding the minimum of a multidimensional function $f(x)$. The technique starts at some point and advances towards the minimum by iteratively moving in a direction opposite to that of the gradient:

$$x_{i+1} = x_i - \alpha \frac{\partial f}{\partial x}$$

where α is some scalar, usually set empirically. *See also* gradient, optimization.

gradient edge detector an edge detector that defines an edge to be present at a pixel only if the magnitude of the gradient at that pixel is greater than some threshold. *See also* edge, edge detection, gradient, Sobel operator.

gradient index optics optical components, e.g., optical fibers, within which the refractive index changes gradually between two extremes.

gradient space a 2-D representation of the orientation of a 3-D surface in space, in which the two components of a point $P \equiv (p, q)$ are the first-order partial derivatives of a surface of the form $z = f(x, y)$.

Gram-Schmidt orthogonalization a recursive procedure for whitening (decorrelating) a sequence of random vectors. *See also* whitening filter.

grammar an ordered 4-tuple ($G = T, V, P, S$), where T is said to be the set of terminals, V is the set of variables or non-terminals, P a set of production rules and $S \in V$ is called the start symbol. Terminals are the symbols with which the strings of the language are made. For example, T may be the English alphabet, the ASCII character set, or the set $\{0, 1\}$. Non-terminals are symbols that are replaced by a string of zero or more terminals and non-terminals. The production rules specify which strings can be used to replace non-terminals. The symbol S is the first symbol with which every production starts. All the strings that can be generated from S using rules in P are said to be in $L(G)$, the language of G.

example: Let G be the grammar (T, V, P, S) such that

$$\begin{aligned} T &= \{a, b\} \\ V &= \{S\} \end{aligned}$$

where S is the start symbol and

$$P = \{S \rightarrow aSb, S \rightarrow \epsilon\}$$

where ϵ is the empty string. The language $L(G)$ is the set of all strings of the form $a^n b^n$. The $\rightarrow$ symbol signifies that S can be replaced with whatever follows the arrow.

grant signal a control signal on a bus that gives permission to control the bus to another module.

graph a couple $G = (E, V)$ where V is a set of nodes and $E \subseteq V \times V$ is a set of edges. Graphs are widely used in modeling networks, circuits, and software.

graph search an optimization technique used to find the minimum cost path from a starting point to a goal point, through a graph of interconnected nodes. Each link between nodes has an associated path cost, which must be selected based on the problem of interest. *See also* optimization.

graphic adapter an adapter for interfacing the computer toward a monitor. *See* MDA, CGA, EGA, VGA.

graphic controller *See* graphic adapter.

graphical kernel system (GKS) a standard for computer graphics recognized by both ANSI and ISO. GKS defines the manipulation of graphic objects, including their visualization, print, etc. All manipulation is performed by regarding the graphic adoption as a independent device driver. In this way, GKS applications can be executed on different kinds of graphics adapters.

graphics the discipline dealing with the generation of artificial images by a computer. Its two main aspects are geometric modeling, whose subject is the computational representation of the geometry and topology of objects and scenes, and rendering, which studies the generation of images from the interaction of light and objects. Graphics has been generalized to the synthesis of animated image sequences, in which case one speaks of computer animation. Also called computer graphics, image synthesis.

Graphics Interchange Format (GIF) a popular image-file format that compresses the image with LZW coding. *See also* file format, image compression, Lempel-Ziv-Welch (LZW) coding.

The Graphics Interchange Format(c) is the Copyright property of CompuServe Incorporated. GIF(sm) is a Service Mark property of CompuServe Incorporated.

grating *See* diffraction grating.

grating lobe a lobe in an antenna radiation pattern whose peak amplitude is equal to that of the main lobe.

grating spectrometer an instrument that provides a spectral decomposition of a optical source using a diffraction grating to give spatial dispersion of wavelengths.

gravitational torque torque that depends upon the position of the robot in the gravitational field.

Gray book *See* IEEE Color Books.

Gray code a code in which each of a sequence of code words differs by one bit from the preceding one, and the assigned value of each code word is one more than that of the preceding one. Such a code avoids glitches (i.e., sharp momentary unwanted spikes) when, in an electromechanical system, the sensors giving the code words are imperfectly aligned. For example, one possible three-bit Gray code is:

000 001 011 010 110 111 101 100.

gray level the individual numerical value corresponding to a particular degree of brightness in a digital image, often on an 8-bit gray scale consisting of 256 gray levels stretching from pure black to pure white.

gray level co-occurrence a means of measuring texture and other brightness variations in digital images by generating matrices which tabulate the frequencies with which different gray levels co-exist at different distance vectors from each other.

gray level saturation the restriction of image gray scale so that intensities above a certain level become fixed at the white level corresponding to the highest numerical value available within the current storage capacity, typically one byte, of each pixel.

gray scale (1) an optical pattern in discrete steps between light and dark.

(2) intrinsic modulation property of the marking technology that enables dots of either different size or intensity to be printed.

(3) in digital images, a method used to represent varying levels of brightness. Typically, gray images use 8-bit gray level for the gray scale so that for each picture element, 0 represents pure black and 255 represent pure

Gray code

decimal digit	0	1	2	3	4	5
Gray code	000	001	011	010	110	111

white with other gray levels in between these extremes.

grayscale *See* gray scale.

Green book *See* IEEE Color Books.

Green's function the function that satisfies a given differential equation having as source term a Dirac delta function. *See* delta function.

Green's theorems consider a closed, regular, surface S bounding a volume V where the two scalar functions ϕ and ψ, continuous together with their first and second derivatives throughout V and on the surface S, are defined. Green's first identity states

$$\int_V \nabla\psi \cdot \nabla\phi \, dV + \int_V \psi\nabla^2\phi \, dV = \int_S \psi \frac{\partial\phi}{\partial n} \, dS$$

while Green's second identity takes the form

$$\int_V \left(\psi\nabla^2\phi - \phi\nabla^2\psi\right) dV = \int_S \psi \frac{\partial\phi}{\partial n} \, dS - \int_S \phi \frac{\partial\psi}{\partial n} \, dS$$

which is frequently referred to as Green's theorem.

grey level *See* gray level.

grey scale *See* gray scale.

grid refers to the regular array of vertical and horizontal wires used for interconnecting the chip.

grid array a technique for combining the output of amplifiers or oscillators in space by using a two-dimensional spatial array of elements placed on a uniformly spaced grid.

GRIN optics *See* graded index optics.

grip a twisted wire tie which secures a wire to an insulator or other fixture.

grip teeth a set of jaws which secures a wire to a hoist or come-a-long *cf* so that it can be pulled into place.

gripple *See* gain ripple.

grooved media on an optical disk, the embossment of the disk surface with grooves such that the disk tracks are either the grooves themselves or the regions between the groves.

ground (1) an earth-connected electrical conducting connection that may be designed or non-intentionally created.

(2) the electrical "zero" state, used as the reference voltage in computer systems.

ground bounce a transient variation in the potential of the ground terminal of a logic device caused by variations in the supply current acting on the ground impedance of the circuit as seen by the device. Usually caused by simultaneous turnon of the pullup and pulldown sections of totem-pole outputs.

ground bounce noise ground bounce occurs when a large number of semiconductor circuit components are mounted on a common semiconductor chip substrate, so that they are imperfectly insulated from each other. In normal operation the substrate should act as an insulator; however, during certain unusual fluctuations in signal levels, the systems power and ground connections can experience fluctuations, which affect the performance of each component in a random way that has the characteristics of noise, much like capacitive coupling.

ground current the current that flows in a power system in a loop involving earth and (in some usages) other paths apart from the three phases.

ground fault interrupter a protective device used in commercial and residential wiring which monitors equipment connected to an electrical outlet and shuts off the power when a ground fault in the equipment is detected.

ground fault neutralizer an inductor connected between the neutral of Y windings of a generator or transformer and ground. It is tuned to the machine's capacitance so as to minimize ground fault current.

ground lamp indicator lamp on electrical distribution switchboards that darkens when a ground condition exists on one (or more) of the busses.

ground loop an undesired conductive path between two conductive bodies in a radial grounding system that are connected to a common ground.

ground plane a perfectly or highly conducting half space beneath an antenna. Also, an unetched layer of metal on a printed circuit board over which microstriplines and printed antennas are formed.

ground rod a metallic, rod-type electrode designed to be driven into the earth. It serves as an earth connection for grounding purposes. Other types of earth electrodes include buried plates, rings, and grids. For buildings, its primary function is to keep the entire grounding system at earth potential.

ground wave a vertically polarized TEM wave propagating close to the ground. It is one of the three modes of propagation (ground, sky, and space waves).

ground-fault circuit interrupter (GFCI) a device designed to detect ground-fault current above a threshold value (several milliamperes) and then interrupt the source of electrical power by opening a circuit breaker or a set of contacts. GFCIs are designed for personnel protection and are generally available in the form of circuit breakers and receptacles.

ground-signal-ground (GSG) (1) configuration of the contact tips of a coplanar microwave probe. A single signal contact is positioned in the center of two parallel ground plane contacts.

(2) a network of wires buried in the earth around a electric power transmission line tower to reduce footing impedance.

grounded system an electrical distribution system in which one of the normal current-carrying conductors, often the neutral, is intentionally grounded.

grounding *See* ground.

grounding transformer a transformer connected to an otherwise ungrounded three-phase system for the purpose of providing a path for ground current flow. Zig-zag transformers and grounded wye-delta transformers can be used as grounding transformers.

group code a recording method used for 6250 bpi (bits per inch) magnetic tapes.

group decision support system a special decision support system used in support of groups of decision makers that might be geographically dispersed.

group delay the derivative of the radian phase with respect to frequency.

group detection a special strategy for multiuser detection in a multiple access system. The users get divided into a number of detection groups according to an appropriate criterion. The users in the designated first group are detected using a predetermined detection technique; the corresponding multiple access interference generated by this group of users is estimated, and then subtracted from the received signal. This detection and cancellation is continued successively until all users in all groups are detected.

group velocity (1) a quantity proved to indicate (in most dispersive media) the speed of energy propagation of wavepackets.

(2) in an optical fiber, the speed at which a signal superimposed on an optical wave propagates.

Groupe Special Mobile (GSM) a digital cellular communications network standard developed in Europe in the 1980s and now implemented in many countries throughout the world. The acronym originally denoted Groupe Special Mobile, after the French-based group that developed the system. Now the acronym denotes Global System for Mobile. GSM is one of a group of systems that are usually referred to as second-generation cellular systems. The system uses 200 kHz channels, GMSK modulation and frequency hopping. GSM transmits digitally encoded speech at a rate of approximately 13 kbps and makes extensive use of channel error-correcting codes.

GSG *See* ground-signal-ground.

GSM *See* Global System for Mobile Communications.

GSVQ gain-shape vector quantization. *See* shape-gain vector quantization.

GTAW *See* gas tungsten arc welding.

GTO *See* gate turnoff thyristor.

guaranteed cost control a methodology of robust controller design whose objective is to ensure that the value of the performance index for the real system represented by the family of models with uncertainty changing within a given set is guaranteed to be not greater than a given value. Guaranteed cost control techniques are usually applied to nominally linear systems and quadratic cost functionals.

guard band a design technique for a color CRT intended to improve the purity performance of the device by making the lighted area of the screen smaller than the theoretical tangency condition of the device geometry.

guard digits those extra digits of the significand in a floating-point operand that must be retained in order to allow correct normalization and rounding of the result's significand.

guarded machine classification describing an electrical machine constructed with an open frame in which rotating components or live electrical parts are guarded by screens. Screen openings are restricted so that a rod with a diameter of 0.75 inches cannot contact any part within 4 inches of the guarded opening, and a rod with a diameter of 0.5 inches cannot contact any part more than 4 inches inside the guarded opening.

guide wavelength the distance over which the fields of propagating modes repeat themselves in a waveguide.

guided scrambling an extension of the self-synchronizing scrambling line code procedure in which the source bit stream is augmented with appropriately valued bits prior to scrambling in order to ensure that the scrambled sequence contains good line code properties.

guided wave interconnect a means for connecting electrical systems such as computers and computer circuit boards optically, using optical fibers and optical circuits of channel waveguides.

guy a wire which extends at an angle from a utility pole to the ground in order to brace the pole against toppling due to unbalanced forces from the utility lines it supports.

guy anchor one of several appliances used to hold a guy under tension in the earth.

guy guard a metal or plastic plate or tube mounted on a guy wire at ground level to increase the visibility of the wire and decrease its ability to cut into a person or object pressed against it.

H

H *See* horizontal.

***H*$_\infty$ design** a group of robust controller design methods based on the methodology of the Hardy space H_∞ consisting of all complex-valued functions of complex variable that are analytic and bounded in the open right half-plane. The least bound that may be imposed on this function is its H_∞ norm. Since the open right half-plane may be replaced by the imaginary axis $j\omega$, H_∞ methods provide a direct generalization of the classical frequency domain approach to control system design.

A standard problem is to design a controller that ensures the internal stability of the closed-loop system and minimizes the H_∞ norm of the transfer function between the inputs (reference signals, disturbances) and errors. Since this transfer function is equal to the sensitivity function, such design results in optimal sensitivity. The standard problem is then transformed into an equivalent model-matching problem with a fixed, possibly unstable transfer function derived from the plant and a "free parameter" stable compensator to be chosen. The compensator is found by minimization of the supremum over all frequencies of the modeling error. Finally, an optimal (or suboptimal) controller is synthesized based on the found optimal (or suboptimal) solution to the model-matching problem. To meet specific dynamic objectives the transfer functions are modified by pre- and postfilters in the form of frequency dependent weighting functions. Although the primary problem is formulated in frequency domain, it may be solved both by input–output and state space techniques. In the former case the algorithms are based on spectral and inner–outer factorizations and approximation theorems for complex functions. In the latter case the problem may be attacked by linear-quadratic game theoretic approach resulting in a set of Riccati equations. H_∞ (H infinity) methods may be used in robust stabilization, robust performance design, disturbance attenuation, optimal tracking, model following, optimal sensitivity design, etc.

H infinity design *See* H_∞ design.

H modes the wave solutions with zero electric field component in the direction of propagation. Also known as transverse electric (TE) modes.

H parameters characterizes a microwave network with an arbitrary number of ports by relating the total voltages and currents at the ports.

H-D curve *See* Hurter–Driffield curve.

H-mode *See* transverse electric wave.

H-plane in measuring an antenna's radiation pattern, the plane that is perpendicular to the current in the element and therefore contains the magnetic field intensity vector field. This plane is perpendicular to the electric field (E) plane cut.

H-plane sectoral horn a horn antenna where the aperture is formed by flaring the walls in the direction of the H-plane. The electric field (E) plane dimension is left unchanged from that of the waveguide feed.

H-tree a popular clock distribution tree topologically that resembles the H shape. It introduces the least amount of clock skew compared to other distribution topologies.

Haar transform unitary transform mapping N samples g(n) to N coefficients $G(k)$ in a way that corresponds to repeated two-point averaging and two-point differencing. The 2×2 Haar transform is

$$H_2 = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$

The scaling factor allows the same matrix to be used for the inverse transform. The 4×4 Haar transform can be interpreted as follows: first apply the 2×2 transform to two independent pairs of samples; then apply the 2×2 transform to the two average coefficients just computed. Larger Haar transforms are constructed by continuing this process recursively.

The Haar transform yields coefficients equal to the subband values generated by dyadic decomposition with the Haar wavelet. This transform has achieved rather less use than the other transforms in this family, such as the Discrete Cosine, Fourier and Hadamard transforms.

Haar wavelet the orthonormal wavelet pair $(\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}), (\frac{1}{\sqrt{2}}, \frac{-1}{\sqrt{2}})$. Analysis and synthesis pairs are identical. This is the most compact wavelet pair. Dyadic subband decomposition with the Haar wavelets yields coefficients equal to those from the Haar transform.

Haas effect states that the first sound heard will mask subsequent short delay arriving sounds, the combination appearing as a louder source. Also called law of the first wavefront.

hacker a person who explores computer and communication systems, usually for intellectual challenge, commonly applied to those who try to circumvent security barriers (crackers).

Hadamard matrix an $n \times n$ matrix H with elements ± 1 is a Hadamard matrix of order n if $HH^T = nI$, i.e., the rows are all mutually orthogonal, as are the columns. Hadamard matrices can only exist for $n = 1, 2$ or n an integer multiple of 4. Hadamard matrices of order 2^i can be constructed by the recursion

$$H_1 = (1)$$
$$H_{2n} = \begin{pmatrix} H_n & H_n \\ H_n & -H_n \end{pmatrix}$$

These are known as the Sylvester matrices. Because of their properties, Hadamard matrices find application in the theory of error control codes, and code division multiple access. Named after Jacques Salomon Hadamard (1865–1963). *See also* orthogonal, Walsh cover.

Hadamard transform a unitary transform mapping N samples $g(n)$ to N coefficients $G(k)$ according to the transform matrix H_N, where

$$H_2 = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$

and larger arrays are formed by the recursive definition

$$H_N = \frac{1}{\sqrt{2}} \begin{pmatrix} H_{\frac{N}{2}} & H_{\frac{N}{2}} \\ H_{\frac{N}{2}} & -H_{\frac{N}{2}} \end{pmatrix}.$$

The inverse transform is identical. The Hadamard transform was formerly used for data compression because its entries are all 1 or -1, allowing computation without multiplications. In this context it is now superseded by the discrete cosine transform. *See also* Walsh–Hadamard transform.

half adder a logic circuit that produces the sum and carry outputs for two input signals. A half adder has no carry input.

half bridge amplifier a class-D amplifier based on a half-bridge inverter configuration. Not suitable for amplification of DC to low-frequency signals because the capacitor leg cannot provide unidirectional current.

half subtracter a logic circuit that provides the difference and borrow outputs for two input signals. A half subtracter has no borrow input.

half-band filter a filter whose even-indexed coefficients are all zeros except the one in the filter center.

half-height point a point at which the membership grade is equal to 0.5.

half-life the average time needed for half the nuclei of a radioactive element to decay.

half-power bandwidth the frequency at which a lowpass filter amplitude response falls to $\frac{1}{\sqrt{2}}$ of the DC response is known as the half-power point. The two-sided half-power bandwidth is twice the half-power point.

half-wave rectifier a device that passes positive polarity portions of a signal and blocks negative polarity portions of an AC signal. Ideally, for a sinusoidal input $v_i(t) = V_m \cos(\omega t)$, the output equals the input while the input is positive and is zero while the input is negative.

half-wave symmetry a periodic function that satisfies $x(t) = -x(t - T/2)$.

half-wave voltage the voltage required to produce an amount of refractive index change in a medium that will retard the phase of a traversing optical wave.

halftone technique of simulating continuous tones by varying the amount of area covered by the colorant. Typically accomplished by varying the size of the printed dots in relation to the desired intensity.

Hall effect the phenomenon whereby charge carriers are displaced perpendicularly to their drift velocity when current flows in the presence of a magnetic field. The resulting shift in carriers inside the conductor or semiconductor produces a transverse Hall voltage that is proportional to the strength of the magnetic field (for constant current).

Hall measurement a semiconductor characterization that uses a crossed electric and magnetic field to yield information on the conductivity of a test sample.

Hall probe a device with a Hall effect transducer to sense a magnetic field.

halogen one of the halide atoms known for being highly reactive.

halt instruction an instruction (typically privileged) that causes a microprocessor to stop execution.

Hamming code an encoding of binary numbers that permit error detection and correction first discovered by Richard Hamming at Bell Laboratories.

A Hamming code is a perfect codes with code word length $n = 2^m - 1$ and source word length $k = n - m$ for any $m > 2$. A Hamming code can correct an error involving a single bit in the binary number. It can also detect an error involving two bits. *See also* parity.

Hamming distance the number of digit positions in which the corresponding digits of two binary words of the same length differ. The minimum distance of a code is the smallest Hamming distance between any pair of code words. For example, if the sequences are 1010110 and 1001010, then the Hamming distance is 3.

Hamming net a pattern recognition network that has a set of prototype patterns stored in its weights. A given input pattern is identified with the prototype whose Hamming distance from the input pattern is least.

Hamming weight the number of nonzero symbols in a given sequence of symbols.

Hamming window a tapering function used to truncate functions spectrally or in the time domain (i.e., in frequency it is a specifically formed low pass filter). It is defined as $w(x) = 0.54 + 0.46 * \cos(2 * \pi * x/x_o)|x| < x_o/2$. The Hamming window sacrifices filter sharpness at the cutoff frequency for a smoother stop band behavior.

hand *See* end-effector.

hand-held computer a small lightweight computer that performs functions such as electronic mail, handwriting recognition for taking notes, and holding addresses and appointments. Also called a "palm-top."

hand-off in a cellular system, the process by which the mobile terminal switches from communicating with one base station to a communication with neighboring base station as the mobile travels through the different radio cells.

handline a rope used to pull tools and equipment from an assistant on the ground to a worker atop a utility pole.

handover *See* hand-off.

handshaking I/O protocol in which a device wishing to initiate a transfer first tests the readiness of the other device, which then responds accordingly. The transfer takes place only when both devices are ready.

handwritten character recognition the process of recognizing handwritten characters that are clearly separated.

Hankel transform the 2-D Fourier transform of a function with circular symmetry and arises in the analysis of optical systems. The (zero-order) Hankel transform $F(\rho)$ of a function $f(r)$ for $r \geq 0$ is

$$F(\rho) = 2\pi \int_0^\infty r f(r) J_0(2\pi\rho r) dr$$

and the (zero-order) inverse Hankel transform is

$$f(r) = 2\pi \int_0^\infty \rho F(\rho) J_0(2\pi\rho r) d\rho,$$

where $J_0(r)$ is the zero-order Bessel function of the first kind, i.e.,

$$J_0(r) = \frac{1}{\pi} \int_0^\pi \cos(r \sin\theta) d\theta.$$

See also Fourier transform.

Hanning window a raised cosine window function whose impulse response is

$$w_n = \begin{cases} 0.5 + 0.5\cos(n\pi/N) & |n| < N \\ 0 & |n| \geq N. \end{cases}$$

hard bake the process of heating the wafer after development of the resist in order to harden the resist patterns in preparation for subsequent pattern transfer. Also called postbake.

hard bug a name for a crimped copper wire connector.

hard contaminant a contaminant or foreign object which is at least partly opaque to X-radiation: typical hard contaminants are pieces of metal, glass or stone.

hard decision demodulation that outputs a q-ary value for each demodulated symbol in a sequence of q-ary symbols. *See also* soft decision.

hard disk a rigid magnetic disk used for storing data. A typically nonremovable collection of one or more metallic disks covered by a magnetic material that allows the recording of computer data. The hard disk spins about its spindle while an electromagnetic head on a movable arm stays close to the disk's surface to read from or write to the disk. Each disk is read and written on both above and below. N disks are read/written by using $2N$ heads. The information is stored by cylinders, circular segments of the collection of the disks. Cylinders are divided in sectors as a pie. The mean time to access data is typically close to 10 msec.

Generally, hard disks are the backing memory in a hierarchical memory. *See also* floppy disk.

hard fault *See* permanent fault.

hard ferrite *See* ceramic ferrite.

hard magnetic material a ferromagnetic material that retains its magnetization when the magnetizing field is removed; a magnetic material with significant coercivity.

hard real-time *See* hard real-time system.

hard real-time system a real-time system in which missing even one deadline results in system failure. *Compare with* soft real-time, firm real-time.

hard X-ray having sufficient photon energy to penetrate "hard" material; usually more than about 15 keV.

hard-decision decoding decoding of encoded information given symbol decisions of the individually coded message symbols. *Compare with* soft-decision decoding.

hardware computer constructs that have a physical manifestation.

hardware accelerator a piece of hardware dedicated to performing a particular function (such as image convolution or matrix-vector products) which would otherwise be performed in software. Although much less flexible, dedicated hardware implementations can give significant speed improvements over software, and are especially useful for real-time applications.

hardware interrupt an interrupt generated by a hardware device, for example, keyboard, the DMA, PIC, the serial adapter, the printer adapter, etc. Other hardware interrupts can be generated by the control unit or by the ALU, for example, for the presence of a division per zero, for attempting to execute an unknown instruction. This last class of hardware interrupts is called internal exception.

hardware noise radio frequency emissions due to arcing of utility lines at defective connectors.

harmonic (1) the name associated with a number used to denote the frequency components that exist in a certain fourier series representation for a certain function of time $f(t)$. The Fourier series representation is given

$$f(t) = \sum_{n=-\infty}^{\infty} F_n * [\cos(n\omega_o t) + j \sin(n\omega_o t)]$$

where $n = 0, 1, 2, 3, \ldots$, $\omega_o = 2\pi/T$, $j = \sqrt{-1}$, T is the period of the function $f(t)$, F_n is the coefficient of the Fourier series for a certain value of n:

1st harmonic has $F_n = F_1$ and

$$[\cos(1\omega_0 t) + j \sin(1\omega_0 t)]$$

2nd harmonic has $F_n = F_2$ and

$$[\cos(2\omega_0 t) + j \sin(2\omega_0 t)]$$

3rd harmonic has $F_n = F_3$ and

$$[\cos(3\omega_0 t) + j \sin(3\omega_0 t)]$$

etc.

