R

$\mathbf{R}_S$ commonly used symbol for source impedance.

$\mathbf{R}_T$ commonly used symbol for transformation ratio.

R-ALOHA *See* reservation ALOHA.

$\mathbf{R}_L$ Typical symbol for load resistance.

Rabi frequency the characteristic coupling strength between a near-resonant electromagnetic field and two states of a quantum mechanical system. For example, the Rabi frequency of an electric dipole allowed transition is equal to μE/hbar, where μ is the electric dipole moment and E is the maximum electric field amplitude. In a strongly driven 2-level system, the Rabi frequency is equal to the rate at which population oscillates between the ground and excited states.

race condition a situation where multiple processes access and manipulate shared data with the outcome dependent on the relative timing of these processes.

raceway a channel within a building which holds bare or insulated conductors.

radar an instrument that transmits electromagnetic waves and receives properties of the reflected electromagnetic wave from the target, which can be used to determine the nature and distance to the target. Radar is an acronym that stands for radio detection and ranging.

radar cross section (RCS) a measure of the reflective strength of a radar target; usually represented by the symbol s, measured in square meters, and defined as 4π times the ratio of the power per unit solid angle scattered in a specific direction of the power unit area in a plane wave incident on the scatterer from a specified direction.

RADHAZ radiation hazards to personnel as defined in ANSI/C95.1-1991 IEEE Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

radial basis function network a fully connected feedforward network with a single hidden layer of neurons each of which computes a nonlinear decreasing function of the distance between its received input and a "center point." This function is generally bell-shaped and has a different center point for each neuron. The center points and the widths of the bell shapes are learned from training data. The input weights usually have fixed values and may be prescribed on the basis of prior knowledge. The outputs have linear characteristics, and their weights are computed during training.

radial intensity histogram a histogram of average intensities for a round object in circular bands centered at the center of the object, with radial distance as the running index. Such histograms are easily constructed, and, suitably normalised, form the basis for scrutinizing round objects for defects, and for measuring radius and radial distances of cylindrically symmetrical features.

radial system a network of straight wires or other conductors radiating from the base of a vertical monopole antenna that simulates the presence of a highly conducting ground plane beneath the antenna. Typically, radial wires are approximately a quarter wavelength long and are arranged to have equiangular spacing between them. The radial wire ends at the base of the monopole are electrically bonded together and to one conductor of the feedline.

radiated emission an electromagnetic field propagated through space.

radiating aperture a basic element of an antenna that in itself is capable of effectively radiating or receiving radio waves. Typical example of a radiating apertures are a slot, and horn antennas or a truncated metallic waveguide.

radiation the phenomenon by which sources generate energy, which propagates away from them in the form of waves.

radiation boundary condition (RBC) a boundary condition that is imposed to truncate the computational domain of a differential equation method so that it satisfies the Sommerfield radiation condition.

radiation condition the condition that specifies the field behavior at infinity; in fact, for an unbounded domain it is necessary to specify the field behavior on the surface at infinity. By assuming that all sources are contained in a finite region, only *outgoing waves* must be present at large distances from the sources; hence the field behavior at large distances from the sources must meet the physical requirement that energy travel away from the source region. This requirement is the Sommerfield "*radiation condition*" and constitutes a boundary condition on the surface at infinity. Let us denote with A any field component transverse to the radial distance r and with k the free-space wavenumber. The transverse field of a spherically diverging wave in a homogeneous isotropic medium decays as $1/r$ at large distances r from the source region; locally, the spherical wave behaves like a plane wave travelling in the outward r direction. As such, each field component transverse to r must behave like $\exp(-jkr)/r$; this requirement may be phrased mathematically as

$$\lim_{r\to\infty} r\left(\frac{\partial A}{\partial r} + jkA\right) = 0$$

radiation efficiency in antenna theory, the ratio of radiated power to the amount of input power to the antenna. Has a value between 0 and 1, inclusive.

radiation intensity in antenna theory, a far-field quantity that is a function of angle that gives the level of radiation in a specific direction. Radiation intensity is the radial component of the time average Poynting vector with all the terms associated with the distance from the antenna normalized out. The units are watts per square radian.

radiation pattern a plot of the far-field radiation as a function of the angle phi or theta while the other angle is held constant. A radiation pattern can be either polar or rectangular, and can be either logarithmic or linear.

radiative broadening a spectral line broadening mechanism that arises due to spontaneous decay of the excited state.

radiative heat transfer the process by which long-wave electromagnetic radiation transports heat from a surface to its surroundings.

radio astronomy the study of celestial objects based on the investigation of their radio frequency electromagnetic waves spectrum.

radio frequency (RF) a general term used to refer to radio signals in the general frequency range from thousands of cycles per second (kHz) to millions of cycles per second (MHz). It is also often used generically and interchangeably with the term microwave to distinguish the high frequency AC portion of a circuit or signal from the DC bias signal or the downconverted intermediate frequency (IF) signal.

radio frequency choke an inductance (a coil of wire) intended to present a very high impedance at radio frequencies. Such frequencies span the range of kilohertz to hundreds of megahertz.

radio frequency integrated circuit (RFIC) integrated circuit designed to operate at radio frequencies as amplifiers, mixers, oscillators, detectors or combinations of above. Typically, RFICs are configured for specific application to operate as a complete RF system.

radio frequency interference (RFI) electromagnetic phenomenon that either directly or indirectly contributes to degradation in the performance of a receiver or other RF system, synonymous with electromagnetic interference. *See also* electromagnetic interference.

radio horizon the maximum range, from transmitter to receiver on Earth's surface, of direct (line-of-sight) radio waves. This is greater than the optical horizon, because the radio waves follow a curved path as a result of the continuous refraction it undergoes in the atmosphere.

radio local loop *See* wireless local loop.

radio waves electromagnetic radiation suitable for radio transmission in the range of frequencies from about 10 kHz to about 300 Mhz.

radiography an imaging modality that uses an X-ray source and collimator to create a projection image. The image intensity is proportional to the transmitted X-ray intensity.

radiology the monitoring and control of radioactivity, especially in regard to human exposure, in a nuclear power plant.

radiometer a passive receiver that detects energy from a transmitting source or reradiated energy from a target. Typically, radiometers are used in remote sensing applications.

radius of curvature one of the parameters characterizing the reflecting surface of a spherical mirror.

radix the base number in a number system. Decimal (radix 10) and binary (radix 2) are two example number systems.

radix complement in a system that uses binary (base 2) data negative numbers, can be represented as the two's complement of the positive number. This is also called a true complement.

Radon transform the Radon transform of a function $f(x, y)$, $r(d, \phi)$ is its line integral along a line inclined at angle ϕ from the y axis and at a distance d from the origin.

radwaste a contraction for "radioactive waste," usually referring to mildly radioactive sludge removed from the coolant in a nuclear reactor.

RAID *See* redundant array of inexpensive disks.

RAKE receiver a receiver type in which the received signal from each (or a few dominating) resolvable propagation ray is individually demodulated and subsequently combined into one decision variable according to some criterion. RAKE receivers are commonly used in wideband transmission systems such as spread-spectrum systems where the large bandwidth allows several rays to be resolved, thus creating a diversity gain (frequency diversity).

RAM *See* random access memory.

RAM neuron a random access memory with n inputs and a single output. The inputs define $2n$ addresses and presentation of a particular input vector allows the contents of the 1-bit register at that address to be read, or to be written into. Training consists of writing 1s or 0s into the 1-bit registers, as

required for the various input vectors in the training set.

RAMA *See* resource auction multiple access.

ram's head the top of a transmission line tower

Raman echo a type of photon echo in which the stimulated emission is assisted by a Raman transition.

Raman laser laser in which the amplification mechanism is considered to be Raman scattering.

Raman scatter frequency-shifted light scatter, utilized as powerful analytical chemistry technique.

Raman scattering scattering of light by means of its interactions with the vibrational response of a molecular system. The scattered light is typically shifted to lower frequencies (*See* Stokes Law); the frequency shift is equal to the vibrational frequency of the molecule, typically 10^13 to 10^14 Hz. In spontaneous Raman scattering (*See* spontaneous light scattering), the scattered light is emitted in nearly all directions. In stimulated Raman scattering (*See* stimulated light scattering), the scattered light is emitted in the form of an intense beam. The emitted beam tends to be intense because it experiences large amplification by an amount given by e^{gIL}, where g is the gain factor of stimulated Raman scattering, I is the intensity of the incident laser beam in units of power per unit area, and L is the length of the interaction region.

Raman, Sir Chandrasekhara Venkata (1888–1970) author of 500 articles and independent investigator of light scatter and acoustics. Winner of a Nobel Prize for the discovery of Raman scattering.

Raman–Nath diffraction in acousto-optics, the regime where many diffraction orders exist due to the thinness of the acoustic grating relative to the acoustic wavelength in the direction of light.

Raman–Nath diffraction regime regime where the acoustic beam width is sufficiently narrow to produce many diffracted beams with significant power.

Raman–Nath mode acousto-optic spectrum analyzer similar to the acousto-optic (AO) Bragg-mode spectrum analyzer, but uses illumination at normal incidence to the face of the AO cell that results in multiple diffracted orders, with the two first order beams being used at the Fourier plane to obtain the input RF signal spectrum.

Raman–Nath scattering the scattering of light from a periodically varying refractive index variation in a thin medium, as contrasted with Bragg scattering, for instance in the operation of an acousto-optic modulator.

ramp a linear function of grey level, usually connecting two contrasting regions. Named after its appearance in one dimension, it is often used as one model of an edge.

Ramsey fringe the spectral feature generated when a quantum mechanical transition is excited by two identical-frequency, time-separated electromagnetic pulses. Ramsey fringes are used in cesium atomic beam clocks.

random access (1) term describing a type of memory in which the access time to any cell is uniform.

(2) a method for allowing multiple users to access a shared channel in which transmissions are not coordinated (or perhaps are partially coordinated) in time or frequency.

random access device *See* random access.

random access memory (RAM) direct-access read/write storage in which each addressable unit has a unique hardwired addressing mechanism. The time to access a randomly selected location is constant and not dependent on its position or on any previous accesses. The RAM has a set of k address lines ($m = 2^k$), n bidirectional data lines, and a set of additional lines to control the direction of the access (read or write), operation and timing of the device.

RAM is commonly used for the main memory of a computer and is said to be static if power has to be constantly maintained in order to store data and dynamic if periodic absences of power do not cause a loss of data. RAM is usually volatile. *See also* static random access memory, dynamic random access memory, nonvolatile random-access memory.

random behavior response without a spectral or amplitude pattern or relationship to the excitation. The excitation may be internal, and may be thermal in nature.

random coding coding technique in which codewords are chosen at random according to some distribution on the codeword symbols. Commonly a tool used in the development of information theoretic expressions.

random logic a digital system constructed with logic gates and flip-flops and other basic logic components interconnected in an non-specific manner. *See also* microprogramming.

random process a mathematical procedure for generating random numbers to a specific rule called a process, $\boldsymbol{x}$ which is defined on continuous $\boldsymbol{x}(\boldsymbol{t}), \boldsymbol{t} \in \mathcal{R}^n$, or discrete $\boldsymbol{x}(\boldsymbol{k}), \boldsymbol{k} \in \mathcal{Z}^n$ space / time. The value of the process at each point in space or time is a random vector. *See also* random variable, random vector. *See also* correlation, covariance, autocorrelation, autocovariance.

random replacement algorithm in a cache or a paging system, an algorithm that chooses the line or page in a random manner. A pseudo-random number generators may be used to make the selection, or other approximate method. The algorithm is not very commonly used, though it was used in the translation buffers of the VAX11/780 and the Intel i860 RISC processor.

random signal a signal $X(t)$ that is either noise $N(t)$, an interfering signal $s(t)$, or a sum of these:

$$X(t) = s_1(t) + \cdots + s_m(t) + N_1(t) + \cdots + N_n(t)$$

random testing the process of testing using a set of pseudo-randomly generated patterns.

random variable a continuous or discrete valued variable that maps the set of all outcomes of an experiment into the real line (or complex plane). Because the outcomes of an experiment are inherently random, the final value of the variable cannot be predetermined.

random vector a vector (typically a column vector) of random variables. *See also* random variable, random process.

randomized decision rule a hypothesis decision/classification rule that is not deterministic (that is, the measurement or observation does not uniquely determine the decision). Although typically not useful given continuous observations, a randomized rule can be necessary given discrete observations. *See also* receiver operating characteristics curve.

range filter an edge detection filter that finds edges by taking the difference between the maximum and minimum values in a local region of the image. The range filter also accepts a weight mask the size of the local image region that controls pixel values before they enter the minimum and maximum

calculations. The weight mask allows edges in certain directions to be searched for.

range image an image in which the intensity of point **x** is a function of the distance between **x** and the corresponding point in the scene (object) projected on the image plane.

range of Jacobian denoted J, it is defined as a subspace $R(J)$ in R^r of the end-effector-velocities that can be generated by the joint velocities, in the given manipulator posture. *See* full rank Jacobian.

rank filter an image transform used in mathematical morphology. Assume that to every pixel p one associates a window $W(p)$ containing it. Let k be an integer > 1 which is less than or equal to the size of each window $W(p)$. The rank filter with rank k and windows $W(p)$ transforms an image I into a filtered image I' whose gray-level $I'(p)$ at pixel p is defined as the k-th least value among all initial gray-levels $I(q)$ for q in the window $W(p)$. In a dual version, the k-th greatest value is selected. When each $W(p)$ is the translate by p of a structuring element W of size n, three particular cases are noteworthy:

1. $k = 1$: the rank filter is the erosion by W.

2. $k = n$: the rank filter is the dilation by $\widetilde{W}$, the symmetric of W.

3. n is odd and $k = (n + 1)/2$: the rank filter is a median filter. *See* dilation, erosion, median filter, structuring element.

rare gas one of the rare gases specified in the periodic table, He, Ne, Ar, Kr, Xe.

rare gas halides excimer molecule formed by a reaction of a rare gas atom and a halogen atom: e.g., XeF, ArF, KrF.

rare gas molecule excimer molecule formed by a reaction of an excited and a neutral rare gas atom, usually with a third atom present. For example, Ar_2, Kr_2.

rare gas oxides an excimer molecule formed by the reaction of a rare gas atom and an oxygen atom.

rare-earth magnet a magnet that has any of the rare-earth elements in its composition. Typically stronger than other magnet materials, these include neodymium iron boron and samarium cobalt.

rare-earth permanent magnet magnet made of compounds of iron, nickel, and cobalt with one or more of the rare-earth elements such as samarium. These materials combine the high residual flux density of the alnico-type materials with greater coercivity than ferrites.

raster a predetermined pattern of scanning lines used to provide uniform coverage of the area used for displaying a television picture.

raster coordinates coordinates in a display system that specifically identify a physical location on the display surface.

raster graphics a computer graphics system that scans and displays an image periodically in a raster, or left-to-right, top-to-bottom fashion.

raster image *See* bitmapped image.

raster width (1) physical distance between raster lines on a display surface and between distinguishable points in the same raster line; the two distances are frequently different.

(2) the physical distance between raster lines on a display surface and between distinguishable points in the same raster line. The two distances are frequently different.

rate distortion function the minimum rate at which a source is represented by one of a set of discrete points.

rate distortion theory a theory aimed at quantifying the optimum performance of source coding systems. Using information theory, for several source models and distortion measures, rate distortion theory provides the optimum distortion function and the optimum rate function. The distortion function is optimum in that the distortion for a given rate is the theoretical minimum value of distortion for encoding the source at the given or lower rate. The rate function is optimum in that the rate at a given distortion is the minimum possible rate for coding the source at the given or lower distortion.

rate equation approximation assumption, in a semiclassical model for the interaction of light with atoms, that all fields and populations change negligibly within the coherence time of the wave functions, loses all information about the phase of the fields and wave functions.

rate equation model model for the interaction of light with atoms in which the atoms are represented only by their populations or population densities and the electromagnetic field is represented only by its intensity, power, energy, or photon density.

rate equations coupled ordinary nonlinear differential equations governing the interaction of an electromagnetic field (represented by an intensity, energy density, or photon density) with an atomic or molecular laser medium (represented by populations of the energy states); phase information relating to the fields and wavefunctions is absent from these equations.

rate split multiple access coding technique for the multiple-access channel in which each user splits their information stream into two or more streams, which are independently encoded. These encoded streams are multiplexed according to some rule prior to transmission. Used to show that time-sharing is not required to achieve certain points in the capacity region of multiple access channels.

rate-adaptive digital subscriber line (RDSL) a digital subscriber line (DSL) in which the rates in each direction are adjusted according to the quality of the channel. In general, longer loops are associated with lower rates.

rate-compatible punctured convolutional (RCPC) code one of a family of punctured convolutional codes derived from one low-rate convolutional parent code by successively increasing the number of punctured symbols, given that the previously punctured symbols should still be punctured (rate-compatibility). These codes have applications in, for example, variable error protection systems and in hybrid automatic repeat request schemes using additional transmitted redundancy to be able to correctly decode a packet. Also called RCPC code.

rate-distortion theory Claude Shannon's theory for source coding with respect to a fidelity criterion, developed during the late 1940s and the 1950s. Can be viewed as a generalization of Shannon's earlier theory (late 1940s) for channel coding and information transmission. The theory applies to the important methods for vector quantization and predicts the theoretically achievable optimum performance.

rated voltage the voltage at which a power line or electrical equipment is designed to operate.

ratio detector a circuit for recovering (demodulating) baseband information (usually audio) from a frequency modulated (FM) wave.

rational function a function that is the ratio of two polynomials. Rational functions often arise in the solution of differential equations by Laplace transforms. *See also* Laplace transform.

ray one of a family of lines (rays) used to represent the propagation of an electromagnetic wave; most useful in real media when the wave amplitude varies slowly compared to the wavelength (see geometrical optics).

ray equation set of second-order differential equations governing the trajectory of a light ray propagating along an arbitrary path.

ray optics approximate representation of electromagnetic wave propagation in terms of light rays, most useful in real media when the wave amplitude varies slowly compared to the wavelength.

ray tracing (1) a high-frequency electromagnetic analysis technique in which the propagation path is modeled by flux lines or "rays." The ray density is proportional to the power density, and frequently, bundles of these rays are called ray tubes.

(2) a rendering technique in which the paths of light rays reaching the viewpoint are computed to obtain realistic images. Given a 3-D description of a scene as a collection of surfaces characterized by different optical properties, rays are traced backward from the viewpoint through the image plane until they hit one of the surfaces or go off to infinity.

ray transfer matrix real two-by-two matrix governing the transformation of the ray displacement and slope with respect to a fixed axis.

Rayleigh criterion a method of distinguishing between rough and smooth surfaces in order to determine whether specular reflection will occur. A surface is considered smooth if the phase difference between waves reflected from the surface is less than ninety degrees.

Rayleigh distribution the probability distribution of the magnitude of a complex quantity whose real and imaginary parts are independent Gaussian random variables with zero mean. Frequently used to approximate multipath fading statistics in non-line-of-sight mobile radio systems.

Rayleigh length distance over which the spot size of a Gaussian beam increases from its value at the beam waist to a value 2.5 larger; a measure of the waist size of a Gaussian beam, π times waist spot size squared divided by wavelength; half of the confocal parameter.

Rayleigh noise the envelope of a zero mean, wide-sense stationary, narrowband Gaussian noise process. The probability density function of a sinusoid in narrowband noise is a generalized Rayleigh distribution, $p(z) = \frac{z}{\sigma} e^{-\frac{z^2}{2\sigma^2}}$, $z \geq 0$. Also known as a Rician distribution.

Rayleigh scattering (1) theory for the interaction between light and a medium composed of particles whose size is much smaller than the wavelength. According to it, the scattering cross section is proportional to the fourth power of the wavelength of the scattered light. This explains both the red and blue colors of the sky.

(2) an intrinsic effect of glass that contributes to attenuation of the guided optical wave. The effect is due to random localized variations in the molecular structure of the glass which acts as scattering centers.

Rayleigh–Ritz procedure a procedure for solving functional equations. *See also* moment method.

Rayleigh-wing scattering of light the scattering of light with no change in central frequency, and with moderate (of the order of 10^11 Hz) broadening of spectrum of the light. Rayleigh-wing scattering occurs when light scatters from anisotropic molecules.

RBC *See* radiation boundary condition.

RC time constant the time needed for signal traveling from an end to the other end of a wire is constant when the wire and the

whole chip is scaled down. As the length of a wire shrinks by a factor of k and the cross-sectional area of the wire is reduced by a factor of k^2, the capacitance of the wire decreases by a factor of k while the resistance increases by a factor of k. The RC time remains constant, and thus the input charging time remains the same, independent of scaling. Consequently, the scaling down of the chip cannot increase the speed of the chip if wire is used. Optical interconnects can speed up the chip.

RCPC code *See* rate-compatible punctured convolutional code.

RCS *See* radar cross section.

RCT *See* reverse conducting thyristor.

RDSL *See* rate-adaptive digital subscriber line.

re-entrancy term describing the number of times that a multiplex armature winding of a commutated machine closes upon itself via the commutator ring. For example, duplex windings can be either singly or doubly re-entrant. In a doubly re-entrant duplex winding, the ends of the two winding circuits close only on themselves and not on each other, creating two distinct circuits through the commutator and two distinct circuit closures. Conversely, in a singly re-entrant duplex winding, the two windings are connected in series through the commutator ring creating only a single circuit closure.

reachability a term that indicates that a dynamical system can be steered from zero initial state to any final state in a given time interval. For many dynamical systems, reachability is equivalent to controllability. This is always true for linear finite-dimensional continuous-time dynamical systems. However, in discrete case, controllability may be the stronger notion than reachability. In this case, the two concepts are equivalent if and only if rank $A = n$. For dynamical systems with delays, these two notions are essentially different. For infinite-dimensional systems, the relations between reachability and controllability depend on the properties of the semigroup $S(t)$ generated by the operator A.

reactance grounded an electrical system in which the neutral is intentionally grounded through a reactance. Frequently used in the neutral of generators and transformers to limit the magnitude of line to ground fault currents.

reactance modulator modulator normally using phase or frequency modulation where the reactance of the circuit is dependent on changes in the input modulating voltage.

reaction a functional in electromagnetics that relates a set of fields and sources to one another. Reaction concepts are often used in the discussion of field reciprocity.

reaction range sum of end-to-end round-trip delay and processing time.

reactive compensation process of counteracting the reactive component of a device by means of capacitors and inductors. Both series and shunt compensation are prevalent.

reactive congestion control in packet networks, a congestion control system whose actions are based on actual congestion occurrence.

reactive ion etching the process of etching materials by the use of chemically reactive ions or atoms. Typically, the reactive ions or atoms are generated in a RF plasma environment or in a microwave discharge.

reactive load a load that is purely capacitive or inductive.

reactive matching impedance transformation achieved by employing a matching

network constructed of only reactive elements.

reactive near field the region close to an antenna where the reactive components of the electromagnetic fields from charges on the antenna structure are very large compared to the radiating fields. Considered negligible at distances greater than a wavelength from the source (decay as the square or cube of distance). Reactive field is important at antenna edges and for electrically small antennas.

reactive power (1) electrical energy per unit time that is alternately stored, then released. For example, reactive power is associated with a capacitor charging and discharging as it operates on an AC system. Symbolized by Q, with units of volt-amperes reactive (VAR), it is the imaginary part of the complex power.

(2) the power consumed by the reactive part of the load impedance, calculated by multiplying the line current by the voltage across the reactive portion of the load. The units are vars (volt-ampere reactive) or kilovars.

reactor a container where the nuclear reaction takes place. The reactor converts the nuclear energy to heat.

reactor containment *See* containment building.

reactor core an array of nuclear fuel rods that are arranged so as to encourage a chain reaction and thus heat water to supply a power for the steam turbine in a nuclear power plant.

reactor refueling the process of shutting down a nuclear reactor for maintenance and fuel replacement, typically every 12 to 24 months.

read ahead on a magnetic disk, reading more data than is nominally required, in the hope that the extra data will also be useful.

read instruction an assembly language instruction that reads data from memory or the input/output system.

read phase the first portion of a transaction during which the executing process obtains information that will determine the outcome of the transaction. Any transaction can be structured so that all of the input information is obtained at the outset, all the computation is then performed, and finally all results are stored (pending functionality checks based on the locking protocols in use).

read-after-write hazard *See* true data dependency.

read-modify-write cycle a type of memory device access that allows the contents at a single address to be read, modified, and written back without other accesses taking place between the read and the write.

read-mostly memory memory primarily designed for read operations, but whose contents also can be changed through procedures more complex and typically slower than the read operations. EPROM, EEPROM, and flash memory are examples.

read-only (ROM) memory semiconductor memory unit that performs only the read operation; it does not have the write capability. The contents of each memory location is fixed during the hardware production of the device and cannot be altered. A ROM has a set of k input address lines (that determine the number of addressable positions 2^k) and a set of n output data lines (that determine the width in bits of the information stored in each position). An integrated circuit ROM may also have one or more enable lines for interconnecting several circuits and make a ROM with larger capacity. Plain ROM does not allow erasure, but programmable ROM (PROM) does. Static ROM does not require a clock for proper operation, whereas dynamic ROM does. *See also* random access memory, programmable read-only memory.

read/modify/write an uninterruptible memory transaction in which information is obtained, modified, and replaced, under the assurance that no other process could have accessed that information during the transaction. This type of transaction is important for efficient implementations of locking protocols.

read/write head conducting coil that forms an electromagnet, used to record on and later retrieve data from a magnetic circular platter constructed of metal, plastic, or glass coated with a magnetizable material. During the read or write operation, the head is stationary while the platter rotates beneath it. The write mechanism is based on the magnetic field produced by electricity flowing through the coil. The read mechanism is based on the electric current in the coil produced by a magnetic field moving relative to it.

Less common are magnetoresistive heads, which employ noninductive methods for reading. A system that uses such a head requires an additional (conventional) head for the writing. *See also* disk head, magnetic recording code.

real address the actual address that refers to a location of main memory, as opposed to a virtual address that must first be translated. Also called a physical address. *See also* memory mapping, virtual memory.

real power consider an AC source connected at a pair of terminals to an otherwise isolated network. The real power, equal to the average power, is the power dissipated by the source in the network.

real-time refers to systems whose correctness depends not only on outputs, but the timeliness of those outputs. Failure to meet one or more of the deadlines can result in system failure. *See also* soft real-time system, firm real-time system, hard real-time system.

real-time clock a hardware counter that records the passage of time.

real-time computing support for environments in which response time to an event must occur within a predetermined amount of time. Real-time systems may be categorized into hard, firm, and soft real-time.

realization for a linear continuous or discrete stationary finite-dimensional dynamical system, a set of four constant matrices A, B, C, D of the state and output equations. The matrices may be calculated using certain algorithms. The realization is said to be minimal if the dimension n of the square matrix A is minimal.

realization problem for 2-D Fornasini–Marchesini model a problem in control. The transfer matrix $T(z_1, z_2)$ of the 2-D Fornasini–Marchesini model

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

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

$$\begin{aligned} T(z_1, z_2) &= C\,[I z_1 z_2 - A_1 z_1 - A_2 z_2]^{-1} \\ &\quad \times (B_1 z_1 + B_2 z_2) + D \end{aligned} \tag{2}$$

where $x_{ij} \in R^n$ 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 $(k = 1, 2)$ are real matrices. Matrices

$$A_!, A_2, B_1, B_2, C, D \tag{3}$$

are called a realization of a given transfer matrix $T(z_1, z_2)$ if they satisfy (2). A realization (3) is called minimal if the matrices A_1 and A_2 have minimal dimension among all realizations of $T(z_1, z_2)$. The (minimal) realization problem can be stated as follows. Given a proper transfer matrix $T(z_1, z_2) \in R^{p \times m}(z_1, z_2)$, find matrices (3) (with minimal dimension of A_1 and A_2) that satisfy (2).

realization problem for 2-D Roesser model the transfer matrix $T(z_1, z_2)$ of the 2-D Roesser model

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

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

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

$$T(z_1, z_2) = C \begin{bmatrix} I_{n_1} z_1 - A_1 & -A_2 \\ -A_3 & I_{n_2} z_2 - A_4 \end{bmatrix}^{-1} \times \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} + D \quad (2)$$

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, and $y_{ij} \in R^p$ is the output vector. Matrices

$$A = \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix}, \quad B = \begin{bmatrix} B_1 \\ B_2 \end{bmatrix}, \quad C, \quad D \quad (3)$$

are called a realization of a given transfer matrix $T(z_1, z_2)$ if they satisfy (2). A realization (3) is called minimal if the matrix A has minimal dimension amongst all realizations of $T(z_1, z_2)$. The (minimal) realization problem can be stated as follows. Given a proper transfer matrix $T(z_1, z_2) \in R^{p \times m}(z_1, z_2)$, find matrices (3) (with minimal dimension of A) that satisfy (2).

received signal strength indicator (RSSI) ratio of signal power level for a single frequency or a band of frequencies to an established reference; the reference is typically 1 mW, and the resultant value is expressed in decibels. RSSI is often used in mobile communications to make assessments such as to which base station a call should be connected or which radio channel should be used for communication.

receiver noise thermal (Boltzmann-type) noise in a receiver, a function of its physical temperature above absolute zero and the noise bandwidth of the receiver's electronic devices. Receiver noise causes finite receiver sensitivity. *See also* thermal noise.

receiver operating characteristics curve plot of the probability of detection (likelihood of detecting the object when the object is present) versus the probability of false alarm (likelihood of detecting the object when the object is not present) for a particular processing system.

receiver sensitivity the minimum radio signal power at the input to a receiver that results in signal reception of some stated quality.

reciprocity (1) a consequence of Maxwell's equations, stipulating the phenomenon that the reaction of the sources of each of two different source distributions with the fields generated by the other are equal, provided the media involved have certain permeability and permittivity properties (reciprocal media). Referring to reciprocal circuits, reciprocity states that the positions of an ideal voltage source (zero internal impedance) and an ideal ammeter (infinite internal impedance) can be interchanged without affecting their readings.

(2) in antenna theory, the principal that the receive and transmit patterns of an antenna are the same.

reciprocity in scattering law according to which the source and detector points can be exchanged, providing the source amplitude and phase are preserved.

reciprocity theorem in a network consisting of linear, passive impedances, the ratio of the voltage introduced into any branch to the current in any other branch is equal in magnitude and phase to the ratio that results if the positions of the voltage and current are interchanged.

recloser a self-contained device placed on distribution lines that senses line currents and opens on overcurrent. Reclosing is employed to reenergize the protected line segment in the case of temporary faults. Reclosers have the capability for fast tripping for fuse saving, and slow tripping to allow sectionalizing fuse operation for faults on laterals. The recloser will retrip on permanent faults and go on to lockout. Reclosers are suitable for pole mounting on overhead lines.

reclosing relay an auxiliary relay that initiates circuit breaker closing in a set sequence following fault clearing. Reclosing relays are typically employed on overhead lines where a high proportion of the faults are temporary.

recoil permeability the average slope of the minor hysteresis loop, which is roughly the slope of the major hysteresis loop at zero applied field (H), and is most often used to determine the effect of applying and removing a demagnetizing field to and from a magnetic material.

recombination the process in which an electron neutralizes a hole. Sometimes this process causes light emission (i.e., through radiative recombination), and sometimes it doesn't (i.e., through nonradiative recombination).

recombination X-ray laser an X-ray laser made by gain from an inverted population where the upper level is inverted due to recombining ions and electrons.

reconstruction the process of forming a 3-D image from a set of 2-D projection images. Also applies to the formation of a 2-D image from 1-D projections. *See* image reconstruction, tomographyand computed tomography.

reconstruction from marker in a binary image, this is the operation extracting all connected components having a non-empty intersection with a marker. This operation can be generalized to gray-level images by a morphological operator applying such a reconstruction on the gray-level slices of the image.

record unit of data, corresponding to a block, sector, etc., on a magnetic disk, magnetic tape, or other similar I/O medium.

recording code a line code optimized for recording systems. *See also* line code.

recording density number of bits stored per linear inch on a disk track. In general, the same number of bits are stored on each track, so that the density increases as one moves from the outermost to the innermost track.

recovery action that restores the state of a process to an earlier configuration after it has been determined that the system has entered a state which does not correspond to functional behavior. For overall functional behavior, the states of all processes should be restored in a manner consistent with each other, and with the conditions within communication links or message channels.

rectangle detection the detection of rectangle shapes, often by searching for corner signals, or from straight edges present in an image. Rectangle detection is important when locating machined parts in images, e.g., prior to robot assembly tasks. *See also* polygon detectionand square detection.

rectangular cavity a section of rectangular waveguide closed on both ends by conducting plates.

rectangular window (1) in finite impulse response (FIR) filter design, the rectangular window constituting the most straightforward window function used usually as a reference in studying other window functions. It is defined as 1 within an even interval centered at the origin and 0 elsewhere.

(2) in image processing, an rectangular area centered at a pixel under consideration.

This area is known as a window, or a mask, or a template. A square window of size 3×3 is used most often. *See also* neighborhood operation.

rectifier a circuit that changes an AC voltage to DC. Switching elements or diodes are used to create the DC voltage. Diode rectifiers and thyristor rectifiers are the two most commonly used rectifiers.

recurrent coding old name for convolutional coding.

recurrent network a neural network that contains at least one feedback loop.

recursion the process whereby a program calls itself. *See also* recursive procedure.

recursive equation a difference equation that is of the form

$$y(k) = \sum_{i=0}^{i=m} a_i x(k-i) - \sum_{i=1}^{i=n} b_i y(k-i)$$

where a_i and b_i are some proper real constants. When all the $b_i = 0$, it is called a nonrecursive equation.

recursive filter a digital filter that is recursively implemented. That is, the present output sample is a linear combination of the present and past input samples as well as the previously determined outputs. Traditionally, the term recursive filter is closely related to infinite impulse filter. In a nonrecursive filter the present output sample is only a linear combination of the present and past input samples.

recursive function *See* recursive procedure.

recursive method method that estimates local displacements iteratively based on previous estimates. Iterations are performed at all levels, as in every pixel, each block of pixels, along scanning line, from line to line, or from frame to frame.

recursive procedure a procedure that can be called by itself or by another program that it has called; effectively, a single process can have several executions of the same program alive at the same time. Recursion provides one means of defining functions.

The recursive definition of the factorial function is the classic example:

if n = 0
    factorial(n) = 1
else
    factorial(n) = n * factorial (n−1)

recursive self-generating neural network (RSGNN) a recursive version of self-generating neural network (SGNN) that can discover recursive relations in the training data. It can be used in applications such as natural language learning/understanding, continuous spoken language understanding, and DNA clustering/classification, etc. *See also* self-generating neural network.

Red book *See* IEEE Color Books.

red head another name for a hot tap.

reduced characteristic table a tabular representation used to illustrate the operation of various bistable devices.

reduced instruction set computer (RISC) processor relatively simple control unit design with a reduced menu of instructions (selected to be simple), data and instructions formats, addressing modes, and with a uniform streamlined handling of pipelines.

One of the particular features of a RISC processor is the restriction that all memory accesses should be by load and store instructions only (the so called load/store architecture). All operations in a RISC are register-to-register, meaning that both the sources and destinations of all operations are CPU registers. All this tends to significantly reduce CPU to memory data traffic, thus improving performance. In addition, RISCs usually have the following properties: most instructions execute within a single cycle, all in-

structions have the same standard size (32 bits), the control unit is hardwired (to increase speed of operations), and there is a CPU register file of considerable size (32 registers in most systems, with the exception of SPARC with 136 and AMD 29000 with 192 registers).

Historically, the earliest computers explicitly designed by these rules were designs by Seymour Cray at CDC in the 1960s. The earliest development of the RISC philosophy of design was given by John Cocke in the late 1970s at IBM. However, the term RISC was first coined by Patterson *et al.* at the University of California at Berkeley to describe a computer with an instruction set designed for maximum execution speed on a particular class of computer programs. Patterson and his team of researchers developed the first single-chip RISC processor.

Compare with complex instruction set computer.

reduced-order model a mathematical representation of a system that is obtained by neglecting portions of a more explicit (detailed) model. In large-scale power system analysis, this term is typically used to indicate a model derived by neglecting the electric transients in the stator voltage equations of all machines and in the voltage equations of power system components connected to the stators of the machines.

reduced-voltage motor starter a device designed to safely connect an electric motor to the power source while limiting the magnitude of its starting current. Various electromechanical configurations may be used: primary resistor, delta-wye, part-winding (requires special motor or dual voltage windings). Power electronic devices may also be utilized to gradually increase the applied voltage to system levels. The complete starter must also include fault and overload protection.

redundancy (1) the use of parallel or series components in a system to reduce the possibility of failure. Similarly, referring to an increase in the number of components which can interchangeably perform the same function in a system. Sometimes it is referred to as hardware redundancy in the literature to differentiate from so called analytical redundancy in the field of FDI (fault detection and isolation/identification). Redundancy can increase the system reliability.

(2) in robotics, the number n degrees of mobility of the mechanical structure, the number m of operational space variables, and the number r of the operational space variables necessary to specify a given task. Consider the differential kinematics mapping $v = J(q)\dot{q}$ in which v is $(r \times 1)$ vector of end-effector velocity of concern for the specific tasks and J is $r \times n$ Jacobian matrix. If $r < n$, the manipulator is kinematically redundant and has $(n-r)$ redundant degrees of mobility. Manipulator can be redundant with respect to a task and nonredundant with respect to another. *See also* redundant manipulator.

redundancy encoding any digital encoding scheme which takes advantage of redundancy in the digital signal. For example, in run-length encoding, a gray scale digital image is represented by the gray level of a pixel and the number of times adjacent pixels with that gray level appear. So an image containing large regions of a single gray level can be represented with a great reduction in digital information.

redundancy statistics model refers to statistical similarities such as correlation and predictability of data. Statistical redundancy can be removed without destroying any information.

redundancy-free channel coding refers to methods for channel robust source coding where no "explicit" error protection is introduced. Instead, knowledge of the source and source code structure is utilized to counteract transmission errors (for example, by means of an efficient index assignment).

redundant array of inexpensive disks (RAID) standardized scheme for multiple-disk data base systems viewed by the operating system as a single logical drive. Data is distributed across the physical drives allowing simultaneous access to data from multiple drives, thereby reducing the gap between processor speeds and relatively slow electromechanical disks. Redundant disk capacity can also be used to store additional information to guarantee data recoverability in case of disk failure (such as parity or data duplication). The RAID scheme consists of six levels (0 through 5), $RAID_0$ being the only one that does not include redundancy.

redundant manipulator the manipulator is called redundant if more degrees of mobility are available than degrees of freedom required for the execution of a given task. *See also* differential kinematics, redundancy.

redundant number system the system in which the numerical value could be represented by more than one bit string.

Reed switch a magnetomechanical device composed of two thin slats of ferromagnetic material within a hermetically sealed capsule that attract each other when an external magnetic field (from an electromagnet or permanent magnet) induces opposite poles at the overlapping ends of both slats.

Reed–Solomon code an extension of BAH codes to nonbinary alphabets developed by Driving Reed and Gustave Solomon independently of the work by Bose, Chaudhuri, and Hocquenghem. Arguably, the most widely used of any forward error control code.

reentrancy the characteristic of a block of software code that, if present, allows the code in the block to be executed by more than one process at a time.

reentrant a program that uses concurrently exactly the same executable code in memory for more than one invocation of the program (each with its own data), rather than separate copies of a program for each invocation. The read and write operations must be timed so that the correct results are always available and the results produced by an invocation are not overwritten by another one.

reference black level picture signal level corresponding to a specified maximum limit for black peaks.

reference frame *See* base frame.

reference impedance impedance to which scattering parameters are referenced.

reference matrix a triangular array of bits used to implement the least recently used algorithm in caches. When the *i*th line is referenced, all the bits in the *i*th row are set to a 1 and then all the bits in the *i*th column are set to a 0. Having 0s in the *j*th row and 1s in the *j*th column identifies the *j*th line as the least recently used line.

reference monitor a functional module that checks each attempt to access memory to determine whether it violates the system's security policy, intercepting it if a violation is imminent. The memory management unit can provide this service, provided that the access control information contained there is known to be consistent with the security policy.

reference node one node in a network that is selected to be a common point, and all other node voltages are measured with respect to that point.

reference point *See* set point.

reference white in a color matching process, a white with known characteristics used as a reference. According to the trichromatic theory, it is possible to match an arbitrary color by applying appropriate amounts of three primary colors.

reference white level picture signal level corresponding to a specified maximum limit for white peaks.

reflectance the physical property of matter to reflect light, defined (punctually) as the ratio between the intensity $I(\mathbf{x})$ of a point $\mathbf{x}$ of an image and the irradiance $L(\mathbf{x})$ in the same point.

reflected power power in the reflected part of an electromagnetic wave.

reflected wave the result that ensues when a high-speed electromagnetic wave reaches the end of a transmission line, when the line is not terminated with an impedance matching the surge impedance of the line. When a surge reaches an open circuited line terminal, the reflected voltage wave equals the incident voltage wave, resulting in a doubling of the level of the voltage surge at that point.

reflection in electromagnetic wave propagation, the change in direction of propagation of a plane wave due to the wave being incident on the surface of a material. Typically, the effect is greater in the case of a material that has a high electrical conductivity.

reflection coefficient (1) the ratio of the reflected field to the incident field at a material interface.

(2) another way of expressing the impedance. The reflection coefficient is defined as how much signal energy would be reflected at a given frequency. Like impedance, the reflection coefficient will vary with frequency if inductors or capacitors are in the circuit. The reflection coefficient is always defined with respect to a reference or characteristic impedance ($= (Z - Z_0)/(Z + Z_0)$). For example, the characteristic impedance of one typical TV transmission line is 75 ohms, whereas another type of TV transmission line has a characteristic impedance of 300 ohms. Hooking up a 75-ohm transmission line to a 300-ohm transmission line will result in a reflection coefficient of value $(300 - 75)/(300 + 75) = 0.6$, which means that 60% of the energy received from the antenna.

reflection grating a diffraction grating that operates in reflection, i.e., the diffracted light is obtained by reflecting off the grating.

reflective notching an unwanted notching or feature size change in a photoresist pattern caused by the reflection of light off nearby topographic patterns on the wafer.

reflectivity a property that describes the reflected energy as a function of the incident energy of an EM wave and a material body. The property may be quantified in terms of the magnitude of the reflection coefficient or the ratio of the incident to the reflected field.

reflectometer instrument that measures reflected power.

reflector antenna an antenna comprised of one or more large reflecting surfaces used to focus intercepted power around a small region where a primary feed antenna is then used to input the power to the receiver electronics. Also used to transmit power in narrow angular sectors.

reflex klystron a high-power microwave tube oscillator.

refraction the process undertaken by an electromagnetic wave wherein the wave changes direction of propagation as it is incident on the edge of a material. The wave undergoes a "bending" action, sometimes referred to as knife edge refraction, and the "bending" angle is less than 90 degrees. Refraction may also occur as a wave propagates through a media such as the atmosphere.

refractive index 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. *See also* index of refraction.

refractivity the refractive index minus 1.

refractory period a period of time after the initiation of an action during which further excitation is impossible (absolute refractory period) or requires a greater stimulus (relative refractory period).

refresh refers to the requirement that dynamic RAM chips must have their contents periodically refreshed or restored. Without a periodic refresh, the chip loses its contents. Typical refresh times are in the 5–10 millisecond range. *See also* memory refresh.

refresh cycle (1) a periodically repeated procedure that reads and then writes back the contents of a dynamic memory device. Without this procedure, the contents of dynamic memories will eventually vanish.

(2) the period of time taken to "refresh" a portion of a dynamic RAM chip's memory. *See also* refresh.

refresh period the time between the beginnings of two consecutive refresh cycles for dynamic random access memory devices.

regeneration the process of returning energy back into a system during a portion of the machine's operating cycle.

regeneration loop a water purification system used to maintain proper conditions of the cooling liquid for a power vacuum tube.

regenerative braking a method for extracting kinetic energy from the load, converting it back to electricity, and returning it to the supply. Used widely in electric train drives and electric vehicles.

region growing the grouping of pixels or small regions in an image into larger regions. Region growing is one approach to image segmentation. *See also* dilation, erosion, image segmentation, mathematical morphology.

region of absolute convergence the set of complex numbers s for which the magnitude of the Laplace transform integral is finite. The region can be expressed as

$$\sigma_+ < Re(s) < \sigma_-$$

where σ_+ and σ_- denote real parameters that are related to the causal and anticausal components, respectively, of the signal whose Laplace transform is being sought. $Re(s)$ represents the real part of s.

region of asymptotic stability *See* region of attraction.

region of attraction the region around an equilibrium state of a system of differential or difference equations such that the trajectories originating at the points in the region converge to the equilibrium state. Trajectories starting outside the region of attraction of the given equilibrium state may "run away" from that equilibrium state.

region of convergence (ROC) (1) an area on a display device where the image displayed meets an accepted criteria for raster coordinate deviation. *See* region of absolute convergence.

(2) the set of complex numbers $s = a + jb$ for which the magnitude of the Laplace transform integral is finite. The region can be expressed as:

$$\sigma_- < \text{Real}(s) < \sigma_+,$$

where σ_- and σ_+ denote real parameters that are related to the causal and anticausal components, respectively, for the signal whose Laplace transform is being sought.

(3) the set of complex numbers $z = e^{st}$ for which the magnitude of the z-transform sum is finite. The region can be expressed as:

$$R_- < |z| < R_+,$$

where R_- and R_+ denote real parameters that are related to the causal and anticausal components, respectively, for the signal whose z-transform is being sought.

region of interest (ROI) a restricted set of image pixels upon which image processing operations are performed. Such a set of pixels might be those representing an object that is to be analysed or inspected.

region of support the region of variable or variables where the function has non-zero value.

register a circuit formed from identical flip-flops or latches and capable of storing several bits of data.

register alias table *See* virtual register.

register direct addressing an instruction addressing method in which the memory address of the data to be accessed or stored is found in a general purpose register.

register file a collection of CPU registers addressable by number.

register indirect addressing an instruction addressing method in which the register field contains a pointer to a memory location that contains the memory address of the data to be accessed or stored.

register renaming dynamically allocating a location in a special register file for an instance of a destination register appearing in an instruction prior to its execution. Used to remove antidependencies and output dependencies. *See also* reorder buffer.

register transfer notation a mathematical notation to show the movement of data from one register to another register by using a backward arrow. Notation used to describe elementary operations that take place during the execution of a machine instruction.

register window in the SPARC architecture, a set or window of registers selected out of a larger group.

registration the process of aligning multiple images obtained from different modalities, at different timepoints, or with different image acquisition parameters. *See* fusion.

regression the methods that use backward prediction error as input to produce an estimation of a desired signal. Quantitatively, the regression of y on X, denoted by $r(y)$, is defined as the first conditional moment, i.e.,

$$r(y) = E(X|y).$$

regular controllability a dynamical system is said to be regularly controllable in time interval $[t_0, t_1]$ if every dynamical system of the form

$$x'(t) = Ax(t)x(t) + b_j u_j(t)$$
$$j = 1, 2, \ldots, m$$

is controllable where b_j is the jth column of the matrix B and $u_j(t)$ is the jth scalar admissible control.

regular cue any regular recurring point/element of a signal that can be used to signal the start of a new signal sequence; e.g., the leading edge of a 60-Hz square wave is a regular cue.

regular form a particular form of the state space description of a dynamical system. This form is obtained by a suitable transformation of the system state. The regular form is useful in control design.

regularization a procedure to add a constraint term in the optimization process that has a stabilizing effect on the solution.

regulation the change in voltage from no-load to full-load expressed as a percentage of full-load voltage.

regulator a controller designed to maintain the state of the controlled variable at a constant value, despite fluctuations of the load.

reinforcement learning learning on the basis of a signal that tells the learning system whether its actions in response to an input (or series of inputs) are good or bad. The signal is usually a scalar, indicating how good or bad the actions are, but may be binary.

rejection criteria criteria such as poor surface texture, existence of scratch marks, and out-of-tolerance distance measures, which constitute reasonable grounds for rejecting a product from a product line.

relational model a logical data structure based on a set of tables having common keys that allows the relationship between data items to be defined without considering the physical database organization.

relative addressing an addressing mechanism for machine instructions in which the address of the target location is given by the contents of a specific register and an offset held as a constant in the instruction added together. *See also* PC-relative addressing, index register, base address.

relative-address coding in facsimile coding, represents the transition between levels on a particular scan line relative to transitions on the preceding scan line. A relative-address coding system has a pass mode codeword for indicating where a pair of transitions on the previous line does not have corresponding transitions on the current line and a runlength coding mode applied when there is no nearby suitable transition on the previous line. CCITT Group IV facsimile uses a form of relative-address coding.

relative controllability a dynamical system with delays in which for a given time interval $[0, t_1]$ if for any initial condition $(x(0), x_0)$ and any final vector $x_1 \in R^n$ there exists an admissible control $u(t), t \in [0, t_1]$, such that the corresponding trajectory satisfies the condition

$$x\,(t_1, x(0), x_0, u) = x_1$$

relative entropy information theoretic quantity representing the "distance" between two probability distribution functions. Also known as the Kullback–Liebler distance. For two probability mass functions $p(x)$ and $q(x)$, the relative entropy $D(p||q)$ is given by

$$D(p||q) = \sum p(x) \log \frac{p(x)}{q(x)} .$$

This quantity is only a pseudo-distance, as $D(p||q) \neq D(q||p)$.

relative intensity noise noise resulting from undesirable fluctuations of the optical power detected in an optical communication system.

relative permeability the complex permeability of a material divided by the permeability of free space: $\mu_r = \mu/\mu_0$.

relative permittivity the complex permittivity of a material divided by the permittivity of free space: $\epsilon_r = \epsilon/\epsilon_0$.

relative refractive index difference the ratio $(n_1^2 - n_2^2)/2n_1^2 \approx (n_1 - n_2)/n_1$ where $n_1 > n_2$ and n_1 and n_2 are refractive indices.

relative sensitivity denoted $\mathbf{S}_x^y(y, x)$ and defined as follows:

$$\mathbf{S}_x^y(y, x) = \frac{\partial y}{\partial x}\frac{x}{y} = \frac{\partial y/y}{\partial x/x} = \frac{\partial \ln y}{\partial \ln x}$$

It is usually used to establish the approximate relationship between the relative changes $\delta y = \Delta y/y$ and $\delta x = \Delta x/x$. Here Δy and Δx are absolute changes. If these relative changes are small, one writes that

$$\delta y \approx \mathbf{S}_x^y \delta x$$

This relationship assumes that $\mathbf{S}_x^y$ is different from zero. If $\mathbf{S}_x^y = 0$, the relative changes δy and δx may be independent. The properties of relative sensitivity established by differentiation only are tabulated and may be found in many textbooks and handbooks. *See also* absolute sensitivity, sensitivity, sensitivity measure, semi-relative sensitivity.

relaxation (1) a general computational technique where computations are iterated until certain parameter measurements converge to a set of values.

(2) the response of a linear time invariant system can be represented as the sum of the zero-input response (system response to a zero input function) plus the zero-state response (system response to an input function when the system is in the zero state). Relaxation is the process of putting a system into its zero-state, i.e., all initial conditions are zero and there are no internal energy stores. A system is considered relaxed if it is in the zero state. *See also* relaxation labeling, optimization.

relaxation labeling an iterative mathematical procedure in which a system of values is processed, e.g., by mutual adjustment of adjacent or associated values, until a stable state is attained. Especially useful for achieving consistent optimal estimates of pixel intensities or deduced orientation values for points on the surface of an object. *See also* relaxation, optimization.

relaxation oscillations the damped output oscillations that occur in some laser oscillators when they are perturbed from steady state.

relaxation time the time in which the initial distribution of charge will diminish to 1/e of its original value.

relay a device that opens or closes a contact when energized. Relays are most commonly used in power systems, where their function is to detect defective lines or apparatus or other abnormal or dangerous occurrences and to initiate appropriate control action. When the voltage or current in a relay exceeds the specified "pickup" value, the relay contact changes its position and causes an action in the circuit breaker. A decision is made based on the information from the measuring instruments and relayed to the trip coil of the breaker, hence the name "relay." Other relays are used as switches to turn on or off equipment.

relay channel a multiterminal channel in which the receiver observes the transmitted signal through two channels: one direct to the transmitter, the other via an intermediate transmitter/receiver pair.

reliability the probability that a component or system will function without failure over a specified time period, under stated conditions.

reliability criteria a set of operating conditions that the system operator adheres to in order to guarantee secure operation.

relocatability the capability for a program to be loaded into any part of memory that is convenient and still execute correctly.

relocation register register used to facilitate the placement in varying locations of data and instructions. Actual addresses are calculated by adding program-given addresses to the contents of one or more relocation registers.

reluctance the resistance to magnetic flux in a magnetic circuit; analogous to resistance in an electrical circuit.

reluctance motor a motor constructed on the principle of varying reluctance of the air gap as a function of the rotor position with respect to the stator coil axis. The torque in these motors arises from the tendency of the rotor to align itself in the minimum re-

luctance position along the length of the air gap.

reluctance torque the type of torque a reluctance machine's operation is based upon. A reluctance torque is produced in a magnetic material in the presence of an external magnetic field, which makes it to line up with the external magnetic field. An induced field due to fringing flux develops a torque that eventually twists the magnetic material around to align itself with the external field.

remanent coercivity the magnetic field required to produce zero remanent magnetization in a material after the material was saturated in the opposite direction.

remanent magnetism *See* residual magnetism.

remanent polarization the residual or remanent polarization of a material after an applied field is reduced to zero. If the material was saturated, the remanent value is usually referred to as the polarization, although even at smaller fields a (smaller) polarization remains.

remanence (1) in a ferromagnetic material, the value of the magnetic flux density when the magnetic field intensity is zero.

(2) the magnetic induction (B) of a magnet after the magnetizing field is removed and an air gap (hence self-demagnetizing field) is introduced to the magnetic circuit. Also called retentivity or residual induction.

remote sensing the use of radar, satellite imagery, or radiometry to gather data about a distant object. Usually, the term refers to the use of microwaves or millimeter waves to map features or characteristics of planetary surfaces, especially the Earth's. Applications include military, meteorological, botanical, and environmental investigations.

remote terminal unit (RTU) hardware that gathers system-wide real-time data from various locations within substations and generating plants for telemetry to the energy management system.

removable disk disk that can be removed from disk drive and replaced, in contrast with a non-removable disk, which is permanently mounted. *See also* exchangeable disk.

rename register *See* virtual register.

rendering (1) the preparation of the representation of an image to include illumination, shading, depth cueing, coloring, texture, and reflection.

(2) common techniques include Phong and Gouraud shading; more complex rendering models such as raytracing and radiosity emphasize realistic physics models for calculating light interactions and texture interactions with objects.

renewable fuse a fuse consisting of a reusable cartridge and a fusible element that can be replaced.

reorder buffer a set of storage locations provided for register renaming for holding results of instructions. These results may be generated not in program order. At some stage, the results will be returned to the true destination registers.

repeatability the ability of a sensor to reproduce output readings for the same value of measurand, when applied consecutively and under the same conditions.

repeater electromagnetic device that receives a signal and amplifies it and retransmits it. In digital systems, the signal is regenerated.

repetition coding the simplest form of error control coding. The information symbol to be transmitted is merely repeated an uneven number of times. A decision regarding the true value of the symbol transmitted is

then simply made by deciding which symbol occurred the greatest number of times.

representation singularity of ϕ a set of orientations for which the determinant of the transformation matrix in the analytical Jacobian vanishes. *See also* analytical Jacobian.

representative level one of the discrete output values of a quantizer used to represent all input values in a range about the representative level. *See also* decision level.

reprocessing the recycling of reactor fuel by separation into fissile, non-fissile, radioactive and non-radioactive components such that wastes can be isolated and fissile material re-used to make more reactor fuel.

repulsion–induction motor a single-phase motor designed to start as a repulsion motor, then run as an induction motor. The rotor has a DC-type winding with brushes shorted together, in addition to the normal squirrel cage winding. Although it is an expensive design, it provides excellent starting torque with low starting current (similar to a universal motor) and relatively constant speed under load.

requirements analysis a phase of software development life cycle in which the business requirements for a software product are defined and documented.

reservation ALOHA (R-ALOHA) a class of multiple access control protocol in which the user transmits the first packet in random access fashion. If successful, the user will have a fixed part of the channel capacity allocated.

reservation station storage locations placed in front of functional units and provided to hold instructions and associated operands when they become available. Used in a superscalar processor.

reset scrambling a technique of randomizing a source bit sequence by adding the sequence to a pseudo-random bit stream using element-wise modulo-2 arithmetic. The source sequence is recovered at the decoder through addition of the demodulated bit stream with the same pseudo-random sequence. The pseudo-random sequences are usually generated with linear feedback shift registers which must be aligned with a reset or framing signal in order to recover the source sequence accurately.

reset time for a line recloser or circuit breaker, a time begins when the device successfully recloses following a temporary fault. After the reset time elapses, the fault cycle is considered over, and any subsequent fault will be treated as the first fault in a new cycle.

residential loop two radial sources coming in to an open point used for switching.

residual current circuit breaker European term for ground fault interrupter.

residual error the degree of misfit between an individual data point and some model of the data. Also called a “residual”.

residual inductance *See* remanence.

residual magnetism a form of permanent magnetism, referring to the flux remaining in a ferromagnetic material after the MMF that created the flux is removed. For example, if a bar of steel is surrounded by a coil and current is applied to the coil, the steel bar will create a magnetic field due to the rotation of the domains in the steel. After the current is removed, some of the domains will remain aligned, causing magnetic flux.

residual overcurrent relay an overcurrent relay that is connected to sense residual current. Residual current is the sum of the three phase currents flowing in a current transformer secondary circuit, and is propor-

tional to the zero sequence current flowing in the primary circuit at that point.

residual pyramid *See* predictive pyramid.

residual vector quantization *See* interpolative vector quantization.

resistivity (1) the product of the resistance of a given material sample times the ratio of its cross-sectional area to its length.

(2) an electrical material property described by a tensor constant indicating the impedance of free electron flow in the material. Resistivity relates the electric field strength to the conduction current, and can be expressed as the inverse of the conductivity.

resistance ratio of the potential of an electrical current applied to a given conductor to the current intensity value.

resistance ground a grounding scheme in which the neutral of Y-connected machines is connected to ground through a resistance such that ground-fault currents are limited.

resistance grounded *See* low resistance grounded system, high-resistance grounded system.

resistive mixer a device used to convert microwave frequencies to intermediate frequencies. Depending on the frequency of microwaves to be converted, the intermediate frequencies can be UHF, VHF, or HF.

resolution (1) the act of deriving from a sound, scene, or other form of intelligence, a series of discrete elements from which the original may subsequently be reconstructed. The degree to which nearly equal values of a quantity can be discriminated.

(2) the fineness of detail in a measurement. For continuous systems, the minimum increment that can be discerned.

(3) the ability to distinguish between two units of measurement.

(4) the number of pixels per linear unit (or per dimension) in a digital image.

(5) the smallest feature of a given type that can be printed with acceptable quality and control.

(6) refers to the ability to resolve two point targets which are closely spaced in time or frequency. For a linear system, resolution can be measured in terms of the width of the output pulse produced by a point target. In imaging applications, resolution refers to the number of independently detectable, controllable or displayable points.

resolvable component a component of a signal that exists in a group of components (a sum of signals) such that the amplitude of the component can be approximately determined by correlation of the overall signal with a component signal of unit amplitude. Typically, the different signal components are delayed versions of the same signal received at a receiver in a channel with multipath propagation. The different delay components are then resolvable if the relative delay between any two components is greater than the reciprocal of the transmitted signal bandwidth.

resolver an electric machine that is used to provide information about the position of a motor-driven system. The shaft of the resolver is connected to the main motor either directly or through gears. The rotor contains a single winding, while the stator typically contains two windings in quadrature. One stator winding and the rotor winding are excited, while the remaining stator winding is shorted. When the resolver is rotated by the main motor, voltages are produced in the stator windings that can be used to determine the position. For multi-turn systems, two resolvers (coarse and fine) may be required.

resonance in an RLC circuit, the resonance is the state at which the reactance of the inductor, X_L, and the reactance of the

capacitor, X_C, are equal.

$$X_L = 2\pi f_L$$
$$X_C = 1/(2\pi f_C)$$

resonance fluorescence the modified fluorescence produced when a quantum mechanical system is strongly driven by one or more near-resonant electromagnetic fields.

resonance Raman system Raman systems that have a near-resonant intermediate state. Resonance Raman systems are sometimes referred to as lambda systems and can exhibit coherent population trapping.

resonant in any circuit or system under excitation, the frequency at which a pair of reactive components cancels (pole or zero) resulting in a natural mode of vibration.

resonant antenna linear antennas that exhibit current and voltage standing wave patterns formed by reflections from the open end of the wire.

resonant cavity cavity with reflecting surfaces or mirrors that can support low-loss oscillations. By closing a metallic waveguide by two metallic surfaces perpendicular to its axis, a cylindrical cavity is formed. Resonant modes in this cavity are designated by adding a third subscript so as to indicate the number of half-waves along the axis of the cavity. When the cavity is a rectangular parallelepiped, the axis of the cylinder from which the cavity is assumed to be made should be designated, since there are three possible cylinders out of which the parallelepiped may be made. More generally, each closed cavity may sustain a discrete infinity of resonant field distributions.

resonant frequency (1) a frequency at which the input impedance of an device is nonreactive, since the capacitive and inductive stored energy cancel each other.

(2) an oscillation frequency of the modes of a resonator.

resonant link inverter an inverter that uses a resonant circuit to convert a constant DC voltage to a pulsating DC voltage. The switching elements in the inverter are then turned off during the times that the input voltage is zero, a technique referred to as soft-switching. Resonant switching techniques reduce the switching losses and allow high switching frequency operation to reduce the size of magnetic components in the inverter unit.

resonant tunneling refers to the process of resonant enhancement of electron tunneling by intermediate energy states. In the simplest case, it occurs when incoming electrons coincide in energy with the states created in the well.

resonator (1) circuit element or combination of elements, which may be either lumped or distributed, that exhibit a resonance(s) at one or more frequencies. Generally, a resonant condition coincides with the frequency where the impedance of the circuit element(s) is only resistive.

(2) cavity with reflecting surfaces designed to support low-loss oscillation modes. *See also* bi-directional resonator, concentric resonator, confocal resonator, high-loss resonator, plane-parallel resonator, ring resonator, standing-wave resonator, unidirectional resonator, unstable resonator.

resonator stability perturbation stability of an axial light ray in a resonator; boundedness of ray trajectories; corresponds to confinement of the resonator modes; not the same as mode stability (unstable resonators have stable modes).

resource auction multiple access (RAMA) a multiple access protocol that stipulates part of the frame for contention. Unlike PRMA and D-TDMA, the contention is not performed by an ALOHA-type of protocol but by an auction — a tree-sorting type of algorithm.

resource conflict the situation when a component such as a register or functional unit is required by more than one instruction simultaneously. Particularly applicable to pipelines.

response formula for general 2-D model the solution to the general 2-D model

$$x_{i+1,j+1} = A_0 x_{ij} + A_1 x_{i+1,j} + A_2 x_{i,j+1} + B_0 u_{ij} + B_1 u_{i+1,j} + B_2 u_{i,j+1} \quad \text{(1a)}$$

$$y_{ij} = C x_{ij} + D u_{ij} \quad \text{(1b)}$$

$i, j \in Z_+$ (the set of nonnegative integers) with boundary conditions $x_{i0}, i \in Z_+$ and $x_{0j}, j \in Z_+$ is given by

$$\begin{aligned} x_{ij} = & \sum_{p=1}^{i} \sum_{q=1}^{j} \left(T_{i-p-1,j-q-1} B_0 + T_{i-p,j-q-1} B_1 + T_{i-p-1,j-q} B_2 \right) u_{pq} \\ & + \sum_{p=1}^{i} \left(T_{i-p,j-1} \begin{bmatrix} A_1 & B_1 \end{bmatrix} + T_{i-p-1,j-1} \begin{bmatrix} A_0 & B_0 \end{bmatrix} \right) \begin{bmatrix} x_{p0} \\ u_{p0} \end{bmatrix} \quad \text{(2)} \\ & + \sum_{q=1}^{j} \left(T_{i-1,j-q} \begin{bmatrix} A_2 & B_2 \end{bmatrix} + T_{i-1,j-q-1} \begin{bmatrix} A_0 & B_0 \end{bmatrix} \right) \begin{bmatrix} x_{0q} \\ u_{0q} \end{bmatrix} \\ & + T_{i-1,j-1} \begin{bmatrix} A_0 & B_0 \end{bmatrix} \begin{bmatrix} x_{00} \\ u_{00} \end{bmatrix} \end{aligned}$$

where $x_{ij} \in R^n$ is the local state vector, $u_{ij} \in R^m$ is the input vector, A_k, B_k $(k = 0, 1, 2)$ are given real matrices, and the transition matrix T_{pq} is defined by

$$T_{pq} = \begin{cases} I \text{ for } p = q = 0 \\ A_0 T_{p-1,q-1} + A_1 T_{p,q-1} + A_2 T_{p-1,q} \text{ for } p, q \geq 0 \\ \quad (p + q \neq 0) \\ 0 \text{ for } p < 0 \text{ or/and } q < 0 \end{cases}$$

Substitution of (2) into (1b) yields the response formula.

restart the act of restarting a hardware or software process.

restoration the act of restoring electric service to a consumer's facility. A distinction is made between restoration and repair as repair implies that whatever was the cause of the outage has been corrected, whereas restoration implies that the power was restored but it may have been through some means other than a repair, for example through switching. *See also* image restoration.

restore instruction an assembly language instruction that restores the machine state of a suspended process to the active state.

retentivity *See* remanence.

reticle *See* mask.

retiming the technique of moving the delays around the system. Retiming does not alter the latency of the system.

retire unit in modern CPU implementations, the module used to assure that instructions are completed in program order, even though they may have been executed out of order.

retrace blanking blanking of a display during vertical retrace to prevent the retrace line from showing on the display.

retrace switch electronic method used to blank a display during retrace blanking.

retrace time amount of time that a blanked vertical retrace takes for a display device. Note that this time is less than the time the display is blanked.

retrograde channel for a MOSFET semiconductor device, the channel region whose doping is less at the surface of the channel than it is at some depth below the surface.

retry a repetition of an operation, disturbed by a transient fault, to obtain good result.

return address the address of an instruction following a Call instruction, where the program returns after the execution of the Call subroutine.

return difference matrix at the input the transfer function matrix relating the difference between the injected and the returned signal in a feedback loop that has been opened at the input. This transfer function matrix characterizes the effect of closing the loop and is the mathematical entity that is central to numerous control engineering theories. For a nonunity feedback configuration with both pre- and postcompensation, it is given by

$$1 + FGK(s)$$

See also return difference matrix at the output.

return difference matrix at the output the transfer function matrix relating the difference between the injected and the returned signal in a feedback loop that has been opened at the output. For a nonunity feedback configuration with both pre- and postcompensation, it is given by

$$1 + GKF(s)$$

See also return difference matrix at the input.

return instruction an instruction, when executed, gets the address from the top of the stack and returns the program execution to that address.

return loss usually expressed in decibels, it is the magnitude of the reflection coefficient; the return loss is a measure of the power reflected due to impedance mismatch of an antenna or other device.

return stroke in lightning, the upward propagating high-current, bright, potential discontinuity following the leader that discharges to the ground some or all of the charge previously deposited along the channel by the leader.

return-to-bias recording *See* magnetic recording code.

return-to-zero recording *See* magnetic recording code.

reusability the possibility to use or easily adapt the hardware or software developed for a system to build other systems.

reuse programming modules are reused when they are copied from one application program and used in another. Reusability is a property of module design that permits reuse.

reuse ratio the ratio of the physical distance between the centers of radio communication cells and the nominal cell radius. This term is usually used with reference to the reuse of particular radio channels (e.g., cochannel reuse ratio).

reverberation inhomogeneities, such as dust, sea organisms, schools of fish, and sea mounds on the bottom of the sea, form mass density discontinuities in the ocean medium. When an acoustic wave strikes these inhomogeneities, some of the acoustic energy is reflected and reradiated. The sum total of all such reradiations is called reverberation. Reverberation is present only in active sonar, and in the case where the object echoes and is completely masked by reverberation, the sonar system is said to be "reverberation-limited."

reverse breakdown the diode operating region in which significant current flows from cathode to anode, due to an applied voltage exceeding the breakdown voltage.

reverse breakdown region the region of the I-V curve(s) of a device in which the device is operating in avalanche or zener breakdown.

reverse breakdown voltage *See* reverse breakdown region.

reverse conducting thyristor (RCT) a variety of asymmetric silicon controlled rectifier in which the diode is integrated into the thyristor structure.

reverse engineering the reverse analysis of an old application to conform to a new methodology.

reverse generation-recombination current part of the reverse current in a diode caused by the generation of hole-electron pairs in the depletion region. This current is voltage-dependent because the depletion region width is voltage-dependent.

reverse isolation device or circuit loss in a path that is the reverse of the path normally desired, expressed as the power ratio in decibels of the RF power delivered to a load at the input port versus the RF power incident at the output port. The negative sign results from the term "loss."

reverse leakage current a nondestructive current flowing through a capacitor subjected to a voltage of polarity opposite to that normally specified.

reverse link *See* uplink.

reverse saturation current part of the reverse current in a diode caused by diffusion of minority carriers from the neutral regions to the depletion region. This current is almost independent of the reverse voltage.

reverse translation buffer *See* inverse translation buffer.

reverse voltage the voltage across the device when the anode is negative with respect to the cathode.

reversible a motor capable of running in either direction, although it may be necessary to rewire the connections to the motor to change the direction of rotation. *See also* reversing.

reversible loss a decrease in magnetic induction (B) of a permanent magnet when subjected to thermal or magnetic demagnetization that is fully recovered (without remagnetization) when the detrimental conditions are removed.

reversible temperature coefficient for permanent magnets, a quantity that indicates the reversible change in magnetic induction with temperature.

reversing a motor that can be run in either direction through the use of suitable switches or contactors.

reversing motor starter a motor controller capable of accelerating a motor from rest to normal speed in either direction of rotation. Some reversing motor starters can go directly from forward to reverse (or vice versa), while others must be stopped before a reversal of direction can take place. Both electromechanical and electronic reversing starters are available.

revolute joint a joint characterized by a rotation angle that is the relative displacement between two successive links.

revolving field the magnetic field created by flow of a set of balanced three-phase currents through three symmetrically displaced windings. The created field revolves in the air-gap of the machine at an angular velocity corresponding to the synchronous speed of the machine. The revolving field theory is the basis of functioning of synchronous and induction machines.

Reynolds number a nondimensional parameter used to determine the transition to turbulence in a fluid flowing in pipes or past surfaces.

RF *See* radio frequency.

RF amplifier amplifier capable of providing gain at radio frequencies.

RF choke a large-valued inductor that exhibits a large reactance at the operating frequency that effectively blocks the RF signal.

RF input power the difference between incident power and reflected power at the input into a device or circuit, expressed in watts. The specific point in the design at which RF input power will be measured is important, since it will affect gain and efficiency calculations.

RF output power the difference in the power available under perfectly matched conditions and the reflected power taking the output return loss into account, expressed in watts. This is the RF power delivered to the load.

RF quadrature part of a radio frequency receiver that contains circuits that can be tuned/varied to pass a desired signal carrier wave while rejecting other signals or carriers.

RF quadrature demodulation radio frequency demodulation of a signal that was produced by two signals separated in phase by 90 degrees.

RF quadrature modulation radio frequency modulation of a signal that is produced by two signals separated in phase by 90 degrees.

RF tuner the part of a radio frequency receiver that contains circuits that can be tuned/varied to pass a desired signal carrier wave while rejecting other signals or carriers.

RFI *See* radio frequency interference.

RFIC *See* radio frequency integrated circuit.

RGB the most widely used image representation, where color is represented by the combination of the three primary colors of the additive light spectrum (*See also* tristimulus value). The RGB space is represented in Cartesian coordinates as a unit cube, where the origin represents black and the point (1, 1, 1) represents white. *See also* color space.

rheobase the minimum current necessary to cause nerve excitation — applicable to a long duration current (e.g., several milliseconds).

rib waveguide a type of dielectric waveguide formed by several planar layers of dielectric media; the upper layer, instead of being planar, presents a ridge (rib) where the field is mostly confined. Used in integrated optics.

Riccati equation a class of equations that arises frequently in statistics and linear systems theory, describing the evolution of the statistics of measured systems. As with the Lyapunov equation, several types exist. In each case, P, Q, R are symmetric positive definite; A, B, C are arbitrary.

Continuous-time, time-varying Riccati Equation:

$$\begin{aligned}\dot{P} = {} & A(t)P(t) + P(t)A^T(t) \\ & + B(t)Q(t)B^T(t) \\ & - P(t)C^(t)R^{-1}(t)C(t)P(t).\end{aligned}$$

Continuous-time algebraic Riccati Equation:

$$0 = AP + PA^T + BQB^T - PC^TR^{-1}CP.$$

Discrete-time algebraic Riccati Equation:

$$\begin{aligned}P = {} & APA^T + BQB^T \\ & - APC^T\left(CPC^T + R\right)^{-1}CPA^T.\end{aligned}$$

See also Lyapunov equation, Kalman filter.

Rice distribution the probability distribution of the magnitude of a complex quantity whose real and imaginary parts are independent Gaussian random variables with nonzero mean. Frequently used to approximate multipath fading statistics in line-of-sight mobile radio systems.

Rice factor for a Rice-distributed signal, the parameter giving the ratio of the power of the static (direct) signal component to the power of the remaining signal components. The remaining signal components (which follow a Rayleigh distribution) are often referred to as the diffuse signal. The Rice factor is a parameter of the Rician probability density function. *See also* fading Rician.

Rician distribution *See* Rayleigh noise.

ridge detection *See* edge detection.

right hand circular polarization the state of an electromagnetic wave in which the electric field vector rotates clockwise when viewed in the direction of propagation of the wave.

rigid body motion motion of bodies that are assumed not to change their shape at all, i.e., deformation is absent or is neglected. In contrast, non-rigid body motion takes deformation into consideration.

rigid link *See* flexible link.

ring bus a power transmission scheme in which a region is supplied by a continuous, closed loop of power transmission lines.

ring coupler a type of planar 180 degree hybrid that can easily be constructed in planar (micro strip or stripline) form.

ring network a network topology where all nodes are connected in a loop. The topology is resilient to breaks in the loop as traffic can be rerouted in either direction. Also known as loop network.

ring numbering for access control, protection scheme in which every memory object is assigned a set of ring numbers and every executing process is assigned a number. The legality of an access attempt is determined by numeric comparisons between the execution ring number and the ring numbers of the object to be accessed. A typical design assigns more privilege to lower numbers, where the system programs reside. If there are three access modes (execute, read, write), three numbers (e, r, w) are assigned to each object. Let p denote the ring number of the executing process. Then execute is permitted if $p < e$, read if $p < r$, and write if $p < w$. This scheme is simple to explain, but does not support general access control policies, since they cannot be mapped to a linear sequence of integer values.

ring resonator resonator in which for much of the mode volume the electromagnetic waves are described in terms of travelling rather than standing waves. Since the ring has no open ends, radiative losses are very small. In such a resonator, the mode volume of the electromagnetic waves are described in terms of travelling rather than standing waves.

ringing (1) the phenomena in discrete-time (sampled data) systems in which a system containing a single pole on the negative real axis in the z-plane can oscillate with a period of twice the sampling interval. Mathematically, this discrete effect can be related back to the discontinuity that exists along the negative real axis in the z-plane.

(2) in image processing, the occurrence of ripples near edges in an image processed by a lowpass filter with a steep transition band.

ripple the AC (time-varying) portion of the output signal from a rectifier circuit.

ripple current the total amount of alternating and direct current that may be applied to an electrolytic capacitor under stated conditions.

ripple-carry adder a basic n-bit adder that is characterized by the need for carries to propagate from lower- to higher-order stages.

RISC *See* reduced instruction set computer processor.

rise time the time required for a digital signal to make the transition from a "low" value to a "high" value.

rise time degradation a measure of the slowing down of the pulse as it passes through an I&P element. It includes both the increase in risetime of the pulse, as well as loss in amplitude.

rising edge in a clock or data signal, that portion of the signal that denotes the change from the "low" state to the "high" state.

RLL *See* run-length limited code.

RMS *See* root-mean-squared error.

RMS delay spread *See* root-mean-squared delay spread.

RMS Doppler spread *See* root-mean-squared Doppler spread.

RMS gain ripple *See* root-mean-squared gain ripple.

RMS phase ripple *See* root-mean-squared phase ripple.

RMS power *See* root-mean-squared power.

RMW memory cycle *See* read-modify-write cycle.

robot a term originated from the Chech word *robota*, meaning work.

A definition used by the Robot Institute of America gives a more precise description of industrial robots: "A robot is a reprogrammable multifunctional manipulator designed to move materials, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of tasks."

The British Robot Association defines a robot as "A reprogrammable device designed to both manipulate and transport parts, tools or specialized manufacturing implements through variable programmed motions for the performance of specific manufacturing tasks."

robot programming language a computer programming language that has special features which apply to the problems of programming manipulators. Robot programming is substantially different from traditional programming. One can identify several considerations that are typical to any robot programming method: The objects to be manipulated by a robot are three-dimensional objects; therefore, a special type of data is needed to operate an object. Robots operate in a spatially complex environment. The description and representation of three-dimensional objects in a computer are imprecise. Also, sensory information has to be monitored, manipulated, and properly utilized. Robot programming languages can be divided into three categories:

1. Specialized manipulator languages built by developing a completely new language. An example is the VAL language developed by Unimation, Inc.

2. Robot library for an existing computer language. It is a popular computer language augmented by a library of robot-specific subroutines. An example is PASRO (Pascal for Robots) language.

3. Robot library for a new general-purpose language. These robot programming languages have been developed by first creating a new general purpose language, and then supplying a library of predefined robot-specific subroutines. An example is AML language developed by IBM.

robot vision a process of extracting, characterizing, and interpreting information from images of a three-dimensional world. This process is also called as machine or computer vision.

robot-oriented programming using a structured programming language that incorporates high-level statements and has the

characteristics of an interpreted language, in order to obtain an interactive environment allowing the programmer to check the execution of each source program statement before preceding to the next one. Robot-oriented programming incorporates the teaching-by-doing method, but allows an interaction of the environment with physical reality. *See also* teaching-by-showing programming.

robust control control of a dynamical system so that the desired performance is maintained despite the presence of uncertainties and modeling inaccuracies.

robust controller design a class of design procedures leading to control systems that are robust in the sense of required performance. Robust design is a feedback process involving robustness analysis. A specific technique used in robust controller design depends on the type of model describing a system and its uncertainty, control objective, and a set of admissible controllers. The first requirement is to ensure robust stability; this could be followed by guaranteed cost, disturbance rejection, robust poles localization, target sets or tubes reachability, or other demands.