(2) sinusoidal component of a periodic waveform that has a frequency equal to an integer multiple of the basic frequency (or fundamental frequency). Thus the third harmonic of a power system voltage in the U.S. has a frequency of 3×60, or 180 Hz. For electric systems powered by sinusoidal sources, harmonics are introduced by nonlinear devices such as saturated iron cores and power electronic devices.

harmonic amplifier a type of amplifier that utilizes various forms of harmonic and mixing actions. These amplifiers may pump up the fundamental by increasing the switching efficiency of the active device. Others may actually be used as frequency multipliers or frequency converters (mixers). All class F, G, and H amplifiers fit into this general group. Parameters such as device characteristics, quiescent bias point, RF load line, significant harmonic and/or mixing frequencies, and amplitude and waveform of the applied signal(s) should be included with the class definition, thus defining the major contributors to the physical actions taking place in one of these amplifiers.

harmonic analysis the branch of mathematics dealing with the decomposition of signal functions as a linear combination of basis functions which represent "waves" of various frequencies. When the basis functions are sines and cosines each with a frequency that is an integer multiple of the signal's frequency, we have trigonometric harmonic analysis, in other words classical Fourier analysis, which provides the amplitudes and phases of the constituent sinusoids. (*See* Fourier transform.) With other basis functions, for example wavelets, we have *non-trigonometric harmonic analysis* (*See* wavelet, wavelet transform). Abstract harmonic analysis studies the generalization of Fourier analysis to abstract spaces.

harmonic balance technique one of several techniques for analyzing nonlinear circuits. The nonlinear circuit is divided into two portions of linear and nonlinear elements, and a portion of linear elements is calculated in a frequency domain and a portion of nonlinear elements is calculated in a time domain, respectively. The calculated voltages or currents at connecting nodes of these portions are balanced by using Fourier transforming or inverse Fourier transforming.

harmonic component a Fourier component of order greater than one of a periodic waveform.

harmonic content the internally generated, harmonically related spectral output from a device or circuit. Harmonic energy is that energy that is at exact multiples of the fundamental frequency, generated by the nonlinearities within the device or circuit acting on the fundamental frequency.

harmonic converter found in a microwave receiver, this component uses the technique of harmonic mixing to convert the RF signal to a lower IF frequency for further processing. Harmonic converters can be used as part of a vector network analyzer.

harmonic distortion caused by the nonlinear transfer characteristics of a device or circuit. When a sinusoidal signal of a single frequency (the fundamental frequency) is applied at the input of a nonlinear circuit, the output contains frequency components that are integer multiples of the fundamental frequency (harmonics). The resulting distortion is called harmonic distortion.

harmonic frequency integral multiples of fundamental frequency. For example, for a 60-Hz supply, the harmonic frequencies are 120, 180, 240, 300, ...

harmonic generation in nonlinear optics, the process in which a laser beam interacts with a material system to produce new frequency components at integer multiples of the frequency of the incident beam. Under carefully controlled circumstances, the lower-order harmonics (e.g., second and third) can be generated with high ($> 50\%$) efficiency. Under different circumstances, harmonics as high as the 30th can be generated.

harmonic load-pull measurement a measurement method where transfer characteristics of a device at the fundamental frequency can be measured by electrically changing the load impedance at harmonic frequencies.

harmonic orthogonal set the set of functions $e^{j\omega t}$. It is called harmonic because each basis function is a harmonic of a certain frequency and because the inner product between any two functions is zero:

$$\int_{-\infty}^{+\infty} e^{j\omega_1 t} e^{j\omega_2 t} \ dt = 0, \omega_1 \neq \omega_2$$

$$\int_{-\infty}^{+\infty} e^{j\omega t_1} e^{j\omega t_2}\ d\omega = 0, t_1 \neq t_2.$$

harmonic tuning the process of tuning an amplifier circuit to a frequency that is an integral multiple of the fundamental frequency at which the circuit would normally operate.

harmonically pumped mixer mixer where the intermediate frequency (IF) signal is at a frequency which is the sum or difference of the RF and an integer multiple (usually two) of the LO (local oscillator) frequency.

Hartley oscillator a particular case of LC-oscillators when $X_1 + X_2 + 2X_m$ is realized as a single tapped coil, and X_3 is a capacitor. Well suited for variable-frequency operation by varying a single capacitor.

Hartley oscillators are usually not used at VHFs of higher frequencies. Similarly, the circuit is avoided at very low audio frequencies. It is important to distinguish the Hartley oscillator from the Armstrong topology. In the Armstrong oscillator, no ohmic connection exists between the two inductors. Instead, coupling is entirely magnetic.

Harvard architecture a computer design feature where there are two separate memory units: one for instructions and the other for data only. The name originates from an early computer development project at Harvard University in the late 1940s. *Compare with* Princeton architecture.

hash table a table storing a mapping function whose domain is sparsely used and that is accessed by indices that are computed from the search field ("key") using a many–one mapping (called a hash function). Hash tables are used for many memory and name mapping functions, such as symbol tables in assemblers and compilers.

hashed page table a page table where the translation of each virtual page number is stored in a position determined by a hash function applied to the virtual page number. This technique is used to reduce the size of page tables.

hashing the act of translating a search key into a table index using a many–one mapping. *See also* hash table.

Hausdorff distance an important distance measure, used in fractal geometry, among other places. Given a distance function d defined on a Euclidean space E, one derives from it the Hausdorff distance H_d on the family of all compact (i.e., bounded and topologically closed) subsets of E; for any two compact subsets K, L of E, $H_d(K, L)$ is the least $r \geq 0$ such that each one of K, L is contained in the other's dilation by a closed ball of radius r, that is:

$$K \subseteq \bigcup_{p \in L} B_r(p) \quad \text{and} \quad L \subseteq \bigcup_{p \in K} B_r(p),$$

where

$$B_r(p) = \{q \in E \mid d(p, q) \leq r\}.$$

Hayes-compatible modem refers to a modem when it is capable of responding at the commands of modems made by Hayes Microcomputer Products. The Hayes set of commands represents a sort of standard for modems.

haystack response bandpass frequency response characterized by flat midband response with sloping sides.

hazard a momentary output error that occurs in a logic circuit because of input signal propagation along different delay paths in the circuit.

hazardous location a classification system used to define locations that are susceptible to fire and explosion hazards associated with normal electrical arcing. A class I hazardous location contains a flammable concentration of flammable vapors. A class II hazardous location contains a combustible concentration of combustible dusts. A class III hazardous location contains an ignitable concentration of ignitable fibers.

hazardous outage an outage which has been assessed to have potential life threatening consequences. The criteria for a hazardous outage varies considerably from one utility to another. In some cases arcing lines is sufficient for a hazardous outage. Other utilities would consider at least fire or explosion to qualify an outage as hazardous.

haze tails when self-converging deflection yokes are used on a CRT, overfocusing occurs on the vertical center line of the beam spot. Around the periphery of the screen, this produces a hazy area above and below the spot, referred to as haze tails. This degrades picture contrast.

HBMT *See* hybrid bipolar MOS thyristor.

HBT *See* heterojunction bipolar transistor.

HDA *See* head disk assembly.

HDSL *See* high-speed digital subscriber line.

HDTV *See* high definition television.

head an electromagnet that produces switchable magnetic fields to read and record bit streams on a platter's track.

head disk assembly (HDA) collection of platters, heads, arms, and acutators, plus the air-tight enclosing of a magnetic disk system.

head-medium gap the distance between the read–write head and the disk in magnetic or optical disk memory devices.

header (1) a data structure containing control information that is placed at the head of a datagram; when placed at the end of a datagram this is referred to as a trailer. Addressing information and checksum are examples of the control information contained in a header.

(2) a section of an image file, usually of fixed size and occurring at the start of the file, that contains information about the image, such as the number of rows and columns and the size of each pixel.

heap data storage structure that accepts items of various sizes and is not ordered. Contrast with stack.

heat sink aluminum mountings of various shapes and sizes used for cooling power semiconductor devices. Heat sinks can be cooled by either natural convection or a fan, and heat dissipation can be improved by a coating of black oxide or if the heat sink is made with fins.

heater *See* overload heater.

Heaviside characteristic an activation function according to which the neuron output takes on the value unity when its weighted input exceeds (or equals) the neural threshold value and zero otherwise.

Heaviside, Oliver (1850–1925) Born: London, England

Heaviside is best known for his theoretical work in electrical engineering. Much of his work is contained in his three-volume work called *Electromagnetic Theory*. The final volume was published in 1912. Heaviside extended and improved the works of Hamilton and Maxwell and deduced the concepts of capacitance, impedance, and inductance. Heaviside was self-taught and irascible. At first, much of his work was dismissed as unorthodox or too theoretical to be of practical value. Heaviside is best known in physics for his correct prediction of the existence of the ionosphere.

heavy water water in which a heavy isotope of hydrogen substitutes for the hydrogen atoms.

Hebb's principle to update the weights of the simple feedforward neural network (e.g., perceptron) a very simple idea, called Hebb's principle, can be used. The principle states the following: Apply a given pattern to the inputs and clamp the outputs to the desired response, then increase the weights between nodes that are simultaneously excited. This principle was formulated by Hebb in 1949, in an attempt to model neural networks. Mathematically it can be expressed as follows:

$$w_{ij}(t+1) = w_{ij} + \gamma u_i(t)\left(y_j^0(t) - y_j(t)\right)$$

where y_j^0 is the desired response and y_j is the response of the network. By regarding the weights as parameters, one may treat the above formula as a gradient method for parameters estimation.

Hebbian algorithm in general, a method of updating the synaptic weight of a neuron w_i using the product of the value of the ith input neuron, x_i, with the output value of the neuron y. A simple example is:

$$w_i(n+1) = w_i(n) + \alpha y(n) x_i(n)$$

where n represents the nth iteration and α is a learning-rate parameter.

Hebbian learning a method of modifying synaptic weights such that the strength of a synapic weight is increased if both the presynaptic neuron and postsynapic neuron are active simultaneously (synchronously) and decreased if the activity is asynchronous. In artificial neural networks, the synaptic weight is modified by a function of the correlation between the two activities.

hedge a special linguistic term by which other linguistic terms are modified. Examples are very, fairly, more or less, and quite.

height defuzzification *See* centroid defuzzification.

heirarchical coding coding where image data are encoded to take care of different resolutions and scales of the image. Additional data is transmitted from the coder to refine the image search. *See also* progressive transmission.

heirarchical interpolation a technique of forming image pyramids. In this method, pixels are interpolated to higher levels in the hierarchy. Thus, only the interpolated pixels need a residual in order to be reconstructed exactly, since the subsampled pixels are already correct.

helical antenna a wire antenna that is helical in shape. Typically, the helical antenna is fed by a coaxial cable, the outer conductor of which is connected to a ground plane and the inner conductor of which protrudes through the ground plane and is shaped in the form of a helix. Since a helical antenna emits an elliptically polarized wave when operating in axial mode, it is often used in satellite communication applications.

helical beam tube a backward wave amplifier based on interaction between a forward helical electron beam launched into a waveguide and backward traveling microwave in the waveguide.

helical scan tape a magnetic tape in which recording is carried out on a diagonal to the tape, by a head that spins faster than the tape movement. Popular for VCRs, camcorders, etc., as it improves recording density and tape speed.

helium neon laser neon laser in which excitation of the neon atoms occurs primarily by collisions with electron-impact-excited helium atoms; the first gas laser, and especially important for its CW visible oscillation lines.

Helmholtz coils a pair of coaxial coils of the same diameter that are spaced one radius apart. They are used to generate a field of uniform strength or to measure the magnetic moment of a magnet.

Helmholtz equation a partial differential equation mathematically described by

$$\left(\nabla^2 + k^2\right)\phi = 3Df\ ,$$

where ∇^2 is the Laplacian, k is the wavenumber, f is the forcing function, and ϕ is the equation's solution.

HEMT *See* high electron mobility transistor.

Henry, Joseph Henry is best known as the first Director (1846) of the Smithsonian Institution, and President of the National Academy of the Sciences. Henry was largely self-taught, but his early experiments garnered him sufficient recognition to become a Professor of Natural Philosophy at New Jersey College (now Princeton). Henry's early experiments resulted in the development of a practical electric motor and a relay later quite important in telegraphy.

hermetic seal a seal that is such that the object is gas-tight (usually a rate of less than 1×10^{-6} cc/s of helium).

Hermite form of 2-D polynomial matrix denote by $F^{m\times n}(z_1)[z_2]$ ($F^{m\times n}[z_1][z_2]$) the set of $m \times n$ polynomial matrices in z_2 with coefficients in the field $F(z_1)$ (polynomial coefficients in z_1). 2-D polynomial matrix $A(z_1, z_2) \in F^{m\times n}[z_1, z_2]$ of full rank has Hermite form with respect to $F^{m\times n}[z_1][z_2]$ if

$$A_H(z_1,z_2) = \begin{cases} \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ 0 & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & a_{nn} \\ 0 & 0 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & 0 \end{bmatrix} & \text{if } m > n \\ \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ 0 & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & a_{nn} \end{bmatrix} & \text{if } m = n \\ \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1m} & \dots & a_{1n} \\ 0 & a_{22} & \dots & a_{2m} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & a_{mm} & \dots & a_{mn} \end{bmatrix} \\ \text{if } m < n \end{cases}$$

where $\deg_{z_2} a_{ii} > \deg_{z_2} a_{ki}$ for $k \neq i$ ($\deg_{z_2}$ denotes the degree with respect to z_2). In a similar way, the Hirmite form of $A(z_1, z_2)$ with respect to $F[z_1][z_2]$ can be defined. $A(z_1, z_2)$ can be reduced to its Hermite form $A_H(z_1, z_2)$ by the use of elementary row operations or equivalently by premultiplication by suitable unimodular matrix $U(z_1, z_2)$ ($\det U(z_1, z_2) \in F(z_1)$), i.e., $A_H(z_1, z_2) = U(z_1, z_2)A(z_1, z_2)$. See for example, T. Kaczorek, *Two-Dimensional Linear Systems*, Springer-Verlag, Berlin, 1985.

Hermite Gaussian beam electromagnetic beam solution of the paraxial wave equation in which the field is a product of a Hermite-polynomial and a Gaussian function of distance from the beam axis.

Hermitian matrix a square matrix that equals its conjugate transpose.

hertz a measure of frequency in which the number of hertz measures the number of occurrences (of whatever is being measured) per second.

Hertz dipole a straight, infinitesimally short and infinitesimally thin conducting filament with uniform current distribution. The current amplitude is usually assumed to vary sinusoidally in time.

Hertz, Heinrich Rudolf (1857-1894) Born: Hamburg, Germany

Hertz is best known as the person who discovered radio waves. Hertz had several professorships including posts at Berlin, Kiel, Karlsruhe, and Bonn. Hertz's work was both theoretical and experimental. He succeeded in proving important elements of Maxwell's equations, and was able to demonstrate that radio waves could be generated. He died early from a degenerative bone disease. We honor his name by referring to the hertz as a unit of frequency.

Hertzian dipole *See* Hertz dipole.

Hertzian potential potentials used for the computation of electromagnetic field. By using the Hertzian vector potentials of electric and magnetic type Π_e, Π_h, respectively, the fields are expressed as

$$\mathbf{E} = k^2\Pi_e + \nabla\nabla\cdot\Pi_e - j\omega\mu\nabla\times\Pi_h$$
$$\mathbf{H} = j\omega\varepsilon\nabla\times\Pi_e + k^2\Pi_h + \nabla\nabla\cdot\Pi_h$$

where ϵ is the dielectric permittivity, μ the magnetic permeability, and $k = \omega\sqrt{\epsilon\mu}$, with ω denoting the angular frequency.

heterodyne detection method of measuring the frequency content of an optical signal in which that signal is combined with a known CW reference signal from a local oscillator by means of a square-law detector; sometimes provides a more direct and sensitive representation of the frequency content of a signal than homodyne detection.

heterodyne receiver a receiver where the low-level RF signal is mixed with a local oscillator signal to produce an intermediate frequency (IF). The IF frequency is usually between 10 to 100 MHz. It can be amplified with a low noise amplifier. Heterodyne receivers have much better sensitivity and noise characteristics than direct detection receivers.

heterogeneous having dissimilar components in a system; in the context of computers, having different types or classes of machines in a multiprocessor or multicomputer system.

heterojunction a junction between two crystals of different bulk composition, typically referring to semiconductor–semiconductor interfaces. The prototype example is AlAs/GaAs.

heterojunction bipolar transistor (HBT) proposed by Shockley (U.S. Patent 2569347).

heterojunction field effect transistor (HFET) a field effect transistor that uses a heterojunction in the channel parallel to the current flow direction to improve the carrier transport by separating the dopant from conduction region. Other names for this device include MODFET, (MOdulation Doped Field Effect Transistor and HEMT, High Electron Mobility Transistor.

heterojunction laser *See* diode laser.

heterostructure refers to a composite structure in which two dissimilar materials are chemically joined at a common interface. Examples are GaAs-AlGaAs, metal on semiconductor, oxide on semiconductor, etc.

Heuristic special problem-specific knowledge that can be used to help direct a search efficiently towards an appropriate, though possibly suboptimal, solution. *See* heuristic search.

heuristic search a search that uses problem-specific knowledge in the form of heuristics in an effort to reduce the size of the search space or speed convergence towards a solution. Heuristic searches sacrifice the guarantee of an optimal solution for reduced search time.

hexadecimal notation expressing numbers in base-16 format. *See also* hexadecimal number system.

hexadecimal number system the numbering system that uses base-16, commonly used in computer systems. The digits 10–15 are generally represented by the letters A–F.

hexagonal pixel *See* pixel.

HFET *See* heterojunction field effect transistor.

HgCdTe semiconductor alloy important as the active photoconductive or photovoltaic element in mid- to long-wavelength infrared detectors.

HgTe/CdTe heterostructure combination with properties similar to the HgCdTe alloy, but with added tailorability from the ability to modify properties such as band gap layer by layer.

hi-bi fiber optical fiber with high linear birefringence. Light launched on one of the fiber's polarization axes will maintain its polarization state as it propagates along the length of the fiber.

hidden layer a layer of neurons in a multilayer perceptron network that is intermediate between the output layer and the input layer.

hidden Markov model (HMM) a discrete-time, discrete-space dynamical system governed by a Markov chain that emits a sequence of observable outputs, usually one output (observation) for each state in a trajectory of such states. More formally, a HMM is a five-tuple $(\Omega_X, \Omega_O, A, B, \pi)$, where Ω_X is a finite set of possible states, Ω_O is a finite set of possible observations, A is a set of transition probabilities, B is a set of observation probabilities, and π is an initial state distribution.

hidden station problem problem related to multiple access protocols in mobile environment where two mobile stations may not be able to detect each other's transmission, leading to the possibility of a transmission collision.

hidden unit a neural unit in a network that has no direct connection to either the network inputs or to the network outputs.

hierarchical clustering a clustering technique that generates a nested category structure in which pairs or sets of items or categories are successively linked until every item in the data set is connected. Hierarchical clustering can be achieved agglomeratively or divisively. The cluster structure generated by a hierarchical agglomerative clustering method is often a dendrogram, but it can be also as complex as any acyclic directed graph. All concept formation systems are hierarchical clustering systems, including self-generating neural networks. *See also* clustering, concept formation, self-generating neural network.

hierarchical coding coding a signal at several resolutions and in order of increasing resolution. In an hierarchical image coder an image is coded at several different sizes and in order of increasing size. Typically, the smaller sized images are used to encode the larger size images to obtain better compression.

hierarchical control operation or structure of the control system, where the controller, or the given control layer, is composed of several local decision units coordinated (*See* coordination) by a supremal unit (coordinator unit); hierarchical control in the above narrow sense is tantamount to the multilevel control, yet the term hierarchical control is also used in broader meaning — covering both multilevel and multilayer control as well as integrated multilayer–multilevel control structures occurring in large industrial and environmental applications.

hierarchical feature map a hybrid learning network structure also called counter-propagation network that consists of a unsupervised (hidden) layer and a supervised layer. The first layer uses the typical (instar) competitive learning, the output will be sent to the second layer, and an outstar supervised learning is performed to produce the result. *See also* counter-propagation learning, outstar training.

Kohonen calls a feature map that learns hierarchical relations as a "hierarchical feature map."

hierarchical memory also known as multi-level memory. The organization of memory in several levels of varying speed and capacity such that the faster memories lie close to the processor and slower memories lie further away from the processor. Faster memories are expensive, and therefore are small. The memories that lie close the processor store the current instruction and data set of the processor. When an object is not found in the memories close to the processor, it is fetched from the lower levels of the memory hierarchy. The top levels in the hierarchy are registers and caches. And the lowest level in the hierarchy is the backing memory, which is usually a disk.

high byte the most significant byte of a multibyte numeric representation.

high definition television (HDTV) a set of standards for broadcast television that incorporate all-digital transmission, greatly improved audio and video quality, audio and video compression, and integration of data with television audio and video.

high electron mobility transistor (HEMT) a depletion-mode field-effect transistor in which the channel is a two-dimensional electron gas at a heterointerface. Other names: MODFET, TEGFET, and 2DEGFET.

high frequency emphasis filter a band-limited filter whose frequency response increases with frequency. Typically such a filter would have unity gain or less at low frequencies.

high order interleaving in memory interleaving, using the most significant address bits to select the memory module and least significant address bits to select the location within the memory module.

high pass filter filter exhibiting frequency selective characteristic that allows high-frequency components of an input signal to pass from filter input to output unattenuated; all lower frequency components are attenuated.

high phase order (HPO) polyphase systems that contain 6, 9, or more phases — rather than the standard three-phase system. HPO systems may be used to provide a means of transmitting more electrical power down existing right-of-ways than three-phase systems, without an increase in transmission voltage, and without an increase in EMF levels at the edge of the right-of-way.

high rupturing capacity (HRC) a term used to denote fuses having a high interrupting rating. Most low-voltage HRC-type fuses have an interrupting rating of 200 kA RMS symmetrical.

high side pertains to the portion of a circuit connected to the higher voltage winding of a power transformer.

high state a logic signal level that has a higher electrical potential (voltage) than the other logic state. For example, the high state of TTL is defined as being greater than or equal to 2.0 V.

high-impedance state the third state of tri-state logic, where the gate does not drive or load the output line. *See* tri-state circuit.

high-level transmitter a transmitter in which the modulation process takes place at a point where the power level is at or near the output power.

high-level vision the highest stage of vision, leading to the full extraction of the 3-D information and to its exploitation for the description and understanding of the scene.

high-loss resonator a resonator having a high value of loss (usually diffraction loss) per round trip; unstable resonator.

high-pass filter a filter that has a transfer function, or frequency response, whose values are small for frequencies lower than some intermediate frequency. A filter whose impulse response is a high-pass signal.

high-pass signal a signal whose Fourier transform, or power spectral density, is a small value for all frequency components that are less than some intermediate frequency value. As a formal definition, if $X(\omega)$ is the Fourier transform of the signal $x(t)$, then $X(\omega) = 0$ for $|\omega| < B$, for some $B > 0$. *Compare with* band-pass signal.

high-performance metal oxide semiconductor (HMOS) technology a variation of the MOS process that scales down devices to achieve higher speed and thus lower power consumption in integrated circuits.

high-rate quantization theory a theory developed by Bennet, Schutzenberger, Zador and others. The theory analyzes and predicts the performance of (infinitely) fine quantization (high-rate quantization).

high-resistance grounded system an electrical distribution system in which the neutral is intentionally grounded through a high resistance. The high-resistance grounded wye system is an alternative to solidly grounded and ungrounded systems. High-resistance grounding will limit ground fault current to a few amperes, thus removing the potential for arcing damage inherent in solidly grounded systems.

high-speed carry in an arithmetic logic unit, a carry signal that is generated separately from the generation of the result and is therefore faster; a lookahead carry.

high-speed digital subscriber line (HDSL) a digital subscriber line (DSL) in which two twisted-pairs provide a rate of 1.544 Mbps (T1 rate) in both directions (full-duplex). Each twisted-pair provides a full-duplex connection of 784 kbps. (This is larger than 1.544/2 Mbps due to the duplication of a synchronization bit).

high-speed metal oxide semiconductor (HMOS) technology *See* high-performance metal oxide semiconductor technology.

high-stability diode gun Plumbicon a diode gun Plumbicon tube with electrostatic focus and magnetic deflection, which uses a high-stability electrode structure evaporated and bonded to the tube envelope.

high-voltage DC (HVDC) transmission transmission of electric power (at typically 500–1500 kV) using DC rather than AC. This can be desirable for several reasons:

1. For economic reasons when a large amount of power is to be transmitted over a long distance, i.e., 300–400 miles, or via underwater cables;

2. For the connection of asynchronous AC systems; and

3. Improved transient stability and dynamic damping of the electrical system oscillations.

higher-order mode mode that spatially varies faster than the fundamental in a cavity, or waveguide.

higher-order unit a neural unit whose input connections provide not the usual weighted linear sum of the input variables but rather a weighted polynomial sum of those variables.

highway *See* bus.