Ackermann's three basic rules of robust controller design are as follows:

1. Require robustness of control system only for physically motivated parameter values and not with respect to arbitrarily assumed uncertainties of the model.

2. When you close a loop with actuator constraints, leave a slow system slow and leave a fast system fast.

3. Be pessimistic in analysis; then, you can afford to be optimistic in design.

See also worst-case design, min-max control, practical stabilization, guaranteed cost control, H infinity design.

robust estimation an estimation scheme in which we optimize performance for the least favorable statistical environment among a specified statistical class.

robust fuzzy controller a fuzzy controller with robustness enhancement or robust controller with fuzzy logic concepts.

robust fuzzy filter a fuzzy filter with robustness enhancement or robust filter with fuzzy logic concepts.

robust stability a property of the family of models for the system with uncertainty which ensures that it remains stable for all possible operating conditions for uncertain variables ranging over their sets. For time-invariant linear systems with uncertainty, robust stability means that the family of characteristic polynomials generated by uncertain parameters defined over the operating sets has all roots endowed with negative real parts. *See* Kharitonov theorem. For nonlinear systems, robust stability could be checked by some techniques based on direct Lyapunov method or Popov criterion. In some cases, the requirement of robust asymptotic stability may be weakened by more realistic practical stability or ultimate boundedness demand. *See also* practical stabilization.

robust statistics the study of methods by which robust measures may be extracted from statistical or numerical data, thereby excluding measurements which are unlikely to be reliable and weighting other measurements appropriately, thereby increasing the accuracy of finally assessed values. Of specific interest is the systematic elimination of outliers from the input data. *See also* robustness, median filter.

robustness (1) a control system quality of keeping its properties in the admissible range in spite of disturbances and other environmental perturbations as well as uncertainties in the system model. The most frequent requirements deal with robust stability and robust performance expressed, for example, in terms of guaranteed cost. Robust systems have the property of being insensitive to changes in the model parameters as well as external disturbances. Usually the

system robustness is reached via robust controller design, although systems could be robust in some sense (for example, robustly stable) without use of any special design techniques. It is, for example, well known that for the majority of real-world plants, standard PID controller suitably tuned ensures sufficient robustness. Nevertheless, in many situations, robustness can be guaranteed only by sophisticated design techniques such as H infinity design, min-max control, practical stabilization, guaranteed cost control, and others.

(2) the property of a process that results in its being able to suppress the effects of noisy or unreliable data, thereby arriving at reliable measures or interpretations, and degrading gracefully as more and more unreliable data is included. With image data, robust procedures are those which are able to detect objects without becoming confused by partial occlusions, noise, clutter, object breakages, and other distortions.

ROC *See* receiver operating characteristics curve, region of convergence.

ROI *See* region of interest.

rollback *See* backward error recovery.

Rollett stability factor the inverse of the Linville stability factor (C), K is a measure of potential stability in a 2-port circuit operating under small signal conditions, but standalone is insufficient to guarantee stability. A 2-port circuit that is matched to a positive real source and load impedance is unconditionally stable if $K > 1, B_1 > 0$ (port 1 stability measure), and $B_2 > 0$ (port 2 stability measure). The design must provide sufficient isolation from the RF input and output ports to the bias ports to allow a reasonable interpretation of the "2-port" device criteria.

$$K = \frac{1}{C} = \frac{1 - |s_{11}|^2 - |s_{22}|^2 + |\Delta|^2}{2 \cdot |s_{12} \cdot s_{21}|}$$

where $\Delta = s_{11} \cdot s_{22} - s_{12} \cdot s_{21}$.

rolling ball a method of determining the lightning protection to nearby structures afforded by a tall, well-grounded structure like a steel tower. A shpere with a radius of 45 meters is imagined rolled against the tower. Any structure which can fit within the space defined by the sphere's point of contact with the earth, the base of the tower, and the sphere's point of contact with the tower is considered to be protected by the tower against lightning strikes. *See* cone of protection.

rolloff transition from pass-band to stop-band.

ROM *See* read-only memory.

Romex cable a heavily insulated, non-armored cable used in residential wiring.

root locus the trajectory of the roots of an algebraic equation with constant coefficient when a parameter varies.

root sensitivity the dependence of the poles and zeros of a lumped parameter circuit function on the circuit elements.

Let a lumped parameter circuit function be represented as

$$F(s) = \frac{a_m \prod_{i=1}^{m} (s - z_i)}{d_n \prod_{i=1}^{n} (s - p_i)}$$

where z_i are zeros and p_i are poles. If $F(s)$ is also a function of the circuit element x, the location of these poles and zeros will depend on this element. This dependence is described by the semirelative root sensitivities

$$\mathbf{S}_x(z_i) = x \frac{\partial z_i}{\partial x} \qquad \mathbf{S}_x(p_i) = x \frac{\partial p_i}{\partial x}$$

The calculation of these sensitivities is simplified when zeros and poles are simple (not multiple). For example, for a simple pole p_i, the denominator of the circuit function satisfies the relationship

$$D(p_i) = D_1(p_i) + x D_2(p_i) = 0$$

and one can find that

$$\mathbf{S}_x(p_i) = x\frac{\partial p_i}{\partial x} = -x\frac{D_2(p_i)}{D'(p_i)}$$

where $D'(p_i)$ is the derivative of the polynomial $D(p)$ calculated at the point p_i. For multiple poles, the calculation of the root sensitivity is more involved. The relationship between the function sensitivity and poles and zeros sensitivities can also be established.

root-mean-squared delay spread a measure of the width of a delay power spectrum. Computed for the delay power spectrum in a similar fashion as the standard deviation is computed for a probability density function. Usually known as RMS delay spread.

root-mean-squared Doppler spread a measure of the width of a Doppler power spectrum. Computed for the Doppler power spectrum like the standard deviation is computed for a probability density function. Also known as RMS Doppler spread.

root-mean-squared (RMS) error the square root of the mean squared error.

root-mean-squared gain ripple the difference of the root-mean-squared (RMS) values of the power gain peaks and gain dips relative to the RMS power across a specified band.

root-mean-squared phase ripple the difference of the root-mean-squared (RMS) values of the phase peaks and phase dips relative to a best fit linear phase response across a specified band.

root-mean-squared power the average power, expressed in watts, delivered to the load over a complete period of time (T), as if the current and voltage were constant over that time period.

$$P_{RMS} = \frac{1}{T}\int_0^T p \cdot dt \ .$$

Also known as RMS power or average power.

rotate a logical operation on a data element that shifts each bit one position to the left or right. The bit at the end of the location is transferred to the opposite end of the element.

rotating excitation system an excitation system derived from rotating AC or DC machines. The output of the system is still DC and connected to the rotor.

rotating wave approximation assumption in a semiclassical model for the interaction of light with atoms that all populations, field amplitudes, and polarization amplitudes change negligibly within one optical cycle.

rotating-rectifier exciter an AC generator, with rotating armature and stationary field, whose output is rectified by a solid-state device located on the same shaft to supply excitation to a larger electrical machine, also connected to the same shaft.

rotational latency the time it takes for the desired sector to rotate under the head position before it can be read or written.

rotational loss one of several losses in a rotating electric machine that are primarily due to the rotation of the armature and include the friction and windage losses. Also called mechanical loss. They can be determined by running the machine as a motor at its rated speed at no load, assuming the armature resistance is negligible.

rotational position sensing a mechanism used in magnetic disks, whereby the disk interrupts the I/O controller when the desired sector is under the read/write head. Used to recognize the different sectors in a track and synchronize the different bits in a sector.

rotational transition transition between rotational states of a molecule.

Rotman lens a constrained cylindrical-lens antenna over a wide instantaneous bandwidth as derived by W. Rotman and P. Franchi (1980). The antenna configuration consists of a stripline lens and line feed. The lens layers can use a microstrip printed-circuit construction. Microstrip lines interconnect radiating elements.

rotor the rotating part of an electrical machine including the shaft, such as the rotating armature of a DC machine or the field of a synchronous machine.

rotor power developed the amount of power developed by the rotor. In DC machines, the developed power, frequently denoted by P_d, is calculated as the product of the induced EMF E_a and the armature current I_a. In induction machines, the rotor power developed is obtained by subtracting the rotor copper losses from the air gap power.

rotor power input represents the total power delivered from the armature coil of an induction motor across the air gap to the rotor via the air gap magnetic flux. It is represented, on a per-phase basis, by

$$\begin{aligned} RPI &= I_s^2 \left(R_{2eq}/s\right) \\ &= I_s^2 R_{2eq} + I_s^2 \left(R_{2eq}(1-s)/s\right) \end{aligned}$$

where I_s is the armature coil current, R_{2eq} is the equivalent per-phase rotor resistance reflected to the armature, and s is the rotor slip speed. The first term on the right-hand side represents the ohmic heating power dissipated in the rotor windings, and the second term represents the conversion of electrical to mechanical power by the rotor. *See also* rotor power loss.

rotor power loss represents the portion of the power transferred across the air gap to the rotor of an induction motor that is lost either through ohmic heating of the rotor windings or due to friction and windage losses in the rotor. The mechanical power available at the motor shaft is the difference between rotor power input and rotor power losses. *See also* rotor power input.

rotor reference frame a two-dimensional space that rotates at the electrical angular velocity of a specified machine rotor. 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 derived in which the physical variables of the system (voltage, current, flux) are referred to variables of the fictitious windings. *See also* Park's transformation, arbitrary reference frame, synchronous reference frame, stationary reference frame.

rotor speed quantification of the rotational operation of the moving part of a rotating electrical machine. The rotor speed is measured either in SI units in radians per second (rad/s) or in practical units in revolutions per minute (rev/min).

rough surface surface whose corrugation is random and appreciable compared with the light wavelength so as to produce light scattering. It is commonly characterized by the root mean square and the correlation length of the random height profile.

round-robin arbitration a technique for choosing which of several devices connected to a bus will get control of the bus. After a device has had control of the bus, it is not given control again until all other devices on the bus have been given the opportunity to get control in a predetermined order. The opportunity to get control of the bus circulates in a predetermined order among all the devices.

rounding an operation that modifies a floating-point representation considered infinitely precise in order to fit the required final format. Common rounding modes include round to nearest, round toward zero, and round toward positive or negative infinity.

router a node, connected to multiple networks, that forwards packets from one network to another. It is much more complex than bridges that work between networks having compatible protocols. Also called a gateway.

routing given a collection of cells placed on a chip, the routing routine connects the terminals of these cells for a specific design requirement.

row decoder logic used in a direct-access memory (ROM or RAM) to select one of a number of rows from a given row address. *See also* two-dimensional memory organization.

row-access strobe *See* two-dimensional memory organization.

RS flip-flop a single-bit storage element, usually formed by connecting two NOR or NAND gates in series. RS stands for reset–set. For state variable Q and next state variable Q', the simplified truth table is given as

R	S	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	X
1	1	1	X

the symbol "X" is used to denote an unknown state for the flip-flop. *See also* JK flip-flop.

RS-170A technical standard developed by the Electronics Industry Association that describes in detail the relationship between vertical, horizontal, and subcarrier components within a video signal. The standard permits synchronization of two or more video signals.

RS-422 technical standard developed by the Electronics Industry Association that defines the exact physical, electrical, and functional characteristics for a 40-pin connector that links a computer to communication equipment.

RSGNN *See* recursive self-generating neural network.

RSSI *See* received signal strength indicator.

RTB reverse translation buffer. *See* inverse translation buffer.

RTU *See* remote terminal unit.

rubbers personal protective wear for line workers, including insulating gloves, sleeves, and rubber boots.

ruby amplifying medium employed in the first man-made optical frequency laser.

ruby laser first man-made optical frequency laser.

run winding the main winding of a single-phase induction motor.

run-length coding the assignment of a codeword to each possible run of 0s (white pel sequence) or run of 1s (black pel sequence) in a scan of the subject copy.

run-length encoding *See* run-length limited code.

run-length limited (RLL) code a line code that restricts the minimum and/or maximum number of consecutive like-valued symbols that can appear in the encoded symbol sequence.

running digital sum the difference between cumulative totals of the number of logic 1s and number of logic 0s in a binary sequence. It is a common measure in the performance of a line code.

running integral for the function $x(t)$, the running integral, $y(t)$ is $y(t) = \int_{-\infty}^{t} x(\tau)d\tau$.

An example of a running integral is the unit step $u(t) = \int_{-\infty}^{t} \delta(\tau)d\tau$, where $\delta(t)$ is the unit impulse function.

S

S-100 a 100-pin bus formerly used by computer hobbyests and experimenters.

S-matrix *See* scattering matrix.

S-parameters *See* scattering parameters.

S-plane the domain of the Laplace transform $F(s)$ of a complex-valued function $f(t)$. Since s is a complex number, the domain of $F(s)$ is the complex plane. The line $s = j\omega$, where ω is a real number, corresponds to where $F(s)$ is the Fourier transform of $f(t)$.

S/H *See* sample-and-hold amplifier.

saddle a U-shaped piece of wire which is crimped to a main conductor so that a hot tap *cf.* can be readily attached at a later time.

saddle-point equilibrium an equilibrium in zero-sum game constituted by a pair of security strategies of the players. The necessary and sufficient condition for existence of the saddle point is equality of the security levels for both players. If J_i denotes a cost function of the zero-sum game and $d_i; i = 1, 2$ a strategy of the ith player, then a pair d_1^*, d_2^* is in saddle-point equilibrium iff

$$J\left(d_1^*, d_2\right) \leq J\left(d_1^*, d_2^*\right) \leq J\left(d_1, d_2^*\right)$$

for all admissible (d_1, d_2). Depending of the type of game, the meaning of the cost functional and strategies and the specific conditions for the existence of the saddle point may vary. If the equilibrium in pure strategies does not exist and the game is played many times in the same conditions, then the saddle point may be defined for average values of the cost function and for mixed strategies defined as probability distributions on the spaces of pure strategies.

Safe Medical Devices Act (SMDA) a public law that imposes reporting requirements on "device-user facilities" including hospitals, ambulatory surgical facilities, nursing homes, and outpatient clinics. They are required to report information that "reasonably suggests" the probability that a medical device has caused or contributed to the death, serious injury, or serious illness of a patient at that facility.

Safeguard a program administered by the International Atomic Energy Agency comprising procedures and inspections which assure that fissile materials from power reactors are not diverted to nuclear weapons use.

safety the probability that a system will either perform its functions correctly or will discontinue its functions in a well-defined, safe manner.

safety-critical system a system that is intended to handle rare unexpected, dangerous events.

sag a decline ranging from 0.1 to 0.9 pu in RMS voltage or current at the supply frequency for a time period of 0.5 cycles to 1 minute.

Sagittal projection a projection of a 3-dimensional object onto a 2-dimensional plane which intersects the object in a front to back direction dividing the objects into right and left halves. Typically with reference to an animal or human body.

Sagnac interferometer a common path interferometer devised by Georges Sagnac to measure the ether wind, then adapted as an optical gyroscope, and most recently utilized for hyperspectral imaging. A Sagnac interferometer is composed of two coils of optical fiber arranged so that light from a single

source travels clockwise in one and counterclockwise in the other.

Sagnac logic gate an all-optical gate based on a Sagnac interferometer.

Sagnac, Georges (1869–1928) Born:

French scientist and professor at the University of Lille and the University of Paris, active in the investigation of radiation produced by X-rays, and the optics of interference. The inventor of the common path Sagnac interferometer.

sail switch a device used in control systems that detects the flow of air, or other gas, and causes a relay to open or close as a result of the motion of the sail.

salient feature a characteristic often local feature on an object which can be detected and used as part of the process of inferring the presence of an object from its features. Typical salient features include point features such as corners and small holes, or fiducial marks (e.g., on printed circuit boards), but may in addition include large-scale straightforwardly detected features such as large circular holes which can also aid the inference process.

salient-pole drive *See* synchronous drive.

salient-pole rotor machine AC motor/generator design in which the rotor is constructed of outward-projecting pole pieces mounted on a shaft-mounted central spider assembly. Spider assemblies are typically spoked. Pole pieces are built up from laminated sheets, which are bolted together between a pole shoe on the outer end and dovetail fixture on the inner end. The dovetails are keyed into slots on the spider to mount the pole pieces to the rotor. Rotor windings are generally constructed from preformed, insulated coils that are fit over the pole pieces during assembly. Salient rotors are typically low-speed designs with short axial length and large diameter.

salt and pepper noise *See* impulse noise.

SAM *See* standard additive model.

samarium cobalt a brittle, high-energy magnetic material that is best known for its performance at high temperatures, which comes in two compositions, $SmCo_5$ and a higher energy Sm_2Co_{17}.

sample a single measurement that is taken to be representative of the measured property over a wider area, frequency range, or time period. When recording digital sound, a sample is a voltage measurement that reflects the intensity of the acoustic signal at a particular moment, and has a time period associated with it, that is, the sample represents the signal until the next measurement is made. In a digital image, a sample is a single measurement of light intensity at a particular point in the scene, and that measurement is used to represent the actual but unmeasured intensity at nearby points.

sample complexity the number of training examples required for a learning system to attain a specified learning goal.

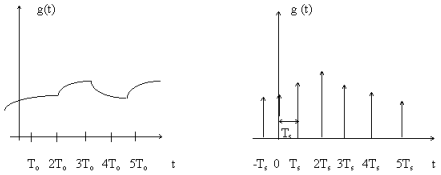
sample space the set of all possible samples of a signal, given the particular parameters of the sampling scheme.

sample-and-hold *See* sample-and-hold amplifier.

sample-and-hold amplifier (SHA) a unity gain amplifier with a mode control switch where the input of the amplifier is connected to a time-varying signal. A trigger pulse at the mode control switch causes it to read the input at the instance of the trigger and maintain that value until the next trigger pulse. Usually the signal is electrical, but other forms, such as optical and mechanical forms, are possible. Also denoted S/H.

sample-and-hold circuit a device with a mode control switch that causes reading the input at the instance of the trigger and maintaining that value until the next trigger pulse.

sampling the act of turning a time-continuous signal into a signal that is time-discrete or time-discontinuous. See the following diagrams, where T_S is the sampling period.



The sampling process.

In order to maintain frequency components of interest in the time-discontinuous signal, the Nyquist sampling criterion needs to be satisfied. This criterion states that the rate of sampling of the time-continuous signal has to be at least twice as great as the frequency of the signal component with the highest frequency which is of interest in the time-continuous signal. Sampling is very common in digital recording and digital communication systems.

sampling frequency in analog-to-digital conversion, the rate or frequency at which an analog signal is sampled and converted into a digital signal.

sampling function a mathematical function used when sampling a signal. In particular, a sampling function $S(t)$ can be multiplied by the continuous function to be sampled, $F(t)$, to obtain the sampled version of F. S is most often a collection of equally spaced impulses.

sampling period the period for which the sampled variable is being held constant.

sampling process *See* sampling.

sampling rate *See* sampling frequency.

sampling theorem *See* Shannon's sampling theorem.

SAR *See* synthetic aperture radar or specific absorption rate.

satellite cell cell with the radius larger than 500 km where the cell is controlled by a satellite. *See also* cell.

satellite imagery the acquisition of pictures of the earth from space. Satellite imagery can be used to enhance maps, collect resource inventories (e.g., forestry, water, land use), assess environmental impact, appraise damage following a disaster, and collect information on the activities of humans. Satellite imagery tends to be multispectral, including a wide range of optical frequencies and, more recently, infrared and radar. *See also* remote sensing.

saturable absorber the nonlinear optical phenomenon in which the absorption coefficient of a material decreases as the intensity of the light used to measure the absorption increases.

saturable absorption the effect of there being less absorption in a material for larger values of the incident illumination.

saturated gain value of the gain in a saturable amplifier for a particular value of intensity.

saturated logic logic gates whose output is fully on or fully off, determined principally by the external circuit.

saturating control a controller producing a bounded control signal. Finite limits on the magnitude of the control signals that are provided by the actuators are due to the fact that the actuators are physical devices and as such are subject to physical constraints.

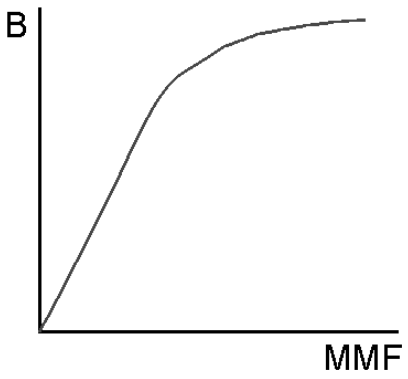
Thus, the actuator saturates, that is, it has "limited authority."

saturation (1) the failure of the output to increase as fast as the input.

For example, often the current regulator used in variable-speed drives is unable to track the commanded current because of insufficient voltage difference between the motor back EMF and the supply.

In an amplifier, saturation results in a reduction of gain in an amplifier or loss in an absorber due the intensity of the signal being amplified or absorbed.

In ferromagnetic circuits, the magnetic flux initially increases linearly with the applied magnetomotive force (MMF), but eventually most of the domains in the ferromagnetic material become aligned, and the rate of increase in flux decreases as the MMF continues to increase. See figure below. *See also* saturation flux density.



Saturation effect in a ferromagnetic circuit.

(2) with respect to color, the amount or purity of the color seen. A pure color is said to be fully saturated, and the saturation decreases as white is added to the mix. The color "pink," for example is a less saturated version of "red."

saturation angle the angular portion of the time-based output signal (in degrees) over which the device is saturated. It is always less than or equal to the conduction angle, since the device must conduct before it can saturate.

saturation flux density the maximum value of intrinsic induction (B_i) beyond which an increase in magnetizing field yields no further improvement, indicating that all magnetic moments in the material have been aligned.

saturation intensity the intensity of a beam of light above which saturation effects become appreciable. *See also* saturable absorption.

saturation magnetization the magnetic moment per unit volume of a material when the magnetization in the sample is aligned (saturated) by a large magnetic field.

saturation parameter reciprocal of the value of intensity for which the gain of an amplifying medium or the loss of an absorbing medium is reduced to one half of its unsaturated value.

saturation polarization the value to which the externally measured electrical dipole moment of a ferroelectric body tends when subjected to an external electrical field greater than the coercive field.

save instruction an assembly language instruction that saves information about the currently executing process.

SAW *See* surface acoustic wave.

SAW device *See* surface acoustic wave device.

saw-tooth coupler transmission line coupler consisting of two parallel transmission lines placed in close proximity to one another. The adjacent edges of the two transmission lines are shaped in a notch or saw-tooth pattern to equalize the phase velocity of the even and odd mode voltage components.

SCA *See* subsidiary communication authorization and station control error.

SCADA acronym for supervisory control and data acquisition. A system which measures critical power system parameters (e.g., voltage, power flow, circuit breaker status, and generator outputs) at remote points in an electric power system and transmits the data to a central control site where these conditions may be monitored.

scalable video coding compression of video such that transmission at different data rates, or reception by decoders with differing performance, is possible merely by discarding or ignoring some of the compressed bitstream, i.e., without recoding the data. The compressed data are prioritized such that low-fidelity reconstruction is possible from the high-priority data alone; addition of lower-priority data improves the fidelity.

scalar network analyzer a test instrument designed to measure and process only the magnitude of transmitted and reflected waves. Used to measure such microwave characteristics as insertion loss, gain, return loss, SWR, and power.

scalar processor a CPU that dispatches at most one instruction at a time.

scalar quantization (SQ) (1) quantization of a scalar entity (a number; as opposed to vector quantization), obtained, e.g., from sampling a speech signal at a particular time-instant. Each input value to the quantizer is assigned a reproduction value, chosen from a finite set of possible reproductions. A device performing scalar quantization is called a (scalar) quantizer.

(2) a type of quantization in which a scalar quantity is quantized into another scalar quantity.

scalar wave wave that can be described by a single scalar function of space and time.

scalar wave equation in optics, a simplification of the Maxwell–Heaviside equations that governs a single scalar function representing an electromagnetic wave; sometimes a complex equation if the waves are harmonic in time.

scale (1) a property of an image relating the size of a pixel in the image to the size of the corresponding sampled area in the scene. A large scale image shows object features in more detail than a small scale image. (*See also* resolution.)

(2) to change the size (i.e., enlarge or shrink) of an image or object while maintaining the overall proportions.

(3) one of two parameters of a wavelet, the other being translation. The scale specifies the duration of the wavelet.

scaled processor architecture (SPARC) name for a proprietary class of CPUs.

scaling function the solution to the multiscale equation; it can be obtained by iterating a low pass filter in the two-channel filter bank an infinite number of times.

scan design a technique whereby storage elements (i.e., flip-flops) in an IC are connected in series to form a shift-register structure that can be entered into a test mode to load/unload data values to/from the individual flip-flops.

scan line in a digital image, a contiguous set of intensity samples reflecting one row or column of the image. A class of image processing algorithms, called scan line or scan conversion methods, looks at the image one or two scan lines at a time in order to achieve the goal.

scan tape *See* helical scan tape.

scan-based testing a mechanism for accessing all the data in a hardware module by treating it as one long shift register and then shifting the data out of the module one bit at

a time. A device with this capability can also be set to any desired state by shifting in the desired state. The method can also be applied to software objects.

scan-test path a technique that enhances circuit observability and controllability by using a register with shift (in test mode) and parallel load (during normal operation) capabilities.

scanner (1) a device used for scanning written documents or printed pictures by tracing light along a series of many closely spaced parallel lines.

(2) any device that deflects a light beam through a range of angles, using mechanisms such as diffraction from electro-optic or acousto-optic gratings or mechanical deflectors.

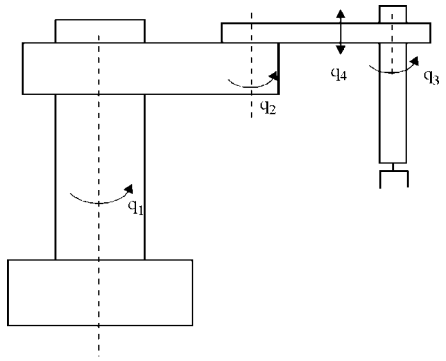
(3) a type of projection printing tool whereby the mask and the wafer are scanned past the small field of the optical system that is projecting the image of the mask onto the wafer.

scanning process for converting attributes of a display at raster coordinate locations, such as color and intensity, into a fixed set of numerical attributes for manipulation, transmission, or storage of the display.

scanning tunneling microscope extremely sensitive method for measuring atomic position at a surface by monitoring the electron current due to tunneling between a moveable metal tip and the surface semiconductor.

scara manipulator a robot with three parallel revolute joints allowing it to move and orient in a plane (q_1, q_2, q_3) with a fourth prismatic joint (q_4) for moving the end-effector normal to the plane. Usually scara manipulators can move very fast and they are used to assemble the parts.

scattering (1) the process by which a radio wave experiences multiple reflections



A scara manipulator.

from a surface or a volume of the propagation medium.

(2) the area of electromagnetics that deals with finding the total fields in a region that contains an incident field and one or more objects (scatters) in the region. The total field is the sum of the incident field when no objects are present, plus the additional field produced when the objects are present.

scattering cross section total energy scattered in all directions, normalized to the wavenumber squared. It has dimensions of area.

scattering function the scattering function is a function of two variables, delay and Doppler shift, characterizing the spread of average received signal energy over time and frequency. In a nondispersive channel (no multipath and no Doppler shift), the scattering function is simply an impulse at zero delay and zero Doppler shift.

scattering holography recovery of the phase of the scattered light by means of its interference with a reference beam, both emanating from the same coherent source, such as the same laser beam.

scattering matrix a $n \times n$ square matrix **S** of complex numbers used to relate an array of incident waves, **a**, and one of reflected waves, **b**, for an n-port network representing a waveguide component or discontinuity. Generally, each matrix element (called

a scattering parameter) is the amplitude of a reflected or transmitted wave to that of an incident wave. The subscripts of a typical coefficient S_{ij} refer to the output and input ports related by the coefficient. These coefficients are generally frequency-dependent and are relative at a specified set of input and output reference planes. The scattering matrix is defined with respect to a specific set of port terminations (normalizations).

Physical interpretations can be given to the scattering coefficients; for example, S_{ij}^2 is the fraction of available power at port i due to a source at port j. The incident and reflected wave amplitudes at port i, a_i, and b_i, respectively, are obtained from the voltage and current, V_i, I_i, at the same port as

$$a_i = \frac{1}{2}\,|ReZ_i|^{-1/2}\,(V_i + Z_i I_i)$$
$$b_i = \frac{1}{2}\,|ReZ_i|^{-1/2}\,\left(V_i - Z_i^* I_i\right)$$

where Z_i is the reference impedance and the asterisk denotes the complex conjugate. It is also known as S-matrix.

scattering parameters parameters that characterize a microwave network with an arbitrary number of ports by relating the voltage waves incident on the ports to those reflected from the ports. Also known as S-parameters. The scattering parameters are often represented in terms of a scattering matrix. *See also* scattering matrix.

scattering resonance sharp increase (or decay) of the scattered energy as a function of either frequency or observation direction, as for the glory or the rainbow.

scatterometer a device to measure the angular distribution of scattered intensity. Its main component contains a photodetector mounted over a goniometer.

scene analysis the process of analyzing a 3-D scene from 2-D images. Typically, this process will involve object and feature detection, inference of the presence of objects from their features, projective invariance properties, analysis of the play of light on surfaces, including approaches such as texture analysis, and many other types of procedure.

scheduler a part of the operating system for a computer that decides the order in which programs will run.

scheduling in an operating system, scheduling of CPU time among competing processes.

schematic a diagram that shows how an electronic device is constructed.

schematic capture a design entry method wherein the designer draws the schematic of the desired circuit using a library of standard cells. The program outputs a netlist of the schematic.

schematic diagram a circuit diagram, divorced of biasing subcircuits, that depicts only the dynamic signal flow paths of an electronic circuit.

Schmoo plot an X-Y plot giving the pass/fail region for a specific test while varying the parameters in the X and Y coordinates.

Schottky barrier diode a two-terminal junction barrier device formed by a junction of a semiconductor and a metal. These diodes are widely used in integrated circuit applications and in very high frequency mixer and multipliers. Also called hot-carrier diode.

Schottky contact a metal-to-semiconductor contact where, in order to align the Fermi levels on both sides of the junction, the energy band forms a barrier in the majority carrier path.

Schottky noise *See* shot noise.

Schrödinger wave equation (SWE) an important relationship in quantum mechanics

that describes the energy states of electrons. In its time-independent form it is expressed as

$$\frac{(h/2\pi)^2}{2m} = \nabla^2\phi_n + (E_n + qV)\,\phi_n = 0$$

where ϕ_n is the wave function corresponding to the subband n whose minimum energy is E_n, V is the potential of the region, m is the particle mass, and h and q are Planck's constant and the electronic charge, respectively.

Schur matrix a square matrix with real elements and whose all eigenvalues have absolute values less than one.

scientific visualization the use of computer graphics techniques to represent complex physical phenomena and multidimensional data in order to aid in its understanding and interpretation.

scintillation the variation of electromagnetic signal strength with time due to random changes in time of refractive index of the atmosphere. Apparent at optical frequencies as the twinkling of stars.

scoreboard term originally used for a centralized control unit in the CDC 6600 processor which enabled out-of-order issue of instructions. The scoreboard unit held various information to detect dependencies. Now sometimes used for the simpler mechanism of having a single valid bit associated with each operand register.

scotopic formally, a description of luminances under which human rod cells are active. Informally, describing dim or nighttime luminances.

scotopic vision vision in the eye determined by the number of and condition of the rods in the eye. Also called night vision.

SCP *See* service control point.

SCR *See* silicon controlled rectifier.

scram the emergency shutdown of a nuclear reactor by the rapid insertion of all control rods. The term is attributed to Enrico Fermi.

scrambling randomization of a symbol sequence using reversible processes that do not introduce redundancy into the bit stream. *See also* reset scrambling, self-synchronizing scrambling.

scrubber a means of removing sulfur dioxide from coal-burning power plant exhaust gas by forcing it through a chemical solution.

SCSI *See* small computer systems interface.

SDH *See* synchronous digital hierarchy.

SDRAM *See* synchronous dynamic RAM.

SDS *See* structured distribution systems.

seal-in relay an auxiliary relay that remains energized through one of its own contacts, which bypasses the initiating circuit until deenergized by some other device.

sealing current the current necessary to complete the movement of the armature of a magnetic circuit closing device from the position at which the contacts first touch each other.

sealing voltage the voltage necessary to complete the movement of the armature of a magnetic circuit closing device from the position at which the contacts first touch each other.

search coil a solenoid that is wound with an air core or around a magnet or permeable component of a magnetic circuit to measure

the change of flux within the coil; used with a fluxmeter.

SECAM *See* sequential color and memory.

second harmonic component the signal component of a periodic signal whose frequency is twice the fundamental frequency.

second order discrete time system a discrete system for which the difference between the input and output signals is of second order.

second order system a continuous time system described by a second order differential equation.

second-harmonic generation the process in which a laser beam of frequency ω interacts with a material system to produce a beam at frequency 2ω by means of the second-order susceptibility. Under carefully controlled circumstances, more than 50% of the incident intensity can be converted to the second harmonic. *See also* harmonic generation.

second-order susceptibility a quantity, often designated χ^2, describing the second-order nonlinear optical response of a material system. It is defined through the relation $P^2 = C\chi^2 E^2$, where E is the applied electric field strength and P^2 is the 2nd-order contribution to the material polarization. The coefficient C is of order unity and differs depending on the conventions used in defining the electric field strength. The second order susceptibility is a tensor of rank 3, and describes nonlinear optical processes such as second-harmonic generation, sum- and difference-frequency generation, and optical rectification. *See also* nonlinear susceptibility.

secondary (1) the load-side winding.

(2) refers to the portion of a nuclear power plant containing non-radioactive components such as turbines and generators.

secondary cache a buffer element between slow-speed peripheral devices, such as disks, and a high-speed computer.

secondary distribution system a distribution system in which a significant the subdivision of power to customers is done on the secondary, or low-voltage side of the distribution transformer, as opposed to the practice of assigning a small distribution transformer to each customer or small group of customers.

secondary memory generic term used to refer to any memory device that provides backup storage besides the main memory. Secondary memory is lower-level, larger capacity, and usually a set of disks.

Only data and programs currently used by the processor reside in main memory. All other information (not needed at a specific time) is stored in secondary memory and is transferred to main memory on a demand basis. It is the highest (big but slow) level in the memory hierarchy of modern computer systems.

secondary resistor a resistor connected to the rotor of a wound-rotor induction machine to permit variation of the effective rotor resistance. By varying the resistance, machine characteristics may be optimized for starting or varying load conditions.

secondary selective service a redundant electric service in a critical load is supplied by two distribution transformers, each of which is served by a separate, independent distribution primary circuit.

secondary service refers to areas serviced by skywaves and not subject to objectionable interference.

secondary side that side of the packaging and interconnecting structure farthest from layer number one. (Also called the soldier side in through-hole component mounting technology.)

secondary storage *See* secondary memory.

secondary system of equations a system of algebraic and differential equations obtained from the primary system of equations by transformation of network variables.

secondary voltage in power distribution work the voltage at the secondary of the distribution transformer.

secondary voltage control an automatic voltage control scheme that is similar in function to the automatic voltage regulator, but its purpose is to control a bus voltage which need not have a synchronous generator connected at the bus.

secondary winding the transformer winding to which the loads are connected. *See also* primary winding.

sectionalizer a switch placed in distribution lines and programmed to open during a line dead time. The sectionalizer will sense the presence of current surges due to faults, and is programmed to open after a set number of faults occur during a short period of time. When the fault is cleared by the protecting recloser or circuit breaker, the sectionalizer will open, allowing the recloser or breaker to successfully reenergize the portion of the line upstream from the sectionalizer.

sectionalizing fuse a sectionalizing fuse is a fuse employed on the primary distribution system to isolate laterals from the main feeder in the event of a fault on that lateral.

sectionalizing switch a switch on primary distribution systems used to isolate laterals and segments of main feeder lines. On radial distribution systems, sectionalizing switches are placed to allow rerouting of power to minimize extended outages following a line segment failure.

sector *See* disk sector.

sector mapping a cache organization in which the cache is divided into sectors where each sector is composed of a number of consecutive lines. A complete sector is not transferred into the cache from the memory; only the line requested. A valid bit is associated with each line to differentiate between lines of the sector that have been transferred and lines from a previous sector. Originally appeared in the IBM System/360 Model 85.

sectorization the action of modifying an omnidirectional antenna in a cellular system so that it is replaced by a number of directional antennas each having a radiation pattern approximately covering a sector of a circle. Common examples in cellular systems are those of sectorization with three sectors per cell (120 degree sectors) and sectorization with six sectors per cell (60 degree sectors).

security the ability of the power systems to sustain and survive planned and unplanned events without violating operational constraints.

security analysis *See* contingency analysis.

SEED *See* self-electro-optic device.

seek time the time that it takes to position the read/write device over a desired track of information.

segment a region in computer memory defined by a segment base, stored in a segment base register and, usually, a segment limit, stored in a segment limit register. *See also* virtual memory.

segment mapping table a memory table within a computer that is used to translate logical segment addresses into physical memory addresses.

segment register a register that stores the base, or starting memory address, of a memory segment.

segment table a table that is used to store information (e.g., location, size, access permissions, status, etc.) on a segment of virtual memory.

segmentation (1) an approach to virtual memory when the mapped objects are variable-size memory regions rather than fixed-size pages.

(2) the partitioning of an image in mutually exclusive elements in which visual features are homogeneous. Region-based segmentation relies on the analysis of uniformity of grey level or color; contour-based segmentation relies on the analysis of intensity discontinuities.

segmentation-based coding a coding scheme that is based on segmentation. *See* segmentation.

segmented architecture in computer architecture, a scheme whereby the computer's memory is divided up into discontinuous segments.

selective controllability a dynamical system is said to be selectively controllable with respect to the ith state variable by jth control variable in $[t_0, t_1]$ if all the dynamical systems with scalar admissible controls $u_j(t), j = 1, 2, \ldots, m$ have the ith state variable $x_i(t), i = 1, 2, \ldots, n$ controllable in $[t_0, t_1]$.

selective fuse coordination *See* fuse coordination.

selectivity the ability of a receiver to receive only its desired band of frequencies and reject those on either side. This not only improves the signal properties but also the noise characteristics of the receiver.

selector channel I/O channel that handles only one I/O transaction at a time. Normally used for high-speed devices such as disks and tapes. *See also* multiplexer channel.

self organizing map (SOM) a neural network that transforms a multi-dimensional input to a 1- or 2-D topologically ordered discrete map. Each neuron has a weight vector $\vec{w}_j$ and for a given input $\vec{x}$, the output is the index of the neuron with minimum Euclidean distance. During training, the weights are updated as

$$\vec{w}_j(n+1) = \begin{cases} \vec{w}_j(n) + \alpha(n)[\vec{x} - \vec{w}_j(n)], & C_j \in N(C_i, n) \\ \vec{w}_j(n), & C_i \notin N(C_j, n) \end{cases}$$

where α is a learning parameter in the range $0 < \alpha < 1$, and $N(C_i, t)$ is the set of classes which are in the neighborhood of the winning class C_i at time t. Initially, the neighborhood may be quite large during training, e.g., half the number of classes or more. As the training progresses, the size of the neighborhood shrinks until, eventually, it only includes the one class.

self-arbitrating bus a communication bus that is capable of resolving conflicting requests for access to the bus.

self-bias a technique employed whereby a transistor only needs a single bias supply voltage between the drain terminal and ground. This is commonly accomplished by placing a parallel combination of a resistor and capacitor between the source terminal and ground.

self-biased amplifier an amplifier that utilizes a voltage-controlled current source as the active device (such as a MESFET), and in which a series resistive feedback element in the DC current path creates the DC voltage required to control the quiescent bias point, thereby resulting in the need for a single bias supply.

self-checking pertaining to a circuit, with respect to a set of faults, if and only if it is fault-secure and self-testing.

self-commutated *See* natural commutation.

self-demagnetizing field a field inside of a permanent magnet that is opposed to its own magnetization, which is due to internal coupling of its poles following the introduction of an air gap in the magnetic circuit.

self-electro-optic device (SEED) a bistable device that is a PIN photodetector and also an optical modulator; the intrinsic region is generally constructed as a quantum-well stack. Detection of light alters the electrical bias on the PIN, which in turn alters the transmission through the device; the optical transmission change exhibits hysteresis and a two-state transmission character.

self-focusing focusing of an electromagnetic beam in a nonlinear medium by the gain or index profile resulting from the action of the beam on the medium.

self-generating neural network (SGNN) networks of self-organizing networks, each node network of which is an incomplete self-organizing network. For this kind of network of neural networks, not only the weights of the neurons but also the structure of the network of neural networks are learned from the training examples.