Hilbert space an inner product space with the additional property that is a complete metric space. An inner product space is a linear space on which an inner product is defined, while completeness means that there are no "missing" vectors arbitrarily close to but not included in the space.

Hilbert transform a transform that relates the real and imaginary parts of a complex quantity, such as the index of refraction. For f, a function of one real variable, the transform $\mathcal{H}(f)$ defined as follows:

$$\mathcal{H}(f)(x) = \lim_{\varepsilon \to 0} \frac{1}{\pi} \int_{|t| \geq \varepsilon} \frac{f(x-t)}{t} \, dt .$$

An alternate formula, which coincides with the previous one, except possibly on a zero-measure set of points of discontinuity of f, is:

$$\mathcal{H}(f)(x) = \lim_{\varepsilon \to 0} \frac{1}{\pi} \int_{-\infty}^{+\infty} f(x-t) \frac{t}{t^2 + \varepsilon^2} \, dt .$$

When f is square-integrable, the Fourier transforms $\mathcal{F}(f)$ and $\mathcal{F}(\mathcal{H}(f))$ of f and $\mathcal{H}(f)$ are related by:

$$\mathcal{F}(\mathcal{H}(f))(u) = -i \, \mathrm{sign}(u) \mathcal{F}(f)(u)$$

almost everywhere; thus for positive frequencies, the Fourier phase is shifted by $-\pi/2$; in particular, f and $\mathcal{H}(f)$ have the same L^2 norm. *See* Fourier amplitude, Fourier phase, Fourier transform.

histogram (1) a plot of the frequency of occurrence of the gray levels in an image.

(2) the frequency distribution of a set of numbers. In image processing, the distribution of the gray levels in an image, typically plotted as the number or percentage of pixels at a certain gray level vs. the gray levels. If the ordinate is the ratio of the number of pixels at a gray level to the total number of pixels, the histogram is an approximation of the probability density function of the gray levels. *See also* probability density function.

histogram equalization a technique for computing an image gray level transformation to redistribute the pixel intensity values and "flatten" the pixel intensity histogram. Histogram equalization can be used to enhance the contrast of the image. Also called histogram leveling, histogram flattening. *See also* contrast enhancement, histogram.

histogram modeling (1) making the histogram of an image have another shape, for example, the flat line produced by histogram equalization. This procedure is usually not automatic, i.e., the shape is usually specified by a person. Also called histogram modification or histogram specification. *See also* histogram equalization.

(2) the fitting of a function to a histogram in order to obtain an analytical expression that approximates the histogram.

histogram sliding the addition of a constant to all pixels in an image to brighten or darken the image. A positive constant makes the histogram slide (translate) to the right; a negative constant makes it slide to the left. *See also* histogram.

histogram stretching expansion or contraction of the gray-level histogram of an image in order to enhance contrast. Usually performed by multiplying or dividing all pixels by some constant value. *See also* contrast enhancement, histogram.

hit the notion of searching for an address in a level of the memory hierarchy and finding the address mapped (and the data present) in that level of the hierarchy. Often applies to cache memory hierarchies.

hit rate the percentage of references to a cache that find the data word requested in the cache. Also the probability of finding the data and given by

$$\frac{\text{number of times required word found in cache}}{\text{total number references}}$$

Also known as hit ratio.

hit ratio *See* hit rate.

hit–miss ratio in cache memory, the ratio of memory access requests that are successfully fulfilled within the cache to those that require access to standard memory or to an auxiliary cache.

hit–miss transform a class of transforms in image processing that locate objects larger than some specific size, S_1, and smaller than some size S_2.

HL7 a data communications protocol for interfacing components of a hospital information system.

HMIC *See* hybrid microwave integrated circuit.

HMM *See* hidden Markov model.

HMOS *See* high-performance metal oxide semiconductor technology.

hold signal an input signal to a processor indicating that a DMA device is requesting the use of the bus. Also called bus request.

hold time the time required for the data input(s) to be held stable prior to (or after) the control input changes to latch, capture, or store the value indicated by the data inputs.

hold-up time the time duration that the output voltage is maintained, within specification, during an interruption of the input power. Typical hold-up time is one to three line cycles.

hole fictitious positive charge representing the motion of electrons in the valence band of a semiconductor; the number of holes equals the number of unoccupied quantum states in the valence band.

hole burning localized reduction in gain of a laser amplifier due to saturation by an intense signal; localization may be in space or frequency.

hole mobility *See* spatial hole burning, spectral hole burning.

Hollerith card a punched card used for data storage. Developed by Herman Hollerith for use in the 1890 U.S. census, these cards were widely used for early computer data storage. Now obsolete.

Hollerith code an encoding of data where the data is represented by a pattern of punched holes in a card.

Hollerith, Herman (1860–1929) Born: Buffalo, New York, U.S.A.

Hollerith is best known for his development of a tabulating machine using punched cards for entering data. This machine was used to tabulate the 1890 U.S. census. The success of this machine spurred a number of other countries to adopt this system. The company Hollerith formed to develop and market his ideas became one of several companies that merged to form IBM, International Business Machines. Hollerith's initial interest in automatic data processing probably stems from his work as an assistant to several census preparers at Columbia University. The success of Hollerith's work gives him claim to the title of the father of automated data processing.

hollow beam an electron beam with hollow core.

hollow cathode a negative electrode formed using a section of hollow tube; used in low pressure discharges.

hologram medium that, when illuminated optically, provides a three-dimensional image of stored information, sometimes called holograph.

holograph *See* hologram.

holographic data storage a technique used to store multiple images, or 2-D arrays of digital information, as multiplexed holograms in an optically sensitive material. Multiplexing techniques include angle, frequency, and spatial position. Angle and frequency multiplexing techniques are based on Bragg selectivity where angle multiplexing favors transmission geometries and frequency multiplexing favors reflection geometries.

holographic interconnect free-space interconnect that uses holograms to control optical paths from sources to detectors. The hologram provides the interconnection by forming the intentionally distorted image of the source array on the detector array. A hologram can be viewed as a combination of gratings. Each grating directs a light beam passing through it to a new direction. The hologram can be displayed by a spatial light modulator to achieve dynamic reconfiguration.

holography the science of making and reading holograms.

homodyne detection method of measuring the frequency content of an optical signal in which that signal is combined with itself by means of a square-law detector; simpler but sometimes less informative and sensitive representation of the frequency content of a signal than heterodyne detection.

homogeneous having all nodes or machines in a multiprocessor or multicomputer be of the same type or class.

homogeneous broadening spectral broadening of a transition in a laser medium due to irreversible dephasing processes like spontaneous emission, collisions, photon interactions, or spin exchange.

homogeneous coordinate representation the representation of an N–component position vector by an $(N+1)$–component vector is called homogeneous coordinate representation. For example, a vector $p = \left[p_x, p_y, p_z\right]^T$ is represented by an augmented vector $\left[wp_x, wp_y, wp_z, w\right]$ in the homogeneous coordinate representation. In the homogeneous transformation matrix it is assumed that $w = 1$.

homogeneous coordinates a 2-D point (x, y) with a third coordinate point (x, y, W), where W is a constant typically 1. Points represented in homogeneous coordinates allow for translation, rotation and scaling to be applied as multiplications of transformation matrices and row vectors. Without homogeneous coordinates, translations are treated as additions while scaling and rotation are treated as multiplications.

homogeneous linear estimator an estimator that is a homogeneous linear function of the data.

homogeneous medium optical medium in which none of the properties (e.g., gain, index of refraction, etc.) are functions of position.

homogeneous solution a system of linear constant-coefficient differential equations has a complete solution that consists of the sum of a particular solution and a homogeneous solution. The homogeneous solution satisfies the original differential equation with the input set to zero. Analogous definitions exist for difference equations.

homogeneous transformation matrix a 4×4 matrix that maps a position vector expressed in homogeneous coordinates from one coordinate system to another coordinate system (reference coordinate frame). A homogeneous transformation matrix has the form

$$T = \begin{bmatrix} R_{3\times 3} & p_{3\times 1} \\ 0_{1\times 3} & 1 \end{bmatrix} = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

where $R_{3\times 3}$ represents the rotation matrix, which consists of three unit vectors n (normal), o (orientation), a (approach). The orientation matrix is an orthonormal matrix. $p_{3\times1}$ represents the position vector of the origin of the rotated coordinate system with respect to the reference system. $0_{1\times3}$ is 1×3 zero vector.

homojunction a junction between regions of the same bulk material that differs in the concentration of dopants. The typical example is the n-p diode.

homomorphic filter an image enhancement technique based upon the illumination-reflectance model. The homomorphic filter assumes the image function $f(x, y)$ is the combination of two functions $i(x, y)$ and $r(x, y)$. By taking the natural log of the images the components are separated and can be processed separately; the reflectance of an image usually contains high frequency components while the illumination component tends to vary slowly (the low frequencies); thus, the filter applied to the logarithm image should affect the low and high frequency components differently. The most common use for the filter is to enhance images by compressing the brightness range while increasing contrast; the filter applied in this case is a circularly symmetric high pass filter with the stop band magnitude < 1 and pass band magnitude > 1.

homomorphic signal processing the processing of signals from a nonadditive model under a tranformation which renders the model additive. For example, a logarithmic transformation may be used to transform a multiplicative noise model into an additive noise model.

homopolar generator an electromagnetic generator in which the magnetic flux passes in the same direction from one magnetic member to the other over the whole of a single air gap area. Such generators have been built to supply very large pulsed currents.

homopolar machine *See* homopolar generator.

homopolar magnetic bearing a magnetic bearing in which the rotating member always experiences a magnetic field of the same polarity.

homothetic a copy of a signal that retains the original shape, but is scaled in size. For a signal $x(t)$, the homothetic $x_\lambda(t) = x(\lambda t)$ retains the shape of $x(t)$ but is scaled along the t axis as a function of the parameter λ. Typically used in association with structuring elements in mathematical morphology.

homotopy method a technique for solving nonlinear algebraic equations $F(x) = 0$ based on higher-dimensional function embedding and curve tracing. The idea is to construct a parameterized function such that at one parameter value, say $\lambda = \lambda_0$, the system of equations is easy to solve or has one or more known solutions, and at another parameter value, say $\lambda = \lambda_f$, the system of equations is identical to that of the system of interest, $F(x) = 0$. A homotopy method may then be interpreted as geometric curve following through solution space from the known solutions of the "easy" problem to the unknown solutions of $F(x) = 0$.

Hopfield memory *See* Hopfield model.

Hopfield model a neural algorithm capable of recognizing an incomplete input. Also known as Hopfield memory.

Hopfield suggested that an incomplete input can be recognized in an iterative process, in which the input is gradually recognized in every cycle of the iteration. The iteration is completed when the input finally matches with a stored memory. The Hopfield model is a sort of associative memory. A hologram can also be directly used as associative memory. The main difference of the non-neural holographic associative memory and the Hopfield model is as follows. The direct holographic associative memory is one step and its signal-to-noise ratio depends on the incompleteness of the input that cannot be improved. The Hopfield model is an iterative process involving a nonlinear operation, such as thresholding in which the signal-to-noise ratio of the input can be improved gradually during the iterative process. A large number of optical systems have been proposed to implement the Hopfield model, including the first optical neural networks. Those optical implementations are primarily based on optical matrix-vector or tensor-matrix multiplication.

Hopfield network a recurrent, associative neural network with n processing elements. Each of the processing elements receives inputs from all the others. The input that a processing element receives from itself is ignored. All of the processing elements output signals are bipolar. The network has an energy function associated with it; whenever a processing element changes state, this energy function always decreases. Starting at some initial position, the system's state vector simply moves downhill on the network's energy surface until it reaches a local minimum of the energy function. This convergence process is guaranteed to be completed in a fixed number of steps. *See also* continuous Hopfield network, discrete Hopfield network.

Hopper, Grace Murray (1906–1992) Born: New York, New York, U.S.A.

Hopper is best known as the author of the first compiler. Hopper began her career as a mathematics professor at Vassar College. During WW II she volunteered for service and was assigned to work at Harvard with Howard Aiken on the Mark I computer. She later joined J. Presper Eckert and John Mauchly working on the UNIVAC computer. It was at this time she wrote the first compiler. Her compiler and her views on computer programming significantly influenced the development of the first "English-like" business computer language, COBOL.

hopping sequence *See* frequency hopping.

horizontal (*H*) in television signals, H may refer to any of the following: the horizontal period or rate, horizontal line of video information, or horizontal sync pulse.

horizontal microinstruction a microinstruction made up of all the possible microcommands available in a given CPU. In practice, some encoding is provided to reduce the length of the instruction.

horizontal polarization a term used to identify the position of the electric field vector of a linearly polarized antenna or propagating EM wave relative to a local reference, usually the ground or horizon. A horizontally polarized EM wave is one with its electric field vector aligned parallel to the local horizontal.

horizontal rate the rate at which a line of video is drawn; for NTSC television, the horizontal frequency is 15,734.264 Hz for a rate of 63.5 μs/line (the same as line rate).

horizontal scanning in radar systems, the rotation of the antenna parallel to the horizon. In video display systems, the process of examining or displaying an image with multiple horizontal lines.

horizontal sync pulse a blacker-than-black signal level contained within the horizontal blanking interval of the composite NTSC signal. The horizontal sync pulse duration is 7.5 $\pm$ 0.5 percent of the horizontal line time and an amplitude of 25% of the peak-to-peak video signal. The horizontal sync pulse frequency is 15750 Hz monochrome and 15734 Hz for color NTSC television formats. The NTSC modified the monochrome horizontal frequency slightly to interleave the color subcarrier and to provide an integer relationship of 286 between the horizontal rate and the 4.5 MHz sound carrier.

During the equalizing pulse interval, the horizontal sync pulse rate is doubled and the pulse width is halved. Accurate horizontal synchronizing the video display is preserved throughout the NTSC frame by measuring the horizontal line time between the blanking level to the sync level transitions.

horn antenna an aperture antenna formed by a waveguide that has been flared out on one end.

horn gap a V-shaped spark gap which provides a method of extinguishing a power-follow arc by allowing the arc to climb the sides of the V until it is too long to be maintained.

horsepower-rated switch a manually operated switching device designed for motor circuit applications. It is designed to interrupt the rated overload current at rated voltage of a motor with a horsepower rating that is less than or equal to the horsepower rating of the switch.

hose *See* line hose.

host a computer that is the one responsible for performing a certain computation or function.

hot an energized conductor.

hot electron an electron in the conduction band of a semiconductor having a superthermal kinetic energy.

hot electron bolometer a superconducting resistor structure that uses rapid heating and cooling of electrons by an RF field to produce a time varying resistance, useful as a mixer element at submillimeter and THz frequencies.

hot electron transistor a transistor, usually fabricated from heterostructure materials, that uses electron transport over an energy step to obtain high electron velocities and hopefully high speed operation.

hot line work work performed on energized electric power lines. *See* glove, hot stick, bare-hand.

hot reserve the state of an idle thermal generating plant whose boilers and turbines are hot and can thus be quickly brought into service.

hot restart reassumption, without loss, of all operations in the system from the point of detected fault.

hot standby a technique for achieving fault tolerance that requires having a backup computer running in parallel with the primary computer so that the backup may take over, if the primary should fail.

hot stick an insulated pole used by line workers to make connections to and otherwise manipulare energized overhead conductors.

hot tap a clamp, applied with a hot stick that connects a branch circuit to an existing conductor and typically applied while the system is energized.

hot wire an energized conductor, particularly as opposed to a neutral or ground wire, both of which are typically maintained at ground potential

hot-carrier diode *See* Schottky barrier diode.

Hotelling transform a transformation whose basis vectors are the eigenvectors of the covariance matrix of the random vectors. *See also* Karhunen–Loeve transform.

Hough transform (1) template-matching method for detecting straight lines and curves in gray level images: given a family of curves, the output of the transform is the set of such curves that are present in the image.

(2) a transform that transforms image features and presents them in a suitable form as votes in a parameter space, which may then be analyzed to locate peaks and thereby infer the presence of desired arrangements of features in the original image space: typically, Hough transforms are used to locate specific types of object or shape in the original image. Hough transform detection schemes are especially robust.

Householder transformation a matrix Q that maps each vector to its reflection through a defined hyperplane; specifically,

$$Q = I - 2\frac{uu^T}{u^T u}$$

reflects through the plane having normal vector u.

HPA acronym for high-power amplifier.

HPO *See* high phase order.

HRC *See* high rupturing capacity.

HSI/HSV System a system whereby color is represented by hue, saturation, and intensity or value, hence the acronym. This system tends to be more intuitive for users than the other two since it is similar to an artist's tint, shade and tone. The HSV hexcone is created in a cylindrical coordinate system, where hue is the angle around the vertical axis, value is the height along the vertical axis and saturation is the perpendicular distance from the vertical axis. *See also* saturation.

HTC *See* hydro-thermal coordination.

HTGR acronym for high temperature gas-cooled reactor.

hue one of the characteristics that distinguishes one color from another. Hue defines color on the basis of its position in the spectrum (red, blue, green, yellow, etc.). Hue is one of the three characteristics of television color. Hue is often referred to as tint. In NTSC and PAL video signals, the hue information at any particular point in the picture is conveyed by the corresponding instantaneous phase of the active video subcarrier.

hue saturation intensity (HSI) a color model based on the specification of hue (H), saturation (S), and intensity (I). A useful and convenient property of this model is the fact that intensity is separate from the color components. The hue and saturation components (together referred to as chromaticity) relate closely to color perception in humans, however the HSI intensities are linear and do not correspond to those observed by the eye. The conversion from RGB to HSI goes as

$$\begin{aligned}
H &= \arccos\,(0.5((R-G) \\
&\quad + (R-B))/\sqrt{((R-G)^2} \\
&\quad + ((G-B)*(R-B)) \\
S &= 1-(3/(R+G+B)) \\
&\quad *(\min\{R,G,B\}) \\
I &= (R+G+B)/3
\end{aligned}$$

See also RGB, color space.

Huffman coding (1) a method for lossless source coding that constructs the code of minimum average length for a random variable. The method is optimal in the sense that no other method can give a higher compression rate. It is capable of achieving the bound on compression given by the source coding theorem. It is due to D. A. Huffman (1952).

(2) a variable length coding scheme whose codewords are generated from the probability distribution of the source. Decoding a Huffman codeword corresponds to traversing an unbalanced binary tree according to the value (0 or 1) of each bit in the word; the leaves of the tree are the source symbols, with the most probable ones being the shortest distance from the root of the tree. Huffman coding achieves an average code rate equal to the source entropy if and only if all the probabilities are negative powers of 2. In general

it achieves less compression than arithmetic coding but is easier to implement.

Huffman encoding *See* Huffman coding.

hum bars horizontal black and white bars that extend over the entire TV picture and usually drift slowly through it. Hum bars are caused by an interfering power line frequency or one of its harmonics.

human visual system (HVS) the collection of mechanisms in humans which process and interpret the visual world. These mechanisms include the eye, the retina, the optic nerve, the visual cortex, and other parts of the brain.

hunting a mechanical oscillation in the speed of a synchronous machine due to changes in the load. Damper windings are used to reduce the hunting by providing a torque that opposes the change in speed.

Hurter–Driffield (H-D) curve the standard form of the H-D or contrast curve is a plot of the relative thickness of resist remaining after exposure and development of a large clear area as a function of log-exposure energy. The theoretical H-D curve is a plot of log-development rate versus log-exposure energy. (Hurter and Driffield are the two scientists who first used a related curve in 1890.)

Hurwitz matrix a square matrix with real elements and whose all eigenvalues have negative real parts.

Hurwitz polynomial a polynomial $p(s) = a_n s^n + a_{n-1} s^{n-1} + a_{n-2} s^{n-2} + \cdots + a_0$, where all of the a_i's are either real or complex numbers, is said to be Hurwitz if all of its roots have negative real part.

Huygen's principle a principle stating that each point of a wave front can be considered to be a source of a secondary spherical wave that combines with the other secondary spherical waves to form a new wave front. Huygen's principle is often used as an approximate technique for solving diffraction and antenna radiation problems. *See also* equivalence theorem, equivalent source.

HVC color coding technique whereby the HVS contrast sensitivity functions for different wavelengths are taken into account for compressing the color planes independently with different sets of parameters.

HVDC transmission *See* high-voltage DC transmission.

hybrid bipolar MOS thyristor (HBMT) like its transistor cousin, it is an advanced device designed to take advantage of the unique characteristics of both bipolar devices (high current capability with low forward voltage drop) and MOS device (high switching speeds with low gate drive requirements).