SGNN can be as complex as acyclic directed graph, but the most frequently used SGNN takes a tree structure and is called a self-generating neural tree (SGNT), which is very similar to self-organizing tree but with much higher ratio of neuron utilization. Since many fewer neurons participate in the competition during the training and classification, the speed of SGNT is much faster. SGNN has found applications in diagnosis of communication networks, image/video coding, large-scale Internet information services, and speech recognition. *See also* self-generating neural tree, self-organizing neural tree.

self-generating neural tree (SGNT) a simplified version of self-generating neural network with a tree structure. SGNT is normally much faster in training and classification, but with less descriptive power compared with the corresponding SGNN because of its simple topological structure. However, if the number of network nodes is the same, SGNT has the same descriptive power, higher ratio of neuron utilization, higher speed, and may end up with higher accuracy, since large-scale networks can be generated and trained quickly. *See also* self-generating neural network, self-organizing neural tree.

self-modifying code a program using a machine instruction that changes the stored binary pattern of (usually) another machine instruction in order to create a different instruction which will be executed subsequently. Definitely not a recommended practice and not supported on all processors.

self-organizing algorithm a training algorithm for a self-organizing system consisting of the following main steps:

1. Calculate the similarities of the training vector to all the neurons in the system and compare them to find the neuron closest to the training vector, i.e., the winner.

2. Update the weights of the winner and its neighborhood according to

$$w_i(t+1) = w_i(t) + \alpha\,(x_i(t) - w_i(t))\,,$$

where $w_i(t)$ is the ith weight of the neuron at time t, $x_i(t)$ is the ith component of the training vector at t, and α is a training rate. The neighborhood of the winner starts from a bigger area and reduces gradually during the training period.

self-organizing neural tree (SONT) a tree-like network of self-organizing neural networks, each node of which is a Kohonen network. Each of the neurons in the higher level networks has its child network

in the lower level of the tree hierarchy. The training method is similar to that of Kohonen's method, but is conducted hierarchically. From the top (root) of the tree down, the winner of the current self-organizing network is found as the closest neuron to the training example. The weights of the winner and its neighbors are updated, and then the child network of the winner will be selected as the current network for further examination until a leaf node network is encountered. This kind of network of neural networks can be useful for complex hierarchical clustering/classification. However, the utilization of the neurons may become poor as the network size growing if the uniform tree structure is adopted. The utilization may be improved if carefully designed structure is used but how to obtain an optimum structure remains an issue. Self-generating neural network (SGNN) may be a solution to this problem. *See also* self-organizing system, self-generating neural network.

self-organizing system a class of unsupervised learning systems that can discover for itself patterns, features, regularities, correlations, or categories contained in the training data, and organize itself so that the output reflects these discovery.

self-phase modulation the nonlinear optical process in which a pulse of light traveling through a material characterized by an intensity-dependent refractive index undergoes spectral broadens as a result of the time-varying phase shift imparted on the beam.

self-pumped phase conjugator (SPPC) a phase conjugator that does not require the external pumping beams. Optical four-wave mixing is a convenient method for the generation of phase conjugate waves. However, the process requires a pair of counterpropagating pump beams. With a self-pumped phase conjugator, an incident beam will pump the photorefractive medium and generate its own phase conjugate wave. There are many physical mechanisms that can yield self-pumped phase conjugation, for example, SPPC with resonators, SPPC with semiresonators, SPPC with stimulated backward scattering, etc.

self-synchronizing scrambling a technique that attempts to randomize a source bit stream by dividing it by a scrambling polynomial using arithmetic from the ring of polynomials over $GF(2)$. Descrambling is performed with only bit-level synchronization through continuous multiplication of the demodulated sequence by the same scrambling polynomial. The division and multiplication procedures can be implemented with simple shift registers, enabling this technique to be used in very high bit rate systems.

self-test a test that a module, either hardware or software, runs upon itself.

self-test and repair a fault-tolerant technique based on functional unit active redundancy, spare switching, and reconfiguration.

self-testing pertaining to a circuit, for a set of faults, if and only if for any fault in this set there exists a valid input code such that the circuit output is noncorrect (does not belong to the valid output codes, i.e., can be detected with a code checker).

Selfoc lens a type of gradient-index lens, using a refractive-index profile across the cross section of the element, typically a cylinder; the profile is generally produced by implantation. *See also* gradient index optics.

selsyn *See* synchro.

semaphore a synchronization primitive consisting of an identifier and a counter, on which two operations can be performed: lock, to decrease a counter, and unlock, to increase a counter.

semi-classical model model for the interaction of light with atoms or molecules in which the atomic or molecular wave func-

tions are described by Schrödinger's equation, while the electromagnetic fields are described by the Maxwell–Heaviside equations.

semi-guarded machine a machine in which some of the ventilating openings, usually in the top half, are guarded as in the case of a guarded machine to prevent accidental contact with hazardous parts, but the others are left open.

semi-insulator *See* semiconductor.

semi-magnetic semiconductor semiconductor alloy or superlattice, usually from the II-VI columns of the periodic table, in which there is a concentration of magnetically active atoms such as manganese that introduce new magneto-optical and magneto-transport properties.

semi-relative sensitivity one of two sensitivity measures used in circuit and system theory. These are

$$\mathbf{S}_x(y,x) = x\frac{\partial y}{\partial x} = \frac{\partial y}{\partial x/x} = \frac{\partial y}{\partial lnx}$$

which is frequently denoted by $\mathbf{S}_x$, and

$$\mathbf{S}^y(y,x) = \frac{1}{y}\frac{\partial y}{\partial x} = \frac{\partial y/y}{\partial x} = \frac{\partial lny}{\partial x}$$

which is also denoted by $\mathbf{S}^y$. Both these quantities are used in a way similar to using relative sensitivity. *See also* absolute sensitivity, relative sensitivity, sensitivity, sensitivity measure.

semi-rigid cable a coaxial cable with a solid metal outer-conductor. Typically used where the cable is bent to fit the application only once.

semiconductor a material in which electrons in the outermost shell are able to migrate from atom to atom when a modest amount of energy is applied. Such a material is partially conducting (can support electrical current flow), but also has properties of an insulator. The amount of current conduction that can be supported can be varied by "doping" the material with appropriate materials, which results in the increased presence of free electrons for current flow. Common examples are silicon and GaAs. Also called semi-insulator.

semiconductor device a transistor, resistor, capacitor, or integrated circuit made from a semiconductor material.

semiconductor diode laser laser in which the amplification takes place in an electrically pumped semiconducting medium.

semiconductor laser *See* diode laser.

semiconductor laser amplifier semiconductor laser in which feedback from the end facets or other reflecting surfaces is unimportant.

semiconductor laser oscillator a laser oscillator in which the amplification takes place in a semiconducting medium.

semiorthogonal wavelets wavelets whose basis functions in the subspaces are not orthogonal but the wavelet and scaling subspaces spanned by these basis functions are orthogonal to each other.

sense amplifier in a memory system, circuitry to detect and amplify the signals from selected storage cells.

sensitivity a property of a system indicating the combined effect of component tolerances on overall system behavior, the effect of parameter variations on signal perturbations and the effect of model uncertainties on system performance and stability. For example, in radio technology, sensitivity is the minimum input signal required by the receiver to produce a discernible output.

The sensitivity of a control system could be measured by a variety of sensitivity functions in time, frequency or performance do-

mains. A sensitivity analysis of the system may be used in the synthesis stage to minimize the sensitivity and thus aim for insensitive or robust design. *See also* robustness, robust controller design, objective function.

sensitivity bound a lower or upper limit on the sensitivity index for a system.

Such a bound exists, for example, for filters whose passive elements are limited to resistors, capacitors, and ideal transformers, and whose active elements are limited to gyrators (characterized by two gyration resistances considered different in sensitivity calculations), and active voltage and current controlled voltage and current sources.

sensitivity function a measure of sensitivity of signals or performance functions due to parameter variations or external signals (disturbances, controls). For small changes in parameters, sensitivity functions are partial derivatives of signals or performance functions with respect to the parameters and could be found from linearized models of the system model under study.

For linear systems, the sensitivity functions in semilogarithmic form could be obtained from the original system model in some special nodes of its block scheme called sensitivity points. Moreover, for linear time-invariant feedback systems, sensitivity may be defined in frequency domain both for small and large parameter deviations. One way to do this is to compare the output errors due to plant parameter variations in the open-loop and closed-loop nominally equivalent systems. The resulting sensitivity function or for multi-input–multi-output systems, sensitivity matrix $S(j\omega)$ is given by a return difference function or its matrix generalization, i.e.,

$$S(j\omega) = (I + K(j\omega))^{-1}$$

where $K(j\omega)$ is an open-loop frequency transfer function (respectively matrix) and I is a unit matrix of appropriate dimension. In the single-input–single-output systems and for the small variations, S is equal to the classical differential logarithmic sensitivity function defined by Bode. *See also* sensitivity index, sensitivity invariant.

sensitivity index a sensitivity measure. For the multiparameter sensitivity row vector one can determine the following two characteristics:

1. the worst-case sensitivity index

$$\nu(F) = \sum_{i=1}^{n} \left| \mathrm{Re}\mathbf{S}_{xi}^{F(j\omega,\mathbf{x})} \right|$$

2. the quadratic sensitivity index

$$\rho(F) = \left[\sum_{i=1}^{n} \left(\mathrm{Re}\mathbf{S}_{xi}^{F(j\omega,\mathbf{x})} \right)^2 \right]^{1/2}$$

These two are used most frequently in sensitivity comparisons, yet other indices, for example, for the case of random circuit parameters, can be derived as well. *See also* sensitivity function, sensitivity invariant.

sensitivity invariant feature of a circuit or system that is insensitive.

Let a circuit function be $F(s, \mathbf{x})$ where $\mathbf{x} = [x_1, x_2, \ldots, x_n]^t$ is a vector of circuit parameters. A sensitivity invariant exists for this circuit if there is a relationship

$$\sum_{i=1}^{n} \mathbf{S}_{x_i}^{F(s,\mathbf{x})} = k$$

Here $\mathbf{S}_{x_i}^{F(s,\mathbf{x})}$ is a component of a multiparameter sensitivity row vector and k is a constant. In most of cases, this constant can have one of three possible values, namely, 1, 0, and -1. The sensitivity invariants are useful to check the sensitivity calculations. *See also* sensitivity, sensitivity function, sensitivity bound.

sensitivity measure a number used to characterize and compare circuits the functions of which depends of more than one component. They are used when the components of multiparameter sensitivity row vector and the circuits component tolerances are

known. The most frequently used are worst-case measure and quadratic measure of sensitivity. *See also* sensitivity, sensitivity index.

sensitivity reduction reducing sensitivity is very desirable in active filter realization. Some general suggestions, at the stage of approximation, ensuring that filter realizations will have low sensitivities to component variations include the following:

1. Increasing the order of approximation and introducing a redundancy.

2. Using predistorted (tapered) specifications in the vicinity of the passband edge.

3. Using transfer functions with a limited value of the maximum Q of the transfer function poles. The realization itself gives the circuits lower sensitivities if the filter is realized as the doubly terminated lossless structure or its active equivalent.

sensor a transducer or other device whose input is a physical phenomenon and whose output is a quantitative measurement of that physical phenomenon. Physical phenomena that are typically measured by a sensor include temperature or pressure to an internal, measurable value such as voltage or current.

sensor alignment alignment of sensors so as to correct the time delay differences arising from spatial differences.

sensorless control a control method in which mechanical sensors are replaced by an indirect estimation of the required variable.

separability the separable property for the signal or system such that the signal or system representation can be expressed by the product of component terms, each depending on fewer independent variables.

separable data a 2-D signal that can be written as a product of two 1-D signals.

separable filter a filter that can be applied in two or more operations without any change in overall function, thereby gaining some computational advantage. In particular, a 2-D mean filter can be re-implemented identically as two orthogonal 1-D mean filters, and is therefore separable. However, a 2-D median filter is non-separable, as its action is not in general identical to that of two orthogonal 1-D median filters. *See also* separable transform.

separable image transform a 2-D separable transform used to transform images.

separable kernel for a 2-D transform a kernel that can be written as the product of two 1-D kernels. For higher dimension transforms a separable kernel can be written as the product of several 1-D kernels. *See* separable transform.

separable transform a 2-D transform that can be performed as a series of two 1-D transforms. In this case the transform has a separable kernel. The 2-D continuous and discrete Fourier transforms are separable transforms. In higher dimensions a separable transform is one that can be performed as a series of 1-D transforms. *See also* separable filter.

separately excited DC machine a DC machine where the field winding is supplied by a separate DC source. Separately excited generators are often used in feedback control systems when control of armature voltage over a wide range is required.

sequency in a transform, the number of zero-crossings of a particular basis function. By extension used to refer to the transform coefficient that corresponds to a particular basis function. For example, in the discrete cosine transform the zero sequency coefficient is the one for which the basis function is flat (and therefore has no zero crossings), often called the DC coefficient. Sequency is roughly analogous to frequency; higher sequency basis functions correspond to higher frequency components of signal energy.

sequential-access storage storage, such as magnetic tape, in which access to a given location must be preceded by access to all locations before the one sought. *See also* random access device.

sequence (012) quantities symmetrical components computed from phase (abc) quantities. Can be voltages, currents, and/or impedances.

sequencer a programmable logic array (PLA) that has a set of flip-flops for storage of outputs that can be fed back into the PLA as inputs, enabling the implementation of a finite state machine.

sequential access data stored on devices such as magnetic tape must be accessed by first moving the media to a particular location and then reading or writing the information. Information cannot be accessed directly; a sequential search must be done first.

sequential color and memory (SECAM) a color television system that transmits the two (B - Y) and (R - Y) color difference signals on alternate horizontal lines as a constant amplitude FM subcarrier. A one-line memory in the receiver allows reconstruction of the color signals on all lines. The SECAM system requires no color controls. The vertical scan parameters for the SECAM television system are based on the European power line frequency of 50 Hz. The SECAM system parameters are shown in the table.

sequential consistency the situation when any arbitrary interleaving of the execution of instructions from different programs does not change the overall effect of the programs.

sequential decoding a suboptimum decoding method for trellis codes. The decoder finds a path from the start state to the end state using a sparse search through the trellis. Two basic approaches exist: depth-first algorithms and breadth-first algorithms.

sequential detection a detection algorithm for tree or trellis structured problems based on depth-first tree/trellis search. *See also* depth-first search.

sequential fault a fault that causes a combinational circuit to behave like a sequential one.

sequential locality part of the principle of (spatial) locality, that refers to the situation when locations being referenced are next to each other in memory. *See also* principle of locality.

sequential logic a digital logic in which the present state output signals of a circuit depend on all or part of the present state output signals fed back as input signals as well as any external input signals if they should exist.

sequential scan *See* progressive scan.

serial bus a data communication path between parts of the system that has a single line to transmit all data elements.

serial I/O interface I/O interface consisting of a single line over which data is transferred one bit at a time. Commonly used for low-speed devices, e.g., printer, keyboard, etc. *See also* parallel I/O interface.

serial operation data bits on a single line are transferred sequentially under the control of a single signal.

serial port a communications interface that supports bit by bit data transmission.

serial printing printing is done one character at a time. The print head must move across the entire page to print a line of characters. The printer may pause or stop between characters. Printing speed is usually given in units of characters per second (cps).

SECAM

Vertical Fields Frequency	50 Hz
Number of Interlaced Fields	2
Vertical Frame Frequency	25 Hz
Number of Horizontal Lines/Frame	625
Horizontal Scan Frequency	15,625 Hz
Video Bandwidth	6 MHz
Color Subcarrier Frequency	4.433618 MHz
Sound Modulation	FM (AM in France)
RF Channel Bandwidth	8 MHz

serial transmission a process of data transfer whereby one bit at a time is transmitted over a single line.

series equalizer in a single-loop feedback system, a series equalizer is placed in the single loop, generally at a point along the forward path from input to output where the equalizer itself consumes only a small amount of energy.

series feed a method of feeding a phased array antenna in which the element feedpoints are located at even or uneven spacings along a single transmission line. Unless phase shifters are placed in the line between elements, the phase shift between elements changes with frequency.

series feedback with reference to a three-terminal device or grounded amplifier, the application of an electrical element in series with the device or amplifier to ground, thereby causing some of the output signal to be fed back in series with the input signal.

series field a field winding of a DC machine consisting of a few turns of thick wire, connected in series with the armature and carrying full armature current.

series resonant converter a power converter that uses a series resonant tank circuit. It has high efficiency from full load to part load, and transformer saturation is avoided due to the series blocking capacitor. The major problem with the series resonant converter is that it requires a very wide change in switching frequency to regulate the load voltage, and the output filter capacitor must carry high ripple current.

series-connected DC machine a direct current machine in which the field winding is connected in series with the armature winding.

serif a small ancillary pattern attached to the original pattern on a mask (usually at the corners) in order to improve the printing fidelity of the pattern.

service control point (SCP) an on-line, real-time, fault-tolerant, transaction-processing database that provides call-handling information in response to network queries.

service drop the wire which extends from the street to the customer's electric meter.

service entrance the point at which the electric power service drop enters a building.

service management system (SMS) an operations support system that administers customer records for the service control point.

service primitive the name of a procedure that provides a service; similar to the name of a subroutine or procedure in a scientific subroutine library.

servo *See* servomechanism.

servo drive an automatic control system in which position, speed, or torque are the control variables.

servomechanism a closed-loop control system consisting of a motor driven by a signal that is a function of the difference between commanded position and/or rate and measured actual position and/or rate to achieve the conformance. Usually a servomechanism contains power amplification and at least one integrating element in the forward circuit.

session an instance of one or more protocols that provides the logical endpoints through which data can be transferred.

set associative cache a cache in which line or block from main memory can only be placed in a restricted set of places in the cache. A set is a group of two or more blocks in the cache. A block is first mapped onto a set (direct mapping defined by some bits of the address), and then the block can be placed anywhere within the set (fully associative within a set). *See also* direct mapped, fully associative cache.

set partitioning rules for mapping coded sequences to points in the signal constellation that always result in a larger Euclidean distance for a trellis-coded modulation system than for an encoded system, given appropriate construction of the trellis. Used in coded modulation for optimizing the squared Euclidean distance.

set point (1) a specified constant value of the controlled variable of a dynamical process that a controller is required to maintain. The controller must generate a control signal that drives the controlled variable to the set point and keeps it there, once it is reached. The set point is often referred to as reference point or operating point. In aircraft flight control, the set point is also called the trim condition.

(2) the intersection of the load line and the normal B-H curve, indicating the flux density and energy a permanent magnet is delivering to a given magnetic circuit geometry.

set-associative cache a cache that is divided into a number of sets, each set consisting of groups of lines and each line having its own stored tag (the most significant bits of the address). A set is accessed first using the index (the least significant bits of the address). Then all the tags in the set are compared with that of the required line to find whether the line is in the cache and to access the line. *See also* cache, direct mapped, and associativity.

set-membership uncertainty a model of uncertainty in which all uncertain quantities are unknown except that they belong to given sets in appropriate vector spaces. The sets are bounded and usually compact and convex. The estimation problem in this case becomes one of characterizing the set of states consistent both with the observations received and the constraints on the uncertain variables. Control objectives are usually formulated in terms of worse-case design tasks, target sets reachability, guaranteed cost control, robust stability or practical stabilization of the uncertain systems.

For linear systems with energy-type ellipsoidal constraints imposed on the uncertain variables representing initial conditions, additive disturbances and observation noises solution of the state estimation problem is given by the estimator similar to the Kalman filter, and a control problem in the form of min-max optimization of a given quadratic criterion leads to the linear-quadratic game. In the case of instantaneous ellipsoidal constraints, the exact solution of estimation and control problems is difficult to obtain, nevertheless, by bounding recursively the sets of possible state approximating ellipsoids leading to suboptimal filtering and control laws similar to the optimal ones for the energy-type constraints.

Generally, efficient results might be found only for bounding sets parameterized by a little number of parameters. Except for the ellipsoids, such property is endowed only by polyhedral sets bounding uncertain variables. In this case, efficient results could be reached by the use of linear programming algorithms.

settling time (1) the time required for a signal to change from one value to another.

(2) refers to the time that it takes stable transients of a dynamic system to decay to a negligible amplitude. This can be quantified to the time it takes an exponential transient mode to decay to a band that is $\pm 37\%$, $\pm 5\%$, or $\pm 2\%$ of its initial value. *See also* time constant.

setup a video term relating to the specified base of an active picture signal. In NTSC, the active picture signal is placed 7.5 IRE units above blanking (0 IRE). Setup is the separation in level between the *video blanking* and *reference black* levels.

setup time *See* hold time.

SF6 *See* sulfur hexaflouride.

SF6 circuit breaker a power circuit breaker where sulfur hexaflouride (SF_6) gas is used as an insulating and arc clearing agent.

SGNN *See* self-generating neural network.

SGNT *See* self-generating neural tree.

SGVQ *See* shape-gain vector quantization.

SHA *See* sample-and-hold amplifier.

shaded pole a magnetic pole-face in which part of the pole is encircled by a shorted conductor (usually copper). The flux through the encircled portion will be out of phase with the flux through the other portion. Shaded pole motors use the phase shift to produce a quasi-rotating magnetic field which develops a weak torque, suitable primarily for small fans. In AC relays, shaded poles are used to prevent chatter (the attempted opening and subsequent closing each time the flux passes through zero).

shaded-pole motor a single-phase induction type motor that uses shaded poles on the stator to create a weak quasi-rotating magnetic field. Shaded-pole motors are only built in small fractional horsepower sizes and produce a very low starting torque that is suitable only for fan-type loads. *See also* shaded pole.

shadow casting logic gate an optical logic gate originally using shadow casting technique. The principle of shadow casting logic gate can be explained as follows. First, NOT A and NOT B are generated from inputs A and B. Second, four products of AB, A (NOT B), (NOT A) B, and (NOT A) (NOT B) are produced by passing a light beam through two transparencies that could be spatial light modulators representing A and B, A and NOT B, NOT A and B, and NOT A and NOT B. Third, the four products are added optically. The sixteen combination of four products are the sixteen Boolean logic operations.

shadowing (1) excess propagation loss resulting from the blocking effect of obstacles such as buildings, trees etc.

(2) the statistical variation of propagation loss in a mobile system between locations the same distance from a base station, usually described by a lognormal distribution.

shaft torque the component of the motor generated electromagnetic torque available at the shaft of the motor after overcoming the operational losses of the motor during the electromechanical energy conversion process.

Shannon, Claude (1916–1989) considered to be the founding father of modern electronic communications theory. His contribu-

tions include the application of Boolean algebra to analyze and optimize switching circuits and, in his classic paper "The Mathematical Theory of Communication," established the field of information theory by developing the relationship between the information content of a message and its representation for transmission through electronic media.

Shannon information the information content of an event x with a probability of occurrence of $p(x)$ defined as

$$I(x) = -\log p(x).$$

The unit of $I(x)$ depends on the base of the logarithm - "bits" for base 2, "nats" for the natural logarithm. *See also* entropy.

Shannon's law fundamental relationship of information theory, which states that the lower bound on the average code-word length for coding a discrete memoryless source is given by the source entropy. *See also* entropy.

Shannon's sampling theorem this mathematical theorem states that when an analog signal is sampled, there is no loss of information and the analog signal can be reconstructed by low-pass filtering, if and only if the largest (absolute value) frequency present in that signal does not exceed the Nyquist frequency, this being half the sampling frequency.

Shannon's source coding theorem a major result of Claude Shannon's information theory. For lossy source coding, it gives a bound to the optimal source coding performance at a particular rate ("rate" corresponds to "resolution"). The theorem also says that the bound can be met by using vector quantization of (infinitely) high dimension. For lossless source coding, the theorem states that data can be represented (without loss of information) at a rate arbitrarily close to (but not lower than) the entropy of the data. *See also* rate-distortion theory.

shape analysis the analysis of shapes of objects in binary images, with a view to object or feature recognition. Typically, shape analysis is carried out by measurement of skeleton topology or by boundary tracking procedures including analysis of centroidal profiles.

shape from the recovery of the 3-D shape of an object based on some feature (e.g., shading) of its (2-D) image.

shape measure a measure such as circularity measure (compactness measure), aspect ratio, or number of skeleton nodes, that may be used to help characterize shapes as a preliminary to, or as a quick procedure for, object recognition.

shape-gain vector quantization (SGVQ) a method for vector quantization where the magnitude (the gain) and the direction (the shape) of the source vector are coded separately. Such an approach gives advantages for sources where the magnitude of the input vector varies in time.

shape-memory effect mechanism by which a plastically deformed object in the low-temperature martensitic condition regains its original shape when the external stress is removed and heat is applied.

shape-memory smart materials include three categories, namely shape-memory alloys (SMA), shape-memory hybrid composites (SMHC), and shape-memory polymers (SMP).

shaping a traffic policing process that controls the traffic generation process at the source to force a required traffic profile.

shared memory characteristic of a multiprocessor system: all processors in the system share the access to main memory. In a physically shared–memory system, any processor has access to any memory location through the interconnection network.

shared memory architecture a computer system having more than one processor in which each processor can access a common main memory.

sharpening the enhancement of detail in an image. Processes that sharpen an image also tend to strengthen the noise in it. *See also* edge enhancement, gradient, image enhancement, Laplacian operator, noise, Sobel operator.

SHDTV *See* super high definition television.

shed a circular roof-like feature of an electrical insulator which presents a long electrical leakage path while permitting the drainage of rainwater.

sheet resistance lateral resistance of an area of thin film in the shape of a square.

shell-type transformer a power transformer in which the magnetic circuit surrounds and normally encloses a greater portion of the electrical winding.

shield wire (1) a ground wire placed above an electric transmission line to shield the conductors from lightning strokes.

(2) a ground wire buried directly above a buried communications cable for lightning protection.

shielding effectiveness a measure of the reduction or attenuation in the electromagnetic field strength at a point in space caused by the insertion of a shield between the source and that point. Typically expressed in decibels: $\mathrm{SE} = 20\log_{10}(E_1/E_2)$ dB, where E_1 = field strength measured without shield and E_2 = field strength measured after shielding is applied.

shift instruction a program instruction in which data in a register or memory location is shifted one or more bits to the left or right. Data shifted off the end of the register or memory location is either shifted into a flag register, used to set a condition flag, or dropped, depending on implementation of the instruction. *See also* rotateinstruction.

shift invariance a characteristic of a property that in some domain it is invariant to displacements within that domain. Particularly important sorts of shift invariance are space invariance and time invariance. The impulse response of a system is independent of the spatial (or temporal) location of the impulse.

shift register a register whose contents can be shifted to the left or right.

sifting property the ability of the impulse function to select a particular value of another function. In discrete time

$$x(n) = \sum_{i=-\infty}^{\infty} x(n)\delta(n-i).$$

In continuous time

$$x(t) - \int_{-\infty}^{\infty} x(s)\delta(t-s)ds.$$

Shockley, William (1910–1989) Born: London, England

Shockley is best known as one of the developers of the transistor. In 1956 Shockley, John Bardeen, and Walter Brattain received the Nobel Prize for their work. Schockley led the group at Bell Labs responsible for the semiconductor research that led to the development of the "point-contact transistor." In later life, Shockley became known for his public pronouncements on various political and genetic issues.

Shoeffler sensitivity when the multiparameter sensitivity row vector is known, then the measure of this vector determined as

$$\rho^2(F) = \sum_{i=1}^{n} \left| \mathbf{S}_{x_i}^{F(j\omega,\mathbf{x})} \right|^2$$

is called Shoeffler multivariable sensitivity.

short circuit a condition on the power system where energized conductors come in contact (or generate an arc by coming in close proximity) with each other or with ground, allowing (typically large) fault currents to flow.

short circuit admittance the admittance into an N-port device when the remaining ports are terminated in short circuits. For port 1 of a 2-port device, it is the input admittance into port 1 when port 2 is shorted.

short circuit gain–bandwidth product a measure of the frequency response capability of an electronic circuit. When applied to bipolar circuits, it is nominally the signal frequency at which the magnitude of the current gain degrades to one.

short code in a spread-spectrum system, periodic spreading code (spreading sequence) with a period equal to a bit duration. *See also* long code.

short duration *See* voltage variation.

short-circuit protection the beneficial effect provided by an overcurrent device when it acts to interrupt short-circuit current.

short-circuit test a transformer test conducted by placing a few percent of rated voltage on the voltage side while the low voltage winding is shorted. By measuring the voltage, current, and input power, it is possible to calculate the equivalent winding impedance for the transformer equivalent circuit.

shortened code a code constructed from another code by deleting one or more message symbols in each message. Thus an (n, k) original code becomes an $(n-1, k-1)$ code after the deleting of one message symbol.

shot noise noise voltage developed at internal device boundaries, such as solid-state junctions, where charges cross from one type of material into another. Also known as Schottky noise.

shotgun a specialized hot stick that is used to install a hot tap.

Shubnikov–de Haas oscillation quantum oscillations in resistance as a function of applied magnetic field.

shunt (1) a device having appreciable impedance connected in parallel across other devices or apparatus and diverting some of the current from it. Appreciable voltage exists across the shunted device or apparatus, and an appreciable current may exist in it.

(2) an inductive element connected across a power line or bus. Those connected to buses are known as bus-connected reactors, while those connected across a power line are called line-connected reactors.

shunt capacitor a capacitor or group of capacitors which are placed across an electric power line to provide a voltage increase or to improve the power factor of the circuit. A switchable shunt may be disconnected from the circuit when conditions warrant, while a fixed shunt is permanently connected to the power line.

shunt DC machine a DC machine with the field winding connected in shunt with the armature. In shunt generators, residual magnetism must be present in the machine iron in order to initiate the generation process. These machines are also known as self-excited, since they supply their own excitation.

shunt field a field winding of a DC machine consisting of many turns of fine wire, connected in parallel with the armature circuit. It may be connected to the same source as the armature or a separate source.

shunt peaking use of a peaking coil in a parallel tuned circuit branch connecting the output load of one amplifier stage to the in-

put load of the following stage, in order to compensate for high frequency loss due to the distributed capacitance of the two stages.

shunt reactor a reactor intended for connection in shunt to an electric system to draw inductive current.

Si periodic table symbol for silicon. *See* silicon.

Si/SiGe/SiGeC silicon-based alloy system providing band offsets that enable heterostructures that can be utilized for heterojunction transistor design and quantum confinement.

side lobe level the ratio of a local maximum in a radiation pattern to the global maximum (main beam) of the radiation pattern.

sideband the signal produced when a carrier signal is modulated. They may be one single sideband, one set of upper and lower sidebands, or a series of sidebands whose number is dependent on the modulation index of the modulation system being used.

sidelobe a lobe in an antenna radiation pattern apart from the main lobe and any grating lobes. Sidelobes have peak amplitudes less than that of the main lobe.

sidelobe level (SLL) the peak amplitude of a sidelobe relative to the peak amplitude of the main lobe. The SLL is usually expressed as the number of decibels below the main lobe peak.

Siemens, Ernst Werner von (1816–1892) Born: Lenthe, Hanover, Germany

Siemens is best known for the German and British companies that bear his name. Siemens was a strong believer in basic research, as well as an avid inventor. His early inventions included an improved gutta-percha wrapped telegraph cable that allowed his companies to secure a number of lucrative cable contracts. His discovery of the dynamo principle, and his use of this in heavy-current applications, allowed his companies to become pioneers in devices to generate electricity and rail applications. Siemens' belief in basic research made him a champion of standards and research institutions that he helped to establish.

SiGe in order to increase the speed of Si semiconductor devices without compromising on Si's ease of device processing, SiGe heterostructures can be used.

sigma-delta A/D conversion an oversampling A/D conversion process where the analog signal is sampled at rates much higher (typically 64 times) than the sampling rates that would be required with a Nyquist coverter. Sigma-delta modulators integrate the analog signal before performing the delta modulation. The integral of the analog signal is encoded rather than the change in the analog signal, as is the case for traditional delta modulation. A digital sample rate reduction filter (also called a digital decimation filter) is used to provide an output sampling rate at twice the Nyquist frequency of the signal. The overall result of oversampling and digital sample rate reduction is greater resolution and less distortion compared to a Nyquist coverter process.

sigma-delta modulation a method for scalar quantization, similar in principle to delta modulation but somewhat more sophisticated. Employed in, e.g., compact-disk players.

sigmoid function a compressive function that maps inputs less than -1 to approximately zero, inputs greater than 1 to approximately 1 and maps values from -1 to 1 into the range 0 to 1. A common sigmoid function is

$$\frac{1}{1+e^{-\frac{x}{T}}}.$$

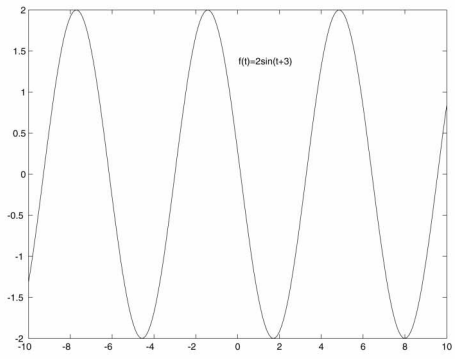
Sigmoid functions are often used as activation functions in neural nets. *See also* activation function.

sigmoidal characteristic a widely used type of activation function, especially in networks trained using schemes like backpropagation that are based upon gradient descent. The most common functions used are the arctan, tanh, and logistic functions, with appropriate variations for binary and bipolar variables.

sign flag a bit in the condition code register that indicates whether the numeric result of the execution of an instruction is positive or negative (1 for negative, 0 for positive).

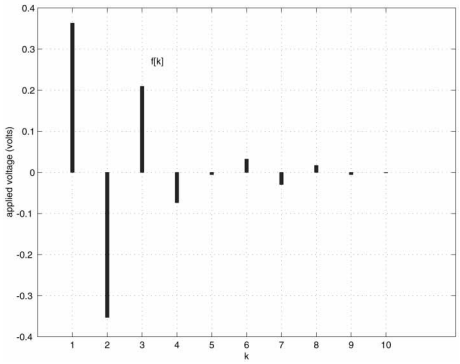
sign-magnitude representation a number representation that uses the most significant bit of a register for the sign and the remaining bits for the magnitude of a binary number.

signal a real or complex function, $f(t)$ of a time variable t. If the domain is the real line $t \in \mathcal{R}$, or an interval of the real line, then the signal is a *continuous time* signal. For example, $f(t)$ could represent the magnitude of a voltage applied to a circuit, as shown in the figure.



Continuous time signal.

If the domain is a discrete set $\{k, k = 0, 1, 2, \ldots\}$, then the signal is a *discrete time* signal. Discrete time signals commonly arise in engineering applications by sampling a continuous time signal, in control and filtering applications. For example, $f[k]$ could represent the above voltage sampled every 0.5 seconds, as shown in the figure.



Discrete time signal.

signal averaging an averaging process that is used to enhance signals and suppress noise, thereby improving the signal-to-noise ratio. *See also* averaging.

signal conditioning a process that is used to improve the appearance or effectiveness of a signal, either by suppressing noise or by transforming the signal into a more suitable form. This latter category includes image enhancement. Signal conditioning is often appropriate in preparing signals for recognition.

signal constellation in digital communications, the set of transmitted symbols represented as points in Euclidean space. For example, the signal constellation for (uncoded) quadrature amplitude modulation is a set of points in the complex plane.

signal decimation *See* decimation.

signal detection detecting the presence of a signal in noise.

signal flow graph graphical representation of the relationships between a set of independent input variables that are linearly related to a set of dependent output variables.

signal level the value of a signal at a particular place and time.

signal processing a generic term that refers to any technique that manipulates the signal, including but not limited to signal averaging, signal conditioning and signal recognition. When applied to images, it is normally referred to as image processing, the term signal processing usually being reserved for 1-D signals.

signal recognition the recognition of signals by appropriate analysis, often with the help of filters such as matched filters or frequency domain filters.

signal recovery the process of extraction of signals from a background of noise or clutter, often in situations, where the signal-to-noise ratio is so low that matched filters, synchronous detectors or lock-in amplifiers have to be used. *See also* synchronous detection.

signal reference subsystem this subsystem provides the reference points for all signal grounding to control static charges, noise, and interference. It may consist of any one or a combination of the lower frequency network, higher frequency network, or hybrid signal reference network.

signal restoration the restoring of data that has been corrupted by instrumentation dynamics and noise.

signal subspace in an orthogonal decomposition of a space, the part to which the desired signal belongs. *See also* noise subspace.

signal transfer point (STP) a packet switch found in the common-channel signaling network; it is used to route signaling messages between network access nodes such as switches and SCPs.

signal variance *See* variance.

signal-to-interference ratio (SIR) the ratio of the average power of the signal component to the average power of the interference component in a case where an information-bearing signal of interest has been corrupted by interfering signals.

signal-to-noise plus interference ratio (SNIR) the ratio of total signal power to the sum of total noise power and total interference power at a receiver. The SNIR is a more complete indicator of received signal quality than either SIR or SNR, where the relative contribution of receiver noise and external sources of interference are either unknown or widely varying. It is a unitless quantity. *See also* signal-to-noise ratio, signal-to-interference ratio.

signal-to-noise ratio (SNR) the ratio of the average power of the information signal component to the average power of the noise component in a signal consisting of the sum of an information signal component and a corrupting noise component. It is a unitless quantity.

signaling procedures used to control (set up and clear down) calls and connections within a telecommunication network.

signaling system 7 (SS7) a communications protocol used in common-channel signaling networks.

signature a characteristic easily computed feature or function by which a particular object or signal may be at least tentatively identified. An example is the centroidal profile for an object having a well defined boundary.

signature analysis (1) a test where the responses of a device over time are compared to a characteristic value called a signature, which is then compared to a known good one.

(2) an analysis of the signature to extract the desired (signal) information.

signed-digit representation a fixed-radix number system in which each digit has a sign (positive or negative). In a binary signed-digit representation, each digit can assume one of the values -1, 0 and 1.

significand the mantissa portion of a floating-point number in the IEEE 754 floating-point standard. It consists of an implicit or explicit leading integer bit and a fraction.

signum function the function

$$\text{sgn}(t) = \begin{cases} +1 & t > 0 \\ 0 & t = 0 \\ -1 & t < 0. \end{cases}$$

Used in modeling numerous types of system functions.

SIL *See* surge impedance loading.

silicon most common element in the earth's crust and a type IV (from periodic table of elements) semiconductor material. The bipolar carriers, both holes (p dopants) or electrons (n dopants) are roughly in proportion to each other, resulting in nearly equal currents in the same direction. They move at about half the speed of comparable GaAs unipolar carriers. The thermal resistance is also about half that of GaAs.

Silicon has an indirect band gap of 1.11 eV, density-of-states masses of 1.1 times the free-electron mass for the conduction band and 0.56 for the valence band.

silicon compiler a set of software programs intended to start with design equations and output the corresponding GDS2 data. Silicon compilers are currently used to translate a standard cell design from one set of design rules to another or to create a new set of standard cells.

silicon controlled rectifier (SCR) a current controlled four-layer (pnpn) device for high power (3000 A) and low speed (500 Hz) applications. SCRs can only be on or off, with no intermediate operating states like transistors. The SCR acts as a switch that is turned on by a short current pulse to the gate, provided that the device is in its forward blocking state. Once latched on, the gate current can be removed and the device will remain on until the anode current goes negative, or the current through the SCR becomes less than its designated holding current. A disadvantage is that a commutation circuit is often needed for forced turn-off (forced commutation).

silicon dioxide (SiO_2) an amorphous compound of silicon and oxygen with a resistivity of 10^{14} to 10^{17} ohm-cm and a bandgap of 8.1 eV. Essential as a dielectric and insulator for silicon devices.

silicon nitride (SiN_4) for a semiconductor manufacturing process, a compound formed of silicon and nitrogen that is deposited and etched back to provide a masking layer appropriate for withstanding subsequent high temperature processing such as oxidation.

SIMD *See* single-instruction stream, multiple-data stream.

similarity between symbol strings *See* distance between symbol strings.

similarity measure the reciprocal concept of distance measure. *See* distance measure.

similarity of 2-D system matrices two system matrices

$$S_i = \begin{bmatrix} P_i & -Q_i \\ C_i & D_i \end{bmatrix} i = 1, 2 \,,$$

of the same dimensions (See input–output equivalence of 2-D system matrices) where there exists a nonsingular matrix M such that

$$\begin{bmatrix} P_1 & -Q_1 \\ C_1 & D_1 \end{bmatrix} = \begin{bmatrix} M^{-1} & 0 \\ 0 & I \end{bmatrix} \begin{bmatrix} P_2 & -Q_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} M & 0 \\ 0 & I \end{bmatrix}$$

The transfer matrix $T_i(z_1, z_2) = C_i P_i^{-1} Q_i + D_i$ $(i = 1, 2)$ and the characteristic polynomial det P_i are invariant under the similarity.

SIMM *See* single in-line memory module.

simple medium a medium that is linear, isotropic, homogeneous, and time-invariant.

simplex term used to describe a method of winding the armature of a commutated electric machine in which consecutive coils are placed in adjacent coil slots around the periphery of the rotor. In a lap winding, this produces two parallel electrical path between brushes for each pole pair. In a wave winding, a simplex arrangement produces two parallel electrical paths between brushes regardless of the number of poles. *See also* duplex, multiplex.

simulated annealing an optimization technique that seeks to avoid local minima by allowing the search trajectory to follow paths that not only decrease the objective function but also sometimes increase it. The probability that an increase in the objective function is allowed by the technique is governed by a quantity that is analogous to temperature. The scheme commences with a high temperature, under which the probability of allowing increases in the objective function is high, and the temperature is gradually reduced to zero, and from then on no further increases in the function are allowed. *See also* annealing.

simulation *See* computer simulation.

simulation model *See* truth model or computer simulation.

simulator a program used to predict the behavior of a circuit.

Simulators may be transistor level, gate level, behavioral level, analog, digital, unit delay, timing, or various combinations.

simulcast systems systems that simultaneously broadcast over two or more different frequency channels or modes of broadcast signals.

simultaneous contrast the phenomenon in which the brightness (perceived luminance) of a region on a dark background is greater than the brightness of an identical region on a light background. Illustrates that brightness (perceived luminance) is different from lightness (actual luminance). *See also* brightness, brightness constancy, human visual system, Mach band.

SiN_4 *See* silicon nitride.

sinc function this function is defined by the relation:

$$\text{sinc}(t) = \frac{\sin \pi t}{\pi t}.$$

A scaled sinc function is the impulse response of an ideal lowpass filter.

sine transform usually refers to the discrete sine transform. It also refers to a continuous time transform similar to the Fourier transform.

sine-squared pulse pulse string made from a standard sinewave with an added DC component equal to one-half of the peak-to-peak value of the sine wave. The pulse string is, therefore, always positive in value.

sinewave brushless DC a permanent magnet brushless motor with sinusoidally distributed stator phase windings. More commonly known as permanent magnet synchronous machine.

single dwell detector a detector in a communications receiver based on a decision on a transmitted symbol being made after a single correlation of the received signal with a reference signal. *Compare with* multiple dwell detector.

single electron transistor solid state device that performs electronic functions using a single transistor's electron.

single in-line memory module (SIMM) a miniature circuit board that contains memory

chips and can be plugged into a suitable slot in a computer motherboard in order to expand the physical memory.

single in-line packaging (SIP) a method of packaging memory and logic devices on small PCBAs with a single row of pins for connection.

single layer perceptron an artificial neural network consisting of a single layer of neurons (perceptrons) with an input layer. *See also* multilayer perceptron, perceptron.

single line to ground fault a fault on a three phase power line in which one conductor has become connected to ground.

single machine infinite bus system a model of a power system consisting of a single generator working into an infinite bus which represents the remainder of the system.

single mode single frequency resonance of a cavity that is usually associated with a unique field distribution.

single phase to ground fault *See* single line to ground fault.

single photon emission computed tomography (SPECT) a form of tomographic medical imaging based upon the density of gamma ray-emitting radionuclides in the body.

single precision floating point numbers that are stored with fewer rather than more bits. Often refers to numbers stored in 32 bits rather than 64 bits.

single scattering weak interaction of the light wave with the medium. This occurs when this is weakly inhomogeneous. This process yields low changes in the phase and amplitude of light, and no variation in its state of polarization.

single sideband modulation (SSB) a method of amplitude modulation in which only one of the sidebands (upper or lower) is transmitted. This method can potentially double the capacity of a single channel.

single variable system *See* single-input–single-output system.

single-address computer a computer based on single-address instructions.

single-address instruction a CPU instruction defining an operation and exactly one address of an operand or another instruction.

single-chip microprocessor a microprocessor that has additional circuitry in it that allows it to be used without additional support chips.

single-electron tunneling the name given to very small capacitors with thin insulators so that tunneling can occur through this insulator. When the capacitor is small, it is possible that the energy change for the tunneling of one electron is larger than the thermal energy, so that fluctuations cannot support the tunneling. In this case, an external source must provide the energy needed for the tunneling process, which occurs usually (in these very small capacitors of order $< 10–18$ F) by the transfer of a single charge from one plate to the other.

single-element fuse a fuse that is constructed with a single fusible element. It does not meet the standard definition of time-delay.

single-ended amplifier an amplifier that has only one signal path and only one set of input and output ports.

single-input–single-output (SISO) system a system that transforms one input signal to one output signal. Also known as sin-

gle variable (SV) system. *See also* system, multiple-input–multiple-output system.

single-instruction stream, multiple-data stream (SIMD) a parallel computer architecture in which a collection of data is processed simultaneously under one instruction. Example in optics is imaging by a lens.

single-instruction stream, single data stream (SISD) a processor architecture performing one instruction at a time on a single set of data. Same as uniprocessor.

single-layer network a feedforward network consisting of input units connected directly to the output units. Thus, the network has a single layer of weights and no hidden units.

single-mode fiber an optical fiber with a relatively small diameter in which only one mode may propagate. However, this mode may have two orthogonal states of polarization that propagate unless a polarization maintaining optical fiber is used.

single-mode optical fiber relatively thin fiber that has low loss for one mode and much higher losses for all other modes. *See also* Flynn's taxonomy.

single-phase inverter an inverter with a single-phase AC voltage output. Half-bridge and full-bridge configurations are commonly used.

single-phase rectifier a rectifier with a single-phase AC voltage input. *See also* half-wave rectifier and full-wave rectifier.

single-phasing a condition that occurs when a three-phase motor has an open circuit occur in one of the three lines. The motor continues to operate with one line to line voltage as a single-phase motor, with an increase in noise, vibration, and current. Proper overload protection should detect the higher current and shut down the motor after some time delay.

single-pole reclosing the practice of clearing a fault which appears on one phase of a three-phase electric power line by disconnecting and reclosing only that phase as opposed to opening and reclosing all three phase conductors.

single-pole double-throw (SPDT) a switch that has a common port and two output ports. Among these two ports, only one selected port can be connected to the common port.

single-pole single-throw (SPST) a switch that has a pair of input–output ports. By changing its status, the switch works as short or open circuit.

single-sided assembly a packaging and interconnecting structure with components mounted only on the primary side.

single-stage decision making decision making involving future operation of the system, as in the case of open-loop feedback control, where no future measurements and decision interventions are assumed when considering the decision taken at a given time.

single-step to operate a processor in such a way that only a single instruction or machine memory access cycle is performed at a time, enabling the user to examine the status of processor registers and the flags. A common debugging method for small machines.

single-tuned circuit a circuit which is tuned by varying only one of it's components, e.g., an IF transformer in which only the secondary coil (rather than both primary and secondary) is tuned.

single-valued a function of a single variable, $x(t)$, which has one and only one value $y_0 = x(t_0)$ for any t_0. The square root is

an example of a function that is not single-valued.

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

$$\begin{aligned} Ex_{i+1,j+1} &= -A_1A_2x_{ij} + A_1x_{i+1,j} \\ &\quad + A_2x_{i,j+1} + Bu_{ij} \\ y_{ij} &= Cx_{ij} + Du_{ij} \end{aligned}$$

$i, j \in Z_+$(the set of nonnegative integers) is called singular 2-D Attasi-type model, 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_1, A_2, B, C, D are real matrices with E singular (det $E = 0$ if E is square or rectangular).

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

$$\begin{aligned} Ex_{i+1,j+1} &= A_0x_{ij} + A_1x_{i+1,j} \\ &\quad + A_2x_{i,j+1} + Bu_{ij} \quad \text{(1a)} \\ y_{ij} &= Cx_{ij} + Du_{ij} \quad \text{(1b)} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) is called the first singular 2-D Fornasini–Marchesini-type model, 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, E, A_k $(k = 0, 1, 2)$, B, C, D are real matrices with E singular (det $E = 0$ if E is square or rectangular). An 2-D model described by the equations

$$\begin{aligned} Ex_{i+1,j+1} &= A_1x_{i+1,j} + A_2x_{i,j+1} \\ &\quad + B_1u_{i+1,j} + B_2u_{i,j+1} \end{aligned}$$

and (1b) is called the second singular 2-D Fornasini–Marchesini-type model, where x_{ij}, u_{ij}, and y_{ij} are defined in the same way as for (1), E, A_1, A_2, B_1, B_2 are real matrices with E singular.

singular 2-D general model a 2-D model described by

$$\begin{aligned} &Ex_{i+1,j+1} = A_0x_{ij} + A_1x_{i+1,j} \\ &+ A_2x_{i,j+1} + B_0u_{ij} + B_1u_{i+1,j} + B_2u_{i,j+1} \\ &y_{ij} = Cx_{ij} + Du_{ij} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) is called singular 2-D general model, 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, E, A_k, B_k $(k = 0, 1, 2)$, C, D are real matrices with E singular (det $E = 0$ if E is square or rectangular). In particular case for $B_1 = B_2 = 0$ we obtain the first singular 2-D Fornasini–Marchesini-type model and for $A_0 = 0$ and $B_0 = 0$ we obtain the second singular 2-D Fornasini–Marchesini-type model.

singular 2-D Roesser-type model a 2-D model described by

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

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

$i, j \in Z_+$ (the set of nonnegative integers) is called singular 2-D Roesser type model, where $x^h_{ij} \in R^{n_1}$ and $x^v_{ij} \in R^{n_2}$ are horizontal and vertical semistate vector, respectively, $u_{ij} \in R^m$ is the input vector, $y_{i,j} \in R^p$ is the output vector, E, A_1,A_2,A_3,A_4, B_1, B_2, C, D are real matrices with E singular (det $E = 0$ if E is square or rectangular). In particular case for $E = I$ we have 2-D Roesser model.

singular matrix a square matrix A is singular if its rows (or columns) are not linearly independent. Singular matrixes cannot be inverted, have zero determinants, and have linearly dependent columns and rows.

singular perturbation for a dynamical system, a state-space model in which the derivatives of some of the states are multiplied by a small positive parameter ε,

$$\left.\begin{aligned} \dot{\mathbf{x}} &= \mathbf{f}(t, \mathbf{x}, \mathbf{z}, \varepsilon) \\ \varepsilon\dot{\mathbf{z}} &= \mathbf{g}(t, \mathbf{x}, \mathbf{z}, \varepsilon) \end{aligned}\right\}$$

The parameter ε represents the parasitic elements such as small masses, inertias, capacitances, inductances, etc. The system properties undergo a discontinuous change when the perturbation parameter ε is set to zero

since the second differential equations becomes an algebraic, or a transcendental equation

$$\mathbf{0} = \mathbf{g}(t, \mathbf{x}, \mathbf{z}, 0).$$

The singular perturbation methods are used in the analyses of high-gain nonlinear control systems as well as *variable structure sliding mode* control systems.

singular value decomposition (SVD) useful decomposition method for matrix inverse and pseudoinverse problems, including the least-squared solution of overdetermined systems. SVD represents the matrix A in the form $A = U\Lambda^{\frac{1}{2}}V$, where Λ is a diagonal matrix whose entries are the singular values of A, and U and V are the row and column eigenvector systems of A. Any matrix can be represented in this way. In image processing, SVD has been applied to coding, to image filtering, and to the approximation of non-separable 2-D point spread functions by two orthogonal 1-D impulse responses.

singularity a location in the workspace of the manipulator at which the robot loses one or more DOF in Cartesian space, i.e., there is some direction (or directions) in Cartesian space along which it is impossible to move the robot end effector no matter which robot joints are moved.

singularity function a function-like operation that is not a proper function in the analytic sense. This is because it has a point at which the function or its derivative is infinite or is undefined. In particular, the Dirac delta function is defined as:

$$\delta(t) = \begin{cases} \infty & m = 0 \\ 0 & \text{otherwise.} \end{cases}$$

Other examples are the step function and the ramp function.

sintered magnet magnet made from powdered materials that are pressed together and then heated in an oven to produce desired shapes and magnetic properties.

sinusoid a periodic signal $x(t) = \cos(\omega t + \theta)$ where $\omega = 2\pi f$ with frequency in hertz.

sinusoidal amplitude modulation amplitude modulation where the carrier signal is a sinusoid. *See* amplitude modulation, carrier signal.

sinusoidal coding parametric speech coding method based on a speech model where the signal is composed of sinusoidal components having time-varying amplitudes, frequencies and phases. Sinusoidal coding is mostly used in low bit rate speech coding.

sinusoidal signal a signal of the form

$$x(t) = A\sin(2\pi f t + \theta)$$

where A is the amplitude and θ is the phase angle.

sinusoidal steady-state response response of a circuit a sine wave input as $t \to \infty$. The output then has two components, a magnitude and a phase, that are the magnitude and the phase of the transfer function itself for $s = j\omega$.

sinusoidal–Gaussian beam electromagnetic beam in which the transverse field distribution is describable in terms of sinusoidal and Gaussian functions.

SiO_2 *See* silicon dioxide.

SIP *See* single in-line packaging.

SIR *See* signal-to-interference ratio.

SISD *See* single-instruction stream, single data stream.

SISO *See* single-input–single-output system.

SISO system *See* single-input–single-output system.

SIT *See* static induction transistor.

site diversity the combination of received signals at widely separated locations having substantially different propagation paths to the transmitter. The resultant signal has reduced fading depth and therefore higher quality communication is possible. Often used in Earth–satellite link to overcome the effects of scintillation and rain fading.

SITH *See* static induction thyristor.

six connected *See* voxel adjacency.

size distribution the size distribution of a family of objects is a function measuring the number or volume of all objects in any size range. In mathematical morphology, this notion is developed by analogy with a family of sieves: each sieve retains objects larger than a given size, and lets smaller objects go through; when two sieves are put in succession, this is equivalent to using the finest sieve. This idea is formalized by taking a one-parameter family of morphological operators γ_r ($r > 0$) such that for all objects X, Y and $r, s > 0$, one has
1. $\gamma_r(X) \leq X$, that is, γ_r is anti-extensive;
2. $X \leq Y$ implies that $\gamma_r(X) \leq \gamma_r(Y)$, that is, γ_r is increasing;
3. $\gamma_r(\gamma_s(X)) = \gamma_{\max(r,s)}(X)$. In particular, each γ_r is an algebraic opening, and for $s > r$ we have $\gamma_s(X) \leq \gamma_r(X)$. *See* mathematical morphology, morphological operator, opening.

skeleton (1) the set of arcs, enclosing a region, resulting from the successive application of a thinning operator on the region.

(2) a shape representation consisting of a connected set of pixel locations of unit width running along the centers of the object limbs. This is a natural representation, where (a) limbs are of approximately uniform width and (b) the width is unimportant for shape analysis, so that all the shape topology is embedded in the skeleton. The prime application relates to interpretation of hand-drawn characters and script.

skeletonization a procedure, usually thinning, that produces an image skeleton.

skew (1) an arrangement of slots or conductors in squirrel cage rotors so that they are not parallel to the rotor axis.

(2) in computer buses, a condition where values on certain bus lines have slightly different transmission times than values on other lines of the same bus. *See also* tape skew.

skewed addressing *See* interleaved memory.

skewed symmetry the nonperpendicular appearance of a symmetry-axes system for an object, when the plane of the object is not perpendicular to the line of sight from the viewpoint.

skewing (1) the bending of a curve away from it's original shape.

(2) In a differential amplifier, the offset between two signals.

skin depth for a lossy material, the distance at which electromagnetic fields experience one neper of attenuation. For a good conductor, the skin depth is given by

$$\frac{1}{\sqrt{\pi \mu f \sigma}}$$

where f is the frequency, μ is the permeability, and σ is the conductivity.

skin effect the tendency of an alternating current to concentrate in the areas of lowest impedance.

skinny minnie a telescoping fiberglass pole with interchangeable tools mounted at its end. It can be extended sufficiently to allow a line worker to service cut-outs and similar pole-top equipment from the ground.

skip instruction an assembly language instruction that skips over the next instruction without executing it.

sky wave a wave that propagates into the ionosphere. It undergoes several reflections and refractions before it returns back to Earth.

slab waveguide a dielectric waveguide useful for theoretical studies and for approximating other types of waveguide such as the rib waveguide. *See* rib waveguide.

slant angle also called "dip angle"; the angle by which a plane slants or dips away from the frontal plane of the observer.

sleeve (1) rubber cover for a line worker's arms.

(2) a type of wire connector.

slew rate the rate of variation of an AC voltage in terms of volts per second.

In an op-amp, if the signal at the op-amp output attempts to exceed this limit, the op-amp cannot follow and distortion ("slew rate limiting") will result.

slice *See* wafer.

SLG *See* single line to ground fault.

slicer a device that estimates a transmitted symbol given an input that is corrupted by (residual) channel impairments. For example, a binary slicer outputs 0 or 1, depending on the current input.

sliding correlation a principle of operation of a correlation receiver in channel measurement, where pseudo-random sequences are utilized. The transmitted signal consists of a carrier modulated (typically employing phase shift keying) by a pseudorandom sequence. The received signal is correlated (multiplied) by a similar reference signal, in which the pseudorandom sequence has a clock rate slightly lower than in the transmitted signal. The difference in clock frequencies causes the relative phase (chip position) of the pseudorandom sequences to slide by each other. The output of a sliding correlator is a time-scaled version of the autocorrelation function of the pseudorandom sequence.

The time-scaling factor depends on the difference of the clock frequencies, and typically cannot be lower than 1000 without significant distortion in the resulting correlation function. This sets an upper bound to the rate of producing complete autocorrelation functions, making sliding correlation not ideally suited to measurement of channels with fast time variance. A sliding correlator must be implemented using analogue signal processing. *See also* stepping correlation.

sliding mode the motion of a dynamical system's trajectory while confined to a sliding surface.

sliding mode control a discontinuous control in which a sliding mode is deliberately induced. The design of a sliding mode controller consists of two phases. In the first phase, a sliding surface is specified by a designer. Then, in the second phase, feedback gains are selected so that the controlled system's trajectories are driven toward the sliding surface. The role of a sliding mode controller is to drive the system's trajectories to the surface and to maintain them on the surface, in sliding mode, for all subsequent time. While in sliding, the system is not affected by *matched uncertainties*. Furthermore, the system in sliding is governed by a reduced set of differential equations. This is called the order reduction, and it is a very useful feature in designing sliding mode controllers.

sliding mode domain a sliding mode domain D where for each $\varepsilon > 0$ there exists a $\delta > 0$ such that any trajectory starting in the n-dimensional δ-neighborhood of Δ may leave the n-dimensional ε-neighborhood of Δ only through the n-dimensional ε-neighborhood of the boundary of Δ.

sliding mode observer *See* sliding mode state estimator.

sliding mode state estimator state estimators of uncertain dynamical plants in which the error between the state estimate and the actual state exhibits sliding mode behavior on a sliding surface in the error space.

sliding surface a surface in the state space specified by a designer of a variable structure sliding mode controller. The role of a sliding mode controller is to drive the system's trajectories to the surface and to maintain them on the surface for all subsequent time. Alternative terms for sliding surface are switching surface, discontinuity manifold, equilibrium manifold.

sliding termination a precision air-dielectric coaxial transmission line that consists of a moveable, tapered termination used as an impedance standard for calibrating vector network analyzers and in other precision microwave measurement applications.

sliding window in an ARQ protocol, the (sliding) window represents the sequence numbers of transmitted packets whose acknowledgments have not been received. After an acknowledgement has been received for the packet whose sequence number is at the tail of the window, its sequence number is dropped from the window and a new packet whose sequence number is at the head of the window is transmitted, causing the window to slide one sequence number.

sliding-mode control a bang-bang control technique that confines the state space trajectory to the vicinity of a sliding line. Assuming a second-order system, the sliding line is defined as $ax_1 + bx_2 = 0$, where x_1 and x_2 are the state variables and a and b are constant coefficients determined by the desired control law. The sliding line exists if the trajectories of the subcircuits on either side of the line are directed toward the sliding line. The sliding line is stable if the motions along the sliding line are toward an operation point. The ideal overall trajectory is independent of the trajectories of the subcircuits.

slip in an induction motor, slip is defined as the ratio of the slip speed to the synchronous speed. The slip speed is the difference between the synchronous speed and the speed of the rotor. *See also* synchronous speed.

slip frequency the frequency of the rotor induced currents in an induction machine. Denoted by f_{sl}, the slip frequency is given by slip $\times$ stator frequency (f_s) and is the prime frequency used in slip frequency control of induction machines.

slip power recovery control a method of controlling the speed of a wound rotor induction machine by recovering the slip frequency power from the rotor to an AC power source or mechanical shaft through the converter connected to the rotor windings of the motor. Slip power recovery control reduces the losses that occur with rotor resistance control.

slip-ring contact a rotating, brush-contacted ring electrode connected to one end of a coil in an AC generator.

SLL *See* sidelobe level.

SLM *See* spatial light modulator or liquid crystal on silicon.

slope detector a circuit consisting of an LC tuned circuit, a detector diode, and a filter circuit that has an IF set to be on the most linear portion of the response curve. The circuit converts FM to AM by having the frequency changes from the FM signal cause the signals to move up and down the response curve which results in amplitude variations.

slope transform transform that plays for morphological operators a role which is to some extent analogous to that of the Fourier transform for linear shift invariant systems. We consider a space E of points x and a space F of slopes α, such that the (bilinear) scalar product $\langle \alpha, x \rangle$ is well-defined (for example

E, resp. F, can be either a Euclidean or a digital space). We consider functions on E or F having real or $\pm\infty$ values. Here the analog of the cisoid function is the linear function l_α of slope α defined by $l_\alpha(x) = \langle \alpha, x \rangle$. For any function f on E one defines its slope transform $\mathcal{S}_\vee(f)$ and its lower slope transform $\mathcal{S}_\wedge(f)$ by

$$\mathcal{S}_\vee(f)(\alpha) = \sup_{x \in E} \big(f(x) - \langle \alpha, x \rangle \big)$$

and

$$\mathcal{S}_\wedge(f)(\alpha) = \inf_{x \in E} \big(f(x) - \langle \alpha, x \rangle \big).$$

The counterpart for dilations and erosions of the convolution theorem in Fourier analysis is given by

$$\mathcal{S}_\vee(f \oplus g) = \mathcal{S}_\vee(f) + \mathcal{S}_\vee(g)$$

and

$$\mathcal{S}_\wedge(f \ominus g) = \mathcal{S}_\wedge(f) - \mathcal{S}_\vee(g).$$

For any function ψ on F one defines the *adjoint upper slope transform* $\mathcal{S}^-_\vee(\psi)$ and the *adjoint lower slope transform* $\mathcal{S}^-_\wedge(\psi)$ by

$$\mathcal{S}^-_\vee(\psi)(x) = \inf_{\alpha \in F} \big(\psi(\alpha) + \langle \alpha, x \rangle \big)$$

and

$$\mathcal{S}^-_\wedge(\psi)(x) = \sup_{\alpha \in F} \big(\psi(\alpha) + \langle \alpha, x \rangle \big).$$

Contrarily to the Fourier inversion formula in Fourier analysis, the adjoint upper/lower slope transform does not provide an exact inversion of the upper/lower slope transform; for every function f on E, $\mathcal{S}^-_\vee(\mathcal{S}_\vee(f))$ is the concave hull of f, in other words the lower envelope of all linear functions $l_\alpha + c$ ($\alpha \in F$, c real) which are $\geq f$, while $\mathcal{S}^-_\wedge(\mathcal{S}_\wedge(f))$ is the convex hull of f, in other words the upper envelope of all linear functions $l_\alpha + c$ which are $\leq f$. *See* dilation, erosion, Fourier transform, linear shift invariant system, morphological operator.

There is a variant theory of slope transforms,, where $\mathcal{S}^-_\vee(f)$ is a multivalued function, and for which an exact inverse transform exists.

slot a space between the teeth used to place windings in electrical machines.

slot pitch the angular distance (normally in electrical degrees) between the axes of two slots.

slotless motor permanent magnet brushless DC motor in which stator teeth are removed and the resulting space is partially filled with copper. The slotless construction permits an increase in rotor diameter within the same frame size, or alternatively an increase in electric loading without a corresponding increase in current density.

slotted ALOHA a multiple access protocol. In slotted ALOHA, time is divided into frames. Any user is allowed to transmit during any frame. The possible collisions result in retransmission at a later time. *See also* pure ALOHA.

slotted line coax or waveguide with a longitudinal slot that accommodates a voltage probe that can measure the voltage anywhere along the slot. Typically used to measure standing wave ratio (SWR).

slow start a congestion control algorithm that rapidly determines the bandwidth available to a transmitter by doubling the number of packets sent each round trip until losses are detected. This algorithm is "slow" when compared to the alternative of sending packets at the maximum rate achievable by the transmitter.

slow wave a wave whose phase velocity is slower than the velocity of light. For example, for suitably chosen helixes the wave can be considered to travel on the wire at the velocity of light, but the phase velocity is less than the velocity of light by the factor that the

pitch is less than the circumference. Slow wave may also be present on structures like coplanar waveguides.

slow-wave structure a short microwave transmission line in a traveling wave tube in which the longitudinal phase velocity of traveling microwave is slowed down to almost equal speed of electrons in the interacting electron beam of the tube.

slowly varying envelope approximation neglect of the second time and/or space derivatives in the wave equation governing nearly monochromatic/nearly plane-wave electromagnetic fields.

slowness surface a plot of the reciprocal of the phase velocity as a function of direction in an anisotropic crystal.

SMA connector a subminiature coaxial connector with both male and female versions capable of an upper frequency limitation of about 26 GHz.

small computer systems interface (SCSI) a high-speed parallel computer bus used to interface peripheral devices such as disk drives.

small disturbance a disturbance for which the equation for dynamic operation can be linearized for analysis.

small disturbance stability power system stability under small disturbances, which can be studied by using linearized power system models.

small gain theorem a sufficient condition for the robust stability of the closed-loop system. It requires the open-loop operator of the system to have a norm less than one. For linear systems, the small gain theorem guarantees well possedness while in the nonlinear case it should be assumed. The theorem may be highly conservative for structured uncertainties. In some cases the conservatism could be decreased by the use of structured norms.

small scale integration (SSI) an early level of integration circuit fabrication that allowed approximately between 1 and 12 gates on one chip.

small signal amplifier amplifier designed for amplifying very low level signals. Typically, small signal amplifiers have an AC signal magnitude that is 1/10 the DC value and operate under class A amplifier biasing conditions.

small-signal stability *See* dynamic stability.

smart antenna a set of antennas used in an intelligent way in one receiver to improve the performance of a communication link. *See also* beamforming, space division multiple access.

smart card credit-card-sized device containing a microcomputer, used for security-intensive functions such as debit transactions.

smart material one of a class of materials and/or composite media having inherent intelligence together with self-adaptive capabilities to external stimuli applied in proportion to a sensed material response. Also called intelligent material.

smart pixel an element in an array of light detectors that contains electronic signal processing circuitry in addition to the light detector; a spatial light modulator in which each pixel is controlled by a local electronic circuit. Smart pixels are fabricated with VLSI technology. Each light modulating pixel is connected to its own tiny electronic circuit adjacent to the pixel. The circuit may consist of detector, switching or logic circuit, memory, and source or additional shutter. It is an advanced, optically addressed spatial light modulator and still immature.

smart sensor sensor with inherent intelligence via built-in electronics.

smart structural material material in which the mechanical (elastic) properties can be modified adaptively through the application of external stimuli.

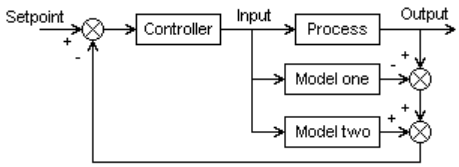
SMB connector a subminiature coaxial connector with snap-on mating and typical upper frequency limit of 10 GHz.

SMDA *See* Safe Medical Devices Act.

SMIB *See* single machine infinite bus system

Smith chart a graphical polar plot of the voltage reflection coefficient superimposed on a plot of two families of circles, with one family representing the real part of a complex impedance (admittance) and the other family representing the imaginary part of the complex impedance (admittance). A Smith chart can be used for many tasks including visualizing transmission line equations as well as matching loads to transmission lines, finding lengths and placements of stub tuners (both single and double stub tuners), finding the voltage standing wave ratio on a transmission line, and finding the reflection coefficient at any point on the transmission line.

Smith predictor a control scheme designed to deal with processes that contain significant dead-time in their responses. Its block diagram configuration is where model



Block diagram configuration for the Smith predictor.

one is an exact replica of the process under control, while model two is the same model with the deadtime term removed. The controller is designed to control model two, thereby allowing faster closed loop responses than would otherwise have been possible. *See also* internal model control.

SMM *See* sub-millimeter.

smoothing (1) an estimation procedure in which a past value of the state vector (see the definition) is estimated based on the data available up to the present time.

(2) the removal from an image (signal) of high-frequency components obtained, e.g., through a convolutional averaging or Gaussian filter, usually performed to remove additive speckle noise.

(3) any process by which noise is suppressed, following a comparison of potential noise points with neighboring intensity values, as for mean filtering and median filtering. Also, a process in which the signal is smoothed, e.g., by a low-pass filter, to suppress complexity and save on storage requirements.

SMS *See* service management system.

SMT *See* surface mount technology.

snake *See* active contour.

Snell's Law the law that gives the angles of reflection and refraction of a plane electromagnetic wave when the wave is incident on a boundary between two media.

Consider a plane wave impinging on a surface between two media with different dielectric constants: part of the incident power will be transmitted to the other region, while part will be reflected. Let us denote the angle of reflection by θ_1^r, the angle of transmission by θ_2^t, and the angle of incidence by θ_1^i. We also denote the electric permittivity and the magnetic permeability by ϵ, μ, respectively; the subscripts 1, 2 refer to the particular medium under consideration. The angle of reflection

is equal to the angle of incidence, i.e.,

$$\theta_1^r = \theta_1^i$$

and the Snell's Law states that

$$\sqrt{\mu_1 \epsilon_1} \sin \theta_1^i = \sqrt{\mu_2 \epsilon_2} \sin \theta_2^t$$

SNIR *See* signal-to-noise plus interference ratio.

snoop in hardware systems, a process of examining values as they are transmitted in order to possibly expedite some later activity.

snooping bus a multiprocessor bus that is continuously monitored by the cache controllers to maintain cache coherence.

snow noise noise composed of small, white marks randomly scattered throughout an image. Television pictures exhibit snow noise when the reception is poor.

SNR *See* signal-to-noise ratio.

snubber an auxiliary circuit or circuit elements used to control the rate of rise or fall of the current flowing into a power electronic device or the rate of fall of the voltage across the device during turn-off. Snubbers are used to limit dv/dt and di/dt and eliminate ringing in a switching circuit during switching transients. Both dissipative and nondissipative snubbers are used. *See also* soft switching.

snubber circuit *See* snubber.

Sobel operator a common digital approximation of the gradient ∇f, often used in edge detection. It is specified by the pair of convolution masks

$$\frac{\partial f}{\partial x} \approx \begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{matrix} \quad \frac{\partial f}{\partial y} \approx \begin{matrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{matrix}.$$

The respective mask responses, g_x, g_y, are components of the local vector gradient, from which edge magnitude and direction can be calculated straightforwardly.

sodium-cooled reactor a nuclear reactor in which the heat is removed from the core by means of circulating liquid metallic sodium.

soft computing is an association of computing methodologies centering on fuzzy logic, artificial neural networks, and evolutionary computing. Each of these methodologies provide us with complementary and synergistic reasoning and searching methods to solve complex, real-word problems. *See also* fuzzy logic, neural network.

soft contaminant a contaminant that to first order is not absorbed by X-rays, and which therefore tends to remain undetected in X-ray images: typical soft contaminants are rubber, wood and many types of plastic (though much depends on the particular atomic composition of the material).

soft decision demodulation that outputs an estimate of the received symbol value along with an indication of the reliability of that value. It is usually implemented by quantizing the received signal to more levels than there are symbol values.

soft facimile for low-capacity channels, images are transmitted and displayed in a progressive (stage by stage) manner. A crude representation is first transmitted and then details are added at each stage. This is referred to as soft facimile. *See also* progressive transmission.

soft fault *See* transient fault.

soft hand-off a hand-off scheme in a CDMA cellular system such as that specified by the IS-95 standard where signal transmission occurs through multiple base stations during the hand-off process. The multiple signal components received from the different base stations are combined using

some type of diversity combining. *See also* hand-off, IS-95.

soft iron a term used to describe iron that has a low coercivity. Note that soft refers to the magnetic properties of the material, not necessarily the physical properties.

soft magnetic material a magnetic material that does not retain its magnetization when the magnetizing field is removed; a material with low coercivity and high permeability.

soft real-time *See* soft real-time system.

soft real-time system a real-time system in which failure to meet deadlines results in performance degradation but not necessarily failure. *Compare with* firm real-time, hard real-time.

soft switching the control of converter switching in order to utilize device and component parasitics and resonance conditions to enable zero current switching (ZCS) or zero voltage switching (ZVS), thereby reducing switching losses, stress and EMI. Typically this is performed with additional resonant components and switches that are activated only during the switching transients.

Soft switching also allows higher switching frequencies in order to reduce the converter size and weight, thus increasing the power density.

softbake *See* prebake.

soft-decision decoding decoding of encoded information given an unquantized (or finely quantized) estimate of the individually coded message symbols (for example, the output directly from the channel). *Compare with* hard-decision decoding.

soft-starter a motor starter that provides a ramp-up of voltage supplied to the motor at starting with the objective of reducing the starting current and torque.

soft X-ray lithography *See* EUV lithography.

softer hand-off similar to the concept of soft hand-off except that it involves transmission/reception through multiple antenna sectors of the same cell as opposed to multiple base stations. In contrast to soft hand-off, softer hand-off need not involve the mobile telephone system switch in the hand-off process.

software design a phase of software development life cycle that maps what the system is supposed to do into how the system will do it in a particular hardware/software configuration.

software development life cycle a way to divide the work that takes place in the development of an application.

software engineering systematic development, operation, maintenance, and retirement of software.

software evolution the process that adapts the software to changes in the environment where it is used.

software interrupt a machine instruction that initiates an interrupt function. Software interrupts are often used for system calls, because they can be executed from anywhere in memory and the processor provides the necessary return address handling. Also known as a supervisor call instruction (SVC) (IBM mainframes) or INT instruction (Intel X86).

software reengineering the reverse analysis of an old application to conform to a new methodology.

soil electrode an electrical connection to the soil, often in the form of a metal stake driven into the earth.

solar–thermal–electric conversion collection of solar energy in thermal form using

flat-plate or concentrating collectors and its conversion to electrical form.

solder duration *See* solder profile.

solder profile the time versus temperature profile required to properly solder a connection without damaging the component to either side of the connection, and without leaving any defects in the solder joint. The solder profile will include preheating, ramp-up, time at solder reflow temperature, ramp-down, and any relevant limits in time and temperature. The profile will be specific to a given system (components, materials, plating, fluxes or gases, solder type, surface preparation, etc.).

solder temperature *See* solder profile.

sole a nonemitting cathode.

solenoid a wound cylindrical and magnetic material assembly used typically for producing linear motions.

solid laser laser in which the amplifying medium is a solid.

solid state disk (SSD) very large-capacity, but slow, semiconductor memory that may be used as a logical disk, extended main memory, or as a logical cache between main memory and conventional disk. SSD is typically constructed from DRAM and equipped with a battery to make it nonvolatile. First used in IBM 3090 and Cray-XMP computer systems.

solid state laser laser in which the amplifying medium is a solid, sometimes considered to exclude semiconductor lasers.

solid state power amplifier (SSPA) a high-power, multistage amplifier using semiconductor devices.

solid state relay a protective relay that employs analog electronics, logic electronics, and magnetics to implement the operating logic.

solid state ultraviolet laser an ultraviolet laser made from a solid state or semiconductor material, e.g., Nd:LaF3, Ce:LaF.

solid state UV laser *See* solid state ultraviolet laser.

solidly grounded an electrical distribution system in which one of the normal current-carrying conductors, often the neutral, is intentionally connected to ground with no impedance other than that of the conductor comprising the connection.

solidly grounded system a grounding scheme in which the neutral wire of a power system is connected to ground at frequent intervals so as to minimize the impedance between neutral and ground.

soliton an optical pulse that preserves its shape while propagating by balancing fiber dispersion and nonlinearity.

soliton transmission system often termed the fifth generation of fiber optic communication systems. *See also* soliton.

solution domain electromagnetic fields can be represented as a function of time, or a *time-domain* description, or as a function of frequency using a (usually) Fourier transform, which produces a frequency-domain description.

SOM *See* self organizing map.

sonar acronym for "sound navigation and ranging" adopted in the 1940s, involves the use of sound to explore the ocean and underwater objects.

sonar equation *See* figure of merit.

SONET *See* synchronous optical network.

sonorant the class of phonemes with a formant-like spectrum. For example, vowels and nasals exhibit a spectrum that is based on formants.

SONT *See* self-organizing neural tree.

SOP *See* sum of products.

sound carrier in a TV signal, the FM carrier that transmits the audio part of the program.

sound velocity profile (SVP) description of the speed of sound in water as a function of water depth.

source (1) refers to the signal generator/device that generates the RF, microwave, or micromilliwatt frequencies.