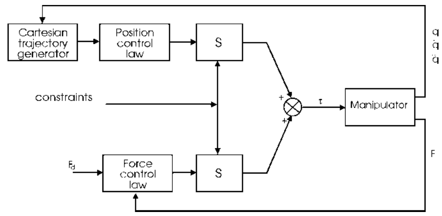
hybrid circuit a circuit based on at least two different technologies. For instance, a circuit built by using solid state circuits and tubes.

hybrid computer a computer based on at least two different technologies. For instance, a computer presenting both digital and analog circuits and signals.

hybrid coupler generally a four port circuit, which has an electrical response such that a signal applied to port one is divided equally in amplitude between ports three and four. The phase of the signals at ports three and four are either 0, 90, or 180 degrees apart, dependent on the type of hybrid coupler. Port two is completely isolated, and no signal appears at this port.

hybrid magnetic bearing an active magnetic bearing that also incorporates permanent magnets, thus reducing energy consumption and improving performance.

hybrid microwave integrated circuit (HMIC) a planar assembly that com-



The hybrid position/force controller.

bines different circuit functions formed by strip or microstrip transmission lines printed onto a dielectric substrate and incorporating discrete semiconductor solid state devices and passive distributed or lumped circuit elements, interconnected with wire bonds.

hybrid mode a solution to Maxwell's equations for a particular structure that is neither TE nor TM.

hybrid numerical method a method that makes use of two or more different techniques (e.g., mode matching and finite differences) in order to efficiently solve a given boundary value problem. *See also* finite differences, mode matching.

hybrid parameters circuit parameters used especially in transistor models; when referring to a two-port, they relate the voltage at port 1 with its current, and the voltage at port 2 with the current of port 2 with its voltage, and the current at port 1 according to the equation

$$V_1 = h_{11}I_1 + h_{12}V_2$$
$$I_2 = h_{21}I_1 + h_{22}V_2$$

hybrid position/force controller a general hybrid position/force controller is presented in the figure. The hybrid controller consists of two subcontrollers. One is a position controller and the second is a force controller. Trajectory generator inputs a Cartesian path in terms of position, velocity, and acceleration. F_d is a desired external force associated with the task in Cartesian space. Matrix S is a selection matrix with ones and zeros on the diagonal. Where a one is present in S, a zero is present in S', and position control is in effect. It is assumed that joint positions, velocities, and accelerations are measured. Next they are transformed via kinematical computations to Cartesian positions, velocities, and accelerations. Desired and actual parameters are compared in position controller. Desired and measured forces are compared in force controller. Finally, manipulator is controlled at the joint force and/or torque level.

hybrid redundancy a technique combining active and passive redundancy. Passive redundancy prevents generation of error results, and active redundancy improves fault tolerance capabilities by replacing faulty hardware with spare elements.

hybrid stepper motor a stepper motor that combines the rotor design characteristics of variable-reluctance and permanent magnet stepper motors. Hybrid stepper motor rotors consist of an axially magnetized cylindrical permanent magnet capped on each pole by toothed, soft iron caps. Teeth on the caps are displaced with respect to each other to provide stepping control. Hybrid stepper motors combine the higher torque capability of permanent magnet motors with the higher step resolution of variable-reluctance motors.

hydroelectric generator large, three-phase synchronous alternator powered by a water-driven turbine. *See also* generator.

hydro-thermal coordination the practice of manipulating water levels in the reservoirs of a power system's hydroelectric plants with respect to the generation levels of the thermal plants in the system with the objective of minimizing generation costs, as well as satisfying waterway considerations such as water conservation, flood control capacity, recreation, and environmental requirements.

hydrophone receiving sensors that convert sound energy into electrical or optical energy (analogous to underwater microphones).

hydropower conversion of potential energy of water into electricity using generators coupled to impulse or reaction water turbines.

hyperpolarizability a measure of the nonlinear optical response of an atom or molecule. The hyperpolarizability of order $n\gamma(n)$ is defined by the relation $p(n) = C\gamma(n)E^n$, where E is the electric field strength of the applied laser field and $p(n)$ is the nth order contribution to the dipole moment per molecule. C is a coefficient of order unity whose definition is different among different workers.

hysteresis (1) the phenomenon that the magnetic state of a substance is dependent upon its magnetic history, so that its magnetization for an increasing magnetizing force differs from that for a decreasing magnetizing force.

(2) the characteristic of magnetic materials that causes the trajectory of the flux density vs. field intensity curve as the intensity is increased to be different from that when the intensity is decreased, giving rise to a loss, which is proportional to the area enclosed by the two trajectories.

hysteresis brake a braking device utilizing hysteresis to provide a constant braking torque irrespective of slip speed.

hysteresis control a time-optimal feedback control method in which the control variable reaches a reference value in the shortest possible time and then stays within a prescribed hysteresis band around the set point through manipulation of the system state between two configurations. The actual variable is compared with the reference value, and if the error exceeds the hysteresis band, then the control input is changed such that the control variable is forced to decrease. On the other hand, if the actual variable falls below the hysteresis band then the control input is changed such that the control variable increases in magnitude.

hysteresis curve a graph describing the relationship between the magnetic flux density and the magnetic field intensity in a (usually ferromagnetic) material.

hysteresis drive *See* hysteresis torque coupling.

hysteresis loss the energy loss due to hysteresis in a magnetic material subjected to a varying magnetic field.

hysteresis motor any of a variety of single-phase AC motors that use the hysteresis properties of hard magnetic materials to develop torque. Stator windings of a hysteresis motor can be of any design that produces a rotating flux within the machine. Motion of the rotating flux over the rotor magnetizes the hard magnetic material on the rotor; however, the hysteresis characteristics of the material cause the alignment of magnet flux to lag the rotating stator flux. This misalignment produces rotor torque. Because of the nature of the torque production, hysteresis motors operate at synchronous speed and have a constant torque characteristic, which permits them to synchronize any load that they can accelerate.

hysteresis torque coupling a magnetic drive in which the magnetizing stator magnet drives a rotor of hysteresis material through the complete hysteresis cycle once per rotation, resulting in a constant torque characteristic irrespective of relative speed.

Hz hertz. *See* frequency.

difference transparent to both ends.

I/O bus a data path connecting input or output devices to the computer.

I/O card a device used to connect a peripheral device to the main computer; sometimes called an I/O controller, I/O interface, or peripheral controller.

I/O channel *See* input/output channel, subchannel I/O.

I/O command one of the elementary types of commands that a computer can execute. I/O commands are typically used to initiate I/O operations, sense completion of commands, and transfer data. Not all computers have I/O commands. *See also* memory mapped I/O.

I/O controller (1) a device used to connect a peripheral device to the main computer; sometimes called an I/O card.

(2) the software subroutine used to communicate with an I/O device. *See also* I/O routine.

I/O device a physical mechanism attached to a computer that can be used to store output from the computer, provide input to the computer, or do both.

I/O interface a device used to connect a peripheral device to the main computer; sometimes called an I/O card or I/O controller.

I/O interrupt a signal sent from an input or output device to a processor that the status of the I/O device has changed. An interrupt usually causes the computer to transfer program control to the software subroutine that is responsible for controlling the device. *See also* interrupt-driven I/O.

I/O port (1) a register designed specifically for data input–output purposes.

I

I and Q the I and Q signals are used in video transmission to generate a chroma phasor or vector. By varying the amplitude of the I and Q signals, all colors in the visible spectrum can be generated and transmitted. The I and Q signals are derived from the RGB signals where $I = .6R - 0.28G - 0.32B$, $Q = .21R - .52G + .31B$.

I_{DC} DC current in amperes.

I_{IN_p} peak input current in amperes.

I_{OUT_p} peak output current in amperes.

I_{DS} FET channel current.

I&P *See* interconnections and packaging.

I-V characteristics the charts describing the current through a diode as a function of its voltage bias.

I/O input/output. Operations or devices that provide data to or accept data from a computer.

I/O bandwidth the data transfer rate into or out of a computer system. Measured in bits or bytes per second. The rate depends on the medium used to transfer the data as well as the architecture of the system. In some instances the bandwidth average rate is given and in others the maximum rate is given. *See also* I/O throughput.

I/O buffer a temporary storage area where input and output are held. Having I/O buffers frees a processor to perform other tasks while the I/O is being done. Data transfer rates of the processor and an I/O device are, in general, different. The I/O buffer makes this

(2) the place from which input and output occurs in a computer. Examples include printer port, serial port, and SCSI port.

I/O processor an input/output processor with a unique instruction set, dedicated to performing I/O operations exclusively, thus alleviating the burden off the CPU. It usually has a separate local bus for I/O operations data traffic, thus permitting the CPU to access memory on the main system bus without interruption. For example, the Intel 8086 CPU has an 8089 I/O processor associated with it. Both can operate simultaneously, in parallel.

I/O register a special storage location used specifically for communicating with input/output devices.

I/O routine a function responsible for handling I/O and transferring data between the memory and an I/O device. *See also* I/O controller.

I/O system the entire set of input/output constructs, including the I/O devices, device drivers, and the I/O bus.

I/O throughput the rate of data transfer between a computer system and I/O devices. Mainly determined by the speed of the I/O bus or channel. Throughput is typically measured in bits/second or bytes/second. In some instances, the throughput average rate is given and in others the maximum rate is given. *See also* I/O bandwidth.

I/O trunk *See* I/O bus.

I/O unit the equipment and controls necessary for a computer to interact with a human operator or to access mass storage devices or to communicate with other computer systems over communication facilities.

I-line a line of the mercury spectrum corresponding to a wavelength of about 365 nm.

IA *See* index assignment.

IAEA International Atomic Energy Agency, an organization which monitors nuclear materials and energy.

IC *See* integrated circuit.

ICE *See* in-circuit emulator.

ideal filter (1) a system that completely rejects sinusoidal inputs of the form $x(t)4 = A\cos\omega t$, $-\infty < t < \infty$, for ω within a certain frequency range, and does not attenuate sinusoidal inputs whose frequencies are outside this range. There are four basic types of ideal filters: low-pass, high-pass, band-pass, and bandstop.

(2) a filter that has zero gain in the stopband, a constant, usually unity, gain in the passband, and a zero transition band width. A 1-D ideal lowpass filter has unity gain for frequencies less than or equal to the cutoff frequency, and zero gain for frequencies greater than the cutoff frequency. An ideal filter is unrealizable in practice.

ideal operating amplifier an op amp having infinite gain from input to output, with infinite input resistance and zero output resistance and insensitive to the frequency of the signal. An ideal op amp is useful in first-order analysis of circuits.

ideal transformer a transformer with zero winding resistance and a lossless, infinite permeability core resulting in a transformer efficiency of 100 percent. Infinite permeability would result in zero exciting current and no leakage flux. For an ideal transformer, the ratio of the voltages on the primary and secondary sides would be exactly the same as the ratio of turns in the windings, while the ratio of currents would be the inverse of the turns ratio.

ideality factor the factor determining the deviation from the ideal diode characteristic $m = 1$. At small and large currents $m \approx 2$.

idempotent an operator is idempotent if applying it twice gives the same result as applying it only once; mathematically speaking, if ψ is the operator and X the object to which it is applied, this means that $\psi(\psi(X)) = \psi(X)$.

idler wave the additional, often unwanted, output wave produced by an optical parametric oscillator designed to generate a signal wave.

IEC *See* International Electro-technical Commission.

IEEE *See* Institute of Electrical and Electronics Engineers.

IEEE Color Books a series of seven books related to industrial and commercial power systems containing recommended IEEE/ANSI standards and practices. The books are color-coded as to subject as follows:

Gray: Power systems in commercial buildings

Green: Grounding industrial and commercial power systems

Brown: Power system analysis

Gold: Design of reliable industrial and commercial power systems

Orange: Emergency and standby power for industrial and commercial power systems

Red: Electric distribution practice in industrial plants

Buff: Protection and coordination of industrial and commercial power systems.

IEEE float encoding *See* NaN.

IEEE representation an encoding convention for the representation of floating-point values within computing systems.

IEEE Standard 754 the specification that defines a standard set of formats for the representation of floating-point numbers.

IF *See* intermediate frequency.

IF amplifier an amplifier having high and controllable gain with a sharp band-pass characteristic centered around the intermediate frequency (IF).

IGBT *See* insulated gate bipolar junction transistor.

ignitron a high-voltage mercury switch. The device is found in modulators used to dump the capacitor bank voltage in the event of a PA crowbar. An ignitron passes electrical current to a pool of liquid mercury at ground potential.

II-VI semiconductor binary semiconductor made from elements in the periodic table two columns to the "left" and "right" of silicon, e.g., CdTe, ZnS, etc.

IID *See* independent and identically distributed.

III-V semiconductor a binary semiconductor made from elements from columns III and V in the periodic table.

illumination (1) in vision science, the amount of light per unit area delivered to a surface and accounting for the spectral sensitivity of the human eye.

(2) informally, the amount of light falling on an object. Also called illuminance. *See also* luminance.

(3) the effect of a visible radiation flux received on a given surface. Illumination is measured by the illuminance, which is the luminous flux received by surface unit, usually expressed in lux. One lux equals 1 lumen/m^2.

illumination system the light source and optical system designed to illuminate the mask for the purpose of forming an image on the wafer.

ill-posed problem a problem whose solution may not exist, may not be unique, or may depend discontinuously on the data. (A problem is well-posed if it can be shown that its solution exists, is unique, and varies continuously with perturbation of the data. If any of the three conditions does not hold, the problem is ill-posed.)

image information stored digitally in a computer, often representing a natural scene or other physical phenomenon, and presented as a picture. The brightness at each spot in the picture is represented by a number. The numbers may be stored explicitly as pixels or implicitly in the form of equations. *See also* bitmapped image, image acquisition, image processing, imaging modalities, pixel, vector image.

image acquisition the conversion of information into an image. Acquisition is the first stage of an image processing system and involves converting the input signal into a more amenable form (such as an electrical signal), and sampling and quantizing this signal to produce the pixels in the image. Hardware, such as lenses, sensors and transducers are particularly important in image acquisition. *See also* analog-to-digital converter, digitization, image, pixel, quantization, sample.

image analysis the extraction of information from an image by a computer. The results are usually numerical rather than pictorial and the information is often complex, typically including the recognition and interpretation of objects in or features of the image.

image classification the division by a computer of objects in an image into classes or groups. Each class contains objects with similar features. Also, the division of the images themselves into groups according to content.

image coding the usual reasons for coding messages lie in the areas of data compression and data security. However, the main motivation for recoding images is to achieve the high rates of data compression required to cope with the storage and transmission of prodigious amounts of image data. *See* still image coding and video codingfor methods.

image coding for videoconferencing this is also called coding at primary rates for videoconferencing. In North America and Japan, one of the most plentiful is the DSI rate of 1.544 Mb/s. In Europe, the corresponding rate is 2.044 Mb/s. The main difference is that in videoconferencing the video camera is fixed and picture data is produced only if there are moving objects in the scene. Typically, the amount of moving data is much smaller than the stationary area.

image compression representation of still and moving images using fewer bits than the original representation. *See* still image coding and video coding for methods.

image compression or coding the process of reducing the number of binary digits or bits required to represent the image.

image correlation the calculation of the correlation function where the two signal inputs are images.

image degradation blurring of an image wavefront due to scattering as it passes an inhomogeneous medium, e.g., astronomical images due to atmospheric scattering.

image dissector a nonstorage photoemission device used as a light detector in early television camera tubes. Electron streams, emitted by light striking a photocathode film, are focused on a plane containing a small aperture into a photomultiplier structure. Scanning is accomplished by magnetically deflecting the electron stream across the aperture.

image enhanced mixer mixer that operates on the principle of terminating the image frequency component at an optimal impedance level that improves the conversion loss of the mixer. The optimal impedance termination allows the image product to remix with the LO frequency component such that the down-converted signal is in phase with the IF component and thus increases its magnitude. The image spectral component is at a frequency that is either the sum or difference of the LO and IF components.

image enhancement processing an image to improve its appearance, or to make it more suited to human or machine analysis. Enhancement is based not on a model of degradation (for which, *See* restoration) but on qualitative or subjective goals such as removing noise and increasing sharpness. Contrast stretching, edge emphasis, and smoothing are examples of enhancement techniques.

image feature an attribute of a block of image pixels.

image frequency rejection ratio ratio of output for the image frequency below that for the desired signal when both image and desired signal levels at the input are the same.

image frequency response output generated in a superheterodyne receiver due to an undesired signal with a frequency spaced by twice the IF from desired frequency.

image fusion the merger of images taken with different imaging modalities or with different types of the same modality, for example, different spectral bands. *See also* multispectral image.

image guide a type of dielectric waveguide based on a dielectric rod waveguide with a conducting plate placed at the plane of symmetry.

image hierarchy a way to organize the image data in order of importance. Each level corresponds to a reconstructed image at a particular resolution or level of quality. Generally, they are classified into fixed and variable resolution hierarchies.

image impedance the input impedance into a passive 2-port device when that device is terminated in an infinite chain of identical devices connected to both ports such that each port is connected to the same port (i.e., port 1 connects to port 1 and port 2 connects to port 2 throughout the infinite chain, giving a perfect match). The impedance looking into port 1 is Z_{I11}, and into port two is Z_{I22}. For a uniform transmission line, the image impedances are equal to each other and also equal to the characteristic impedance of the line.

image processing the manipulation of digital images on a computer, usually done automatically (solely by the computer) but also semi-automatically (the computer with the aid of a person). The goal of the processing may include compressing the image, making it look better, extracting information or measurements from it or getting rid of degradations. *See also* image acquisition, image analysis, image classification, image compression, image enhancement, image recognition, image restoration.

image recognition the identification and interpretation of objects in an image. Image recognition is a higher-level process that requires more intelligence than other parts of image processing such as image enhancement. Artificial intelligence, neural nets or fuzzy logic are often used. *See also* artificial intelligence, artificial neural network, fuzzy logic, classifier, image classification, image understanding, pattern recognition.

image reconstruction (1) the process of obtaining an image from nonimage data that characterizes that image.

(2) the conversion of a digital image to a continuous one suitable for display. *See also* analog-to-digital converter, interpolation.

(3) in tomography, the reconstruction of a spatial image from its projections. *See also* computed tomography, Radon transform.

image registration the spatial alignment of a pair of images, which may involve correcting for differences in translation, rotation, scale, deformation or perspective. Especially important in binocular vision.

image rejection filter a filter usually placed before a mixer to preselect the frequency, which when "mixed" with the local oscillator frequency, will down-convert to the desired intermediate frequency. In the absence of an image rejection filter, there are two RF frequencies, which when mixed with the local oscillator frequency f_{lo}, will down-convert to the intermediate frequency f_{if}. Specifically, these are given by $f_{lo} + f_{if}$ and $f_{lo} - f_{if}$. For example, if the local oscillator frequency is 10 GHz and the local oscillator frequency is 1 GHz, then signals at both 11 GHz and 9 GHz will produce an intermediate frequency signal of 1 GHz without an image rejection filter.

image resolution a measure of the amount of detail that can be present in an image. Spatial resolution refers to the amount a scene's area that one pixel represents, with a smaller area being a higher resolution. Brightness resolution refers to the amount of luminance or intensity that each gray level represents, with a smaller amount being a higher resolution.

image restoration (1) recovery of the amplitude and/or the phase of an image wavefront, degraded on scattering, by either digital or optical procedures, e.g., deconvolution, inverse scattering, or speckle interferometry techniques.

(2) the removal of degradations in an image in order to recover the original image. Some typical image degradations and possible causes are: blurring (intervening atmosphere or media, optical abberrations, motion), random noise (photodetectors, electronics, film grain), periodic noise (electronics, vibrations) and geometric distortions (optical abberrations, angle of image capture). *See also* degradation, motion compensation, noise, noise suppression.

image reversal a chemical process by which a positive photoresist is made to behave like a negative photoresist.

image segmentation the division of an image into distinct regions, which are later classified and recognized. The regions are usually separated by edges; pixels within a region often have similar gray levels. *See also* edge detection, image classification, image recognition.

image smoothing the reduction of abrupt changes in the gray levels of an image. Usually performed by replacing a pixel by the average of pixels in some region around it. Also called image averaging. *See also* smoothing.

image theory a solution technique for determining the fields radiated by sources in the presence of material boundaries; typically the boundary is between a dielectric and a perfect electric conductor. The equivalence theorem is used to generate an equivalent problem in a homogeneous medium with image sources that provide the same boundary conditions as the original problem.

image transform the conversion of the image from the spatial domain to another domain, such as the Fourier domain. It is often easier and more effective to carry out image processing such as image enhancement or image compression in the transformed domain. *See also* block transform, cosine transform, discrete Fourier transform (DFT), discrete Hadamard transform, discrete Hadamard transform, discrete cosine transform (DCT), discrete sine transform (DST), discrete wavelet transform (DWT), distance transform, Fourier transform,Haartransform,Hadamardtransform, Hankel transform, Hilbert transform, Hotelling transform, Hough transform, Karhunen–Loeve transform (KLT), medial axis transform

(MAT), Radon transform, separable image transform, sine transform, slope transform, top hat transform, transform, Walsh transform, wavelet transform.

image understanding the interpretation by a computer of the contents of an image. The process seeks to emulate people's ability to intelligently extract information from or make conclusions about the scene in an image. Also called image interpretation.

imaginary power *See* reactive power.

imaging modalities the general physical quantity that the pixels in an image represent; the type of energy an image processing system converts during image acquisition. The most common modality is visible light, but other modalities include invisible light (infrared or x-ray), sound (ultrasound) and magnetism (nuclear magnetic resonance). *See also* computed tomography (CT), fluoroscopy, image acquisition, magnetic resonance imaging (MRI), multispectral image, nuclear magnetic resonance, positron emission tomography (PET), synthetic aperture radar (SAR), tomography, ultrasound, X-ray image.

IMC *See* internal model control.

immediate addressing an addressing mode where the operand is specified in the instruction itself. The address field in the instruction holds the data required for the operation.

immediate operand a data item contained as a literal within an instruction.

immersed flow a flow of electrons emitted from an electron gun exposed to the focusing magnetic fields.

immittance a response function for which one variable is a voltage and the other a current. Immittance is a general term for both impedance and admittance and is generally used where the distinction is irrelevant.

immunity to a disturbance an equipment or systems capability to operate if an electromagnetic disturbance occurs.

impact excitation excitation of an atom or molecule resulting from collision by another particle such as an electron, proton, or neutron.

IMPATT diode acronym for impact avalanche and transit time diode. Negative resistance device used at high frequencies used to generate microwave power. Typically used in microwave cavity oscillators.

impedance (1) electrical property of a network that measures its ability to conduct electrical AC current for a given AC voltage. Impedance is defined as the ratio of the AC voltage divided by the AC current at a given point in the network. In general, impedance has two parts: a real (resistive) part and an imaginary (inductive or capacitive "reactive") part. Unless the circuit is purely resistive (made up of resistors only), the value of impedance will change with frequency.

(2) in an antenna, usually defined at the input to an antenna, the impedance is the ratio of the applied (or induced) voltage to the current flowing into (or out of) the antenna input. More generally, it is defined as the ratio of the electric field to the magnetic field.

impedance inverter circuit whose input impedance, when terminated with a load, is inversely proportional to said load impedance — typically implemented with a quarter-wave transmission line.

impedance matching one of the main design activities in microwave circuit design. An impedance matching network is made up of a combination of lumped elements (resistors, capacitors, and inductors), or distributed elements (transmission lines of varying characteristic impedance and length). Impedance matching networks transform network impedance from one value to another. For example, on the input to a low noise transistor, the impedance of an incoming 75 ohm transmission line would be transformed by the input matching network to the impedance Zopt, required to achieve the minimum noise figure of the transistor. The Smith chart is a tool commonly used by microwave engineers to aid with impedance matching.

impedance matching network a combination of reactive elements connected between a circuit and a load that transforms the load impedance into another impedance value to achieve improved performance such as maximum power transfer, reduced reflections, or optimum noise performance.

impedance matrix the matrix formed in the method of moments by expanding the electric current in a series of basis functions, expressing the electric field in terms of the current, and taking the inner product with a set of testing functions. The resulting matrix equation is of the form

$$[V_m] = [Z_{mn}][I_n]$$

where $[V_m]$ represents the known excitation, $[Z_{mn}]$ is the impedance matrix, and $[I_n]$ is the unknown current.

impedance measurement measurement of the impedance (ratio of voltage to current) at a circuit port.

impedance parameters circuit parameters relating the voltages across the ports of a multiport to the port currents.

impedance relay a protective relay that senses the operational impedance at a location, i.e., the ratio of voltage to current at any given time. During fault conditions on the protected line, the impedance relay will sense the impedance (distance in ohms) between the location of the relay and the fault. Typical impedance relay characteristics are mho and reactance. Impedance relays are widely used in sensing phase faults on transmission lines. Ground impedance relays are available that measure the distance to a single phase to ground fault using a modified technique. Also known as distance relay.

impedance scaling modifying a filter circuit to change from a normalized set of element values to other usually more practical element values by multiplying all impedance by a constant equal to the ratio of the desired (scaled) impedance to the normalized impedance.

impedance standard substrate (ISS) a substrate, usually made of alumina, containing thin film gold calibration standards used in the calibration of vector network analyzers used in conjunction with microwave coplanar probes.

impedance transformation *See* matching.

implicant a first-order implicant is a pair of logically adjacent minterms. A second-order implicant is a set of logically adjacent first-order implicants, and so on.

implication a rule of reasoning which states that the truth of a proposition or condition implies the truth of another. A common implication rule is of the form “If A then B.”

implied addressing a form of addressing where the register or memory address is not specified within the instruction but is assumed.

imprecise interrupt an implementation of the interrupt mechanism in which instructions that have started may not have completed before the interrupt takes place, and insufficient information is stored to allow the processor to restart after the interrupt in exactly the same state. This can cause problems, especially if the source of the interrupt is an arithmetic exception. *See also* precise interrupt.

imprecision a sense of vagueness where the actual value of a parameter can assume the specified value to within a finite tolerance limit.

impressed current a current generated from an independent source. Often used to represent antennas.

improper modes in open waveguides the eigenfunctions relative to the continuous spectrum, which are defined over an infinite interval, are often referred to as improper modes.

impulse a unit pulse. *See also* impulsive transient, surge.

impulse breakdown a test of electrical insulation in which lightning or switching impulses are applied.

impulse function a function $I(n)$ whose value is non-zero at sample position $n = 0$, and zero elsewhere. The unit impulse function $\delta(n)$ is unity at sample position $n = 0$ and zero elsewhere. A shifted impulse is also termed an impulse. *See also* Dirac's delta function.

impulse generator (1) an electronic device delivering single pulses of various shapes, preferably square.