(2) the terminal of a FET from which electrons flow (electrons in the FET channel flow from the source, and current flow is always in the negative direction of electron movement, since electrons are negative). It is usually considered to be the metal contact at the surface of the die.

source code (1) software code written in a form or language meant to be understood by programmers. Must be translated to object code in order to run on a computer.

(2) a set of codewords used to represent messages, such that redundancy is removed, in order to require less storage space or transmission time.

source coding the process of mapping signals onto a finite set of representative signal vectors referred to as codewords.

source compression *See* source coding.

source encoder a device that substantially reduces the data rate of linearly digitized audio signals by taking advantage of the psychoacoustic properties of human hearing, eliminating redundant and subjectively irrelevant information from the output signal. Transform source encoders work entirely within the frequency domain, while time-domain source encoders work primarily in the time domain. Source decoders reverse the process, using various masking techniques to simulate the properties of the original linear data.

source follower *See* common drain amplifier.

source operand in ALU operations, one of the input values.

source routing method of routing packets in which the entire route through the network is prepended to the packet. From any node in the route, the next entry in the source root determines the node to which the packet should next be forwarded.

source-coupled pair *See* differential pair.

space division multiple access (SDMA) multiple access technique where the users' channels are separated into spot-beams with highly directional or adaptive antennas allowing reuse of time and frequency resources between users. Used in conjunction with FDMA/TDMA/CDMA.

space invariance a system which a shift (translation) in the spatial coordinates for all inputs yields the same output except for an identical shift. Thus, in two dimensions, for an input $I(x, y)$, output $O(x, y)$ and system S, if

$$O(x - x_0, y - y_0) = S\{I(x - x_0, y - y_0)\}$$

for all (x_0, y_0) and all inputs $I(x, y)$, the system S is space invariant.

spacer cable another name for messenger cable.

SPARC *See* scaled processor architecture.

spark gap a pressurized high-current switch using a principle of electric field disruption to start the electron flow.

sparse equation when a set of linear simultaneous equations has very few nonzeros in any row, the system is said to be sparse. Normally for a system to be considered sparse, less than 10% of the possible entries should be nonzero. For large integrated circuits, less than 1% of the possible entries are nonzero.

sparse matrix a rectangular array of numbers, most of whose elements are zero or null.

sparse vector in computer instruction processing, a matrix in which most elements have such small values that are treated as zeros. Special representation schemes can be used to save memory space, with a cost of increased execution time to access single elements of the matrix.

spatial coherence *See* coherence.

spatial dispersion occurs in a medium when its dielectric function depends on the wave number.

spatial domain the representation of a signal, usually an image, as a function of spatial coordinates. *See also* frequency domain.

spatial filtering a technique used to either filter out interfering signals in a communication system, or as a multiple access technique that enables two or more subscribers, controlled by the same base station to use the same time, frequency and code resources on the grounds of their physical location or spatial separation. *See also* beamforming.

spatial frequency the variables of the 2-D Fourier transform of a function of spatial coordinates are referred to as horizontal and vertical spatial frequencies. The spatial frequency of a 2-D sinusoidal signal in a given dimension is the number of cycles per unit distance in that dimension.

spatial hole burning spatially localized reduction in the gain of a laser amplifier due to saturation by an intense signal; transverse spatial hole burning due to the transverse beam profile is distinguished from longitudinal spatial hole-burning due to the standing wave nature of the fields and possibly also to high gain per pass; spatial relaxation (or cross-relaxation) reduces spatial hole burning.

spatial light modulator (SLM) a device that alters both the spatial and temporal character of a light beam. A three-port device with input, readout, and control or modulation ports. Modulation signals can be applied either electrically, i.e., an electrically addressed spatial light modulator, or optically, i.e., optically addressed spatial light modulator. Also called a light valve.

spatial light modulator in optical computing a device for modulating amplitude or phase of light passing through it. If the input signal is a light beam, it is called optically addressed spatial light modulator. If the input signal is electronic, it is called electrically addressed spatial light modulator. Light modulation is usually based on the electro-optic effect. In optical computing, an optically addressed spatial light modulator is a device used as a medium for controlling or switching light using light. Since a light beam cannot directly affect another light beam, a spatial light modulator is required. The modulation process can be seen, first, as the modulating light affecting the spatial light modulator; then the affected spatial light modulator modulates another light beam.

spatial locality *See* locality.

spatial power combining the power generated from many devices can be combined coherently into space. These techniques are

used in order to alleviate circuit losses at high microwave frequencies.

spatial redundancy the redundancy between samples of an image or random process that is a function of spatial coordinates. Images typically exhibit a high degree of spatial redundancy which can be exploited to obtain a high compression ratio.

spatial resolution (1) the ability to resolve two closely spaced points or a periodic pattern. Rayleigh proposed the criterion that two stars could be resolved when the maximum in the image pattern from one star coincides with the first minimum in the other. Units of spatial resolution are lines or line pairs per millimeter.

(2) a measure of the ability of a system to resolve spatial details in a signal. For a discrete image, spatial resolution generally refers to the number of pixels per unit length, giving possibly different horizontal and vertical spatial resolutions. *See also* frequency resolution.

spawn to create a new process within a multitasking computing system.

SPDT *See* single-pole double-throw.

speaker identification a task that consists of identifying which speaker (of a closed set) pronounced a given portion of speech signal. The basic assumption is that no speaker different from the defined closed set is considered. The emphasis is on the discrimination of the given speakers, whereas no strong rejection constraints are commonly required.

speaker verification a task that, unlike speaker identification, the speaker set for this problem is open. As a consequence, one has to verify the given speaker against any potentional impostor that is not known in advance. Basically, one cannot rely on the knowledge of the probability distribution of the "negative examples," since there is no restriction on who is supposed to use the verification system.

SPEC *See* System Performance and Evaluation Cooperative.

SPEC benchmarks suites of test programs created by the System Performance and Evaluation Cooperative.

special-purpose digital signal processor digital signal processor with special feature for handling a specific signal processing application, such as FFT.

specific absorption rate (SAR) the deposition of energy over time into a body. The units are generally watts per kilogram of body mass. This is the attribute on which findings by various researchers can be compared and on which the exposure standards base their guidelines.

specific inductive capacity *See* dielectric constant.

specification a statement of the design or development requirements to be satisfied by a system or product.

speckle (1) grainy light pattern that results when coherent light scatters from a rough surface.

(2) granular image noise due to fluctuations in the number of photons arriving at an image sensor. Speckle often occurs in night-vision equipment and X-ray images. Also called quantum mottle.

speckle pattern grainy appearance of the intensity of scattered light due to random interference. The grain size is inverse of the illuminated area of the scattering medium in wavelength units.

SPECT *See* single photon emission computed tomography.

spectral completeness characteristic of a linear dynamical system whose eigenfunctions connected with eigenvalues form a basis in the state space. Spectral completeness depends on the matrix A_1. System is spectrally complete if and only if

$$\text{rank} A_1 = n$$

spectral controllabillity a linear dynamical system characteristic where every subsystem connected with an eigenvalue is controllable.

spectral density function the Fourier transform of the covariance for a wide-sense stationary process.

spectral domain the transform domain obtained by taking a Fourier transform in order to solve a boundary value problem. This technique is particularly convenient for the analysis of microstrip circuits and antennas.

spectral hole burning a technique used to render an absorbing material transparent at select frequencies by bleaching a portion of the (inhomogeneously broadened) absorption spectrum.

spectral linewidth *See* line width.

spectral quantum efficiency for a photodetector, the ratio of the average number of free electrons produced per monochormatic input photon of wavelength λ. The relationship between spectral quantum efficiency $(Q_e(\lambda))$, wavelength (λ) is

$$S(\lambda) = (124)\,(Q_e(\lambda))\,/\lambda$$

where $S(\lambda)$, $(Q_e(\lambda))$, and λ are given in units of milliamperes per watt, percentage, and nanometers, respectively.

spectral representation *See* spectral domain.

spectral width *See* line width.

spectrometer optical instrument that disperses broadband light into its component wavelengths, allowing the measurement of light intensity at each individual wavelength. Spectrometers may use prisms or gratings for wavelength dispersion and any of a variety of light detectors including photomultiplier tubes or charge-coupled devices.

spectroscopy the measurement of the intensities of wavelength dispersed light to identify a chemical component or measure its concentration.

spectrum (1) a range of electromagnetic energy ordered in accordance with their relative periodicity.

(2) the magnitude of the Fourier transform of a (deterministic) signal. The word spectrum is also used to refer to the power spectrum of a random process.

spectrum analyzer a test system that measures RF or microwave devices in terms of signal frequency and signal power.

spectrum reuse reusing frequencies over and over again in a confined area, resulting in more efficient utilization and higher radio network capacity.

specular *See* specular reflection.

specular intensity the energy reflected from a rough surface in the specular direction. Sometimes called coherent component of the scattered intensity.

specular reflection (1) the process by which a radio wave reflects from an electrically "even" surface experiencing changes only in amplitude, phase, and polarization, comparable to light reflecting from a mirror.

(2) the part of an electromagnetic wave that is reflected in the direction specified by Snell's law of reflection.

specular scattering *See* specular reflection.

specular transmittance the effect on a signal passing through a diffusely transmitting surface such as that the signal scattered in all directions.

speculative execution a CPU instruction execution technique in which instructions are executed without regard to data dependencies. *See also* lookahead.

speech activity factor the fraction of time for which a speech signal is nonzero-valued, over a long period of time. Zero-valued speech time segments occur as a result of pauses in the speech process. The speech activity factor is an important concept in the theory of statistical multiplexing of voice signals in a telephone switch. It is also an important concept in the IS-95 CDMA cellular system.

speech analysis process of extracting time-varying parameters from the speech signal that represent a model for speech production.

speech coding source coding of a speech signal. That is, the process of representing a speech signal in digital form using as low rate (in terms of, e.g., bits per second) as possible.

speech compression the encoding of a speech signal into a digital signal such that the resulting bit rate is small and the original speech signal may be reproduced with as little distortion as possible. The transformation of a coded speech signal into another coded speech signal of lower bit rate in such a way that there is insignificant loss in speech quality of the decoded and play-back signal.

speech enhancement improvement of perceptual aspects of speech signals.

speech preprocessing the first step in all problems of speech processing. In preprocessing, the objective is to condition the signal so as to come up with more compressed and informative representations. Within portions of about 10 ms (frames), in practice the speech signal turns out to be quasi-stationary. For each frame, all relevant speech preprocessing approaches return a vector of parameters that make it possible to reconstruct the signal. Speech preprocessing is mainly carried out by using frequential approaches (e.g., the short-time Fourier transform) or linear prediction.

speech recognition the process of recognizing speech portions carrying out linguistic information. The recognition can involve phonemes, single and connected words. Because of the crucial role of time, most successful approaches to automatic speech recognition are currently based on HMM (hidden Markov models) that incorporate very naturally the time dimension.

speech recognizer system for performing speech recognition.

speech synthesis the process of turning information into synthesized speech. When the synthesis involves restrictive linguistic domains (e.g., announcements in railway stations), the process often consists simply of playing back speech recorded in EPROM memories using proper coding (e.g., ADPCM). However, if one makes no restrictions on the information to synthesize, only artificial speech production is possible, which is commonly based on systems that predict phonetic units from linguistic information.

speech synthesizer system for performing speech synthesis.

speech understanding the process of understanding the meaning of a given portion of speech containing one or more sentences. Unlike speech recognition, the problem is not that of translating spoken to written units (e.g., words), but to extract the meaning. Models of speech understanding cannot simply be based on the recognition of linguistic units, but must also take into account the domain semantics.

speed droop a linear characteristic that is provided to governors of two or more units operating in parallel for stable load division in case of load increase.

speed of light (1) a scalar constant in vacuum roughly equal to 3×10^8 meters per second.

(2) the phase velocity representing the rate of advance of the phase front of a monochromatic light wave.

speed range the minimum and maximum speeds at which a motor must operate under constant or variable torque load conditions. A 4:1 speed range for a motor with a top speed of 1800 rpm means that the motor must be able to operate as low as 450 rpm and still remain within regulation specifications. The controllable speed range of a motor is limited by the ability to deliver required torque below base speed without additional cooling.

speed regulation the variation of the output speed of an electromechanical device as the load on the shaft is increased from zero to some specified fraction of the full load or rated load. Usually expressed as a percentage of the no-load speed. A large speed regulation is most often considered as a bad regulation from a control point of view.

speed sensor a device used to detect the speed of the rotor of an electric machine. Optical (strobe) and electromagnetic tachometers are commonly used.

speed servo a servo where the speed is the controlled parameter. *See also* servo.

speed-power product an overall performance measurement that is used to compare the various logic families and subfamilies.

speedup factor the ratio of execution time for a problem on a single processor using the best sequential algorithm to the execution time on a multiprocessor using a parallel algorithm under consideration. Provides a performance measure for the parallel algorithm and the multiprocessor.

spent fuel irradiated fuel whose fissile component has been reduced such that it is no longer useful as reactor fuel.

sphere gap a spark gap whose electrodes are metal spheres. A sphere gap with carefully-calibrated electrode spacing is used as a measuring instrument for voltages in the kilovolt to megavolt range.

spherical mirror a mirror in which the reflecting surface is spherical.

spherical wave an electromagnetic wave in which each wavefront (surface of constant phase) forms a sphere and propagates in toward or away from the center of the sphere. A uniform spherical wave has the same amplitude over an entire wavefront; a nonuniform spherical wave has varying amplitude.

spherical wrist a wrist where all of its revolute axes intersect at a single point. Such a wrist is typically thought of as mounted on a three-degree-of-mobility arm of a six-degree-of-mobility manipulator. For manipulators with a spherical wrist it is possible to solve the inverse kinematics from the arm separately from the inverse kinematics for the spherical wrist. This is equivalent to the inverse kinematics problem subdivided into two subproblems, since the solution for the position is decoupled from that for the orientation.

SPICE a computer simulation program developed by the University of California, Berkeley, in 1975. Versions are available from several companies. The program is particularly advantageous for electronic circuit analysis, since DC, AC, transient, noise, and statistical analysis is possible.

spike *See* surge.

spike suppressor any of several devices e.g., metal-oxide varistors that clamp short-duration power line overvoltages to an acceptable level.

spillover phenomenon that occurs when radiation from a feed extends past the reflector edges and is not intercepted by the reflector.

spin echo an oscillating electromagnetic field emitted by a macroscopic orientation of atomic or nuclear spins, generated by reversing the dephasing process in an inhomogeneously broadened material.

spin coating the process of coating a thin layer of resist onto a substrate by pouring a liquid resist onto the substrate and then spinning the substrate to achieve a thin uniform coat.

spin lock a mutual exclusion mechanism where a process spins in an infinite loop waiting for the value of a variable to indicate a resource availability.

spindle *See* disk spindle.

spiral computed tomography (CT) an imaging modality that uses a rotating X-ray source and detector revolving around a continuously moving gantry. As viewed from the gantry, the X-ray source appears to travel in a spiral. A continuous set of projection images is gathered around the spiral and is interpolated to obtain traditional transverse cross-section images. Also known as helical CT.

spiral CT *See* spiral computed tomography.

spiral inductor an integrated circuit implementation of a common electrical element that stores magnetic energy. Two extreme behaviors of an inductor are that it will act as a short circuit to low frequency or DC energy, and as an open circuit to energy at a sufficiently high frequency (how high is determined by the inductor value). In an MMIC, a spiral inductor is realized by a rectangular or circular spiral layout of a narrow strip of metal. The value of the inductance increases as the number of turns and total length of the spiral is increased. Large spiral inductors are very commonly used as "bias chokes" to isolate the DC input connection from the RF circuit. Since a large valued inductor essentially looks like an open circuit to high frequency RF/microwave energy, negligible RF/microwave energy will leak through and interact with the DC bias circuitry.

splice a permanent connection between two fibers made by melting or fusing the two fibers together in an electric arc or gas flame. Or they may be held together in a variety of mechanical devices that align the two fiber cores. In fusion splicing, connections can be achieved with losses < 0.1 dB.

spline (1) a continuous function, interpolating a set of data points p_i, that is composed of segments, having p_i and p_{i+k} as extremes. The segments are linked together in such a way that the continuity constraint is satisfied.

(2) piecewise polynomial, with a smooth fit between the pieces.

spline wavelet wavelet that is in the form of a spline.

split and merge procedure often used in image or signal segmentation. The procedure involves splitting, iteratively applied if needed, the inhomogeneous regions of an image or sections of a discrete signal and followed by merging similar regions or sections is a split and merge.

split transaction a bus transaction (e.g., memory read or write) in which a request and the corresponding response are sent in two different bus transactions.

SPM laser *See* synchronously pumped-modelocked laser.

spontaneous decay process by which an atom or molecule in the absence of outside influence undergoes a transition from one energy state to another lower state.

spontaneous emission radiation resulting when an atom or molecule in the absence of outside influence undergoes a transition from one energy state to another lower state. *Contrast with* stimulated emission.

spontaneous lifetime coefficient representing the time after which a population of isolated atoms in an excited state may be expected to fall to one over e of its initial value, transition lifetime.

spontaneous light scattering scattering of light from thermally produced refractive index variations, e.g., spontaneous Brillouin scattering and spontaneous Raman scattering.

spontaneous polarization the internal electrical dipole moment of ferroelectric crystal.

spontaneous pulsations periodic or chaotic pulsations in the output of a laser oscillator when there is no modulation of the laser excitation or cavity loss.

spool (1) acronym for "simultaneous peripheral operation on-line." Area managed by a process (called a spooler) where data from slow I/O operations are stored in order to allow their temporal overlapping with other operations.

(2) a cylindrical ceramic insulator, typically used for secondary conductors in distribution work.

spooler *See* spool.

spooling sending printer output to a secondary storage device, such as a disk, rather than directly to the printer. This is done because disk devices can accept data at a much higher rate than printers.

spot size the $1/e$ amplitude radius of the electromagnetic field of a Gaussian beam, squeezed light.

SPPC *See* self-pumped phase conjugator.

SPR *See* strictly positive real.

SPR function *See* strictly positive real function.

spread-spectrum a modulation procedure in which the spectrum of an information bearing signal is spread by some techniques such as multiplication by a pseudo-noise sequence. The result is a signal with much wider bandwidth that has better protection again interference.

spread-spectrum multiple-access a multiple-access system in which each sender transmits their data using a frequency bandwidth significantly greater than the information bandwidth of the signal.

spreading code a sequence used for spreading the spectrum of the information signal in a spread-spectrum system, commonly done either by direct multiplication of the faster-varying spreading signal with the data sequence (direct-sequence, DS), or by hopping the carrier-frequency (frequency-hopping, FH). Also known as spreading sequence. *See also* short code, long code.

spreading gain in a spread-spectrum system, the number of dimensions used for transmitting the signal divided by the number of dimensions actually needed if spreading was not used. This is approximately equal to the ratio between the bandwidth after spreading and the bandwidth before spreading. In a BPSK system, it is equal to the number of

chips per bit in a direct sequence system. Also called processing gain.

spreading sequence *See* spreading code.

SPST *See* single-pole single-throw.

spur a conductor which branches off of a main line.

spur-free dynamic range of Bragg cell regime of Bragg cell $f_1 + f_2$ multifrequency drive condition given by the ratio of the diffracted light intensity at the true frequency spatial/spectral locations f_1 or f_2 to the intensity of the intermodulation products at $2f_1 - f_2$ and $2f_2 - f_1$.

spurious undesired, nonharmonically related, nonrandom signals or spectral content generated internal to a nonlinear circuit. Generally, spurious signals are created by internal mixing of multiple input signals, by internally generated oscillations, and by combinations thereof.

spurious interrupt unwanted, random interrupt.

SQ *See* scalar quantization.

square detection a special case of rectangle detection.

square pixel *See* pixel.

square-law detector the square-law behavior for detector diodes is the usual operating condition, but can only be obtained over a restricted range of input powers. If the input power is too large, small-signal conditions will not apply, and the output will become saturated and approach a linear, and then a constant, i versus p characteristic. At very low signal levels, the input will be lost in the noise floor of the device.

square-wave a waveform of square shape which is usually periodic with known periodicity. Often used as a test signal.

square-wave brushless DC motor a permanent magnet brushless DC motor with concentrated stator phase windings. The concentrated windings create a square wave flux distribution across the air gap and a trapezoidal shaped back-EMF.

square-wave inverter a self-commutated inverter with a square-wave output. The frequency is set by the switching frequency while the amplitude may be controlled by adjusting the input DC voltage.

squelch to automatically reduce the gain of the audio amplifier of a receiver in order to suppress background noise when no input signal is being received. The circuit performing this function is called the squelch circuit, and it acts as a controllable receiver input switch to allow reception of strong signals and block the weak and noisy signals.

squeeze-on a large crimped connector which requires a special press for installation.

squirrel-cage induction motor an induction motor in which the secondary circuit (on the rotor) consists of bars, short-circuited by end rings. This forms a squirrel cage conductor structure, which is disposed in slots in the rotor core. *See also* cage-rotor induction motor.

SRAM *See* static random access memory.

SS7 *See* signaling system 7.

SSB *See* single sideband modulation.

SSD *See* solid state disk.

SSI *See* small scale integration.

SSPA *See* solid state power amplifier.

stability (1) the condition of a dynamic or closed-loop control system in which the output or controlled variable always corresponds, at least approximately, to the input or command within a limited range. In most devices, this is a measure of the inherent ability of the circuit to avoid internally generated oscillations.

In oscillators, stability denotes the ability of the circuit to maintain a stable internally generated amplitude and frequency. The circuit components, bias, loading, drive and environmental conditions, and possible variations therein, must be accounted for. *See also* Linville stability factor and Rollett stability factor.

(2) in electronic drives, the ability of a drive to operate a motor at constant speed (under varying load), without hunting (alternately speeding up and slowing down). It is related to both the characteristics of the load being driven and electrical time constants in the drive regulator circuits.

stability circles circles plotted on the Smith chart that graphical indicate the regions of instability for an RF device.

stability criteria boundaries on regions of stable and unstable behavior in laser parameter space.

stability factors two factors, K and $B1$, that specify the necessary and sufficient conditions for a linear circuit or device to be conditionally or unconditionally stable when the input and output ports are terminated in arbitrary impedances. For unconditional stability, factors K must be greater than unity, and $B1$ must simultaneously be greater than 0.

stability limit the maximum power flow possible through a point in a power system if the system is to remain stable. *See* transient stability, steady-state stability.

stability of 2-D Fornasini–Marchesini model the second 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) is called asymptotically stable if for zero inputs $u_{ij} = 0$ $i, j \in Z_+$ and bounded $\|X_0\|$ we have $\lim_{i\to\infty} \|X_i\| = 0$, where $x_{ij} \in R^n$ is the local state vector, $u_{ij} \in R^m$ is the input vector,

$$X_k := \{x_{ij} : i + j = k; i, j \in Z_+\}$$
$$\|X_i\| = \sup_{k\in Z+} \|x(i-k,k)\|$$

and $\|x\|$ denotes the Euclidean norm of x. The model is asymptotically stable if and only if

$$\det\left[I_n - A_1 z_1^{-1} - A_2 z_2^{-1}\right] \neq 0$$

for $\|z_1^{-1}\| \leq 1, \|z_2^{-1}\| \leq 1$.

stability of 2-D Roesser model 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)

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

is called asymptotically stable if for zero inputs $u_{ij} = 0$, $i, j \in Z_+$ and bounded $X^h := \sup_{j\in Z_+} ||x^h_{0j}||$ and $X^v := \sup_{j\in Z_+} ||x^v_{i0}||$ we have bounded $\sup_{j\in Z_+} ||x_{ij}||$ and $\lim_{i,j\to\infty} ||x_{ij}|| = 0$, 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, D are real matrices, and $\|x\|$ denotes the Euclidean norm of x. The model is asymptotically stable if and only if

$$\det \begin{bmatrix} I_{n_1} - A_1 z_1^{-1} & -A_2 z_1^{-1} \\ -A_3 z_2^{-1} & I_{n_2} - A_4 z_2^{-1} \end{bmatrix} \neq 0$$

for

$$\left\|z_1^{-1}\right\| \le 1, \quad \left\|z_2^{-1}\right\| \le 1$$

stability study the determination of conditions which will cause a power system to become unstable so that these conditions can be avoided or corrected.

stabilizability the property of a system concerning the existence of a stabilizing state feedback or output feedback control. For linear systems, it is characterized as the controllability (see the definition) of all the unstable modes.

stabilization of linear 2-D systems the 2-D Roesser model

$$\begin{bmatrix} x_{i+1,j}^h \\ x_{i,j+1}^v \end{bmatrix} = \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \begin{bmatrix} x_{ij}^h \\ x_{ij}^v \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} u_{ij}$$

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

$$y_{ij} = [C_1 \;\; C_2] \begin{bmatrix} x_{ij}^h \\ x_{ij}^v \end{bmatrix} + Du_{ij}$$

is called stabilizable by state feedback

$$u_{ij} = [K_1 \;\; K_2] \begin{bmatrix} x_{ij}^h \\ x_{ij}^v \end{bmatrix}$$

if there exists $K_1 \in R^{m \times n_1}$ and $K_2 \in R^{m \times n_2}$ such that the closed-loop system is asymptotically stable, i.e.,

$$\det \begin{bmatrix} I_{n_1} - (A_1 + B_1K_1)\, z_1^{-1} & -(A_2 + B_1K_2)\, z_1^{-1} \\ -(A_3 + B_2K_1)\, z_2^{-1} & I_{n_2} - (A_4 + B_2K_2)\, z_2^{-1} \end{bmatrix} \ne 0$$
$$\text{for } \left\|z_1^{-1}\right\| \le 1, \quad \left\|z_2^{-1}\right\| \le 1$$

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 $y_{ij} \in R^p$ is the output vector, A_1, A_2, A_3, A_4, B_1, B_2, C_1, C_2, D are real matrices. Similarly, the model is called stabilizable by output feedback $u_{ij} = Fy_{ij}$ if there exists $F \in R^{m \times p}$ such that the closed-loop system is asymptotically stable, i.e.,

$$\det \begin{bmatrix} I_{n_1} - (A_1 + B_1FC_1)\, z_1^{-1} & -(A_2 + B_1FC_2)\, z_1^{-1} \\ -(A_3 + B_2FC_1)\, z_2^{-1} & I_{n_2} - (A_4 + B_2FC_2)\, z_2^{-1} \end{bmatrix} \ne 0$$
$$\text{for } \left\|z_1^{-1}\right\| \le 1, \left\|z_2^{-1}\right\| \le 1$$

stabilized beam current the amount of beam current required to stabilize the target when a given amount of light is incident on the target. The beam current is normally set at two times picture white.

stable a system characteristic in which the transients all decay to zero in finite time is said to be stable. If any transient term grows with time, then the system is unstable. If the transient persists, then the system is marginally stable. (An oscillator is a common example of marginal stability.)

Much of control engineering theory deals with the problem of classifying closed-loop systems into those that are stable and those that are unstable, with marginally stable systems defining the boundary between the two.

stable equilibrium an equilibrium point (see the definition) such that all solutions that start "sufficiently close," stay "close" in time. If the point is not stable, it is called unstable.

stable state (1) the equilibrium state of a dynamic system described by a first-order vector differential equation is said to be stable if given $\epsilon > 0$ there exists a $\delta = \delta(\epsilon, t_0)$, such that

$$\| x(t_0) - x_e \| < \delta \Rightarrow \| x(t) - x_e \| < \epsilon \quad \forall t \ge t_0$$

(2) in storage elements, being in a condition that is highly unlikely to undergo a spontaneous transition to another state.

stable system a system is stable if the output of the system is bounded for all

bounded inputs. *See also* bounded-input bounded-output stability.

stack a hardware or software data structure in which items are stored in a last-in-first-out manner, similar to a cafeteria plate dispenser.

stack algorithm a sequential decoding algorithm for the decoding of convolutional codes, proposed by Zigangirov in 1966.

stack architecture *See* zero-address computer.

stack machine *See* zero-address computer.

stack pointer a register in a processor that holds the address of the top of the stack memory location. The address varies as information is stored on or retrieved from the stack; it always points to the top of the stack.

stack program concept a class of CPU or data structure in which items are stored in a last-in-first-out manner, similar to a cafeteria plate dispenser.

stacked microstrip antenna a microstrip patch configuration where two or more patches are stacked on top of each other separated by one or more dielectric layers. Typically, the lower patch is fed directly and the upper patch is electromagnetically coupled to the lower patch. This arrangement results in improved bandwidth compared to that of a single layer microstrip patch antenna.

Stackelberg equilibrium a hierarchical equilibrium solution in non-zero-sum games in which one of the players has the ability to force his strategy on the other players. The player who holds the powerful position is called the leader, while the other players who react to the leader's strategy are called the followers. In the case of multiperson games, there exists a variety of possible multilevel decision making structures with many leaders and followers. Thus, the definition of the Stackelberg equilibrium is uniquely and clearly set only for two-person decision problems, but it could be adopted for any given hierarchical structure. If J_1, J_2 denote cost functions of leader and the follower, respectively, and d_1, d_2 their admissible strategies, then the set $R(d_1)$ defined as: $\{d$ (admissible for the follower): $J_2(d_1, d) \leq J_2(d_1, d_2)$ for each admissible $d_2\}$ is called the optimal response or rational reaction set of the follower. Then a strategy d_1^* is a Stackelberg strategy for the leader if

$$J_1^* = \max_{d_2 \in R(d_1^*)} J_1\left(d_1^*, d_2\right) \leq \max_{d_2 \in R(d_1)} J_1\left(d_1, d_2\right)$$

for all admissible d_1. J_1^* is the Stackelberg cost of the leader and any $d_2^* \in R(d_1^*)$ is an optimal strategy for the follower that is in equilibrium with d_1^*. The pair (d_1^*, d_2^*) is a Stackelberg solution and corresponding values of the cost functions give the Stackelberg equilibrium outcome. The Stackelberg outcome of the leader may be lower than his Stackelberg cost. If the rational reaction set of the follower is a singleton, then they are equal and they are not worse than the outcome that could be achieved by the leader in the Nash equilibrium if it exists. *See also* Nash equilibrium.

Stackelberg game *See* Stackelberg equilibrium.

stacking factor a design factor for the core of an electromagnetic device that accounts for the effects of the insulating material on the surface of laminations. The stacking factor gives the percentage of cross-sectional area of the core that is actually ferromagnetic material. Usually expressed as the ratio of the thickness of the laminations without the coating to the thickness with the coating.

stall a pause in processing instructions in a pipeline, usually caused by a data dependency or resource conflict. Instructions in

the pipeline before the condition causing the stall are prevented from proceeding through the pipeline.

standard additive model (SAM) a fuzzy system that stores IF-THEN rules that approximate a function $F : X \to Y$. In a simple SAM, the rules may have the form "IF $x = A_j$ THEN $y = B_j$," where $x \in X$, $y \in Y$, and A_j, B_j are fuzzy sets. The SAM then computes the output $F(x)$ given the input x using a centroidal defuzzifier. An example of a centroidal defuzzifier is

$$F(x) = \frac{\sum a_j(x) c_j}{\sum a_j(x)} ,$$

where a_j is a membership function of the fuzzy set A_j and c_j is the centroid of the fuzzy set B_j. The term SAM was coined by B. Kosko. *See also* fuzzy system.

standard array decoding during decoding of a forward error correction code, the process of associating an error pattern with each syndrome by way of a look-up table.

standard cell an element of a standard cell library designed using rules from the targeted wafer fabricator. Standard cells are usually designed to be of constant height and variable width with interconnection points located along the bottom and possibly the top of the cell. This is done to facilitate use of an auto-place-and-route program.

standing wave (1) the phenomenon where waves propagating in opposite directions interfere and result in diminished, or eliminated, energy transfer.

(2) class of laser resonators (often having only two mirrors) in which the right and left waves are largely overlapping.

standing wave effect caused by standing waves of light intensity in the resist, this is horizontal, periodic ridges formed along the sides of a resist profile.

standing wave pattern a pattern of the envelope of the wave resulting from interference of two same-frequency waves travelling in opposite directions.

standing wave ratio (SWR) the ratio of the magnitudes of the incident to reflected signal levels for a traveling wave. The SWR has a value between one and infinity inclusive.

standing-wave laser a class of lasers (often having only two mirrors) in which the right and left waves are largely overlapping.

standing-wave resonator superposition of equal amplitude right and left travelling waves. One of a class of laser resonators (often having only two mirrors) in which the right and left waves are largely overlapping. Also called a Fabry–Perot resonator.

standstill frequency response test a test in which the rotor of a machine is held fixed, and the appropriate windings are energized over a frequency range large enough to determine machine parameters.

star connection *See* Y connection.

star network a network topology where a central node broadcasts radially to all subscribers. The central node is a vulnerable element on which the whole network depends.

star–star transformer *See* wye-wye transformer.

Stark broadening inhomogeneous spectral broadening of a transition in a laser medium due to Stark shifts that vary among the laser atoms or molecules in the medium.

start bit the first bit (low) transmitted in an asynchronous serial transmission to indicate the beginning of the transmission.

starting torque the torque at zero speed obtained at the very beginning of the starting

process of an electrical machine. The condition to obtain the rotation of the rotor is that the starting torque has to be greater than the load torque at zero speed.

starvation a condition when a process is indefinitely denied access to a resource while other processes are granted such access.

state a set of data, the values of which at any time t, together with the input to the system at the time, determine uniquely the value of any network variable at the time t.

state automaton *See* finite state machine.

state diagram (1) a form of diagram showing the conditions (states) that can exist in a logic system and what signals are required to go from one state to another state.

(2) a simple diagram representing the input–output relationship and all possible states of a convolutional encoder together with the possible transitions from one state to another. Distance properties and error rate performance can be derived from the state diagram.

state equations equations formed by the state equation and the output equation.

state feedback the scheme whereby the control signal is generated by feeding back the state variables through the control gains.

state machine a software or hardware structure that can be in one of a finite collection of states. Used to control a process by stepping from state to state as a function of its inputs. *See also* finite state machine.

state plane *See* phase plane.

state space conditional codec an approach where the number of codes is much less than with conditional coding. The previous $N-1$ pixels are used to determine the state s_j. Then the jth variable word-length is used to code the value.

state space model a set of differential and algebraic equations defining the dynamic behavior of systems. Its generic form for linear continuous-time systems is given by

$$\frac{d}{dt}x(t) = Ax(t) + Bu(t)$$
$$y(t) = Cx(t) + Du(t)$$

where $u(t)$ is the system input signal, $x(t)$ is its internal or state space variable, and $y(t)$ is its output. Matrices A, B, C, D of real constants define the model. The internal variable is often a vector of internal variables, while in the general multivariable case all the input and output signals are also vectors of signals. Although not identically equivalent, the state space model can be related to the transfer function (or transfer function matrix) model by

$$G(s) = C[sI - A]^{-1}B + D$$

assuming that the initial conditions on all internal variables are zero. The Laplace variable is denoted by s. Similar equations, based on difference and algebraic equations, define state space model for linear discrete-time (digital) dynamic systems.

$$x_{t+1} = Ax_t + Bu_t$$
$$y_t = Cx_t + Du_t$$

See also transfer function.

state space variable the internal variable (or state) in a state space model description of a dynamic process. These internal variables effectively define the status or energy locked up in the system at any given instant in time and hence influence its behavior for future time.

state transition diagram a component of the essential model; it describes event-response behaviors.

state variable one of a set of variables that completely determine the system's status in the following sense: if all the state variables are known at some time t_0, then the values

of the state variables at any time $t_1 > t_0$ can be determined uniquely provided the system input is known for. The vector whose components are state variables is called the state vector. The state space is the vector space whose elements are state vectors.

state vector a vector formed by the state variables.

state-space averaging a method of obtaining a state-model representation of a circuit containing switching elements by averaging the state models of all the switched topologies.

state-space averaging model a small-signal dynamic modeling method for PWM switching circuits. The circuit is viewed as two linear subcircuits, one with the switch on and one with the switch off. A duty-ratio weighted average of the state-space equations for the two subcircuits is then linearized and used to obtain the small-signal transfer function for the switching circuit.

static excitation system an excitation system derived from solid state devices such as thyristors that convert the AC terminal voltage to DC before application to the rotor.

static induction thyristor (SITH) a self-controlled power device with high switching frequency. The structure is similar to the static induction transistor (SIT) (hence, not really a thyristor), but has an additional p-layer added to the anode side. It is a normally-on device with the n-region saturated with a minority carrier. The device does not have reverse blocking capability.

static induction transistor (SIT) a high-power, high-frequency device that is essentially a solid-state version of the triode vacuum tube. It is a normally-on device, and a negative gate voltage holds it off. The current ratings of the SIT can be up to 300 A, 1200 V, and the switching frequency can be as high as 100 kHz.

static prediction a method of branch prediction that relies of the compiler selecting one of the two alternative instructions for after the branch instruction (either the next instruction or that at the target location specified in the branch instruction). A bit is provided in the branch instruction, which is set to a 0 for one alternative and 1 for the other alternative. The processor then follows this advice when it executes the branch instruction.

static random access memory (SRAM) random access memory that, unlike dynamic RAM, retains its data without the need to be constantly refreshed.

static system a system whose output does not depend upon past or future input is a *static*, or *memoryless* system. For example, consider a voltage $v_{in}(t)$ applied to an amplifier with gain K that yields the output

$$v_{out}(t) = K v_{in}(t) \ .$$

The output voltage at a particular instant in time depends only on the input applied at that same instant, thus the amplifier is a static system. If a system is not static, then it is a system *with memory*, or a *dynamic* system.

static var compensator a device for fast reactive compensation, either inductive or capacitive, brought about by thyristor-based control of an effective shunt susceptance. It is typically used to regulate voltage at a bus on the high voltage transmission system.

static VAR regulator also called a static VAR compensator. A nonrotating electrical device designed to adjust the reactive power flow of an AC power system. It typically consists of a reactive load (either inductive or capacitive) and a series electronic switch (thyristor) that controls the reactive power.

static-column DRAM DRAM that is organized in the same manner as a page-mode DRAM but in which it is not necessary to tog-

gle the column access strobe on every change in column address.

station battery a battery used to provide operating energy for the protective relay operations and to initiate circuit breaker operations in a generating station. The battery is necessary, as the equipment must work reliably during severe voltage sags and outages on the AC system.

station control error in economic dispatch studies, the difference between the desired generation of all plants in a control area and the actual generation of those plants.

station insulator refers to a large-sized insulator used in substations.

stationarity interval the interval of either time (temporal stationarity interval) or space (spatial stationarity interval) over which the conditions required for a WSSUS approximation is valid. That is, the stationarity interval is the period of time or spatial separation over which the scattering function of the channel, and consequently also the delay and Doppler power spectra, stays fixed. This requires that the significant scatterers should remain the same.

stationary a dynamic system described by a first-order vector differential equation that does not depend explicitly on time. In other words, such a system is governed by an equation of the form

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

stationary process a stochastic process $x(t)$, for which the joint probability distribution of $x(t_1)$ and $x(t_2)$ depends only on $|t_1 - t_2|$.

stationary reference frame a two-dimensional space that is fixed (nonrotational). 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 derived in which the physical variables of the system (voltage, current, flux) are referred to variables of the fictitious windings.

statistical quality control methods of quality improvement based on statistical techniques. The main idea is to use statistical methods for identification of unusual variations of the controlled process and to pinpoint the causes of such variations. By collecting data at every stage of the production process and statistical analysis of those data (*See* control chart), the process is maintained in a state of statistical control. The main difference between the statistical quality control and quality inspection is that the latter enables only quality control while the former leads to quality improvement. This in turn results in increased productivity.

statistical multiplexing multiplexing of a number of variable bit rate (VBR) sources. A result of statistical multiplexing is that for a sufficiently large number of VBR sources, the aggregate bit rate is less than the sum of the peak bit rates of the individual sources.

statistical pattern recognition methods for carrying out the recognition of patterns on the basis of statistical analysis. These methods are typically based on the learning of unknown pattern probability distributions from examples.

statistical sensitivity a statistic derived from statistical interpretation of the variation of the circuit function, $F(s, x)$ around the average value $\underline{x}$.