(2) a high-voltage trigger generator.

impulse noise refers to a noise process with infrequent, but very large, noise spikes; it is also known as shot noise or Salt and Pepper noise. The phrase "Impulsive noise" is frequently used to characterize a noise process as being fundamentally different from Gaussian white noise, in being derived from a probability density function with very heavy (long) tails. Applying impulsive noise to an image leaves most pixels unaffected, but with some pixels very bright or dark.

impulse response the output of a linear time-invariant system when the input is a pulse of short time duration. The system can be entirely characterized by the impulse response.

In the case of a continuous time system with input $f(t)$, the impulse signal $\delta(t)$ is defined as

$$(i) \quad \delta(t) = 0, \quad t \neq 0$$

$$(ii) \int_{-\epsilon}^{\epsilon} \delta(t)dt = 1, \quad \text{for any } \epsilon > 0,$$

and the impulse response is the zero state system response to an input $f(t) = \delta(t)$. In the case of a discrete time system with input $f[k]$, the impulse signal is defined as

$$(i) \ \ \delta[k] = 1, k = 0$$

$$(ii) \ \delta[k] = 0, k \neq 0 \ ,$$

and the impulse response is the zero state system response to input $f[k] = \delta[k]$.

impulse train a signal that consists of an infinitely long series of Dirac delta functions with period T: $\sum_{n=-\infty}^{\infty} \delta(t - nT)$. This signal can be used to sample a continuous-time waveform.

impulsive transient a rapid frequency variation of voltage or current during steady-state operation in which the polarity is mostly unidirectional.

in-circuit emulator (ICE) a device that replaces the processor and provides the functions of the processor plus testing and debugging functions.

in-line gun a CRT electron gun structure that has the red, green, and blue electron gun components aligned in a horizontal plane. The in-line gun structure requires color registration (color convergence) correction in the vertical CRT face plate axis only.

in-order issue the situation in which instructions are sent to be executed in the order that the instructions appear in the program.

in-phase signal in quadrature modulation, the signal component that multiplies $\cos 2\pi f_c t$, where f_c is the carrier frequency.

INA *See* inverse Nyquist array.

incandescent lamp a lamp made by heating a metal filament in vacuum; not a burning candle.

incident power power in an electromagnetic wave that is traveling in an incident direction.

incoherent illumination a type of illumination resulting from an infinitely large source of light that illuminates the mask with light from all possible directions. This is more correctly called spatially incoherent illumination.

incoherent light light in which detailed knowledge of the fields at one point in space does not permit prediction of the fields at another point.

increment to add a constant value (usually 1) to a variable or a register. Pointers to memory are usually incremented by the size of the data item pointed to.

incremental encoder similar to an absolute encoder, except there are several radial lines drawn around the disc, so that pulses of light are produced on the light detector as the disc rotates. Thus incremental information is obtained relative to the starting position. A larger number of lines allows higher resolution, with one light detector. A once per rev counter may be added with a second light detector. *See also* encoder.

incremental gain a system $H : \mathcal{X}_e \to \mathcal{X}_e$ is said to be Lipschitz continuous, or simply continuous, if there exists a constant $\Gamma(H) < \infty$, called incremental gain, such that

$$\Gamma(H) = \sup \frac{\|(Hx_1)_T - (Hx_2)_T\|}{\|(x_1)_T - (x_2)_T\|}$$

where the supremum is taken over all $x_1, x_2 \in \mathcal{X}_e$ and all real numbers T for which $x_{1T} \neq x_{2T}$. *See also* extended space, gain.

incremental model small-sign differential (incremental) semiconductor diode equivalent RC circuit of a diode, biased in a DC operating point.

incremental passivity a system $H : X_e \to X_e$ is said to be incrementally passive if

$$\langle Hx_1 - Hx_2, x_1 - x_2 \rangle_T \geq 0$$
$$\forall x_1, x_2 \in \mathcal{X}_e$$

See also extended space, inner product space, and passivity.

incremental resistance the slope dV/dI of the I-V characteristic of a circuit element.

incremental strict passivity a system $H : X_e \to X_e$ is said to be incrementally strictly passive if there exist δ such that

$$\langle Hx_1 - Hx_2, x_1 - x_2 \rangle_T \geq$$
$$\delta \langle x_1 - x_2, x_1 - x_2 \rangle_T$$
$$\forall x_1, x_2 \in \mathcal{X}_e$$

See also extended space, inner product space, passivity, strict passivity, and incremental passivity.

incrementally linear system a system that has a linear response to changes in the input, i.e., the difference in the outputs is a linear (additive and homogeneous) function of the difference in the inputs. *See also* linear system.

independence a complete absence of any dependence between statistical quantities. In terms of probability density functions (PDFs), a set of random quantities are independent if their joint PDF equals the product of their marginal PDFs:

$$p_{x_1,x_2,\ldots}(\boldsymbol{x}_1, \boldsymbol{x}_2, \ldots) = p_{x_1}(\boldsymbol{x}_1) \cdot p_{x_2}(\boldsymbol{x}_2) \cdot \ldots .$$

Independence implies uncorrelatedness. *See also* correlation. *See also* probability density function.

independent and identically distributed (IID) a term to describe a number of random variables, each of which exhibits identical statistical characteristics, but acts completely independently, such that the state or output of one random variable has no influence upon the state or output of any other.

independent event event with the property that it gives no information about the occurrence of the other events.

independent identically distributed process a random process $\boldsymbol{x}[i]$, where $\boldsymbol{x}[i]$ and $\boldsymbol{x}[j]$ are independent for $i \neq j$, and where the probability distribution $p(\boldsymbol{x}[i])$ for each element of the process is not a function of i. *See also* independence, probability density function, random process.

independent increments process a random process $\boldsymbol{x}(t)$, where the process increments over non-overlapping periods are independent. That is, for $t_i < s_i$, $s_i \leq t_{i+1}$, then

$$(\boldsymbol{x}(s_1) - \boldsymbol{x}(t_1)), (\boldsymbol{x}(s_2) - \boldsymbol{x}(t_2)), \ldots$$

are all independent. *See also* independence, random process.

independent joint control control of a single joint of a robot while all the other joints are fixed.

index that part of memory address used to access the locations in the cache, generally the next most significant bits of the address after the tag.

index assignment (IA) each reproduction vector in a (vector) quantizer is represented by an index that is transmitted or stored. The index assignment problem is the problem of assigning indices to reproduction vectors, in such a way that errors in the transmission (or storage) influence the reproduction fidelity as little as possible.

index grating through the photorefractive effect. This volume index grating is referred to as a photorefractive grating. The photo-induced refractive index grating can also be erased by the illumination of another beam of light. *See also* index-guided laser diode.

index of fuzziness an index to measure the degree of ambiguity of a fuzzy set by computing the distance between the fuzzy set and its nearest ordinary set.

index of refraction (1) a parameter of a medium equal to the ratio of the velocity of propagation in free space to the velocity of propagation in the medium. It is numerically equal to the square root of the product of the relative permittivity and relative permeability of the medium.

(2) in optics, a complex quantity describing the optical transmission properties of a medium; the real part corresponds to the ratio of speed of light in vacuum to the speed of light in the medium, while the imaginary part corresponds to attenuation of the light by the medium.

index register register used to index a data structure in memory; the starting address of the structure will be stored in a base register. Used in indexed addressing.

index-guided laser electrically pumped semiconductor laser in which the mode fields are confined in the transverse direction by the profile of the index of refraction.

index-guided laser diode *See* index-guided. laser.

indexed addressing an addressing mode in which an index value is added to a base address to determine the location (effective address) of an operand or instruction in memory. Typically, the base address designates the beginning location of a data structure in memory such as a table or array and the index value indicates a particular location in the structure.

indexing *See* indexed addressing.

indicator *See* flag.

indirect addressing an addressing mode in which an index value is added to a base address to determine the location (effective address) of an operand or instruction in memory. Typically, the base address designates the beginning location of a data structure in memory such as a table or array and the index value indicates a particular location in the structure. Also known as deferred addressing.

indirect weld parameters (IWP) a collection of parameters that establish the welding equipment setpoint values. Examples include voltage, current, travel, speed, electrode feed rate, travel angle, electrode geometry, focused spot size, and beam power.

indiscernibility relation in Pawlak's information system $S = (U, A)$ whose universe U has n members denoted $x, y, z, \ldots$ and the set A consisting of m attributes $\mathbf{a}_j$, the indiscernibility relation on U with respect to the set $B \subseteq A$ defines the partition U/B of U into equivalence classes such that $x, y \in U$ belong to the same class of U/B if for every attribute $\mathbf{a} \in B$,

$$\mathbf{a}(x) = \mathbf{a}(y).$$

In terms of negotiations, the partition U/B may be interpreted as the partition of the inverse U into blocks of negotiators that have the same opinion on all of the issues of B.

induced emission enhanced emission of electromagnetic radiation due to the presence of radiation at the same frequency; also called stimulated emission.

induced voltage voltage produced by a time-varying magnetic flux linkage. *See also* Faraday's law.

inductance a parameter that describes the ability of a device to store magnetic flux. The units are henrys per meter.

induction furnace a method of smelting or heating metals with eddy currents induced by a high-frequency coil surrounding the crucible.

induction generator an induction machine operated as a generator. If the machine is connected to an AC system and is driven at greater than synchronous speed, the machine can convert mechanical energy to electrical form. The induction generator requires a source of reactive power.

induction machine classification of any of a variety of electrical machines in which an AC current in the stator coils is used to produce a rotating magnetic flux that, by Faraday action, induces an AC voltage in a set of coils (the induction coils) on the machine's rotor. The rotor coils are shorted to cause a second AC current to flow in the rotor coils, which produces, in turn, a second rotating flux. The interaction of the rotor- and stator-produced fluxes creates torque.

induction motor *See* induction machine.

induction regulator *See* induction voltage transformer.

induction theorem states that if the incident tangential magnetic and electric fields are known everywhere on some closed surface, then these fields may be replaced with equivalent electric and magnetic surface currents.

induction voltage transformer specially constructed transformer with a rotating primary coil that is used to provide voltage regulation on individual power circuits. The secondary of an induction regulator is mounted on the stationary shell of cylindrical core, and the primary is mounted on a movable, center rotor. In the neutral position, the magnetic axes of the primary and secondary coils are oriented 90 degrees to each other, reducing the magnetic coupling to zero. In this position, energizing the primary does not induce voltage in the secondary; however, rotating the primary coil in either direction from the neutral position creates mutual flux linkage and causes a secondary voltage to appear. Rotation in one direction causes secondary voltage to be in phase with the primary; rotation in the opposite direction causes secondary voltage to be out of phase with the primary. Voltage regulation is provided by connecting the primary coil across the line to be regulated and connecting the secondary coil in series with the load. By positioning the primary coil based on load demand in the line, secondary voltage can be used to adjust line voltage either up or down. Induction regulators are also equipped with a short-circuited coil mounted on the primary in spatial quadrature with the primary coil. In the neutral position, this coil has maximum coupling with the secondary coil, which minimizes the inductive reactance in the load line due to the secondary coil.

inductive coupling a means of transferring electrical energy from one part (area) of a circuit to another part without requiring any ohmic (wire) connection. Instead, magnetic flux linkages couple two inductors (coils). The coils must be in close proximity in order to establish sufficient mutual inductance.

inductive discontinuity a type of discontinuity that exhibits an inductive, or quasi-inductive, behavior. As an example, magnetic plane iris in metallic rectangular waveguides produces this type of response.

inductor a two-terminal electrical element that satisfies a prescribed algebraic relationship in the flux-current ($\phi - I$) plane.

industrial inspection the use of computer vision in manufacturing, for example, to look for defects, measure distances and sizes, and evaluate quality. *See also* computer vision, inspection system.

industrial robot a mechanical structure or manipulator that consists of a sequence of rigid body (links) connected by means of articulation joints. A manipulator is characterized by an arm, a wrist, and an end-effector. Motion of the manipulator is imposed by actuators through actuation of the joints. Control and supervision of manipulator motion is performed by a control system. Manipulator is equipped with sensors that measure the status of the manipulator and the environment.

inelastic scattering situation where there is energy exchange between the impinging wave and the medium. Inelastic scattering also produces frequency shifts.

inertia constant the energy stored in an electric machine running at synchronous speed and given in megajoules per megavoltampere of machine rating.

inertial confinement a method of initiating and containing the plasma of a fusion reaction by illuminating a pellet of solid heavy hydrogen with powerful laser beams from all directions simultaneously.

inference engine a reasoning mechanism for manipulating the encoded information and rules in a knowledge base to form inferences and draw conclusions.

infinite bus an electrical supply with such large capacity that its voltage (and frequency, if AC) may be assumed constant, independent of load conditions. If a machine's capacity is small relative to the electric supply system to which it is connected, it may be assumed to be operating on an infinite bus.

infinite impulse response (IIR) filter any filter having an impulse response of infinite length, therefore having a frequency response with at least one pole. In direct contrast with finite impulse response (FIR) filters, IIR filters employ feedback, which leads to an impulse response of infinite extent; consequently a causal IIR filter will depend on all previous inputs. As a simple example, every autoregressive process can be expressed as the output of an IIR filter driven by white noise. *See also* finite impulse response filter, autoregressive .

infinite symmetric exponential filter (ISEF) one type of optimal edge detecter. In two dimensions, the filter is

$$f(x, y) = a \times e^{-p(|x|+|y|)}$$

The resulting edge detector has excellent localization and signal-to-noise ratio. *Compare with* Canny edge detector.

infinite-dimensional dynamical system a linear stationary system described by the following abstract ordinary differential state equation:

$$x'(t) = Ax(t) + Bu(t)$$

where $x(t)$ is the state vector that belongs to infinite-dimensional Banach space X, $u(t)$ is the input vector that belongs to infinite-dimensional Banach space U, A is a linear generally unbounded operator that is a generator of a strongly continuous semigroup of linear bounded operators $S(t) : X \to X$, for $t > 0$, $B : u \to x$ is a linear bounded operator. The solution of the state equation has the form

$$x(t, x(0), u) = S(t)x(0) + \int_0^t S(t-s)Bu(s)ds$$

information a mathematical model of the amount of surprise contained in a message. For a discrete random source with a finite number of possible symbols or messages the information associated with the symbol x_k is

$$I_k = -\log_2(p_k)$$

where p_k is the probability of the symbol x_k. The expected value of the information of the symbols is the first order entropy of the source.

information gain for an attribute in a set of objects to be classified, a measure of the importance of the attribute to the classification. The information gain G_i of the ith attribute A_i of a set of n objects S in the classification is defined as

$$G_i = I(S) - E_i$$

where $I(S)$ is the expected information (or entropy) for the classification and E_i is the expected information required for the value of A_i to be known. $I(S)$ is defined as

$$I(S) = -\sum_{c=1}^{N_c} \frac{n_c}{n} log_2 \frac{n_c}{n}$$

where N_c is the total number of classes in the classification, and n_c is the number of objects in the cth class C_c. E_i is defined as

$$E_i = \sum_{k=1}^{N_i} \frac{n_{ik}}{n} I(S_{ik})$$

where S_{ik} is the subset of S in which A_i of all objects takes its kth value, N_i is the number of values A_i can take, n_{ik} is the number of objects in S_{ik}, and the information required in S_{ik} is

$$I(S_{ik}) = -\sum_{c=1}^{N_c} \frac{n_{ikc}}{n_{ik}} \log_2 \frac{n_{ikc}}{n_{ik}}$$

where n_{ikc} is the number of objects in S_{ik} belonging to class C_c.

information hiding a program design principle that makes available to a function only the data it needs.

information theory theory relating the information content of a message to its representation for transmission through electronic media. This subject includes the theory of coding, and also topics such as entropy, modulation, rate distortion theory, redundancy, sampling.

infrared detector semiconductor or other material with a measurable change, usually, but not always, in electrical conductivity, when exposed to infrared light.

infrared (IR) invisible electromagnetic radiation having wavelengths longer than those of red light; often considered to range from about 0.7 micrometers to 100 micrometers.

infrared laser laser producing its output in the infrared region of the spectrum.

InGaAs/InAlAs/InP lattice matched semiconductor heterostructure system used for

1. optical fiber communications sources and detectors, and

2. high-speed electronic circuits.

inheritance in object orientation, the possibility for different data types to share the same code.

inhibit to prevent an action from taking place; a signal that prevents some action from occurring. For example, the READY signal on a memory bus for a read operation may inhibit further processing until the data item has become available, at which time the READY signal is released and the processor continues.

inhibit sense multiple access (ISMA) protocol multiple access protocol attempting to solve the hidden station problem. In ISMA, the base station transmits an "idle" signal at the beginning of a free slot. Each user has to monitor this signal before it attempts to access the base station. ISMA is sometimes called busy tone multiple access (BTMA). *See also* busy tone multiple access.

inhomogeneous broadening spectral broadening of a transition in a laser medium due to intrinsic differences between the constituent atoms or molecules.

inhomogeneous medium medium whose constitutive parameters are functions of position. For example, in optical media, the properties of gain, index of refraction, etc., might be functions of position.

initial rest a system satisfies an initial rest assumption if the output of the system is zero until the input of the system becomes nonzero ($x(t) = 0, t \leq t_0 \Rightarrow y(t) = 0, t \leq t_0$). Systems described by linear constant-coefficient differential or difference equations are causal, linear, and time invariant if at initial rest.

initialize (1) to place a hardware system in a known state, for example, at power up.

(2) to store the correct beginning data in a data item, for example, filling an array with zero values before it is used.

injection electroluminescence refers to the case where the electroluminescence the injection of carriers across a p-n junction.

injection laser diode semiconductor laser in which amplification is achieved by injection of holes or electrons into the active region.

injection locking two oscillators can be injection-locked together by providing small coupling between them. In that case, the phase relation between the two oscillators is going to be constant over time.

inner product space over the field F, $\mathcal{H}$ is an inner product space if it is a linear space together with a function $\langle , \rangle : \mathcal{H} \times \mathcal{H} \to F$, such that

1. $\langle x, y\rangle = \overline{\langle y, x\rangle}, \quad \forall x, y \in \mathcal{H}$.

2. $\langle \lambda x + \mu y, z\rangle = \lambda\langle x, z\rangle + \mu\langle y, z\rangle$, $\forall x, y, z \in \mathcal{H}, \forall \lambda, \mu \in F$.

3. $\langle x, x\rangle \geq 0$.

4. $\langle x, x \rangle = 0$ if and only if $x = 0$.

The field F could be either the real or the complex numbers.

input data conveyed to a computer system from the outside world. The data is conveyed through some input device.

input admittance the inverse of input impedance, measured in mhos.

input backoff *See* backoff.

input buffer a temporary storage area where input is held. An input buffer is necessary when the data transfer rate from an input device is different from the rate at which a computer system can accept data. Having an input buffer frees the system to perform other tasks while waiting for input.

input current shaping a technique to force the line current to assume the same shape as the line voltage of a rectifier in order to achieve low harmonic distortion and high power factor correction.

input device a peripheral unit connected to a computer system, and used for transferring data to the system from the outside world. Examples of input devices include keyboard, mouse, and light pen.

input impedance (1) when a voltage is applied to a conducting material, a current will flow through the material. The ratio of the voltage to the current is known as the input impedance and is a complex number with magnitude measured in units of ohms. *See also* Ohm's Law.

(2) impedance seen when looking into the input terminals of an antenna.

input layer a layer of neurons in a network that receives inputs from outside the network. In feedforward networks, the set of weights connected directly to the input neurons is often also referred to as the input layer.

input neuron a neuron in a network that receives inputs from outside the network. In feedforward networks, the set of weights connected directly to the input neurons is often also referred to as the input layer.

input register a register to buffer transfers to the memory from the I/O bus. The transfer of information from an input device takes three steps:

1. from the device to its interface logic,

2. from the interface logic to the input register via the I/O bus, and

3. from the input register to the memory.

input return loss negative ratio of the reflected power to the incident power at the input port of a device, referenced to the source or system impedance, expressed in decibels. The negative sign results from the term "loss." Thus, an input return loss of 20dB results when 1/100th of the incident power is reflected.

input routine (1) a function responsible for handling input and transferring the input to memory.

(2) the software subroutine used to communicate with an input device. *See also* I/O controller and I/O routine.

input stability circle circular region shown graphically on a Smith chart that defines the range of input impedance terminations for which an active device or circuit remains unconditionally stable, and those regions for which it is potentially unstable, at a particular frequency.

input vector a vector formed by the input variables to a network.

input-output curve a plot of the rate of fuel consumption vs. the power output for a thermal generating plant.

input–output equivalence of generalized 2-D system matrices the 2-D polynomial matrix

$$\begin{bmatrix} P & -Q \\ C & D \end{bmatrix}$$

$$P := Ez_1z_2 - A_0 - A_1z_1 - A_2z_2$$
$$Q := B_0 + B_1z_1 + B_2z_2$$

is called the system matrix of the generalized 2-D model

$$\begin{aligned} Ex_{i+1,j+1} &= A_0x_{ij} + A_1x_{i+1,j} \\ &\quad + A_2x_{i,j+1} + B_0u_{ij} \\ &\quad + B_1u_{i+1,j} + B_2u_{i,j+1} \\ y_{ij} &= Cx_{ij} + Du_{ij} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) where $x_{ij} \in R^n$ is the semistate local vector, $u_{ij} \in R^m$ is the input vector, $y_{ij} \in R^p$ is the output vector and E, A_k, B_k $(k = 0, 1, 2)$, C, D are real matrices with E possibly singular or rectangular. Two system matrices $S_i := \begin{bmatrix} P_i & -Q_i \\ C_i & D_i \end{bmatrix}$ for $i = 1, 2$ are called input–output equivalent if $C_1P_1^{-1}Q_1 + D_1 = C_2P_2^{-1}Q_2 + D_2$.

input-output stability system condition where bounded outputs are obtained as a response to bounded inputs. *See also* bounded function.

input/output channel (I/O channel) input/output subsystem capable of executing a program, relieving the CPU of input/output-related tasks. The channel has the ability to execute read and write instructions as well as simple arithmetic and sequencing instructions that give it complete control over input/output operations. (IBM terminology) *See also* direct memory access, selector channel, multiplexer channel.

input/output port a form of register designed specifically for data input/output purposes in a bus-oriented system.

INR *See* interference to noise ratio.

inrush current the transient current drawn by an electrical apparatus when it is suddenly connected to a power source. The inrush current may be larger in magnitude than the steady-state full-load current. The transient response is short in time and the electrical equipment generally supports the inrush current, provided it does not happen frequently. For a single transient, the thermal limit of the equipment is not reached, but if it is switched on and switched off several times within a short period, the temperature can rise very quickly. In case of transformers, the inrush current is not sinusoidal even if the voltage is due to the hysteresis of the ferromagnetic core.

insertion loss (1) worst-case loss of the device across the stated frequency range. The loss due to the insertion of the unit in series with a signal path.

(2) transmission loss of an RF or microwave component or system, typically measured in decibels.

insolation incident solar radiation.

inspection system an image processing system, usually automatic or semi-automatic, that performs industrial inspection.

instantaneous the range of 0.5 to 30 cycles of the supply frequency.

instantaneous contact the contacts of a contactor or relay that open or close with no time delay.

instantaneous frequency (1) the time rate of change of the angle of an angle-modulated wave.

(2) the frequency of radiation at some chosen instant of time; the rate of change of phase in radians per second, divided by 2π.

instantaneous overcurrent relay an overcurrent relay that operates with no intentional delay following sensing of a power frequency overcurrent, i.e., a current above its set point.

instantaneous power power in an AC or modulated signal at a given instant in time.

instantaneous-trip circuit breaker essentially an inverse-time circuit breaker with the thermal element removed. It will only trip magnetically in response to short-circuit currents. Thus, it is often referred to by other names, such as magnetic circuit breaker and magnetic-only circuit breaker.

instar *See* instar configuration.

instar configuration a term used for a neuron fed by a set of inputs through synaptic weights. An instar neuron fires whenever a specific input pattern is applied. Therefore, an instar performs pattern recognition. *See also* instar training. *Compare with* outstar configuration.

instar training an instar is trained to respond to a specific input vector and to no other. The weights are updated according to

$$w_i(t+1) = w_i(t) + \mu(x_i - w_i(t))$$

where x_i is the ith input, $w_i(t)$ the weight from input x_i, μ is the training rate starting from about 0.1 and gradually reduced during the training. *See also* instar configuration. *Compare with* outstar training.

Institute of Electrical and Electronics Engineers (IEEE) a professional organization of electrical engineers and computer scientists. The world's largest professional organization.

instruction specification of a collection of operations that may be treated as an atomic entity with a guarantee of no dependencies between these operations.

instruction access fault a fault, signaled in the processor, related to abnormal instruction fetches.

instruction cache *See* code cache.

instruction counter the memory register within a computer that maintains the location of the next instruction that will be fetched for execution. This register is also called a program counter.

instruction decoder the part of a processor that takes instructions as input and produces control signals to the processor registers as output. All processors must perform this function; some perform it in several steps, with part of the decoding performed before instruction issue and part after.

instruction decoder unit in modern CPU implementations, the module that receives an instruction from the instruction fetch unit, identifies the type of instruction from the opcode, assembles the complete instruction with its operands, and sends the instruction to the appropriate execution unit, or to an instruction pool to await execution.

instruction fetch unit in modern CPU implementations, the module that fetches instructions from memory, usually in conjunction with a bus interface unit, and prepares them for subsequent decoding and execution by one or more execution units.

instruction field a portion of an instruction word that contains a specified value, such as a register address, a 16-bit immediate value, or an operand code.

instruction format the specification of the number and size of all possible instruction fields in an instruction-set architecture.

instruction issue the sending of an instruction to functional units for execution.

instruction pipeline a structure that breaks the execution of instruction up into multiple phases, and executes separate instructions in each phase simultaneously.

instruction pointer another name for program counter, the processor register holding the address of the next instruction to be executed.

instruction pool in modern CPU implementations, a holding area in which instructions that have been fetched by an instruction fetch unit await access to an execution unit.

instruction prefix a field within a program instruction word used for some special purpose. Found only rarely. The Intel X86 architecture occasionally uses instruction prefixes to override certain CPU addressing conventions.

instruction reordering a technique in which the CPU executes instructions in an order different from that specified by the program, with the purpose of increasing the overall execution speed of the CPU.

instruction repertoire *See* instruction set.

instruction scheduling the relocation of independent instructions, which is done to maximize instruction-level parallelism (and/or minimize instruction stalls).

instruction set the instruction set of a processor is the collection of all the machine-language instructions available to the programmer. Also known as instruction repertoire.

instruction window for an out-of-order issue mechanism, a buffer holding a group of instructions being considered for issue to execution units. Instructions are issued from the instruction window when dependencies have been resolved.

instruction-level parallelism the concept of executing two or more instructions in parallel (generally, instructions taken from a sequential, not parallel, stream of instructions).

instrument transformer a two-winding transformer designed and optimized for metering applications. The essential features are accurate input to output ratios for the measured parameter and minimal burden (or load) on the circuit being tested. *See also* current transformer, voltage transformer.

insulated gate bipolar junction transistor (IGBT) a hybrid electronic switch that has the high input impedance and high speed characteristic of a MOSFET with the conductivity characteristic (low saturation voltage) of a bipolar transistor.

insulation class specification of insulating material. Primarily determined by the maximum temperature that the material can withstand. The class of insulating system used in a transformer or electrical machine is a key factor in determining its rated load.

insulation coordination the practice of selecting the insulation of a power system such that breakdowns from overvoltages (such as from a lightning strike) will occur at points where the least harm will result.

insulation resistance measured value of electrical resistance of the insulation of a product or device.

insulator a device designed to separate and prevent the flow of current between conductors. Properties of the dielectric (insulating) material and geometry of the insulator determine maximum voltage and temperature ratings.

insulator string a chain of two or more strain insulators that are coupled together to increase the total insulation level of the assembly.

integer a fixed-point, whole number value that is usually represented by the word size of a given machine.

integer unit in modern CPU implementations, a type of execution unit designed specifically for the execution of integer-type instructions.

integral control control scheme whereby the signal that drives the actuator equals the time integral of the difference between the input/desired output and the measured actual output.

integral equation a type of equation where the unknown function appears under an integral. When this is the only place that the unknown appears, the integral equation is commonly called a first-kind equation, while if the unknown also appears outside the integral, it is a second-kind integral equation.

One-dimensional examples are

$$y(s) = \lambda \int_a^b K(s,t)x(t)dt$$

and

$$x(s) = y(s) + \lambda \int_a^b K(s,t)x(t)dt$$

where λ is a possibly complex scalar parameter and $y(s)$ is known (often called the driving term); $x(t)$ is the unknown function and $K(s,t)$ is the known kernel. The above are linear Fredholm integral equations of the first and second kind, respectively.

integral horsepower motor a motor built in a frame as large as or larger than that of a motor of open construction having a continuous rating of one horsepower at 1700–1800 rpm.

integrated AOTF acousto-optical tunable filter device using integrated wave guide optics and surface acoustic waves (SAWs) for acousto-optical interaction.

integrated circuit (IC) (1) an assembly of miniature electronic components simultaneously produced in batch processing, on or within a single substrate, that performs an electronic circuit function.

(2) many transistors, resistors, capacitors, etc., fabricated and connected together to make a circuit on one monolithic slab of semiconductor material.

integrated optics also known as guided-wave optics; generally, describes the devices that couple to fiber optics, but does not include the fibers.

integrated project support environment a software engineering environment supporting all the stages of the software process from initial feasibility studies to operation and maintenance.

integrated services digital network (ISDN) a network that provides end-to-end digital connectivity to support a wide range of services, including voice and nonvoice services, to which users have access by a limited set of standard multipurpose user–network interfaces.

integrating A/D device that takes an analog input signal and integrates it over time to produce a digital signal that represents the area under the curve, or the integral.

integrator for an input of $x(t)$ and an output of $\int_{-\infty}^{t} x(\tau)d\tau$, is one of the basic signal processing building blocks. Integrators can be implemented using operational amplifiers.

integrity (of data) (1) a belief in the truth of the information represented by a set of data.

(2) a condition stating that the information in a set of data does satisfy a set of logical constraints (the integrity constraints).

intelligence the aggregated and processed information about the environment, including potential adversaries, available to commanders and their staff.

intelligent control a sensory-interactive control structure incorporating cognitive characteristics that can include artificial intelligence techniques and contain knowledge-based constructs to emulate learning behavior with an overall capacity for performance and/or parameter adaptation. Intelligent control techniques include adaptation, learning, fuzzy logic, neural networks, genetic algorithm, as well as their various combinations.

intelligent material *See* smart material.

intelligibility objective quantitative measure of speech perception.

intensifying transformer one of a class of hedges — for example very, extremely — which intensifies the characteristics of a fuzzy set.

intensity a measure of the strength of a light field. Two different definitions of intensity are commonly encountered. Especially in the discipline of radiometry, intensity is usually defined to be power per unit solid angle. Alternatively, especially in laser physics, define intensity to be power per unit area. The intended definition can usually be deduced from context or from dimensional analysis.

intensity average spatially or temporally averaged value of the intensity.

intensity modulation alteration of the power level of an optical beam, usually to impose information onto the beam.

intensity optical same as optical power per unit area; time-average value of the Poynting vector $E \times H$ measured in watts per meter squared, sometimes also representable as the energy density times the speed of light.

intensity-dependent refractive index the property of many materials that the measured value of the refractive index depends on the intensity of the light field used to perform the measurement. Typically, the refractive index changes by an amount describable by $\delta n = n_2 I$, where n_2 is the coefficient of the nonlinear refractive index and I is the intensity of the field in units of power per unit area.

inter-area mode oscillation this mode of oscillation is characterized by the swinging of many machines in one part of the system against machines in other parts. These oscillations are caused by the presence of weak ties between two or more areas.

inter-cell interference the interference caused by the transmitters in a cellular communications system (base station or mobile terminal) on a receiver of interest where the interfering transmitters are located on cells other than the receiver cell. *Compare with* intra-cell interference.

inter-feature distance the distance between a pair of feature points in an image, often used to help identify the object, or (in conjunction with other measures of this type) to infer the presence of the object.

inter-record gap the space between two records of data stored on a magnetic medium such as a tape. This space helps preventing interference between the two records. It can also contain markers marking the beginning and end of the records.

interaction region a region where an electron beam and microwaves transfer energy to each other.

interaural attribute attribute of ear input signals (e.g., localization in the horizontal plane) that depend on differences between, or ratios of measures of, two ear input signals.

interconnect the physical manifestation of an interconnection network.

interconnection density number of interconnection channels per unit area or unit volume. The interconnection density of optical interconnects is high because unlike electrons, light beams can cross each other without any change.

interconnection network the combination of switches and wires that allows multiple processors in a multiprocessor or multicomputer to communicate.

interconnections and packaging (I&P) elements of the electrical signal transmission path from the driver chip to the receiver chip. Various elements that make up I&P are chip wirebonds and package pins, circuit boards, connectors, motherboards, and cables.

interdigital capacitor a capacitor consisting of two pieces of electrodes that have multiple fingers. Each finger of these electrodes is adjacently arranged in turn with a narrow gap. It utilizes the gap capacitance between adjacent fingers.

interdigital filter filter consisting of parallel coupled transmission line resonators where each resonator is grounded on one side and is either open-circuited or capacitively loaded to ground on the other side. Adjacent resonators are grounded on the opposite ends.

interface the set of rules specified for communicating with a defined entity.

interface state for a semiconductor device such as a transistor, a region where trapping of charge carriers can occur at the interface between regions of differing electrical properties.

interface trap energy level at the insulator/semiconductor interface that can trap electrons or holes. The occupation of these traps follow Fermi statistics.

interference (1) a process in which two waves interact. Interference occurs when the complex properties of the wave are combined instead of simply their two amplitudes. The wave interference can be constructive when they both have the same phase, or destructive when they have opposite phases.

(2) a disturbance on a communication system caused by the presence of a signal, or small number of signals, of man made origin. The interference may be due to the presence of signals external (other systems) or internal (e.g., multiple access interference) to the system of interest. *Compare with* background noise.

(3) an interaction whereby a process that is supposed to be independent (and isolated) from another process does indeed perform some action that has an effect visible from the second process. Interference can be caused by direct writing to the state of the second process or by indirect effects, such as by monopolizing the use of a system module.

(4) any external electrical or electromagnetic disturbance which causes an undesired response or degradation of the desired signal.

(5) the mutual influence of two waves or vibrations of any kind, producing certain characteristic distorting phenomena, is known as interference. For example, radiofrequency interference (RFI) or crosstalk and intersymbol interference (ISI) caused by interference between successive pulses in an optical fiber.

interference cancellation a signal processing technique where an interfering signal is estimated, regenerated based on the estimate, and then canceled from the received signal, leaving a potential interference-free, desired signal. Examples are multiple access interference cancellation, co-channel interference cancellation, echo cancellation.

interference channel a multiple transmitter, multiple receiver communications system in which each received signal is a (possibly non-deterministic) function of two or more transmitted signals. *See also* broadcast channel, multiple access channel.

interference to noise ratio (INR) the total interference measured at a receiver divided by the receiver noise power. The INR is a useful measure for comparing the interference distributions between different types of radio systems.

interframe referring to the use of more than a single image frame (e.g., an algorithm that differences successive image frames or detects frame-to-frame motion). *See also* intraframe.

interframe coding (1) the process of coding the difference of consecutive video frames based on motion estimation, instead of the frames themselves.

(2) image coding schemes that utilize the temporal correlation between image frames.

interframe coding 3-D in situations where motion picture film or television images need to be coded, three-dimensional transform coding is used. In this approach, the frames are coded L at a time and partioned into $L \times L \times L$ blocks per pixel prior to transformation.

interframe hybrid transform coding $L \times L$ blocks of pixels are first 2-D-transformed. The resulting coefficients are then DPCM (interframe) coded and transmitted to the receiver. This is then reversed at the receiver for reconstruction. In the interframe hybrid transform coding, the DC components are determined exclusively by the amount of spatial detail in the picture.

interframe prediction this technique uses a combination of pixels from the present field as well as previous fields for prediction. For scenes with low detail and small motion, field difference prediction appears to perform better than frame difference prediction.

interharmonic component the frequency component that is not an integer value of the periodic supply waveform.

interior permanent magnet machine a permanent magnet machine in which the permanent magnets are buried in the rotor iron. With this construction the airgap is small, allowing the airgap flux to be reduced by current control. This allows an operating mode in which the top speed of the motor can be as much as five times the base speed, and is one of the main features of this motor.

interlaced *See* interlaced scanning.

interlaced scanning a system of television and video scanning whereby the downward rate of travel of the scanning electron beam is increased by sending every other line whereby field 1 (odd field) is superimposed on field 2 (even field) to create one picture frame. Interlaced scanning is used to reduce flicker.

interleaved memory a memory system consisting of several memory modules (or banks) with an assignment of addresses that makes consecutive accesses fall into different modules. This increases the effective memory bandwidth, as several memory requests can be satisfied (concurrently by several modules) in the same time as it would take to satisfy one memory requests. For example, a simple arrangement (sequential interleaving), which favors sequential access, is to assign address k to memory bank $k \bmod N$, where N is the number of modules employed: the reference stride is 1, so consecutive requests are to different bands.

There are other schemes for assigning addresses to banks, all of which schemes aim to (for nonunit strides) give the same performance as with a stride of 1. These include skewed addressing, which is similar to sequential interleaving but with a fixed displacement (the skew) added to the chosen module number; dynamic skewed addressing, in which the skew is variable and determined at run-time; pseudo-random skewing, in which the module number is chosen on a pseudo-random basis; prime-number interleaving, in which the number of modules employed is prime relative to the degree of interleaving; and superinterleaving, in which the number of modules exceeds the degree of interleaving.

interleaved storage the notion of breaking storage into multiple pieces that may be accessed simultaneously by the same request, increasing the bandwidth from the storage.

interleaving (1) regular permutation of symbols usually used to split bursts of errors caused by channels with memory (e.g., fading channels) making a coding scheme designed for memoryless channels more effective. The two main categories are *block interleaving* and *convolutional interleaving*. The inverse process is called deinterleaving.

(2) a characteristic of a memory subsystem such that successive memory addresses refer to separately controlled sections or banks of memory. Sequential accesses to interleaved memory will activate the banks in turn, thus allowing higher data transfer rates.

interlock the mechanism that stalls a pipeline while a result needed in the pipeline is being produced.

intermediate frequency (IF) (1) the frequency produced when two signals are combined in a mixer circuit.

(2) an operating frequency of an internal stage used in a superheterodyne system. This frequency is converted from radio frequency by using a local oscillator and a mixer for receivers. From this frequency, radio frequency is converted by using a local oscillator and a mixer for transmitters.

intermediate-level vision the set of visual processes related to the perception/description of surfaces and of their relationships in a scene.

intermittent fault a fault that appears, disappears, and then reappears in a repeated manner.

intermodal distortion distortion in the temporal shape of an optical signal transmitted through an optical fiber caused by the differential time delays between the numerous modes propagating in a multimode fiber.

intermodulation the heterodyning (or mixing) of at least two separate and distinct electrical signals within a nonlinear system. For two waves mixing together, the resultant intermodulation products are given by

$$F_{IM} = PF_1 + QF_2$$

where F_{IM} is the resultant intermodulation product frequency, P and Q are integers (zero, positive, or negative), and the order, R, of the intermod is given by

$$R = \mid P \mid + \mid Q \mid$$

intermodulation distortion in optical devices, nonlinear transfer functions that result from the interaction of multiple signal components among each other. Strong signal components lead to levels of distortion that limit the low end of a device dynamic range.

intermodulation intercept point a figure of merit for intermodulation product suppression, measured in decibels.

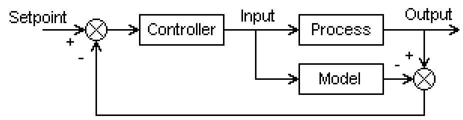
internal bus a bus used to connect internal components of a computer system, such as processors and memory devices.

internal forwarding a mechanism in a pipeline that allows results from one pipeline stage to be sent directly back to one or more waiting pipeline stages. The technique can reduce stalls in the pipeline.

internal fragmentation in paging, the effect of unused space at the end of a page. On average the last page of a program is likely to be 50% full. Internal fragmentation increases if the page size is increased.

internal memory main memory of a computer.

internal model control (IMC) a feedback control structure in which the output from a model of the process is subtracted from the process output to form the feedback signal. Using this loop configuration as



Internal model control structure.

a theoretical construct, the design of closed loop controllers (which is a difficult nonlinear mathematical problem) becomes equivalent to the design of an open loop controller (which is a simpler linear problem). IMC is a special case of Q-parametrization or Youla parametrization of all stabilizing controller, and is closely related to the Smith Predictor invented in the late 1950s. Unstable processes need to be stabilized first by an inner loop before application of this theory. Practical designs for processes subjected to input disturbances should be checked for internal performance. *See also* inverse response compensator.

internal model principle in process control, one of the most common problems is regulation. This implies the importance of considering the attenuation of disturbances that act on the process. One of the many ways of dealing with disturbances is called internal model principle.

Using the internal model principle, the pole placement procedure can be modified to take disturbances into account. In many cases, the disturbances have known characteristics, which can be captured by assuming that the disturbance in the process model is generated by some dynamical system. Using internal model principle implies that a model of the disturbance is included in the controller.

internal performance defines the performance of a feedback system to stimuli that enter the loop at internal points. Naive designs may produce automatic control loops that have good performance in the traditional sense, yet exhibit poor internal performance. As an example, the process modeled by the transfer function

$$g(s) = \frac{4}{1 + 7s}$$

when controlled in a unity feedback configuration by the digital control law

$$k(z) = \frac{0.794(z - 0.842)}{z - 1}$$

illustrates clearly the difference between the traditional concept of performance and that of internal performance. The control loop has good performance in the traditional sense, as its response to a setpoint change (at time $t = 0$) and an output disturbance (at $t = 10$) is much faster than the open loop system, yet its internal performance is poor since it rejects input disturbances sluggishly (after $t = 20$). The concept is particularly important for processes subjected to input disturbances in which the closed loop is faster or more damped than the open loop process itself. *See also* internal stability.

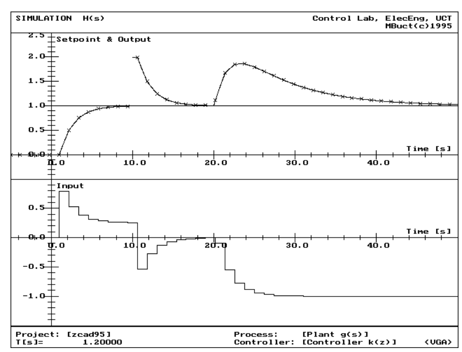


Illustration of the difference between performance and internal performance.

internal photoemission emission of energetically excited electrons or holes over a energy barrier into its contacting collector by a process in which the emitting electrons or holes are optically excited from the ground state of the contacting emitter.

internal quantum efficiency the product of injection efficiency and radiative efficiency corresponds to the ratio of power radiated from the junction to electrical power supplied.

internal stability defines the stability of a system to signals that enter the loop at all possible points. The difference between the traditional concept of stability and the modern concept of internal stability is illustrated by the open loop control configuration, which is internally unstable yet might easily have been classified as stable under the traditional definition. The relevant equations are

$$\begin{aligned} y &= g(s)k(s) \times e + g(s) \times v \\ &= \frac{1}{s+1} \times e + \frac{1}{s-1} \times v \end{aligned}$$

where blocks $g(s)$ and $k(s)$ are transfer functions, signals e and v are inputs, signal u is an internal variable, and signal y is the output. Clearly the relationship between y and e is stable, while that between y and v remains unstable. The traditional definition of stability would have missed the latter phenomena. Exactly the same effect is observed when the above system is put into closed loop. The concept of internal stability relates closely to those of controllability and observability in state space theory of dynamic systems. *See also* internal performance.

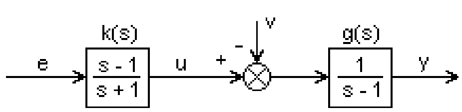


Illustration of internal stability.

International Electro-technical Commission (IEC) the international standards and conformity assessment body for all fields of electrotechnology.

International Radio Consultative Committee (CCIR) one of two international committees that exist for the purpose of carrying out studies of technical and other problems related to the interworkings of their respective national telecommunication systems to provide a worldwide telecommunications network. It operates under the auspices of the International Telecommunication Union (ITU). After each plenary assembly, the ITU publishes recommendations that deal with point-to-point radio relay systems. A purpose of those recommendations is to make the performance of such systems compatible with metallic line systems that follow the CCITT (The International Telegraph and Telephone Consultative Committee) recommendations.

internet a network formed by the interconnection of networks.

interpixel redundancy the tendency of pixels that are near each other in time or space redundancy to have highly correlated gray levels or color values. Reducing interpixel redundancy is one way of compressing images. *See also* image compression.

interpolation (1) the process of finding a value between two known values on a chart or graph.

(2) the reconstruction of missing signal samples based on observed samples. Frequently, the conversion of a discrete signal to a discrete signal on a finer time step or (in the limit) to a continuous signal.

interpolative coding coding schemes that involve interpolation.

interpolative vector quantization (IRVQ) technique in which a subsample of the interpolated original image is used to form the predicted image, and then a residual image is formed based upon this prediction. This approach reduces blocking artifacts by using a smooth prediction image.

interpole a set of small poles located midway between the main poles of a DC machine, containing a winding connected in series with the armature circuit. The interpole improves commutation by neutralizing the flux distortion in the neutral plane caused by armature reaction.

interpreter a computer program that translates and immediately performs intended operations of the source statements of a high-level language program.

interprocess communication (IPC) the transfer of information between two cooperating programs. Communication may take the form of signal (the arrival of an event) or the transfer of data.

interrupt an input to a processor that signals the occurrence of an asynchronous event. The processor's response to an interrupt is to save the current machine state and execute a predefined subprogram. The subprogram restores the machine state on exit, and the processor continues in the original program.

interrupt descriptor table used in protected mode to store the gate descriptors for interrupts and exceptions.

interrupt disable (1) a state in which interrupts to the CPU are held, but not processed. In most systems it is possible to disable interrupts selectively, so that certain types of interrupts are processed, while others are disabled and held for later processing.

(2) the operation that changes the interrupt state of the CPU from enabled to disabled.

interrupt enable (1) a state in which interrupts to the CPU can be processed.