Let $F(s, x)$ be a circuit function that depends on a random parameter x. Then the statistical sensitivity can be approximated as

$$F(s, x) \approx F\left(s, \underline{x}\right) + \left(x - \underline{x}\right) \left.\frac{\partial F(s, x)}{\partial x}\right|_{x=\underline{x}}$$

The values $\underline{x}$, $F(s, \underline{x})$, and $\partial F(s, x)/\partial x$ calculated at $x = \underline{x}$ are considered constants (the last one is usually denoted as $\partial F(s, \underline{x})/\partial x$). If instead of x and $F(s, x)$

are used, their relative deviations from the average values, namely $\delta x = (x - \underline{x})/\underline{x}$ and $\partial F(s) = (F - \underline{F})/\underline{F}$, one obtains that

$$\delta F(s) \approx \left[\frac{\underline{x}}{F\left(s, \underline{x}\right)} \frac{\partial F\left(s, \underline{x}\right)}{\partial x} \right] \delta x = \mathbf{S}_x^{F(s,\underline{x})} \delta x$$

Hence, in the first-order approximation the random variables $\delta F(s)$ and δx are proportional. Then this equation is interpreted statistically. For example, on the $j\omega$ axis the averages of $\delta F(j\omega)$ and δx are related by

$$\mu_{\delta F} \approx \mathbf{S}_x^{F(j\omega,\underline{x})} \mu_{\delta x}$$

The relationships for other statistical parameters can be obtained as well.

statistical spectral compression a common approach to compression used in picture coding. In this approach, the statistical redundancy of the image is exploited and the compression is also obtained by coding the spectral components of the transformed image.

stator the portion of a motor that includes and supports the stationary active parts. The stator includes the stationary portions of the magnetic circuit and the associated windings and leads.

status callback a request made by a consumer for the utility to give them a phone call which indicates the change of status of their service request. An example of this would be calling the consumer once a crew has arrived on the scene of an outage or has located the root cause of an outage.

status register a register in a processor that holds the status of flags; individual bits in the register represent flag status.

steady-state control operation and mechanisms of the control system in which the main objective is to keep the controlled process in the condition where the state variables relevant to the controlled process performance are constant — i.e., to keep the process in a required operating point. Steady-state control structure may be composed of several control layers, including direct regulatory layer, optimization layer and, eventually, other layers; steady-state control is widely used in chemical and power industries.

steady-state gain the gain that a system applies to DC (constant) input signals.

steady-state error the difference between the desired reference signal and the actual signal in steady state, i.e., when time approaches infinity.

steady-state response in network analysis, a condition that the response reaches a constant value with respect to the independent variable. In control system studies, it is more usual to define steady state as the fixed response at infinity with respect to the fixed input under the stable circumstances.

steady-state stability a power system is steady-state stable if it reaches another steady-state operating point after a small disturbance. *See* dynamic stability.

steepest descent algorithm *See* gradient descent.

steering vector in an antenna array, the complex weights associated with each antenna element to form a specific radiation pattern are called the steering vector, since these weights steer the radiation pattern in a specified direction.

Steinmetz constant a constant n that relates the area of the hysteresis loop of a magnetic material to the maximum flux density in the material.

$$A_h = K_h B_{\max}^n$$

where A_h is the area of the hysteresis loop, K_h is a constant of the material, $B_{\max}$ is the maximum flux density, and n is the Steinmetz constant.

step and repeat camera *See* stepper.

step edge an idealized edge across which the luminance profile takes the form of a step function, i.e., a line separating two regions having different average gray-levels. *See* edge.

step index fiber a type of optical fiber where there is an abrupt transition from the core to cladding region, each region having a different refractive index; optical fiber in which the a homogeneous core region has a higher index of refraction than a homogeneous cladding region, in contrast to a graded index fiber. This configuration is more typical of single mode fibers, than multimode fibers, which suffer from modal dispersion effects.

step index optical fiber *See* step index fiber.

step response the output of a linear time-invariant system when the inputs are varied as a step signal.

step size when solving for the transient behavior of an electrical circuit, the associated differential equations are solved at specific points in time. The difference between two adjacent solution time points is known as the step size.

step-and-scan a type of projection printing tool combining both the scanning motion of a scanner and the stepping motion of a stepper.

step voltage in power system safety studies, the voltage measured across two points on the ground which are separated by a distance equal to an average person's step while walking over the area in question.

step-down converter *See* buck converter.

step-up converter *See* boost converter.

stepped leader in lightning, a discharge following the preliminary breakdown that propagates from a cloud toward the ground in a series of intermittent luminous steps with an average speed of 10^5 to 10^6 m/s. Negatively charged leaders clearly step, while positively charged leaders are more pulsating than stepped.

stepper a type of projection printing tool that exposes a small portion of a wafer at one time, and then steps the wafer to a new location to repeat the exposure. Also called a step-and-repeat camera.

stepping correlation a principle of operation of a correlation receiver in channel measurement, where pseudo-random sequences are utilized. The transmitted signal consists of a carrier modulated (typically employing phase-shift keying) by a pseudo-random sequence. The received signal is correlated (multiplied) by an exact replica of the transmitted signal by stepping the chip position of the reference signal with respect to the received signal through all or part of the chip positions. The output of a stepping correlator is a time-scaled version of the autocorrelation function of the pseudo-random sequence, or a part of it. The time-scaling factor depends on the rate with which all the chip positions of interest can be stepped. The rate of producing autocorrelation functions can be made much higher than in sliding correlation. *See also* sliding correlation.

stereo imaging *See* binocular imaging.

stereo vision a vision model in which imaged objects are projected onto two image planes, to extract depth information from the scene. *See also* binocular vision.

stereospecific directional covalent bonding between two atoms.

sticky bit the least significant guard digit in floating-point representations. It is an indicator bit obtained through a logical "OR"

operation of the discarded bits, indicating whether at least one of the discarded bits was equal to 1.

stiction in variable-speed drives, the initial static friction that must be overcome when the load is at rest.

stiff system when an electrical circuit has widely separated time constants, the circuit is said to be stiff. The system of equations associated with the circuit is known as a stiff system, and special numerical methods must be used to maintain stability and accuracy when simulating a stiff system.

stiffness as applied to a tie-line between generators, a low-impedance connection which forces the two generators to run in synchronization regardless of load variations on one or the other.

stiffness control in stiffness control a generalized joint force and/or torque is generated in response to small position error as to a constant task space stiffness matrix. *See also* stiffness matrix.

stiffness matrix the stiffness matrix of the arm endpoint is the inverse of the compliance matrix. *See also* compliance matrix.

stiffness of a manipulator arm an attribute of a robot arm.

Assume that a force is applied to the end-effector of a manipulator arm. The end-effector will deflect by an amount that depends on the stiffness of the arm and the force applied. In other words, the stiffness of the arm's end-effector determines the strength of the manipulator arm. Usually, actuator itself has a limited stiffness determined by its feedback control system, which generates the drive torque based on the discrepancy between the reference position and the actual measured position. We model the stiffness by a spring contact that relates the small deformation at the joint to the force or torque transmitted through the joint itself. It is called the joint stiffness. *See also* stiffness matrix.

still image stationary image or single frame as opposed to moving image or video. Includes photographic images, natural images, medical images, remote sensing images. Usually implies multilevel (grayscale or color) rather than bilevel.

still image coding compression of a still image. A coder consists of the four steps: data representation (typically by transform, decomposition into subbands or prediction), quantization (in which data is approximated or discarded according to some measure of its importance), clustering of nulls (in which runs or blocks of zero values are coded compactly), entropy coding (in which the statistical properties of the data are exploited in lossless compression).

stimulated emission enhanced emission of electromagnetic radiation due to the presence of radiation at the same frequency; also called induced emission.

stimulated light scattering scattering of light from refractive index variations that are produced or amplified by the interaction of laser light with the material system, e.g., stimulated Brillouin scattering and stimulated Raman scattering.

stirrup *See* saddle.

stochastic ARMA (ARMAX) model a generalized ARMA model in which the uncertain environmental effects are included as an independent noise input.

stochastic independence independence of two random variables or two random processes.

stochastic neuron an artificial neuron whose activation determines the probability with which its output will enter one of its two possible states. The most commonly

used expression for the probability that the neuron output y takes on the value $+1$ is $Pr\{y = +1\} = 1/(1 + e^{-2\text{net}/T})$, where net represents the activation of the neuron and T is a quantity analogous to temperature that controls the uncertainty in the neuron output. When T is infinite, a positive activation leads to an output of $+1$ with probability 0.5, and when T is zero, a positive activation leads to an output of $+1$ with probability 1.0.

stochastic process a collection of vector random variables defined on a common probability space and indexed by either the integers (discrete stochastic process) or the real numbers (continuous stochastic process). A stochastic process $x = x(t)$ is a vector function of both time t and the sample path.

stochastic sampling a type of sampling that varies the time intervals between samples. Stochastic sampling allows for a signal to be sampled at a lower apparent sampling frequency achieving equal results to a signal sampled at a much higher sampling frequency. The apparent benefits of stochastic sampling are counterbalanced by the fact that the sampling interval, since it is changing, must be recorded in addition to the signal samples, to reconstruct the signal correctly.

stochastic signal processing the branch of signal processing that models and manipulates signals as stochastic processes rather than as deterministic or unknown functions. *See also* signal processing. *See also* random process.

Stokes Law of light scattering the statement that the scattering of light is typically accompanied by a shift to lower (not higher) frequencies.

Stokes scattering *See* Stokes Law of light scattering and Raman scattering.

Stokes theorem let $\mathbf{A}(\mathbf{r})$ be any vector function of position, continuous together with its first derivative throughout an arbitrary surface S bounded by a contour C, assumed to be resolvable into a finite number of regular arcs. Stokes theorem states that

$$\oint_C \mathbf{A}(\mathbf{r}) \cdot d\ell = \int_S [\nabla \times \mathbf{A}(\mathbf{r})] \cdot \mathbf{n}\, dS$$

where $d\ell$ is an element of length along C and $\mathbf{n}$ is a unit vector normal to the positive side of the element area dS. This relationship may also be considered as an equation defining the curl.

stopband the band of frequencies in a filter or application at which substantial attenuation or suppression is required relative to a passband. Stop band filtering is utilized to eliminate known high-level signals, which will disrupt system operation. *Compare with* passband.

stopband edge the frequency at which the attenuation of a signal diminishes; typically the frequency at which the signal is attenuated at 3 dB from the maximum response.

stop bit the last bit (high) transmitted in an asynchronous serial transmission to indicate the end of a character. In some serial transmissions, one and a half to two bits are used as stop bits.

storage temperature the maximum nonoperating long-term temperature that a device or assembly will be exposed to or stored at without experiencing permanent degradation or damage.

store (1) the act of placing a value into storage.

(2) the place where data and instructions are stored.

store instruction a machine instruction that copies the contents of a register into a memory location. *Compare with* load instruction.

stored program computer a computer system controlled by machine instructions

stored in a memory; the instructions are executed one after the other unless otherwise directed.

STP *See* signal transfer point.

straight edge detection the location of straight edges in an image by computer. Often accomplished with the Hough transform.

strain semiconductors, strained either by external forces or due to lattice mismatched epitaxial growth, have modified band structures, especially the band gap and effective masses.

strain insulator an insulator which forms an insulated tensile link between two conductors in overhead line work.

strained layer superlattices epitaxially grown lattice mismatched alternating layers, usually designed to optimize a desirable property such as band gap, effective mass, quantum confinement, etc.

strained-layer laser diode surface emitting laser diode.

stranded cost a facility like a nuclear power plant which cannot be charged to ratepayers after electric utility de-regulation takes place.

strap a conducting ring that ties tips of poles of magnetron or magnetron-like devices in a specified fashion for microwave potential and phase equalization.

strap fed device strapped magnetron-like device that operates by microwaves fed through the strapping such as amplitron amplifies and platinotron oscillators.

stray light analysis a computation to determine the intensity of unwanted light at various locations in an optical system, combining factors such as diffraction, surface scatter, spurious reflections, and optical design.

streak camera a camera that performs one-dimensional imaging while also measuring the temporal evolution of the image.

stream the sequence of data or instructions that flows into the CPU during program execution.

stream cipher an encryption system or cipher in which the information symbols comprising the plaintext are transformed into ciphertext individually. An important property of a stream cipher is that like-valued plaintext symbols are not necessarily transformed into the same ciphertext. A stream cipher normally acts in an additive sense and in the case of bits being encrypted, the information bits X_n are added modulo-2 to the bits, Z_n, generated by the so-called running-key generator. The ciphertext Y_n is therefore given by $Y_n = X_n \oplus Z_n$, $n = 1, 2, \ldots, N$, where the plaintext consists of N bits and $\oplus$ denotes modulo-2 addition. Generally, the running key bits and the encryption key bits are not the same. The encryption key merely specifies the mechanism used to generate the running-key bits. Such a mechanism could be a number of linear feedback shift registers whose outputs are combined to form the running-key bits. *See also* block cipher, encryption.

stream line *See* direction line.

streamer a precursor of the high-voltage electrical breakdown of a gas which consists of a linked series of local electron avalanches forming a finger-like structure extending from one electrode toward another. Before a lightning strike, streamers extend from points on the earth up towards the thundercloud.

strength duration curve a curve expressing the functional relationship between the threshold of excitation of a nerve fiber and the duration of a unidirectional square-wave electrical stimulus.

strict consistency the situation when a processor reads a shared variable and obtains the value produced by the most recent write to the shared variable irrespective of the processor that did the write operation.

strict equivalence of 2-D system matrices two 2-D system matrices

$$S_i = \begin{bmatrix} P_i & -Q_i \\ C_i & D_i \end{bmatrix} \quad i = 1, 2$$

(*See also* input–output equivalence of generalized 2-D system matrices) of the same dimensions are called strictly equivalent if

$$\begin{bmatrix} M & 0 \\ K & I \end{bmatrix} \begin{bmatrix} P_1 & -Q_1 \\ C_1 & D_1 \end{bmatrix} = \begin{bmatrix} P_2 & -Q_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} N & L \\ 0 & I \end{bmatrix}$$

holds for M, N unimodular matrices and K, L polynomial matrices. The transfer matrix $T_i(z_1, z_2) = C_i P_i^{-1} Q_i + D_i$ and the degree of det P_i are invariant under the strict equivalence, i.e., $T_1 = T_2$ and deg det $P_1 =$ deg det P_2.

strict passivity a system $H : X_e \to X_e$ where there exists a $\delta > 0$ such that

$$\langle x, Hx \rangle_T \to \geq \delta \langle x, x \rangle_T \to \qquad \forall x \in \mathcal{X}_e$$

See also extended space, inner product space, and passivity.

strictly Hurwitz polynomial *See* Hurwitz polynomial.

strictly positive real (SPR) a rational transfer function $G(s)$ with real coefficients such that

$$\mathrm{Re} G(s) \geq 0 \quad \text{for} \quad \mathrm{Re} s \geq 0$$

A transfer function G is strictly positive real if $G(s-\varepsilon)$ is positive real for some real $\varepsilon > 0$.

A rational transfer function $G(s)$ with real coefficients is strictly positive real if and only if the following conditions hold.

1. The function has no poles in the right half-place.

2. The function has no poles or zeros on the imaginary axis.

3. The real part of G is nonnegative along the $i\omega$ axis.

strictly positive real function *See* strictly positive real.

strictly proper transfer matrix a 2-D transfer matrix

$$T(z_1, z_2) = \frac{N(z_1, z_2)}{d(z_1, z_2)}$$
$$N(z_1, z_2) \in R^{p \times m}[z_1, z_2]$$
$$d(z_1, z_2) = \sum_{i=0}^{n_1} \sum_{j=0}^{n_2} d_{ij} z_1^i z_2^j$$

such that $d_{n_1,n_2} \neq 0$ ($d(z_1, z_2)$ is acceptable) and $\deg_{z_1} n_{ij}(z_1, z_2) < n_1$, $\deg_{z_2} n_{ij}(z_1, z_2) < n_2$ for $i = 1, \ldots, p$; $j = 1, \ldots, m$, where $n_{ij}(z_1, z_2)$ are the entries of $N(z_1, z_2)$ and $\deg_{z_1}$ ($\deg_{z_2}$) denotes the degree with respect to z_1 (z_2).

strictness attribute of a function whereby one can compute the value error whenever one or more of their arguments have the value error.

stride the spacing (measured in memory address space) between the addresses of consecutive elements of a vector that are accessed during the execution of a program loop. If the stride is one, all elements are accessed in order; if it is two, every other element is skipped. *See also* memory stride.

stripline a transmission line formed by a printed conductor sandwiched between two conductive-backed dielectrics.

strong inversion the range of gate biases corresponding to the "on" condition of the MOSFET. At a fixed gate bias in this region, for low drain-to-source biases, the MOSFET behaves as a simple gate-controlled resistor. At larger drain biases, the channel resistance can increase with drain bias, even to the point

that the current saturates or becomes independent of drain bias.

strong localization of light confinement of light inside a highly inhomogeneous medium due to very strong scattering.

strong SPR function *See* strictly positive real function.

strong strictly positive real function *See* strictly positive real function.

structural controllability a dynamically where for a structured pair of matrices (A, B) there exists an admissible pair (A^-, B^-) that is controllable.

structural pattern recognition methods for carrying out the recognition of pattern on the basis of a structured representation. For instance, in many interesting problems, the patterns can effectively be given linguistic descriptions based on grammars.

structure estimation determination of the structure of objects, i.e., the 3-D coordinates of surface points of objects, from sequences of images. It is a task sometimes closely related to motion estimation.

structured cell an element of a standard cell library designed using rules from the targeted wafer fabricator. Structured cells are integral multiples of a unit cell with interconnection points on all four sides of the cell. Structured cells normally interconnect simply by being placed next to another structured cell. Unwanted connections are broken as opposed to desired connections being made.

structured distribution systems (SDS) a topology that advocates cabling saturation of a desired environment to accommodate all potential personnel movements and reconstructions within that office.

structured light patterns of light projected onto objects which are to be viewed by cameras and interpreted by computer. For example, a grid of parallel straight lines of light projected on to a curved object will appear from a separate viewpoint to be curved and will provide information on the 3-D shape of the object.

structured matrix a matrix whose entries are either zeros or independent free parameters.

structured noise noise that is not random but that is typically periodic, or contains elements of some unwanted signal. This category of noise includes clutter, crosstalk, easily recognized spikes, and so on.

structured uncertainty low-order parameter perturbations or unmodeled variations represented by a family of models with uncertain parameters ranging within a prespecified set. In the case of linear systems with models in frequency domain, an uncertain system with structured uncertainties is represented by a family of rational matrices with given the highest order and a prespecified set for each uncertain parameter. In the state space counterpart, an uncertain system with structured uncertainties is represented by a family of matrices (in the state equations of known dimensions depending on uncertain parameters from the prespecified set).

structuring element an image or shape that is used in a morphological operator as a probe interacting with the image to be analyzed, leading thus to a transformation of that image. It can be either a set of points (a colorless shape), or a gray-level image (a shape with a gray-level profile on it). In contrast with the natural image to be processed, the structuring element is chosen by the user and generally has a small support. *See* morphological operator.

stub a short section of transmission line, usually short-circuited or open-circuited at one end, designed to present a specific im-

pedance at the other end. Stubs are typically employed as impedance matching elements.

stub tuner matching network, either double-stub or triple-stub, used to match all load admittances.

stuck-at fault a fault model represented by a signal stuck at a fixed logic value (0 or 1).

stuck-open in logic circuits, refers to a fault wherein the value of a signal is "stuck" at the open-circuit value.

sub-band coding (1) a method for source coding where the input signal is divided into frequency sub-bands, through the use of, e.g., a filter bank. The sub-bands are then quantized separately. Such methods utilize the fact that most real-world signals contain low amounts of information in some frequency regions and much information in other. Hence, enhanced compression can be obtained by focusing (only) on "important" frequency regions.

(2) image coding scheme in which the image is first filtered to create a set of images containing a limited range of frequencies. These images are down sampled and encoded using one or more coders. The reverse is carried out at the receiver to reconstruct the original image.

sub-band pyramid sub-band coding using quadrature mirror filters (QMF) provides a natural hierarchical structure and is called sub-band pyramid. This is quite similar to the Laplacian pyramid.

sub-block a part of a cache line that can be transferred to or from the cache and memory in one transaction. This is applicable in the cases where the complete line cannot be transferred in one transaction. Each sub-block requires a valid bit.

sub-millimeter (SMM) the portion of the electromagnetic spectrum corresponding to wavelengths less than a millimeter, but longer than those of the long-wave infrared ($>$ 20–30 μm).

subband analysis decomposition of a signal into a set of subbands by using a filter bank, followed by an appropriate subsampling. *See also* subband synthesis.

subband coding *See* sub-band coding.

subband signal the outputs of subband analysis are referred to as subband signals.

subband synthesis a process in which a signal is generated from the subband signals through upsampling and filtering. *See also* subband analysis.

subchannel I/O the portion of a channel subsystem that consists of a control unit module, the connections between the channel subsystem and the control unit module, and the connections between the control unit module and the devices under its control. In earlier versions of the IBM channel architecture, the subchannel was known as an I/O channel.

subcircuit a simulation approach that allows an efficient description of repetitive circuitry.

subjective contour illusory contours perceived by the visual system even in the presence of no real intensity change. A typical example is Kanisza triangle.

submersible transformer a transformer, used in underground distribution work, which is capable of operation while submerged in water.

subroutine a group of instructions written to perform a task, independent of a main program; can be accessed by a program or another subroutine to perform the task.

subroutine call and return (IE) the subroutine call is a specialized JUMP or BRANCH instruction that provides a means to return to the instruction following the call instruction after the subroutine has been completed. A RETURN instruction is usually provided for this purpose.

subsampling pyramid a spatial domain hierarchy is generated by repeatedly subsampling the original image data. The reconstruction at any level simply uses the subsampled points from all previous levels in conjunction with the new points from the current level.

subsidiary communication authorization (SCA) services for paging, data transmission, specialized foreign language programs, radio readings services, utility load management and background musing using multiplexed subcarriers from 53–99 kHz in connection with broadcast FM.

subspace based algorithm based on splitting the whole space into two orthogonal complements, the signal and noise subspaces, and exploiting properties of the desired signal in these two subspaces. *See also* MUSIC, ESPRIT, signal subspace, noise subspace.

substation a junction point in the electric network. The incoming and outgoing lines are connected to a busbar through circuit breakers.

substation battery a battery used to provide operating energy for the protective relay operations and to initiate circuit breaker operations in a generating substation. The battery is necessary, as the equipment must work reliably during severe voltage sags and outages on the AC system.

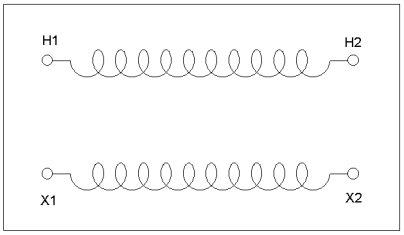
substrate a dielectric or semiconductor slab over which active devices, planar transmission lines, and circuit components are fabricated. This can be a PCB, a ceramic, or a silicon or other semiconductor wafer that has electronic components interconnected to perform a circuit function. *See also* wafer.

subsynchronous resonance an electric power system condition where the electric network exchanges energy with a turbine generator at one or more of the natural frequencies of the combined system below the synchronous frequency of the system.

subthreshold the range of gate biases corresponding to the "off" condition of the MOSFET. In this regime, the MOSFET is not perfectly "off" but conducts a leakage current that must be controlled to avoid circuit errors and power consumption.

subtracter a circuit that subtracts two values.

subtractive polarity polarity designation of a transformer in which terminals of the same polarity on the low- and high-voltage coils are physically opposite each other on the transformer casing. With subtractive polarity, a short between two adjacent terminals results in the difference of the two coil voltages appearing between the remaining terminals. Subtractive polarity is generally used on transformers larger than 500 kVA and higher than 34.5 kV. Smaller units use additive polarity. See the diagram below. *See also* additive polarity.



Transformer with subtractive polarity.

subtransient current the fault current that flows during the subtransient period

when the generator and motor apparent impedances are their respective subtransient impedances.

subtransient impedance the series impedance that a generator or motor exhibits during the subtransient period, typically the first few cycles of a fault. Subtransient impedances are generally used in calculating fault currents for determining instantaneous relay settings.

subtransient open-circuit time constant *See* quadrature-axis transient open-circuit time constant and direct-axis subtransient open-circuit time constant.

subtransmission the circuits which connect bulk power substations to distribution substations.

subway transformer another name for a submersible transformer.

sub-critical the state of a fission chain reaction which is not self-sustaining because an insufficient number of neutrons are produced at each fission.

successive approximation an A/D conversion process that systematically evaluates the analog signal in n steps that produce an n-bit code. The analog signal is successively compared to determine the digital code, beginning with the determination of the most significant bit of the code.

successive cancellation multiple-access receiver technique in which users are estimated one by one, first subtracting previously estimated data from the received signal.

sudden pressure relay a protective relay that senses the internal pressure in a transformer tank, and operates on sudden changes in this pressure. These sudden pressure changes reliably indicate a fault inside the tank.

sufficient statistic for a parameterized family of probability distributions $f(x;\theta)$, depending upon some parameter θ, it is a common problem to estimate θ from observation of a sample, X drawn according to an unknown member of this family. A statistic $S(X)$ is called a sufficient statistic of X for θ if it retains all the information available in X for the estimation of θ.

Sugeno fuzzy rule a special fuzzy rule in the form if x is A and y is B then $z = f(x, y)$ where "if x is A and y is B" is the *antecedent*, A and B are fuzzy sets, and the *consequent* is the crisp (nonfuzzy) function $z = f(x, y)$. *See also* fuzzy IF-THEN rule, fuzzy inference system.

sulfur hexaflouride a heavy, highly-electronegative gas used as a high-voltage, self-healing insulation.

sum of products (SOP) a standard form for writing a Boolean equation that contains product terms (input variables or signal names either complemented or uncomplemented ANDed together) that are logically summed (ORed together).

sum-frequency generation the process in which two light beams of frequencies ω_1 and ω_2 interact with a nonlinear optical material to produce a beam at frequency $\omega_3 = \omega_1 + \omega_2$ by means of the second-order susceptibility.

super high definition television (SHDTV) television at resolutions of 2000×2000 pixels and higher.

super-critical the state of a nuclear fission reaction which more neutrons are produced than are necessary to compensate for neutron absorbtion and leakage.

super-resolution the process of combining data from multiple, similar images of the same object to form a single image with increased spatial resolution.

supercomputer at any given time, the most powerful class of computer available.

superconducting magnetic bearing a magnetic bearing utilizing levitation between a magnet and a superconductor.

superconductivity a state of matter whereby the correlation of conduction electrons allows a static current to pass without resistance and a static magnetic flux to be excluded from the bulk of the materials.

superconductor a material that loses all electrical resistance below a certain temperature. Superconductors prevent externally applied magnetic fields from penetrating their interior. They are considered perfect diamagnetic materials. Once the externally applied field exceeds a critical value, the materials revert back to a nonsuperconducting status.

superdirectivity a condition of a phased array in which the excitation of the array elements is adjusted to obtain a directivity greater than that achievable with uniform excitation. Such antennas are often impractical, because high excitation currents are usually required, leading to ohmic losses that more than offset the additional directivity. Superdirective antennas also typically have high reactive fields and thus exhibit very narrow bandwidth.

superfluorescence usually refers to the enhanced spontaneous emission that occurs due to self-organization into a coherent state by a system of atoms or molecules.

superheater a heat exchanger that increases the steam temperature to about 1000 degrees F. It is heated by the flue gases.

superheterodyne an architecture used in virtually all modern-day receivers. In the early days of radio, tuned stages of amplification were cascaded in order to secure a sufficiently high level of signal for detection (demodulation).

superheterodyne receiver most receivers employ the superheterodyne receiving technique, which consists of either down-converting or up-converting the input signal to some convenient frequency band, called the intermediate frequency band, and then extracting the information (or modulation) by using an appropriate detector. This basic receiver structure is used for the reception of all types of bandpass signals, such as television, FM< AM< satellite, and radar signals.

superinterleaving *See* interleaved memory.

superlattice a stack of ultrathin layers of material. Layer thicknesses are sufficiently thin to produce quantum-confined effects, typically 100–1000 angstroms; generally, there are two different layer compositions, and the superlattice is built with layer composition in an alternating scheme.

supernode a cluster of nodes, interconnected with voltage sources, such that the voltage between any two nodes in the group is known.

superparamagnetism a form of magnetism in which the spins in small particles are exchange coupled by may be collectively switched by thermal energy.

superpipelined processor a processor where more than one instruction is fetched during a cycle in a staggered manner. That is, in an n-issue superpipelined processor, an instruction is fetched every $1/n$ of a cycle. For example, in the MIPS R4000, which is two-issue superpipeline, a new instruction is fetched every half cycle. Thus, in effect, the instruction pipeline runs at a frequency double than the system (in the R4000 the pipeline frequency is 100 MHz, while the external frequency is 50 MHz). Superpipeline processors usually have a relatively deep pipeline, of about 7 stages or more (8 stages on the R4000).

superpipelining a pipeline design technique in which the pipeline units are also pipelined internally so that multiple instructions are in various stages of processing within the units. The clock rate is increased accordingly.

superpolish methods for producing a surface of low RMS roughness, typically 10 angstroms RMS or less; methods include special mechanical, chemical, and ion polishing techniques.

superposition for a system $T[]$, the property that

$$T[a_1x_1(t) + a_2x_2(t)] = a_1t[x_1(t)] + a_2t[x_2(t)].$$

superposition coding multiple-access channel coding technique in which each user encodes independently, such that at the receiver, the transmitted signals may be estimated using successive cancellation. *See also* successive cancellation.

superposition integral for a linear shift-invariant system characterized by an impulse response, $h(t)$, the output, $y(t)$, for a given input, $x(t)$, is calculated as

$$y(t) = \int_{-\infty}^{\infty} x(s)h(t-s)ds.$$

Also called the convolution integral.

superradiance usually refers to the strongly enhanced spontaneous emission that is emitted by a coherently prepared system of atoms or molecules.

superscalar processor a processor where more than one instruction is fetched, decoded, and executed simultaneously. If n instructions are fetched and processed simultaneously, it is called an n-issue superscalar processor. For example, the Pentium is a two-issue, and the DEC 61164 is a four-issue superscalar processor. This feature was implemented both on CISC (Pentium) and RISC (61164) processors.

supervised learning (1) a procedure in which a network is trained by comparing its output, in response to each training data item, with a target value (label) for that item. Network weights are adjusted so as to reduce the differences between outputs and targets until these differences reach acceptable values.

(2) a training technique in statistical pattern recognition or artificial neural networks in which the training set includes a predefined desired output.

supervised learning for self-generating neural network there are two ways for supervised learning in SGNN. The first is the same as that of supervised learning for a self-organizing system. The second is to make use of information gains of the attributes to the classification. That is, use the inner product of the training vector and the information gain vector corresponding to its attributes to train the network. Experiments show that this way of supervised learning for SGNN can significantly improve both the performance of the network and the training speed. *See also* self-generating neural network, information gain, learning vector quantization.

supervised learning for self-organizing system *See* learning vector quantization.

supervised neural network neural network that requires input–output pairs to form the interconnection weight matrix of a network. The Hopfield model, perceptron, and backpropagation algorithm are supervised neural networks.

supervisor call instruction (SVC) *See* software interrupt.

supervisor instructions processor instructions that can be executed when the processor is running in supervisor mode. The separation of supervisor instructions is re-

quired to isolate the system's control information from tampering by user programs.

supervisor mode one of two CPU modes, the other being user mode. Sometimes called privileged mode, this mode allows access to privileged system resources such as special instructions, data, and registers.

supervisor state one of two CPU states, the other being user state. When the CPU is in supervisor state, it can execute privileged instructions.

support of a fuzzy set the crisp set of all points x in X with membership positive ($\mu_A(x) > 0$), where A is a fuzzy set in the universe of discourse X. *See also* fuzzy set, membership function.

supporting plane a planar structure that is an external support for a packaging and interconnecting structure, used to alter the structure's coefficient of thermal expansion.

supremal decision unit control agent or a part of the controller of the partitioned system, which perceives the objectives and the operation of this system as a whole and is concerned with following these overall objectives; in case of a large-scale system with hierarchical multilevel (two-level) controller, the coordinator unit is often regarded as the supremal decision unit.

supremum operator an operation that gives the least upper bound function. For example, if S is the supremum of a set A, then S is the upper bound of A, and no value less than S is an upper bound of A.

surface acoustic wave (SAW) a surface acoustic wave (also known as a Rayleigh wave) is composed of a coupled compressional and shear wave. On a piezoelectric substrate, there is also an electrostatic wave that allows electroacoustic coupling. The wave is confined at or near the surface and decays away rapidly from the surface.

surface acoustic wave (SAW) device in this device, electrical signals are converted to acoustic signals, processed, and then converted back to electrical energy. Due to their small propagation velocity, acoustic waves have small wavelengths; thereby, one can construct miniature high performance components such as filters using SAW devices.

surface impedance the impedance exhibited by the surface of a conductor/dielectric due to the variation in its conductivity with frequency.

surface mount technology (SMT) the electrical connection of components to the surface of a conductive pattern without component lead holes.

surface mounting *See* surface mount technology.

surface plasmon a surface polariton in a plasma medium.

surface polariton a polariton that propagates as a wave along the interface between two media.

surface rendering *See* rendering.

surface roughness the RMS value of the peaks and valleys in the profile of a solid surface. High frequency currents flow near the skin of conductors due to a skin effect phenomenon. Therefore, high frequency currents follow the contours on the surface of conductors. For this reason, surface roughness should be minimized so the patch of current flow is as short as possible.

surface scattering scattering at the rough boundary between two media of different refractive index.

surface texture *See* texture, texture analysis, texture modeling.

surface wave a wave that propagates with dissipation in one direction and exponentially decays (without propagating) in the other directions. Most of the field is contained within or near the interface.

Surface waves are supported, for example, by a dielectrically coated conductor or by a corrugated conductor.

surface-emitting laser logic (SELL) a device that integrates a phototransistor with a low-threshold vertical-cavity surface-emitting laser.

surface-mounted package in both electrical and mechanical devices, a mounting technique between chip and substrate using solder joints between pads on the two surfaces. The advantage is that higher circuit densities can be achieved on the board.

surge a short-duration (microsecond to millisecond) increase in power line voltage. Also called a spike or an impulse.

surge arrestor a device that limits overvoltages by conducting large currents in response to an overvoltage. Surge arrestors are typically connected line to ground in transmission and primary distribution systems. They can be employed in a variety of connections in secondary distribution, and can be necessary in communications, sensing, and control circuits.

surge impedance the ratio of voltage to current on that line for a high speed wave propagating down the line. The surge impedance of a line is a constant which depends on the line geometry and conductor characteristics. On power transmission lines, these waves are typically generated by lightning strokes, circuit breaker switching, etc. Also called characteristic impedance.

surge impedance loading (SIL) of a transmission line, the characteristic impedance with resistance set to zero (resistance is assumed small compared to reactance). The power that flows in a lossless transmission line terminated in a resistive load equal to the line's surge impedance is denoted as the surge impedance loading of the line.

surge response voltage the voltage that appears at the output terminals of surge protection equipment and is seen by loads connected to that device both during and after a surge condition.

surge tank an empty vessel located at the top of the penstock. It is used to store water surge when the turbine valve is suddenly closed.

susceptibility the part of the permittivity or permeability that is attributable to the electromagnetic behavior of the medium. In a linear, isotropic medium, the electric susceptibility is numerically equal to the relative permittivity minus one, and the magnetic susceptibility is equal to the relative permeability minus one. *See also* electric susceptibility.

sustained interruption all interruptions that are not momentary. Generally used when referring to long duration voltage interruptions of greater than 1 minute.

SV system single variable system. *See also* single-input–single-output system.

SVC supervisor call instruction. *See also* software interrupt.

SVD *See* singular value decomposition.

SVP *See* sound velocity profile.

Swan, Joseph (1828–1914) Born: Sunderland, England

Swan is best known as the inventor of the incandescent lamp. During his life he acquired seventy patents in many areas. He

was a devoted experimentalist with interests in photography, the development of miner's lamps, batteries, electroplating, and artificial silk. Swan teamed with Edison in 1883 to form the Edison and Swan United Electric Light Company after Edison's suit for patent infringement was dismissed. J. W. Starr and W. E. Staite were the early pioneers who inspired Swan to research that led to his knighthood in 1904.

swap in assembly language, an instruction that swaps two values one for the other.

SWE *See* Schrödinger wave equation.

sweep generator a frequency source that can be setup to sweep from a start frequency to a stop frequency in a specified time interval.

swell a voltage or current RMS value at supply frequency that increases for a time period from 0.5 cycles to 1 minute.

swing curve a sinusoidal variation of a parameter, such as the critical dimension or the dose-to-clear, as a function of resist thickness caused by thin film interference effects.

swing bus in power-flow studies, a bus in the power system which is assigned unknown real and reactive power so as to compensate for losses in the system.

swing equation a nonlinear differential equation utilized in determining the dynamics of synchronous machines. *See also* electromechanical equation.

switch (1) a device that allows current flow when closed and provides isolation when open. The switch provides similar functions to the circuit breaker, but cannot interrupt fault currents. Some switches are capable of making and breaking load currents, while others are only able to break charging current. Switches can be either manually controlled or motor controlled. *See also* single-pole single-throw, single-pole double-throw, transmit/receive switch, all-optical switch.

(2) a device comprising a number of input and output ports and circuitry to switch packets from one input port to one or more output ports based on the addressing information contained in the packet header.

switchable shunt *See* shunt capacitor.

switchboard literally, a large panel or board upon switches were mounted in early electrical systems.

switched combining a method of diversity combining in which the receiver is switched between alternative communication channels to find the channel that yields the best signal quality. *See also* angle diversity, antenna diversity.

switched reluctance machine a doubly salient, singly excited electrical machine that contains a different number of poles on the stator and rotor. Since there are a different number of poles on the rotor and stator, only one stator phase can be aligned at a time with the rotor.

When operated as a motor, the stator phases are sequentially switched on and off to pull the rotor into alignment with them. This requires knowledge of the rotor position to properly excite the stator phases. The switched reluctance machine can also operate as a generator. In this case the stator windings are charged with a current as the rotor comes into alignment. When the current reaches a determined level, the windings are reconnected to send current out of the machine. As the rotor is driven, the inductance drops, causing an increase in current.