(2) the operation that changes the interrupt state of the CPU from disabled to enabled.

interrupt handler a predefined subprogram that is executed when an interrupt occurs. The handler may perform input or output, save data, update pointers, or notify other processes of the event. The handler must return to the interrupted program with the machine state unchanged.

interrupt line a wire carrying a signal to notify the processor of an external event that requires attention.

interrupt mask a bit or a set of bits that enables or disables the interrupt line to be transmitted at the interrupt detector circuit (inside or outside the CPU). The mechanisms of masking are typically implemented into interrupt controllers.

interrupt priority a value or a special setting that specifies the precedence to serve the corresponding interrupt with respect to other interrupt signals.

interrupt service the steps that make up the operation by which the CPU processes an interrupt. Briefly, the CPU suspends execution of its current program and branches to a special program known as an interrupt handler or interrupt routine to take appropriate action. Upon completion of the interrupt service, the CPU will take one of a number of actions, depending on circumstances: it can

1. return to the previous task if conditions permit;

2. process other pending interrupts, or

3. request further action from the operating system.

interrupt-driven I/O an input/output (I/O) scheme where the processor instructs an I/O device to handle I/O and proceeds to execute other tasks; when the I/O is complete, the I/O device will interrupt the processor to inform completion. An interrupt-driven I/O is more efficient than a programmed I/O where the processor busy-waits until the I/O is complete.

interruptible load a load, typically of a commercial customer, which by contract may be interrupted by the utility for purposes of system stability.

interrupting capacity *See* interrupting rating.

interrupting rating for a circuit breaker, fuse, or switch, the maximum fault level that the device can safely interrupt. The interrupting rating can be expressed in terms of amps or volt-amps.

interruption *See* sustained interruption, momentary interruption, temporary interruption.

intersection of fuzzy sets a logic operation, corresponding to the logical AND operation, forming the conjunction of two sets. In a crisp (non-fuzzy) system, the intersection of two sets contains the elements which are common to both. In fuzzy logic, the intersection of two sets is the set with a membership function which is the smaller of the two.

Denoted $\cap$, fuzzy intersection is more rigorously defined as follows. Let A and B be two fuzzy sets in the universe of discourse X with membership functions $\mu_A(x)$ and $\mu_B(x)$, $x \in X$. The membership function of the intersection $A \cap B$, for all $x \in X$, is

$$\mu_{A\cap B}(x) = \min\{\mu_A(x), \mu_B(x)\}$$

See also fuzzy set, membership function.

intersubband laser a type of quantum well laser in which the lasing transition couples states that are accessible to a single type of carrier, (i.e., either electrons or holes).

intersymbol interference (ISI) the distortion caused by the overlap (in time) of adjacent symbols.

intersymbol interference postcursor intersymbol interference caused by the causal part of the channel impulse response $h(t)$ (i.e., $h(t)$, $t > 0$). For each transmitted symbol, postcursor intersymbol interference is contributed from preceding transmitted symbols.

intertie another name for tie line.

interval polynomial a polynomial

$$p(s, \mathbf{a}) = a_0 + a_1 s + a_2 s^2 + \cdots + a_n s^n$$

with the uncertain coefficient vector

$$\mathbf{a} = [a_0, a_1, a_2, \ldots, a_n]$$

that may take values from the $n + 1$ dimensional rectangle

$$\mathbf{A} = \left\{\mathbf{a} | a_i \in \left[a_i^-; a_i^+\right], i = 0, 1, 2, \ldots, n\right\}$$

intra-cell interference interference arising in a cellular communication system that due to other transmitters (base stations or mobile terminals) in the same cell. *Compare with* inter-cell interference.

intra-chip optical interconnect optical interconnect in which the source and the detector are connected to electronic processing elements in a single chip.

intrafield predictor for television a technique used to deal with problems caused in TV signal prediction. In particular, problems due to lack of correlation because of the presence of chrominance components. One method of overcoming such difficulties is to sample the composite signal at integral multiples of subcarrier frequencies. Predictors can be designed to match the bimodal spectrum of the composite signal to predict the baseband luminance and modulated chromiance with one predictor.

intraframe image or video processing method that operates within a single frame without reference to other frames. *See also* interframe.

intraframe coding image coding schemes that are based on an intraframe restriction, that is, to separately code each image in a sequence.

intramodal distortion distortion in the temporal shape of an optical signal transmitted through an optical fiber caused by the wavelength dispersion of a propagating mode due to the finite spread of wavelengths in the optical source used to transmit the signal.

intrinsic term associated with the inside or interior. In devices and device modeling, intrinsic refers to that part of the device or model associated with the active semiconductor structures that control device operation, or provide the desired functions.

intrinsic coercive force the demagnetizing field required to reduce the intrinsic induction to zero; the x-intercept of the intrinsic demagnetization curve. This quantity is used to gage the field required to magnetize a material and its ability to resist demagnetization.

intrinsic demagnetization curve the second quadrant portion of the hysteresis loop generated when intrinsic induction (B_i) is plotted against applied field (H), which is mathematically related to the normal curve; most often used to determine the effects of demagnetizing (or magnetizing) fields.

intrinsic fiber optic sensor a fiber optic sensor where a property of the fiber itself responds to the measured parameter. Examples include microbend and interferometric sensors.

intrinsic image an image onto which physical properties of the imaged scene (e.g., range, orientation, reflectance) are mapped.

intrinsic impedence (1) the impedance presented when a source is open-circuited.

(2) a characteristic parameter associated with a medium that is the ratio of the magnitudes of the transverse components of the electric field intensity and magnetic field intensity for a wave propagating in a given direction. It has units of ohms.

intrinsic induction the vector difference between the magnetic induction and the applied external magnetic field, or the magnetic field established by the magnetic material itself.

intrinsic permutation symmetry *See* symmetries of nonlinear susceptibility.

intrinsic semiconductor a semiconductor material in which the number of holes equals the number of electrons.

invalid entry an entry in a table, register or module that contains data that is not consistent with the global state. Invalidity is used in cache coherence mechanisms.

invariant subspace of generalized 2-D model a linear subspace V of the local state space X that satisfies certain conditions. It is called an (E, A, B)- invariant subspace of the generalized 2-D model

$$\begin{aligned} Ex_{i+1,j+1} &= A_1 x_{i+1,j} + A_2 x_{i,j+1} \\ &\quad + B_1 u_{i+1,j} + B_2 u_{i,j+1} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) if

$$\begin{bmatrix} A_1 \\ A_2 \end{bmatrix} V \subset EV \times EV + Im \begin{bmatrix} B_1 \\ B_2 \end{bmatrix}$$

in product space $X \times X$ where $x_{ij} \in R^n$ is the local semistate vector, $u_{ij} \in R^m$ is the input vector, and E, A_k, B_k $(k = 1, 2)$ are real matrices. There exists a state feedback $u_{ij} = Kx_{ij}, i, j \in Z_+$ such that

$$\left(\begin{bmatrix} A_1 \\ A_2 \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} K \right) V \subset EV \times EV$$

if and only if V is an (E, A, B)-invariant subspace of the model.

inverse Chebychev filter filter that exhibits an inverse Chebychev response in the stop-band region. That is, in the stop-band region of the filter, the gain of the filter as a function of frequency is equal ripple in magnitude. This is in contrast with many other types of filters, which in the filter stop-band region exhibit a gain response that is monotonic with frequency.

inverse dynamics the inverse dynamics problem consists of determining the joint generalized forces $\tau(t)$ (acting at the joints of the manipulator) needed to generate the motion specified by the joint generalized position $q(t)$, velocities $\dot{q}(t)$, and accelerations $\ddot{q}(t)$. The inverse dynamics solution is used in model based control algorithms for manipulators.

inverse dynamics linearizing control inverse dynamics linearizing control is an operational space control scheme that uses a feedback control signal that leads to the system of double integrators. In this case, nonlinear dynamics of the manipulator is compensated and the inverse dynamics linearizing control allows full trajectory tracking in the operational space.

inverse filter for a linear time invariant (LTI) filter, the filter which, when cascaded with it produces white noise output for a white noise input. The inverse filter of an LTI filter with impulse response $h(n)$ has impulse response $a(n)$, where $h(n) * a(n) = \delta(n)$. Alternatively, in the frequency domain, the inverse filter $A(z)$ satisfies the relation $A(z)H(z) = 1$. The inverse filter $A(z)$ is said to whiten the filter $h(n)$ to produce $\delta(n)$

inverse Fourier transform *See* Fourier transform.

inverse homogeneous transformation matrix in general, the inverse of the homogeneous transformation matrix describes the reference coordinate frame with respect to the transformed frame and has the form

$$T^{-1} = \begin{bmatrix} n_x & n_y & n_z & -p \cdot n \\ o_x & o_y & o_z & -p \cdot o \\ a_x & a_y & a_z & -p \cdot a \\ 0 & 0 & 1 & 1 \end{bmatrix}$$

where "·" denotes a scalar product between two vectors.

inverse kinematics problem for a desired position and orientation of the end-effector of the manipulator and the geometric link parameters with respect to the reference coordinate system, calculates a set of desired joint variables vector. The inverse kinematics problem has usually multiple solutions. In general, the inverse kinematics can be solved using algebraic, interactive, or geometric methods.

inverse Laplace transform *See* Laplace transform.

inverse Nyquist array (INA) an array of Nyquist plots of the elements of the inverse frequency response matrix $\hat{Q}(j\omega)$ of a multi-input–multi-output transfer function model $Q(s)$ of an open loop multivariable system. Each diagonal graph can be viewed as a single-input–single-output inverse Nyquist diagram from which the stability of the multivariable system can be deduced, under certain conditions relating to diagonal dominance. A typical INA diagram, for a MIMO system with two inputs and two outputs, clearly shows the individual polar plots and the Gershgorin circles forming a band with canters along the diagonal elements. Rosenbrock, H. H., *Computer-Aided Control System Design*, Academic Press, London, 1974. *See also* Gershgorin circle.

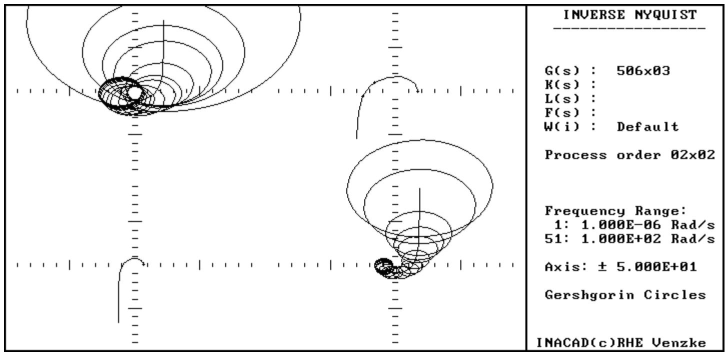
inverse Nyquist plot a graphical representation of the complex function

$$\hat{q}(jw)$$

which is the inverse of the frequency response model of the open loop transfer function system $q(s)$ that is connected in a unity feedback control loop. The stability of the resulting closed loop system is deduced by the principle of the argument applied to this complex function.

inverse problem essentially, the problem of inverting a "forward" system. More specifically, suppose we have some system $\mathcal{S}(x)$ parameterized in terms of x, and suppose we can define observations

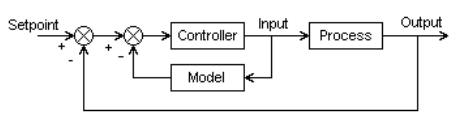
$$y = \mathcal{O}(\mathcal{S}(x)).$$



Typical inverse Nyquist array diagram.

Then the "forward" problem is the deduction of y (or its statistics) based on knowledge of x. The "inverse" problem is the deduction of x (or its statistics) based on knowledge of y (and possibly given prior statistics for x).

inverse response compensator a feedback control configuration in which the dynamics of the process are canceled by a cascade pre-compensator that includes a model of the process. The block diagram for an inverse response compensator is shown in the figure. Other configurations based on the



Block diagram for an inverse response compensator.

model are also possible. For example, the inner control loop might easily have been a state space control law, with or without asymptotic setpoint tracking.

inverse scattering theory yields physical parameters of the inhomogeneous medium from knowledge of the scattered intensity distribution.

inverse system the inverse of a system S_1 that transforms input signals x into output signals y is the system S_2 that, when placed in series with S_1, results in a larger cascade that leaves the input signal unchanged (x in, x out). *See also* invertible system.

inverse translation buffer (ITB) a device to translate a real address into its virtual addresses, to handle synonyms. Also called a reverse translation buffer and an inverse mapper.

inverse wavelet transform a computation procedure that calculates the function using the coefficients of the wavelet series expansion of that function.

inverse-time circuit breaker a circuit breaker in which the allowed current and time are inversely proportional. It contains a thermal element and a magnetic element in series. The thermal element is designed to trip as a result of heating over time in response to overload currents, while the magnetic element is designed to trip magnetically, with no intentional time delay, in response to short-circuit currents. Also called a thermal-magnetic circuit breaker.

inversion when a positive (negative) voltage is applied between a conductor and a p-type (n-type) semiconductor separated by a thin dielectric layer, the majority carrier holes (electrons) are repelled and minority carrier electrons (holes) are trapped at the surface.

inversion layer an equilibrium layer of minority carriers at a semiconductor surface or interface.

inversion population usually the density of atoms or molecules in the higher state of a laser transition minus the density in the lower state.

inversion symmetry the study of how the physical properties of a material change under the hypothetical inversion of the coordinate of each particle through the origin of the coordinate system. *See also* centrosymmetric medium.

inversionless laser a laser that operates without the need for a population inversion. In general, there are two types of inversionless lasers: those that have a hidden inversion in some eigenstate basis and those that do not. Raman and Mollow lasers can be included in the category of hidden inversion. Lasers in the category of no hidden inversion are possible because it is polarization, not population, that produces gain. These lasers generally require at least three quantum mechanical states (for example, lambda and vee systems) and make simultaneous use of Raman-like gain as well as induced transparency of the type associated with coherent population trapping or Fano interference. Oscillators based on parametric gain, for example optical parametric oscillators or phase conjugate oscillators, are generally not considered inversionless lasers.

inverted magnetron a radial magnetron in which the anode structure is at inside and the cathode structure is at outside.

inverted page table the number of entries in a conventional page table in a virtual memory system is the number of pages in the virtual address space. In order to reduce the size of the page table, some systems use an inverted page table that has only as many entries as there are pages in the physical memory, and a hashing function to map virtual to physical addresses in nearly constant time.

inverter (1) switching circuit that converts direct current to alternating current. An inverter can be classified as a natural-commutation type or a self-commutation type. The output AC of a natural-commutated inverter is synchronized to the AC line. This type of inverter is a thyristor rectifier in a reversed order. The output AC of a self-commutated inverter is independent, i.e., both the frequency and amplitude may be controlled. Commonly used self-commutated inverters include square-wave inverters and PWM inverters.

(2) a physical or logical gate that changes a signal from high to low, or low to high.

invertibility of generalized 2-D linear system let

$$\begin{aligned} T &= T(z_1, z_2) \\ &= C\left[Ez_1, z_2 - A_0 - A_1 z_1 - A_2 z_2\right]^{-1} \\ &\quad \times (B_0 + B_1 z_1 + B_2 z_2) + D \end{aligned}$$

be the transfer matrix of the generalized 2-D model

$$\begin{aligned} Ex_{i+1,j+1} &= A_0 x_{ij} + A_1 x_{i+1,j} + A_2 x_{i,j+1} \\ &\quad + B_0 u_{ij} + B_1 u_{i+1,j} \\ &\quad + B_2 u_{i,j+1} \\ y_{i,j} &= C x_{ij} + D u_{ij} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) where $x_{ij} \in R^n$ is the local semistate vector, $u_{ij} \in R^m$ is the input vector, $y_{ij} \in R^p$ is the output vector and E, A_k, B_k $(k = 0, 1, 2)$ C, D are real matrices with E possibly singular. The model is called (d_1, d_2)-delay invertible if there exists a generalized 2-D model.

$$\begin{aligned} \bar{E}z_{i+1,j+1} &= F_0 z_{ij} + F_1 z_{i+1,j} + F_2 z_{i,j+1} \\ &\quad + G_0 y_{ij} + G_1 y_{i+1,j} \\ &\quad + G_2 y_{i,j+1} \\ u_{ij} &= H z_{ij} + J y_{ij} \end{aligned}$$

with transfer matrix

$$\begin{aligned} T_L &= T_L(z_1, z_2) \\ &= H\left[\bar{E}z_1, z_2 - F_0 - F_1 z_1 - F_2 z_2\right]^{-1} \\ &\quad \times (G_0 + G_1 z_1 + G_2 z_2) + J \end{aligned}$$

such that $T_L T = z_1^{-d_1} z_2^{-d_2}$, where $z_{ij} \in R^{n'}$ is the local semistate vector, $\bar{E}$, F_k, G_k ($k = 0, 1, 2$) H, J real matrices, and d_1, d_2 are nonnegative integers.

invertible system a system S_1 is invertible if there exists a system S_2 such that, when S_1 and S_2 are placed in series, the larger cascaded system leaves the input unchanged (x in, x out). For example, the multiplier $y(t) = k * x(t)$ is invertible with an inverse system $y(t) = x(t)/k$, while the absolute value function $y(t) = |x(t)|$ is not. *See also* inverse system.

ion beam lithography lithography performed by exposing resist with a focused beam of ions.

ion implantation a high-energy process, usually greater than 10 keV, that injects ionized species into a semiconductor substrate. Often done for introducing dopants for device fabrication into silicon with boron, phosphorus, or arsenic ions.

ionic transition coupling of energy levels in an ion by means of absorption or emission processes.

ionized vapor a gaseous vapor in which the atoms are ionized, usually by electron impact or by photoionization.

ionizing radiation the process in which sufficient energy is emitted or absorbed to cause the generation of electron-hole pairs.

ionosphere consists of several layers of the upper atmosphere, ranging in altitude from 100 to 300 km, containing ionized particles. The ionization is due to the effect of solar radiation, particularly ultraviolet and cosmic radiation, on gas particles. The ionosphere serves as reflecting layers for radio (sky) waves.

IPC *See* interprocess communication.

IPP Independent Power Producers, who produce electrical energy but who are not owned by utility companies.

IR *See* infrared.

IRE (1) a unit equal to 1/140 of the peak-to-peak amplitude of a video signal, which is typically 1 V. The 0 IRE point is at blanking level, with the sync tip at −40 IRE and white extending to +100 IRE.

(2) *Institute of Radio Engineers,* an organization preceding the IEEE, which defined the unit IRE.

iron core transformer a transformer where the magnetic core is iron or principally iron. Two classes of iron cores are iron alloy and powdered iron. Iron alloy cores are usually restricted to low-frequency applications (2 kHz or less) because of eddy current losses. Powdered iron cores are used at higher frequencies because they consist of small iron particles electrically isolated from each other with significantly greater resistivity than laminated cores, and thus lower eddy current losses.

irradiated fuel nuclear fuel which has been part of a nuclear reaction and is thus highly radioactive.

irreducible polynomial a polynomial $f(x)$ with coefficients in Gallois field $GF(q)$ that can not be factored into a product of lower-degree polynomials with coefficients in $GF(q)$.

irreversible loss a reduction in the magnetization of a permanent magnet that can only be recovered by remagnetizing the material, usually caused by temperature extremes, reversing fields, or mechanical shock.

IRVQ *See* interpolative vector quantization.

IS-54 an interim standard of the U.S.-based Telecommunications Industries Association (TIA) for a digital cellular communication system. One of a set of digital cellular systems commonly classified as second generation cellular systems. A standard originally designed to succeed the AMPS cellular standard. This interim standard has now been finalized in the standard known as IS-136. The standard is based on the use of the same channel structure as the AMPS standard (30 kHz channels), similar frequency reuse and concept of hand-off, but with the use of a digital modulation scheme, known as $\pi/4$-shifted DQPSK, to transmit a digital signal at the rate of approximately 47 kbps on a 30 kHz channel. This signal typically carries three digital voice signals encoded at the rates of 8 kbps, excluding additional overhead bits that are used for the purpose of error correction.

IS-95 an interim standard of the U.S.-based Telecommunications Industries Association (TIA) for digital cellular communication systems. One of a set of systems commonly classified as second-generation cellular systems. The standard is based on spread spectrum modulation employing CDMA. This standard makes use of the concepts of power control, soft hand-offs, pilot signals, pilot phase offsets, orthogonal CDMA, and Walsh functions.

ISDN *See* integrated services digital network.

ISEF *See* infinite symmetric exponential filter.

ISI *See* intersymbol interference.

ISMA *See* inhibit sense multiple access protocol.

ISO (1) International Standards Organization.

(2) Independent System Operator, an entity created to operate power generation and transmission systems but which does not own these facilities.

iso-dense print bias the difference between the dimensions of an isolated line and a dense line (a line inside an array of equal lines and spaces) holding all other parameters constant.

isodata a special elaboration of K-means used for clustering.

isofocal bias the difference between the desired resist feature width and the isofocal linewidth.

isofocal linewidth the resist feature width (for a given mask width) that exhibits the maximum depth of focus.

isokeraunic map a map which denotes the variation of lightning activity over an area by making use of observations of the incidence of thunder.

isolated a power electronic circuit that has ohmic isolation between the input source and the load circuit.

isolated buck-boost converter *See* flyback converter.

isolated I/O an I/O system that is electrically isolated from where it is linked to. Isolated I/O is often found in embedded systems used for control.

isolation (1) the separation of a part from other parts of the system so that the effects of undesired changes in the system are not seen by the separated part.

(2) a figure (usually expressed in decibels) to describe how well a transmitting device (source) and receiving device (receiver) are separated electrically; the amount of (usually undesirable) signal appearing at the receiver from the transmitting source from an undesirable signal path such as leakage in a coupler, mutual coupling, or multipath.

isolation switch *See* bypass switch.

isolation transformer a transformer, typically with a turns ratio of 1:1, designed to provide galvanic isolation between the input and the output.

isolator (1) a two-port passive device based on the Faraday effect. Signals passing in one direction suffer minimal loss, however, in the reverse direction they are strongly attenuated.

(2) in optics, a device inserted in an optical fiber that prevents optical power from flowing in the reverse direction from the transmitted power. Optical fiber isolators can be made either dependent or independent of the polarization direction of the optical energy in the fiber.

isotope a variant of an element whose nucleus contains a greater or lesser number of neutrons but the same number of protons as the base element.

isotropic antenna a fictitious reference antenna which radiates power equally in all directions. Such an antenna cannot be realized exactly in practice.

isotropic medium medium in which the constitutive parameters are not a function of the vector direction of the electric or magnetic fields. In such a medium, the constitutive parameters are scalar quantities, and there is no magnetoelectric coupling.

ISS *See* impedance standard substrate.

issue the act of initiating the performance of an instruction (not its fetch). Issue policies are an important design consideration in systems that use parallelism and execution out of program order to achieve more speed.

ITB *See* inverse translation buffer.

iterative coordination coordination process concerned with exchange of information between the coordinator and the local decision (control) units, which — after a number of iterations — leads to the local solutions being satisfactory from the overall (coordinator) point of view; iterative coordination is used in multilevel optimization, in particular in the direct method and the price method.

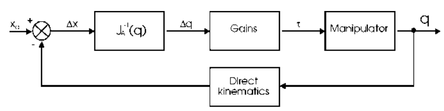
iterative decoding decoding technique that uses past estimates to provide additional information to improve future estimates. Used in the decoding of turbo-codes.

iterative selection a thresholding algorithm based on a simple iteration. First select a simple threshold (say, 128) and segment the image, computing the mean of the black and white pixels along the way. Next, calculate a new threshold using the midpoint between the black and white pixels as just computed. Next, repeat the entire process, using the new threshold to perform the segmentation. The iteration stops when the same threshold is used on two consecutive passes.

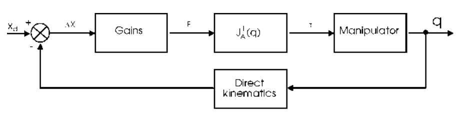
IWP *See* indirect weld parameters.

J

Jacobian inverse control one of the Cartesian-based control schemes. The Jacobian inverse control is presented in the figure. In this scheme, the end-effector location in the operational space is compared with desired quantity and an error ΔX is computed. Assuming that deviation is small ΔX can be transformed into corresponding joint space deviation, Δq, through the inverse of the manipulator analytical Jacobian. The gains correspond to the joint stiffness, which is constant for each joint. *See also* Cartesian-based control.



Jacobian inverse control scheme.



Jacobian transpose control scheme.

Jacobian of the manipulator a matrix that maps the joint velocities into end effector velocities.

Jacobian transpose from a mathematical point of view, the transpose of the Jacobian. Jacobian transpose can be used in inverse kinematics algorithm with operation space error as a feedback.

Jacobian transpose control depicted in the figure. In this case the operational space error, ΔX, is calculated first. Output of the gains block, F, can be treated as the elastic force generated by a generalized spring. This operational space force is transformed into the joint space generalized forces, τ, through the transpose of the Jacobian. *See also* Cartesian-based control, Jacobian inverse control.

JANTX a prefix denoting that the military specification device has received extra screening and testing, such as a 100% 168-h burn-in.

JANTXV a JANTX part with an added precapsulation visual requirement.

Jensen's inequality for a function f, convex on the support $\mathcal{X}$ and a random variable $X \in \mathcal{X}$,

$$Ef(x) \leq f(EX) \,,$$

provided the expectation exists. Named after its discoverer, Danish mathematician Johan L. W. V. Jensen (1859–1925).

jet a gas turbine peaking generator *See* peaking unit.

JFET *See* junction field-effect transistor.

JFET oscillator device often used as the active element in any of the LC-oscillators. A special attention deserves using JFET as the active element of the tuned-gate oscillator. In this configuration, the tuned circuit is not loaded by the FET, its loading due to the transistor output impedance is exceptionally small, and the Miller effect is also minimized. This oscillator can be clamp-biased, and the oscillation amplitude may be stabilized with the FET operating completely within its square-law region.

jitter a signal sample is temporarily displaced by an unknown, usually small, interval.

JK flip-flop device that uses two inputs (J and K) to control the state of its Q and Q' outputs. A negative edge-sensitive clock input samples J and K and changes the outputs accordingly. The simplified truth table for the JK flip flop is as follows:

J	K	Q	Q'
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

Johnson noise *See* thermal noise.

joint a lower-pair joint connects two links and it has two surfaces sliding over one another while remaining in contact. Six different lower-pair joints are possible: revolute (rotary), prismatic (sliding), cylindrical, spherical, screw, and planar. Of these, only rotary and prismatic joints are common in manipulators. Each has one degree of freedom.

joint detection *See* multi-user detection.

Joint Electron Device Engineering Council (JEDEC) a part of the EIA.

joint flexibility small deformations characterized as being concentrated at the joints of the manipulator. We often refer to this situation by the term "elastic joints" in lieu of flexible joints. As an example, joint flexibility can be a dynamic, time-varying displacement that is introduced between the position of the driving actuator and that of the driven link. This is due to presence of transmission elements such as harmonic drives transmission, belts, and long shafts.

joint offset the relative displacement between two successive links in a robotic arm.

Joint Photographic Experts Group (JPEG) (1) group that standardizes methods for still picture compression. Baseline JPEG compression uses an 8×8 *discrete cosine transform*, quantization and zigzag ordering of transform coefficients, combined run-length/value coding, and Huffman or Arithmetic lossless coding.

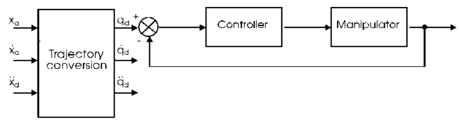
(2) a still picture compression method that uses the spectral components of an image to perform compression. The JPEG baseline must be present in all JPEG modes of operation which use DCT. *See also* JPEG.

joint source-channel coding *See* combined source-channel coding.

joint space a position and orientation of a manipulator of n degrees of freedom is specified as a result of the forward kinematics problem. This set of variables is called as the $n \times 1$ vector. The space of all such joint vectors is referred to as joint space.

joint space control depicted in the figure. The joint space control scheme consists of the trajectory conversion, which recalculates the desired trajectory from the operational space $(X_d, \dot{X}_d, \ddot{X}_d)$ into the joint space $(q_d, \dot{q}_d, \ddot{q}_d)$. Then, a joint space controller is designed that allows tracking of the reference inputs. Notice that only joint inputs are compared with joint positions, velocities, and accelerations. The joint space control does not influence the operational space variables which are controlled in an open-loop fashion through the manipulator mechanical structure. Joint space control is usually a single-input–single-output system; therefore, manipulator with n degrees of freedom has n such independent systems. A single-input–single-output system has PI (proportional-integral), PD (proportional-derivative), or PID (proportional-integral-derivative) structure. These schemes do not include dynamics of the manipulator. Dynamics of the manipulator can be included in, for example, computed torque control. *See also* computer torque control.

joint stiffness *See* stiffness of a manipulator arm.



Joint space control scheme.

Joint Tactical Information Distribution System (JTIDS) system that uses spread spectrum techniques for secure digital communications; used for military applications.

joint time frequency analysis (JTFA) techniques the aim of which is to represent and characterize a signal in time and frequency domain simultaneously by using different kinds of transformation and kernel functions.

joint transform correlator a type of optical correlator that employs two parallel paths, one for each signal, instead of an in-line cascade.

joystick an input device in the form of a control lever that transmits its movement in two dimensions to a computer. Joysticks are often used in games for control. They may also have a number of buttons whose state can be read by the computer.

JPEG *See* Joint Photographic Experts Group.

JPEG baseline *See* Joint Photographic Experts Group baseline.

JPEG DCT there are two DCT modes of JPEG, the sequential DCT mode and the progressive DCT-based mode. In the sequential mode the image components are coded individually or in blocks by a single scan in one pass. In the progressive mode several scans are taken to code parts of the quantized DCT coefficients.

JTFA *See* joint time frequency analysis.

JTIDS *See* Joint Tactical Information Distribution System.

jump instruction an instruction that causes an unconditional transfer of control to a different instruction sequence in memory.

jump linear quadratic problem optimal control problem in which a controlled process is modeled by linear system with Markov jumps and a control objective is to minimize an average quadratic criterion given by

$$J = E\{\int_0^T [x'(t)Q(\xi(t))x(t) + u'(t)R(\xi(t))u(t)]dt | x(0), \xi(0)\}$$

where $x(t), u(t), \xi(t)$ denote, respectively, process state, process control, and mode, and matrices R, Q are real valued, symmetric respectively positive definite and positive semidefinite weighting matrices of respective dimensions T is finite or infinite control horizon and E is an averaging operator. In the finite time case the optimal control law is given as

$$u(t) = p(x(t), \xi(t), t) = -P(\xi(t), t)x(t)$$

for each $\xi(t)$ taking value in finite set $\mathbf{S} = \{1, 2, \ldots, s\}$ where

$$P(\xi, t) = R(\xi)^{-1}B'(\xi)K(\xi, t)x(t)$$

where for each $\xi(t) = i$ matrices $K(i, t)$ are the unique positive semidefinite solutions of differential coupled Riccati equations. Assuming that the system is stochastically stabilizable and for each $\xi(t) = i$ the pairs $(A(i), \sqrt{Q(i)})$ are observable, then for infinite control interval $T \to \infty$ the solution of the jump linear quadratic (JLQ) problem is given by the optimal steady state control:

$$\begin{aligned} u(t) &= \hat{p}(x(t), \xi(t)) \\ &= -\hat{P}(\xi(t))x(t) \\ &= -R(\xi)^{-1}B'(\xi)\hat{K}(\xi)x(t) \end{aligned}$$

where for each $\xi(t) = i$ matrices $\hat{K}(i)$ are the unique positive semidefinite solutions of algebraic coupled Riccati equations. This solution may be also found as the steady-state value of $K(i, t)$. *See also* linear systems with Markov jumps.

jumper a plug or wire used for setting the configuration of system. It can be used for changing the hardware configuration by forcing some line to be high or low. It is used to change software configuration (especially on embedded systems) when the status of the jumper is read by the microprocessor.

jumping jack a voltmeter.

junction capacitance change in charge of immobile ions in the depletion region of a diode corresponding to a change in reverse bias voltage on a diode.

junction field-effect transistor (JFET) a type of FET in which the high input resistance at the gate is achieved by use of a reverse biased p-n junction between the gate and the drain-source channel.

junction-to-case thermal resistance the proportionality constant at thermal equilibrium between the temperature difference of the bipolar device junction ($T_{junction}$) and a specified case surface (T_{case}) to the dissipated power in the junction (p_w), in units of $C°/W$. The specified surface is usually the most effective in reducing the temperature. It includes the thermal resistance of the chip, die attach material (solder or adhesive), packaging and mounting medium, as applicable.

$$\theta_{jc} = \left. \frac{T_{junction} - T_{case}}{P_w} \right|_{equilibrium}$$

K

K (1) symbol for the Linville stability factor, a dimensionless quantity.

(2) abbreviation for 1024 (not for 1000).

K-factor rating an indication of a transformer's capability to provide a specified amount of harmonic content in its load current without overheating. K-factor rated transformers typically use thinner laminations in the core to reduce the eddy current losses, larger conductors to reduce skin effect, and for three-phase transformers a larger neutral conductor to conduct zero-sequence harmonic currents.

K-means algorithm (1) a clustering algorithm known from the statistical literature (E. W. Forgy, 1965), that relies on the same principles as the Lloyd algorithm and the generalized Lloyd algorithm.

Given a set of patterns and K, the number of desired clusters, K-means returns the centroid of the K clusters. In a Pascal-like, the algorithm runs as follows:

```
function K-Means(Patterns:set-of-pattern):
                Centroids;
begin   repeat
        for h = 1 to N do
          Assign point h to class k for which the distance (x_h −
μ_k)^2 is a minimum
        For k = 1 to K do
          Compute μ[k] (average of the assigned points)
       until no further change in the assignment
end
```

The algorithm requires an initialization that consists of providing K initial points, which can be chosen in many different ways. Each of the N given points is assigned to one of the K clusters according to the Euclidean minimum distance criterion. The average in the clusters is computed and the algorithm runs until no further reassignment of the points to different clusters occurs.

(2) statistical clustering algorithm. N, m-component training vectors $v_1 \ldots v_N$ are to be approximated by k prototypes $w_1 \ldots w_k$, for example, in vector quantization. After initialization of the w_i, randomly, uniformly or in some other way, the algorithm iterates the following two steps: 1. associate v_i with prototypes according to a closest distance criterion (e.g., minimum euclidean distance); 2. find the mean vector of all the v_i associated with a particular prototype w_j, and move that prototype to the mean point. Iteration ceases when there is no more movement of prototypes or according to some other stopping condition.

K-nearest neighbor algorithm a method of classifying samples in which a sample is assigned to the class which is most represented among the k nearest neighbors; an extension of the nearest neighbor algorithm.

Kaczmarz's algorithm the recursive least-squares algorithm has two sets of state variables, parameters vector and covariance matrix, which must be updated at each step. For large dimension, the updating of the covariance matrix dominates the computing effort. Kaczmarz's projection algorithm is one simple solution that avoids updating the matrix at the cost of slower convergence. The updating formula of the least squares algorithm using the Kaczmarz's algorithm has the form

$$\hat{\theta}(t) = \hat{\theta}(t-1) + \frac{\phi(t)}{\phi^T(t)\phi(t)}\left(y(t) - \phi^T(t)\hat{\theta}(t-1)\right)$$

where $\hat{\theta}$ is parameter's estimates vector, ϕ is regressor vector. This approach is also called the normalized projection algorithm.

Kaiser window a function defined by

$$w[n] = \begin{cases} \frac{I_0[\beta(1-[(n-\alpha)/\alpha]^2)^{\frac{1}{2}}]}{I_0(\beta)} & \text{if } 0 \le n \le M \\ 0 & \text{otherwise} \end{cases}$$

where M is the length of the filter minus one, $\alpha = \frac{M}{2}$ and β is a term that depends on the desired ripple level of the filter.

Kalman decomposition of linear systems one of several decompositions for linear systems.

Every linear, stationary finite-dimensional continuous-time dynamical system can be decomposed into four subsystems: controllable and observable, controllable and unobservable, uncontrollable and observable, uncontrollable and unobservable. This decomposition does not depend on any nonsingular transformations in the state space R^n. The transfer function matrix always describes only the controllable and observable part of the dynamical system and does not depend on any nonsingular transformations in the state space R^n. Similar statements hold true for linear stationary finite-dimensional discrete-time dynamical systems.

Kalman filter the method of recursively estimating the state vector of a linear dynamic system based on noisy output measurements. This method combines the knowledge of system parameters, statistical characteristics of initial state, process and measurement noises, and the current measurement to update the existing estimate of the state. Kalman filter is the minimum variance filter if the initial state and the noises are Gaussian distributed; otherwise, it is the linear minimum variance filter. In addition to providing the expected value of the state conditional on the measurement, this filter generates the estimation error covariance, which signifies the uncertainty associated with this estimate. This covariance can be calculated off-line before running the filter.

Kanerva memory a sparse distributed memory developed for the storage of high-dimensional pattern vectors. Memory addresses are randomly generated patterns, and a given pattern is stored at the address that is closest in terms of Hamming distance. Patterns are usually bipolar, and those stored at the same address are added together. Suitable thresholding of this sum allows a close approximation to individual patterns to be recalled, so long as the memory is not overloaded.

Karhunen–Loeve transform (KLT) an optimal image transform in an energy-packing sense.

If the images are transformed by $\mathbf{y} = \mathbf{Ax}$, then the corresponding quadratic term associated with the covariance matrix becomes $\mathbf{x'A'RAx}$. Hence the image uncorrelation is reduced to finding A such that

$$\mathbf{A'RA} = \Lambda = \mathbf{diag}(\lambda_\mathbf{1}, \ldots, \lambda_\mathbf{n}) \; .$$

This equation can be solved by finding in the following three steps.

1. Solve equation $|\mathbf{R} - \lambda\mathbf{I}| = 0$ (find the $\mathbf{R}$'s eigenvalues).

2. Determine the n solutions of $(\mathbf{R} - \lambda_i \mathbf{I})\mathbf{a_i} = 0$ (eigenvectors).

3. Create the desired transformation $\mathbf{A}$ as follows:

$$\mathbf{A} = [\mathbf{a_1}, \ldots, \mathbf{a_n}] \; .$$

In this transform a limited number of transform coefficients are retained. These coefficients contain a larger fraction of the total energy in the image. This transform is heavily dependent on the image features and requires a covariance function estimate for performing the transform. *See also* discrete cosine transform.

Karnaugh map a mapping of a truth table into a rectangular array of cells in which the nearest neighbors of any cell differ from that cell by exactly one binary input variable.

KCL *See* Kirchoff's current law.

kcmil *See* circular mil.

KDP *See* potassium dihydrogen phosphate.

kernel (1) the term for the portion of the operating system that operates in privileged mode.

(2) the set of basis functions for a transformation.

(3) the set of convolution weights for filtering.

Kerr coefficients describes the quadratic electro-optic effect, particularly for gases and liquids.

Kerr effect the quadratic electro-optic effect, particularly in the case for gases and liquids.

key (1) in a table, the value used to select the desired entry (or entries).

(2) in an access control system, a value held by a process to permit it to make access to certain objects within the system.

key point detection a technique usually employed in specialized linear or morphological filters designed for measuring gray-level changes in several directions. A key point is an isolated image point corresponding to a peculiar physical or geometrical phenomenon in the scene from which the image arises; it can be for example a corner, a line termination, a junction, a bright or dark spot, etc. Key points are distinguished from edges by two properties: they are sparse and display strong gray-level variations in two or more directions (while edge points are grouped into lines, and have gray-level variations essentially in the direction normal to that line). *See* edge. *See also* salient feature.

key punch a device with a keyboard used for storing data in paper cards or paper tapes by punching holes. The pattern of holes punched across these cards or tapes represent the data keyed in. Now obsolete.

keyboard an input device with a set of buttons (or keys) through which characters are input to a computer. In addition to the keys for inputing characters, a keyboard may also have function keys and special keys, such as power-on or print-screen.

keyboard controller the device controller that processes keyboard input. Because of its importance, I/O from the keyboard controller is often handled differently from other I/O processes, with its own direct connection to the CPU.

keystone distortion a distortion that presents an image in the shape of a trapezoidal. For projection television displays, off-axis projections of the red and blue tubes can cause keystone distortion. For direct view television displays, unequal deflection sensitivities for the two sections of the deflection yoke can result in keystone distortion. A horizontal trapezoid is the result of the vertical yoke deflection sensitivities. Similarly, a vertical trapezoid is the result of the horizontal yoke deflection sensitivities.

KGD *See* known good die.

Kharitonov theorem the most popular necessary and sufficient condition of robust stability for characteristic interval polynomials. It states that robust stability of uncertain linear time-invariant system with characteristic interval polynomial $p(s, \mathbf{a})$ is stable if and only if the following four polynomials have all roots endowed with negative parts:

$$p_1(s) = a_0^+ + a_1^- s + a_2^- s^2 + a_3^+ s^3 + a_4^+ s^4 + \dots$$

$$p_2(s) = a_0^+ + a_1^+ s + a_2^- s^2 + a_3^- s^3 + a_4^+ s^4 + \dots$$

$$p_3(s) = a_0^- + a_1^+ s + a_2^+ s^2 + a_3^- s^3 + a_4^- s^4 + \dots$$

$$p_4(s) = a_0^- + a_1^- s + a_2^+ s^2 + a_3^+ s^3 + a_4^- s^4 + \dots$$

where a_i^-, a_i^+ are bounds for coefficients of the characteristic interval polynomial. The polynomials are called Kharitonov polynomials, and the required property could be checked by four Routh–Hurwitz tests. Some generalizations of this result for dependent coefficient perturbations and more general zero location regions are known.

Kilby, Jack St. Clair (1923–) Born: Jefferson City, Missouri, U.S.A.

Kilby is best known as the person who first suggested and then implemented the concept of integrating transistors, with capacitors and resistors, on a single silicon wafer. This concept, simple-sounding today, formed the basis for the first early integrated circuits. Kilby's employer, Texas Instruments, launched a patent suit against Fairchild Industries to establish their and Kilby's claim to the technology. The court ruled in favor of Robert Noyce and Fairchild. Despite this, Kilby is universally recognized for his pioneering work, especially in the practical implementation of IC technology.

kilovar *See* VAR.

kilovolt-ampere (KVA) a measure of apparent power, often in the rating of a piece of equipment or the measure of an electrical load, which is obtained by multiplying the device voltage in kilovolts by the current in amperes.

kilowatt-hour (KWH) a measure of electrical energy: 1000 watts delivered for one hour.

kinematic calibration a procedure to finding accurate estimates of Denavit–Hartenberg parametersfromaseriesofmeasurements of the manipulator's end-effector locations. *See also* Denavit–Hartenberg notation.

kinematic singularity a point for which the geometric Jacobian is not invertible. In other words, those configurations at which Jacobian is rank-deficient are termed kinematic singularities. As a consequence, in singular configurations infinite solutions to the inverse kinematics problem may exist. From practical point of view small velocities in the operation space will cause large velocities in the joint space.

kinematically simple manipulator a manipulator where some or all link offset angles equal 0, $-90°$, or $90°$ and link distances and offsets equal zero. Kinematically simple manipulators are found in most of the industrial robots. For these robots, forward kinematics problem can be solved in a closed form solution and dynamics equations are the simplest. *See also* Denavit–Hartenberg notation.

kinetic energy energy of motion.

kinetic energy conservation principle any change of kinetic energy of an electron is transformed into a change in electric potential energy with which the electron is interacting, and vice versa.

kineto-static duality the static relationship combined with the differential kinematics equation defines a kineto-statics duality. For the description of differential kinematics. *See* differential kinematics. The static relationship describes the end point force and equivalent joint generalized force balance assuming that we neglect gravity and friction at the joints. This relationship is described by the transpose of the manipulator Jacobian and has the form $\tau = J^T F$, where F is a vector of exerted end point forces and τ is a vector of joint generalized forces. As a consequence of the last definition, the following properties can be defined.

1. The range of J^T is the subspace $R(J^T)$ in R^n of the joint forces and/or torques that can balance the end-effector forces, in the given manipulator posture.

2. The null of J^T is the subspace $N(J^T)$ in R^T of the end-effector forces and/or torques that do not require any balancing joint generalized forces, in the given manipulator posture.

Kirchhoff, Gustav Robert (1824–1887) Born: Konigsberg, Germany

Kirchhoff is best known for discovering the laws that govern electric flow in networks, known now as Kirchhoff's laws. Kirchhoff is also famous as the inventor of spectroscopy, and his theoretical work led to the quantum theory of matter. Kirchhoff first held a teaching post in Berlin, followed by appointments in Breslau and Heidelberg. In the latter two universities, Kirchhoff had very fruitful collaborations with Robert Bunsen. Kirchhoff's studies in electricity provided a foundation for Maxwell and Lorenz's description of electromagnetic theory.

Kirchoff's current law (KCL) a fundamental law of electricity that states that the sum of the currents entering and exiting a circuit node must be equal to 0.

Kirchoff's laws laws that govern the relationships between voltages/currents in a circuit/network. *See also* Kirchoff's voltage law, Kirchoff's current law.

Kirchoff's voltage law (KVL) a fundamental law of electricity that states that the sum of the voltage drops and rises in a closed loop must equal 0.

Kleinman symmetry *See* symmetries of nonlinear susceptibility.

KLT *See* Karhunen–Loeve transform.

klydonograph a measuring instruments for high-voltage impulses which makes use of Lichtenburg figures impressed on photographic film.

klystrode an amplifier device for UHF-TV signals that combines aspects of a tetrode (grid modulation) with a klystron (velocity modulation of an electron beam). The result is a more efficient, less expensive device for many applications. (Klystrode is a trademark of EIMAC, a division of Varian Associates.)

knife-edge diffraction classical diffraction model defined by the interaction of a propagating electromagnetic wave with a perfectly conducting, infinitely thin obstructing boundary. Knife-edge diffraction is often used is terrain propagation calculations as an approximation for hills and ridges.

knob-and-tube wiring a form of residential wiring, now obsolete, in which lightly-insulated wires are supported on porcelain insulators (knobs) or porcelain bushings (tubes) through joists or studs.

knowledge engineering the process of developing an expert system.

Knowlton's technique a pyramidal type of hierarchical approach, in which a reversible transformation takes adjacent pairs of k-bit pixel values and maps it into a k-bit composite value and a k-bit differentiator.

known good die (KGD) bare silicon chips (die) tested to some known level.

Kogelnik transformation *See* ABCD law.

Köhler illumination a method of illuminating the mask in a projection imaging system whereby a condenser lens forms an image of the illumination source at the entrance pupil (entrance aperture) of the objective lens, and the mask is at the exit pupil of the condenser lens.

Kohonen network a 2-dimensional array of neurons with each neuron connected to the full set of network inputs. Learning is unsupervised: the neuron whose vector of input weights is closest to an input vector adjusts its weights so as to move closer to that input vector; the neuron's neighbors in the array adjust their input weights similarly. As a result, clusters of weights in different parts of the array tend to respond to different types of input.

Kolmogorov complexity the minimum length description of a binary string that would enable a universal computer to reconstruct the string.

Kraft inequality a theorem from information theory that sets a restriction on instantaneous codes (codes where no codeword is a prefix of any other codeword, i.e., a code containing 0 and 01 is not an instantaneous code). The Kraft inequality states that for an instantaneous code over an alphabet with size D and codeword lengths $l_1, l_2, l_3, \ldots, l_m$ the following must be true:

$$\sum_{i=1}^{m} D^{-l_i} <= 1.$$

Kramer drive an electric drive system in which the output of the driven frequency converter is fed to the slip rings of the wound rotor. Unlike its predecessor Leblanc system, the variable transformer is connected to the wound rotor slip rings instead of to the line.

Kramer's generalization a sampling theory based on other than Fourier transforms and frequency.

Kramers–Kronig relations relates the real and imaginary components of the index of refraction of a medium. *See also* Hilbert transform.

Kronecker delta function The discrete-time unit impulse function defined as $\delta_{ij} = 1$ for $i = j$, $\delta_{ij} = 0$ for $i \neq j$. *See also* delta function.

ku-band frequency band of approximately 11–12 GHz.

Kubo formula a fundamental relationship, developed by Ryogo Kubo, between, e.g., the conductance and the current fluctuations. The Kubo formula is an example of the fluctuation–dissipation theorem in statistical physics, in which the average value of the current (conductance) is determined by an integral over the correlation function of the current fluctuations.

Kullback–Liebler distance *See* relative entropy.

Kuroda's identities four identities are used to achieve practical microwave filter implementation by using redundant transmission line sections.

kVA *See* kilovolt-ampere.

Kvhler illumination a method of illuminating the mask in a projection imaging system whereby a condenser lens forms an image of the illumination source at the entrance pupil (entrance aperture) of the objective lens, and the mask is at the exit pupil of the condenser lens.

KVL *See* Kirchoff's voltage law.

KWH *See* kilowatt-hour