This type of machine requires an external capacitor bank, switches and diodes in each phase, and a sophisticated control system to operate.

switched-mode power supply *See* switching power supply.

switching amplifier a type of amplifier that utilizes switching between the cutoff and saturated states to minimize the time in the lossy transition states, thus achieving high efficiencies. All class D, E, and S 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.

switching flow graph model a large-signal dynamic modeling method for PWM switching circuits. The circuit is viewed as two linear sub-circuits, one with the switch on and one with the switch off. Flow graphs are obtained for the subcircuits and then combined using switching branches to form a switching flow graph. The switching flow graph provides a graphical representation of the dynamic switching circuit from which the large-signal, small-signal, and steady-state behaviors can be extracted.

switching frequency the frequency at which converter switches are switched. In sine-triangle PWM switching applications, the switching frequency is defined by the triangle wave frequency, i.e., the carrier frequency.

switching node a computer or computing equipment that provides access to networking services.

switching order procedure which includes the sequence of switching operations to shift load.

switching power supply a power supply, with one or more outputs, based on switching converters. The output(s) may be regulated via a control technique.

switching surface *See* sliding surface.

switching surge a momentary overvoltage in a power system which results from energy stored in the magnetic filed of a long power line being injected into the system at the instant that the line is switched out of service.

switching time the time required for an entity to change from one state to another.

SWR *See* standing wave ratio.

symbol error rate a fundamental performance measure for digital communication systems. The symbol error rate is estimated as the number of errors divided by the total number of demodulated symbols. When the communication system is ergodic, this is equivalent to the probability of making a demodulation error on any symbol.

symbol synchronization a technique to determine delay offset or rate of symbol arrival from the received signal. Can be based on either closed or open loop methods.

symbolic substitution *See* symbolic substitution logic gate.

symbolic substitution logic gate an optical logic gate using a specific algorithm developed for optical computing called symbolic substitution. In symbolic substitution, one or more binary input data are together represented by an input pattern. In its original method, four identical patterns are duplicated from the input pattern. The four patterns are shifted to different directions. The shifted patterns are added. The added pattern is thresholded. The previous procedure is then repeated. The thresholded pattern is split into four identical patterns. The four identical patterns are shifted to different directions and then combined as output patterns. All these steps are equivalent to first, recognizing input pattern, and then substituting it with output pattern. In the improved method, input pattern can be substituted with output pattern using two correlators, the first

correlator for recognition and the second for generating output pattern, or using a holographic associative memory. Output pattern can be any of sixteen Boolean logic operations or their combinations.

symmetric half plane field the class of image models which can be implemented recursively pixel by pixel. That is, if the pixels in an image are ordered lexicographically (either by rows or by columns), then a symmetric half plane model is one in which a pixel p is a function of only those pixels preceding p in the ordering. *See also* Markov random field.

symmetric multiprocessor a multiprocessor system where all the processors, memories, and I/O devices are equally accessible without master–slave relationship.

symmetric resonator a standing-wave resonator with identical right and left mirrors; usually refers to the mirror curvatures and not the mirror transmissions.

symmetrical component the method by which unbalanced three-phase power system operation (particularly unbalanced fault performance) can be efficiently analyzed. Symmetrical components convert unbalanced line currents and voltages to three sets of balanced sequence components: positive sequence, negative sequence, and zero sequence.

The transformed phasor variables f_{+-0s} are obtained by applying the appropriate Fortescue transformation to any multiphase set of phasor variables. Denoted, f_{+s}, f_{-s}, f_{0s}, these are the positive sequence, negative sequence, and zero sequence components, respectively. The variables are so named because any unbalanced set of currents can be expressed (in phasor form) in terms of

1. a balanced set of currents with magnitude i_{+s} that has a phase sequence which produces counterclockwise rotor rotation in a machine (positive sequence).

2. a balanced set of phasor currents with magnitude i_{-s} that has a phase sequence which produces clockwise rotor rotation in a machine (negative sequence), and

3. a set of three equal phasors with magnitude f_0 (zero sequence) which does not produce rotor rotation in machine.

symmetrical fault another term for a three-phase fault, a fault in which all three conductors of a three-phase power line are short-circuited together. System faults are symmetrical and can be analyzed by using single phase circuit.

symmetrical fault current the total current flowing to a fault less the DC offset current. In many cases, fault current calculations are expressed in terms of symmetrical amps.

symmetries of nonlinear susceptibility the elements of the nonlinear susceptibility tensor are not all independent. For instance, any rotational symmetries of the material medium will be reflected in tensor properties of the susceptibility. In addition, there are symmetries that depend on the frequency dependence of the susceptibility. For instance, intrinsic permutation symmetry states that the susceptibility is unchanged under simultaneous interchange of two input frequencies and two input tensor indices. Likewise, full permutation symmetry states that the susceptibility is unchanged under simultaneous interchange of two frequencies and two tensor indices, input and output considered interchangeably. Kleinman symmetry states that the susceptibility is unchanged under interchange any two tensor indices, input and output considered interchangeably.

sync distribution a system that allows for the distribution of sync pulses to multiple devices.

sync generator (1) signal generator that is designed to produce a specified signal waveform in order to synchronize a specific electronic device or system.

(2) an electronic unit used to generate the sync (synchronizing) information used in a video signal. Sync generators typically provide signals, such as horizontal sync, vertical sync, composite sync, and blanking. The sync generator signals are used in a video facility to keep all video signals properly aligned with each other.

sync interval the time period between neighboring sync pulses.

sync separator electronic circuitry used to separate the horizontal and vertical sync information that are contained in a composite video or composite sync signal.

sync tip the sync level that represents the peaks of the sync signal.

sync-locking a condition in which a circuit will continue to follow the sync pulse even with variations in amplitude and phase.

synchro also called a selsyn (for self-synchronous). An AC servo machine used in pairs primarily for remote sensing and shaft positioning applications. Its construction is essentially that of a wound-rotor induction machine with either a single-phase or 3-phase rotor winding. Various stator and rotor interconnections are possible, depending on desired function and required torque.

synchro-check relay a device used to monitor the frequency and phase angle of the voltages across an open circuit breaker. Synchro-check relays are commonly used to prevent breaker closing or reclosing on excessive voltage or frequency difference.

synchronization (1) a situation when two or more processes coordinate their activities based upon a condition.

(2) the process of determining (usually channel) parameters from a received signal, for example carrier frequency offset, carrier phase, or symbol timing.

synchronized CDMA a CDMA system where all the users are time-synchronized, i.e., the signals associated with all users arrive at the receiver with identical time delays.

synchronizing coefficient electrical torque component in phase with the rotor angle.

synchronizing relay a relay that monitors the voltage across an open circuit breaker to determine the frequency and phase relationship of the voltage sources on either side of the breaker. Synchronizing relays are used on generator breakers to bring the generator to the system frequency and to match the phase angle between the generator and system prior to closing the breaker.

synchronous an operation or operations that are controlled or synchronized by a clocking signal.

synchronous bus a bus in which bus transactions are controlled by a common clock signal and a fixed number of clock periods is allocated for specific bus transactions. *Compare with* asynchronous bus.

synchronous circuit a sequential logic circuit that is synchronized with a system clock.

synchronous condenser an unloaded, over-excited synchronous motor that is used to generate reactive power.

synchronous demodulation a form of a phase sensitive angle demodulation in which local oscillator is synchronized or locked in frequency and phase to the incoming carrier signal.

synchronous detection demodulation scheme using a balanced modulator to translate the center frequency of an IF signal down to DC (i.e., zero Hz). A local oscillator (LO) tuned to the IF center frequency is injected into one of the input ports of the balanced detector, while the AM or SSB signal contain-

ing the information is applied to the other. When used in this manner, the LO is often referred to as a beat frequency oscillator (BFO). Low-pass filtering the output results in retrieval of the intelligence signal, superimposed upon a DC voltage (or current, dependent upon the actual device). The DC value may either be discarded via high-pass filtering, or used as a received signal strength indicator for use in automatic gain control circuits.

synchronous digital hierarchy (SDH) an international interface specification for high-speed optical fiber transmission networks that allows different manufacturers' equipment to be interconnected with full maintenance and signal transparency. Specifies the optical parameters and the basic rates and formats of the signal. Emphasizes protection from faults and fast restoration of service after service interrupts.

synchronous drive a magnetic drive characterized by synchronous transmission of torque, typically using a salient pole structure. There is no slip between the driver and the follower.

synchronous dynamic RAM (SDRAM) a type of dynamic random access memory with an added synchronizing clock signal that allows for burst mode access of a series of successive bits. *See also* dynamic random access memory.

synchronous machine an AC electrical machine that is capable of delivering torque only at one specific speed (n_s), which is determined by the frequency of the AC system (f) and the number of poles (P) in the machine. The relationship between synchronous speed and the other variables is

$$n_s = 120 f / P$$

synchronous motor an AC motor in which the average speed of normal operation is exactly proportional to the frequency to which it is connected. A synchronous motor generally has rotating field poles that are excited by DC.

synchronous operation an operation that is synchronized to a clocking signal.

synchronous optical network (SONET) a U.S. interface specification for high-speed optical fiber transmission networks that allows different manufacturers' equipment to be interconnected with full maintenance and signal transparency. SONET emphasizes protection from faults and fast restoration of service after service interrupts.

synchronous reactance the inductive reactance of the armature windings in synchronous machines under steady-state conditions. Designated by the symbol X_s, expressed in ohms per phase, the synchronous reactance is a function of the stator inductance and the frequency of the stator currents.

synchronous reference frame a two-dimensional space that rotates at an angular velocity corresponding to the fundamental frequency of the physical stator variables (voltage, current, flux) of a system. 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 derived in which the physical variables of the system (voltage, current, flux) are referred to variables of the fictitious windings. *See also* arbitrary reference frame, rotor reference frame, stationary reference frame.

synchronous reluctance machine a type of synchronous machine that has no rotor winding. The rotor consists of salient poles, which causes the reluctance to vary as a function of position around the airgap. When operated as a motor, a rotating magnetic field is established by the stator windings that causes a reluctance torque on the rotor as the path

of lowest permeability stays aligned with the peak of the stator flux wave.

synchronous reluctance motor a synchronous motor that depends on a reluctance variation on the rotor for the mechanism of torque production. The rotor shape is designed to provide a high difference in the reluctances between the d and q axes.

synchronous speed speed of the rotating magnetic flux produced by three-phase currents in stationary coils in three-phase AC machines. The synchronous speed is calculated by a knowledge of the number of poles of the machine and the frequency of the stator currents as

$$N_s = 120 f_s / P$$

synchronous transfer mode a method of multiplexing messages onto a channel in which each period of time (also called a frame) on the channel is divided into a number of slots; one slot is allocated to each source for the transmission of messages, and a slot's worth of data from each source is sent every period.

synchronous updating all units in a neural network have the values of their outputs updated simultaneously.

synchronously pumped-modelocked (SPM) laser a laser in which periodic pump pulsations arrive at the amplifying medium of a laser oscillator in synchrony with the circulating mode-locked pulses, a standard technique for obtaining sub-picosecond pulsations.

synchroscope a device used to determine the phasor angle between two 3-phase systems. It is normally used to indicate when two systems are in phase so that they can be connected in parallel.

syndrome bit pattern used for error-detection and correction that is formed by multiplying the received vector by the parity-check matrix. Any two n-tuples that have the same syndrome can differ at most by a code word.

synonym in a virtual addressed cache, when a real address has more than one virtual address, the name given to the virtual addresses.

syntax the part of a formal definition of a language that specifies legal combinations of symbols that make up statements in the language.

synthesis filter a bank of filters that recombines the components decomposed by analysis filters from different frequency bands.

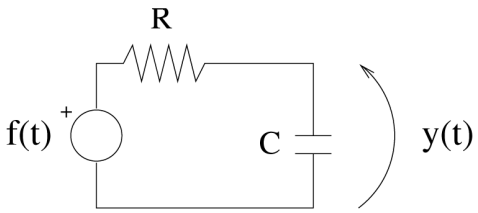
synthesizer a software program that creates GDS2 data from a hardware description language specification such as VHDL or Verilog.

synthetic aperture radar (SAR) a technique for overcoming the need for large antennas on side-looking airborne radar (SLAR) systems. The effect of a large antenna is synthesized by using Doppler shifts to classify the return signals, generating a very small effective beamwidth. The process is quite similar to that of holography, since the amplitude and frequency of the signals is recorded over time.

synthetic diamond diamond grown artificially, usually as a film, for industrial purposes such as hardness, thermal conductivity, or optical properties.

system a physical process or device that transforms an input signal to an output signal. For example, the following figure describes a system consisting of a RC circuit with an input of voltage, and an output of measured voltage across the capacitor:

Often the behavior of systems is governed by a physical law, which when applied yields



System example.

a mathematical description of the behavior. For example, application of Kirchoff's voltage law and Ohm's Law leads to the following differential equation description of the above electric circuit input/output behavior:

$$\frac{d}{dt}y(t) + \frac{1}{RC}y(t) = \frac{1}{RC}f(t)$$

system bus in digital systems, the main bus over which information flows.

system identification a field of control engineering dealing with the derivation of mathematical models for the dynamics of processes, often by a detailed study of its input and output signals. It includes the design of experiments for enhancing the accuracy of the models.

system implementation a phase of software development life cycle during which a software product is integrated into its operational environment.

system interaction a stream of energy, material, or information exchanged between the sub-systems of a large-scale system. Relevant attributes of those streams are, respectively, interaction inputs or interaction outputs). Interactions are described by the interaction equations, which relate interaction inputs to a given subsystem to interaction outputs from other subsystems.

system noise factor a value, in decibels, representing the ratio of the signal-to-noise ratio (S/N) appearing at the input of a system to that appearing at the output.

$$\text{system NF}_{dB} = 10\log_{10}\left(\frac{\text{S/N}_{\textbf{input}}}{\text{S/N}_{\textbf{output}}}\right)$$

where S/N is the ratio (not in decibels) of the signal power to noise power at a given temperature. This value indicates the amount of signal-to-noise degradation from input to output of a system of components. If the S/N and power gain of each individual component in the system is known, then Friis' formula can be used to predict the overall system noise factor:

$$\begin{aligned}\text{system NF}_{dB} &= 10\log_{10}\text{NR}_1 \\ &+ (\text{NR}_2 - 1)/P_{G1} \\ &+ (\text{NR}_3 - 1)/(P_{G1} \times P_{G2}) \\ &+ (\text{NR}_4 - 1)/[P_{G1} \times P_{G2} \times P_{G3}] + \cdots \\ &+ (\text{NR}_n - 1)/\left[P_{G1} \times P_{G2} \ldots P_{G(n-1)}\right]\end{aligned}$$

where all values for S/N and power gain are in ratio (non-decibel) format, and the noise ratio, NR, of each stage is defined as NR $= (\text{S/N}_{\textbf{input}})/(\text{S/N}_{\textbf{output}})$. Also referred to as system noise figure.

System Performance and Evaluation Cooperative (SPEC) a cooperative formed by four companies, Apollo, Hewlett-Packard, MIPS, and Sun Microsystems, to evaluate smaller computers.

system transfer function the result of sending a known test signal (often an impulse function or sine wave) through a system and defines what a system will do when presented with an input signal. Test signals often must be varied in frequency since system transfer functions are often frequency dependent (e.g., a stereo amplifier or speakers).

system with memory a system whose output at time t depends on the input at other times (and possibly including) that instant t. If the output of the system at time t depends only on the input to the system at time t the system is said to be memoryless.

systematic code a code for which the information sequence itself is a part of the coded sequence. For block codes, it is common to assume that the information sequence is the first (or last) part of the codeword.

systems engineering an approach to the overall life cycle evolution of a product or system. Generally, the systems engineering process comprises a number of phases. There are three essential phases in any systems engineering life cycle: formulation of requirements and specifications, design and development of the system or product, and deployment of the system. Each of these three basic phases may be further expanded into a larger number. For example, deployment generally comprises operational test and evaluation, maintenance over an extended operational life of the system, and modification and retrofit (or replacement) to meet new and evolving user needs.

systolic flow of data in a rhythmic fashion from a memory through many processors, returning to the memory just as blood flows from and to the heart.

T

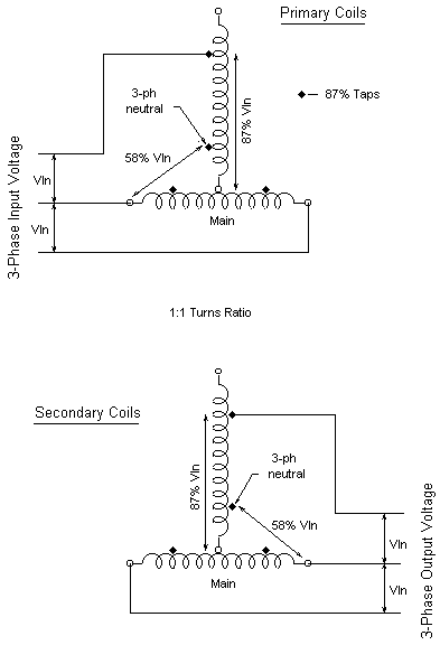
T common symbol for temperature, usually expressed in degrees Kelvin.

T-bracket a metal frame which holds a lightning arrester and a cut-out to the top of a utility pole.

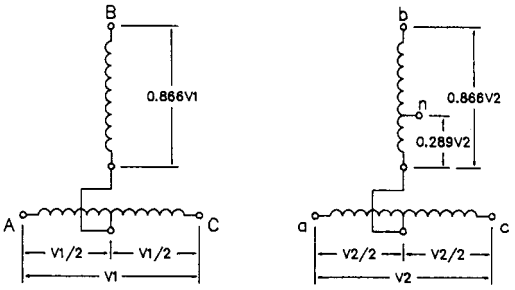
T-connection term often used to describe, with some ambiguity, two distinct transformer connections — one to simply convert voltage levels in a 3-phase power system, and the other to convert between 3-phase and a 2-phase voltages. Both connections use only two single-phase transformers, one called the main and the other the teaser, arranged in a T configuration. Details of each configuration are described below. These connections are also often referred to as Scott connections, since they were first proposed by Charles F. Scott.

Conversion of 3-phase voltage levels: In this configuration, the main transformer in the T-connection is a center-tapped unit that is connected between two lines of the three-phase system. The teaser transformer is connected between the center-tap of the main transformer and the third line of the 3-phase power system. Additionally, the coils of the teaser transformer have 86.6% of the turns in the corresponding coils in the main transformer. The result is a balanced three-phase voltage on the secondary. In most applications, the main and teaser transformers are actually identical, full voltage units with center taps and two 86.6% taps, one with respect to each terminal. This allows main and teaser units to be interchanged, plus it provides for true, 3-phase, 4-wire system with a neutral connection. This is illustrated in the diagram.

Conversion of 3-phase to 2-phase voltage: The main and teaser transformers in this connection are arranged as they are in the Scott connection. However, while the voltage connections to the primary of the teaser coil are made at the 86.6% tap, the secondary voltage is taken from the full coil. This produces two equal secondary voltages with a 90 degree phase difference, as illustrated in the diagram. *See also* teaser transformer.



Scott transformer connection.



T transformer connection.

t-conorm *See* triangular co-norm.

t-norm *See* triangular norm.

T/R switch *See* transmit/receive switch.

TAB *See* tape automated bonding.

tableau formulation a method for formulating the equations governing the behavior of electrical networks. The tableau method simply groups the KVL, KCL, and branch relationships into one huge set of equations.

taboo channels channels that the FCC does not currently assign in order to avoid interference from adjacent channels.

tachometer a instrument used to measure the speed of a rotating device. Several types of tachometers are available. Friction devices are placed against the shaft of the device being measured. Others used magnetic variation or reflected light pulses to determine the speed. Tachometer generators are mounted on the shaft of the device being measured and provide a voltage proportional to the speed. Tach generators are often used in servo systems.

tachometer-generator a small generator that is connected to the shaft of a rotating machine and produces an output voltage directly proportional to the rpm of the machine. Typically used for closed-loop speed control.

tag (1) that part of a memory address held in a direct mapped or set associative cache next to the corresponding line, generally the most significant bits of the address.

(2) a field attached to an object to denote the type of information stored in the object. The tag can flag control objects to prevent misuse. Tags can be used to identify the type of each object and thereby to simplify the instruction set, since, for example, only one ADD instruction would be necessary if each numeric object were tagged with its type (integer vs. real, for example).

(3) a temporary sign which is affixed to a network device to identify particular instructions. An example of this might be placing a tag which indicates "Do Not Close" on a circuit breaker which has been opened to permit downstream work.

tagged image file format (TIFF) a popular image-file format that is very flexible. TIFF can hold compressed or uncompressed images, or different types of pixels, and is usable on different operating systems. *See also* file format, image compression, Lempel-Ziv-Welch coding.

tail biting a frame-by-frame transmission scheme for which the data is convolutionally encoded so that the encoder begins and ends in the same state, which, however, is unknown to the decoder. The advantage of this scheme is that no tail (overhead) is added to the data to force the encoder into a (by the decoder) known state. *Compare with* fractional rate loss.

Takagi–Sugeno–Kang fuzzy model a fuzzy model that was studied by Takagi, Sugeno, and Kang. It is called the TSK or just TS fuzzy model, and it can be viewed as a special case of SAM. *See also* fuzzy system.

take-off *See* spur.

tangential sensitivity amount of input signal power to a two-port network to produce the output signal-to-noise power ratio unity.

Tanimoto similarity for vectors x and y, defined as

$$S_T = \frac{(x, y)}{\| x \|^2 + \| y \|^2 - (x, y)}$$

where (x, y) is the inner product of x and y and $\| x \|$ is the Euclidean norm of x.

tank the container for the coils and core of a transformer, which is usually oil-filled for insulation and cooling.

tap a connection (actually one of several) to a coil, allowing the number of turns in the coil to be varied.

tap changer a device to change the tap setting on a transformer coil, allowing voltage control. *See also* tap, tap changing under load.

tap changing under load (TCUL) a type of transformer in which the output voltage can be adjusted while the load is connected to the transformer. The voltage is adjusted by changing the turns ratio of the primary and secondary coils. That, in turn, is accomplished by bringing out connections (taps) at several points on the coil. Changing from one tap to another either adds or subtracts turns from the coil and raises or lowers the voltage, respectively.

tape automated bonding (TAB) a manufacturing technique in which leads are punched into a metal tape, chips are attached to the inside ends of the leads, and then the chip and lead frame are mounted on the MCM or PCB.

tape skew misalignment of magnetic tape during readout, leading to a difference between bits positions as written and as recognized for reading. Generally not a serious problem for low recording density or low tape speed; otherwise, a correction is required, e.g., by the use of "deskewing buffers."

tape-wound core a ferromagnetic core constructed by winding ribbon-like steel instead of stacking thicker, punched lamination. Usually used for higher frequency devices, or where it is desired to reduce the eddy current losses.

tapered mirror mirror in which the reflection profile varies across the mirror surface; useful for discriminating against high-order transverse modes in a resonator. *See also* variable reflectivity mirror.

tapped delay line a realization of a digital filter which represents a unit time delay by unit spatial difference in a transmission line.

TAR *See* top antireflective coating.

target architecture the architecture of a system that is being emulated on a different (host) architecture.

task-level programming *See* object-oriented programming.

task-oriented space *See* external space.

TCSC *See* thyristor-controlled series compensator.

TCUL *See* tap changing under load.

TDD *See* total demand distortion or time division duplexing.

TDM *See* time division multiplexing.

TDMA *See* time division multiple access.

TE mode *See* transverse electric mode.

TE polarizaion *See* transverse electric polarization.

TE wave *See* transverse electric wave.

TEA laser *See* transverse-excitation-atmospheric laser.

teaching-by-doing *See* teaching-by-showing programming.

teaching-by-showing programming a programming technique in which the operator guides the manipulator manually or by means of a teach pendant along the desired motion path. During this movement, the data read by joint position sensors (all robots are equipped with joint position sensors) are stored. During the execution of the motion (playing back), these data are utilized by the joint drive servos. Typical applications of this kind of programming are spot welding, spray painting, and simple palletizing. Teaching-by-doing does not require special

programming skill and can be done by a plant technician. Each industrial robot is equipped with these capabilities. Also called teaching-by-doing.

team decision decision taken independently by several decision makers being in charge of a given process (or a decision problem) and forming a team, i.e., contributing to a commonly shared goal.

teaser coil *See* teaser transformer.

teaser transformer one of two single-phase transformers used to make up a Scott or T-connection transformer. The teaser transformer is connected between one line of the three-phase voltage system and the center-tap of the main transformer in the T-connection. Also called teaser coil. *See also* T-connection.

tee-structured VQ A method for structured vector quantization, where the input signal is successively classified and coded in a manner described by a mathematical structure known as a "tree."

TEGFET *See* high electron mobility transistor.

telepoint a generic term used to describe public-access, cordless, telephone systems.

television (1)literally, seeing at a distance.

(2) representation and transmission of moving images electrically (*See also* video).

(3) receiver for displaying such pictures.

Tellegen's theorem states the orthogonality of $\mathbf{v}, \mathbf{i}'$ and of $\mathbf{v}', \mathbf{i}$ for two different networks, N and N', with identical topologies, i.e., with the same directed graph and with $\mathbf{v}, \mathbf{i}$ the branch quantities of network N and $\mathbf{v}', \mathbf{i}'$ the branch quantities of network N'.

TEM *See* transverse electromagnetic wave.

TEM wave *See* transverse electromagnetic wave.

TEM00 mode term sometimes used to describe the fundamental Gaussian beam mode, though this mode has small longitudinal components of the electric and magnetic field vectors.

temperate plasma a preferred term used to describe the "cold plasma" to convey the following limits on the thermal velocity of the electrons. The electron thermal velocity is much less than the phase velocity of the wave in the medium but much greater than the induced velocity increments produced by the electromagnetic fields.

temperature coefficient of resistance the change in electrical resistance of a resistor per unit change in temperature.

template a pattern, often in the form of a mask, that can be used to locate objects and features in an image. For large objects which might appear in many orientations, this procedure is very computation intensive, and it is normal to use small templates to search just for features, and then infer the presence of the objects. Template matching is commonly performed for tasks such as edge detection and corner detection.

template mask a mask that forms a pixellated template of an object or feature, and which may then be used for template matching. *See also* template.

template matching a technique in which a model and an optimization method are used to deform a template to a study in order to find the best match for the purpose of detection or recognition.

temporal alignment the process of aligning two sequences by using dynamic programming.

temporal averaging averaging a signal in the time domain. For discrete signals, temporal averaging by a finite impulse response filter is a way to smooth out the signal.

temporal frequency a frequency that represents the change of an image with time; temporal frequency components can result from motion between completed images or from the methods used to construct a complete image. A monochrome interlaced television frame requires two (2) fields or 30 Hz temporal frequency in constructing a complete monochrome television frame. Similarly, the NTSC color subcarrier frequency is interlaced with the horizontal line frequency and creates a 15 Hz temporal frequency component to the color television frame.

temporal locality *See* locality.

temporal resolution the ability to resolve two closely spaced targets in the time domain. *See also* resolution.

temporary fault a fault that will not reoccur if the equipment is deenergized and then reenergized. An example of a temporary fault is when a lightning stroke causes an uninsulated overhead line to arc over an insulator, with no equipment damage.

temporary interruption a loss of voltage of less than 0.1 pu for a duration of 3 seconds to 1 minute.

terahertz (THz) a frequency unit, 10^{12} hertz.

terminal bushing *See* bushing.

termination a circuit element or device placed at the end of a transmission line that reflects and/or absorbs signal energy.

terminator (1) a device connected to the physical end of a signal line that prevents the unwanted reflection of the signal back to its source.

(2) a data item in a stream that marks the end of some portion or all of the data.

ternary logic digital logic with three valid voltage levels.

tertiary winding a third winding on a transformer. A tertiary winding may be used to obtain a second voltage level from the transformer. For example, in a substation it may be necessary to have low voltage power for the substation equipment in addition to the distribution voltage. Another application of a tertiary winding is in a wye-wye three-phase transformer. Here the tertiary is connected in delta, to provide a path for the triple harmonic components of the exciting current and prevent distortion of the phase voltages.

tesla a unit of magnetic flux density equal to one weber per square meter, i.e., one volt-second per square meter. Denoted by T. The unit is named in honor of Nikola Tesla, an early pioneer in the electric industry, who is most commonly credited with building the first practical induction motor.

Tesla, Nikola (1856–1943) Born: Smiljan, Croatia

Tesla is best known as the electrical pioneer who championed the use of alternating current. When Tesla first came to the United States he worked for Edison. He soon split with Edison, because Tesla approached invention from a theoretical standpoint, whereas Edison was a "trial and error" type experimentalist. Together with his financial backer, George Westinghouse, they battled with Edison, who championed the use of direct current for electrifying the world. Tesla is also known for his many inventions including the Tesla coil and the AC induction motor. It was Westinghouse who made a fortune from Tesla's inventions. Tesla was known for his eccentricities and died a recluse in New York City.

tesselation in the Euclidean plane, a subdivision of that plane into polygonal cells

which cover the whole of it, and such that two neighboring cells have disjoint interiors (in other words they have in common either a vertex, or a side with its two end-vertices). When the cells are isometric regular polygons, one of the following three cases occurs:

1. Each cell is a regular hexagon and has 6 neighboring cells each having a side in common with it.

2. Each cell is a square and has 8 neighboring cells, of which 4 have a side in common with it, and 4 have a vertex in common with it.

3. Each cell is an equilateral triangle and has 12 neighboring cells, of which 3 have a side in common with it, 3 have a vertex in common with it in such a way that the two neighboring cells are symmetric with respect to the common vertex, and 6 have a vertex in common with it but without symmetry with respect to the common vertex.

The tesselation of the plane into regular cells is a mathematical model of the subdivision of an image into pixels, and the corresponding digital space is made of the centers of all the cells. In both the hexagonal and square tesselations, there is a vector basis such that the cell centers coincide with points with integer coordinates. Modern technology accords with Cartesian tradition in favoring the square tesselation, but the hexagonal tesselation has a simpler topology (with fewer neighboring cells, and all of the same type), which simplifies certain types of algorithm — such as thinning algorithms. *See also* pixel adjacency.

test access port a finite state machine used to control the boundary scan interface.

test fixture a device or software module that is attached to another device or module so that tests can be run on the unit in question.

test function *See* moment method.

test pattern input vector such that the faulty output is different from the fault-free output.

test point (1) a physical contact for a hardware device that can be monitored with an external test device.

(2) a data element within a software module that is accessible to an external test module.

test register a register used in the processor to ease testing of some functional blocks (e.g., cache memory) by simplifying accesses to their internal states.

test response compaction the process of reducing the test response to a signature. Common compaction techniques use signal transition counting, accumulated addition, CRC codes, etc.

test set specialized sets of instruments used to verify the operation of relays, fault indicators, or other instrumentation.

test vectors a test scheme that consists of pairs of input and output. Each input vector is a unique set of 1s and 0s applied to the chip inputs and the corresponding output vector is the set of 1s and 0s produced at each of the chip's output.

test-and-set instruction an atomic instruction that tests a Boolean location and if FALSE, resets it to TRUE. *See also* atomic instruction.

testability the measure of the ease with which a circuit can be tested. It is defined by the circuit controllability and observability features.

testing a phase of software development life cycle during which the application is exercised for the purpose to find errors.

testing function one of a set of functions used in the method of moments to multiply both sides of the integral equation (in which the current has been expanded in a set of basis functions) to form a matrix equation that

can be solved for the unknown current coefficients.

textural edgedness a measure of the mean edge contrast at every position in an image, where the average is taken over a significant region so as to smooth out small scale variations, thereby providing an indication of the type of texture present.

textural energy a measure of the amount of statistical, periodic or structural variation at a location in a texture, 'energy' being a suitable square-law unit corresponding to the variance imposed on the mean intensity at that location in the texture.

texture quantitative measure of the variation of the intensity of a surface that can be described in terms of properties such as regularity, directionality, smoothness/coarseness, etc.

texture analysis the process of analyzing textures that appear at various positions in images. The term also includes the process of demarcating the boundaries between different textural regions and leads on to the interpretation of visual scenes.

texture modeling the process of modeling a texture with a view to (a) later recognition or (b) generating a similar visual pattern in a graphics or virtual reality display. Textures are usually partly random in nature, and texture models usually involve statistical measures of the intensity variations.

THD *See* total harmonic distortion.

thermal control *See* thermal management.

thermal expansion mismatch the absolute difference in thermal expansion of two components.

thermal fin an extension of the surface are in contact with a heat transfer fluid, usually in the form of a cylinder or rectangular prism protruding from the base surface.

thermal light light generated by spontaneous emission, such as when a group of excited atoms or molecules drops to a lower energy state in a random and independent manner emitting photons in the process; contrasted with laser light.

thermal management the process or processes by which the temperature of a specified component or system is maintained at the desired level. Also called thermal control.

thermal noise a noise process that affects communication channels and electrical circuits which is due to the random motion of electrons in materials and more specifically resistors. In such a circuit, the resistor produces a level of noise that is proportional to the resistance of the component, the ambient temperature, and the bandwidth of the circuit. Also known as Johnson, Nyquist, or white noise.

thermal neutrons neutrons which move at the same velocity as the random thermal motions of the atoms of the ambient medium.

thermal reactor a reactor which maintains a critical reaction with thermal neutrons.

thermal resistance a thermal characteristic of a heat flow path, establishing the temperature drop required to transport heat across the specified segment or surface; analogous to electrical resistance.

thermionics direct conversion of thermal energy into electrical energy by using the Edison effect (thermionic emission).

thermit welding a welding process that produces coalescence of metals by heating them with superheated liquid metal from a chemical reaction between a metal oxide and aluminum with or without the application of pressure.

thermomagnetic process the process of recording and erasure in magneto-optical media, involving local heating of the medium by a focused laser beam, followed by the formation or annihilation of a reverse-magnetized domain. The successful completion of the process usually requires an external magnetic field to assist the reversal of the magnetization.

thermomagnetic recording recoding method used with magneto-optical disks. It involves first using a focused laser beam to heat the disk surface and then forming or annihilating magnetized domains.

thermometer coding a method of coding real numbers in which the range of interest is divided into nonoverlapping intervals. To code a given real number, say x, the interval in which x lies is assigned the value $+1$, as are all intervals containing numbers less than x. All other intervals are assigned the value 0 (in the binary case) or -1 (in the bipolar case).

thick lens lens inside of which internal ray displacements and beam profile evolution are too large to be neglected.

thickening image operator that symmetrically enlarges an image around a skeleton to eventually produce an image that had been previously reduced to the skeleton by thinning. *Compare with* thinning.

thin film capacitor *See* metal–insulator–metal capacitor.

thin lens lens inside of which internal ray displacements and beam profile evolution are so small that they may be neglected.

thinning image operator that clears, somehow symmetrically, all the interior border pixels of a region without disconnecting the region. Successively applying a thinning operator results in a set of arcs forming a skeleton. *Compare with* thickening.

third rail a method of transmitting power to an electric locomotive. An insulated steel rail is laid along the railbed just outside the traction rails. This third rail is maintained at (typically) 600 volts DC by the railroad power supply, and contact is made to the locomotive by a shoe which slides atop the rail. Ground return is through the traction rails.

third-harmonic generation the process in which a laser beam of frequency ω interacts with a nonlinear optical system to produce a beam at frequency 3ω. *See also* harmonic generation.

third-order intercept (TOI) point this gives a measure of the power level where significant undesired nonlinear distortion of a communication signal will occur. It is related to the maximum signal that can be processed without causing significant problems to the accurate reproduction of the desired information (e.g., TV signal). Technically, the TOI is the hypothetical power in decibelmeter at which the power of the "third-order intermodulation" nonlinear distortion product between two signals input to a component would be equal to the linear extrapolation of the fundamental power.

third-order susceptibility a quantity, often designated χ^3, describing the third-order nonlinear optical response of a material system. It is defined through the relation $P^3 = C\chi^3 E^3$, where E is the applied electric field strength and P^3 is the 3rd order contribution to the material polarization. The coefficient C is of order unity and differs depending on the conventions used in defining the electric field strength. The third-order susceptibility is a tensor of rank 4 and describes nonlinear optical processes including third harmonic generation, four-wave mixing, and the intensity dependent refractive index. *See also* nonlinear susceptibility.

Thomson, William (Lord Kelvin) (1824–1907) Born: Belfast, Ireland

Thomson is best known as a physicist who championed the absolute temperature system that now bears his name (Kelvin). Thomson did significant work to expand Faraday's ideas. It was Thomson's work that Maxwell would extend into his seminal publications on electromagnetics. Thomson received a knighthood for his theoretical suggestions for the use of low-voltage signals in the trans-Atlantic telegraph cable. Thomson was proved correct when on a third attempt, a cable was laid and worked. An earlier high-voltage cable had failed.

thoriated pertains to a metal to which the element thorium has been added.

thrashing in a paging system, the effect of excessive and continual page transfers that can occur because the memory is overcommitted and programs cannot obtain sufficient main memory.

thread in software processes, a thread of control is a section of code executed independently of other threads of control within a certain program.

three-antenna gain measurement method technique based on Friis transmission formula in which the gain of each of three different antennas is calculated from a measurement of three insertion loss values (corresponding to all three combinations of antenna pairs) and the calculated propagation loss between the antenna pairs.

three-gun color display a color-TV picture tube having a separate gun for each primary color (red, green, and blue).

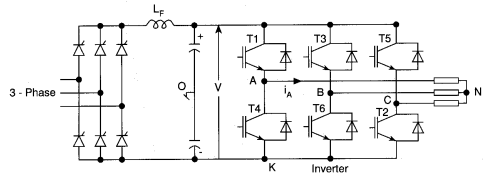
three-lamp synchronizing a method used to connect a three-phase power system in parallel to another one. In order to connect two systems, they must have the same voltage magnitude, frequency, and phase-shift. To determine that is the case, an open switch is connected between the phases of the two systems and a lamp is connected across the open switch pole in each phase. If the criteria previously listed are met, the lamps will all be dark. If there is a difference in voltage, the lamps will glow. If there is a difference in frequency, the lamps will alternately glow and go dark in unison. Finally, if the two sides have different phase rotations, the lamps will blink sequentially as only one phase can be aligned at a time. In order to synchronize the two systems, it is necessary to close the contactor when the phase-shift is minimum, which means that the three lights are dark.

three-level laser 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* four-level laser.

three phase fault a fault on a three phase power line in which all three conductors have become connected to each other and possibly the ground as well.

Three-Mile Island typically refers to a cooling failure at a nuclear power plant on the Susquehanna River in central Pennsylvania, USA in 1979.

three-phase inverter an inverter with a three-phase AC voltage output.



Three-phase inverter.

three-phase rectifier a rectifier with a three-phase AC voltage input.

three-point starter a manual DC motor starter in which a handle is pulled to start

the motor. The motion of the handle causes a contact to move across a variable resistance in the armature circuit to limit the starting current. When the handle is moved to its fullest extent, the resistance is out of the armature circuit and an electromagnet holds the handle in place. With a three-point starter, the electromagnet is in series with the shunt field and loss of the field will shut down the motor. The disadvantage is that if it is desired to weaken the field for speed control, the motor starter may drop out. Also, the three-point starter cannot be used on a series DC motor.

three-point tracking a tracking error reduction technique in which the preselector and local oscillator have trimmed capacitors added in parallel to the primary tuning capacitor and the local oscillator has an additional padder capacitor in series with the tuning coil.

three-state circuit *See* tri-state circuit.

three-terminal line a branched transmission line with three ends, each of which is terminated with circuit breakers such that all three breakers must trip to clear a fault anywhere in the line.

three-terminal device an electronic device that has three contacts, such as a transistor.

three-winding transformer a transformer with three windings, typically primary, secondary, and tertiary. Common three phase, three winding transformers employ wye connected primary and secondary windings and a delta connected tertiary winding. In some cases, an autotransformer is used to form the primary–secondary combination.

three-wire method in the three-wire method, the remote resistor (which plays the role of active gauge) is connected to the bridge circuit by three wires. One end of this resistor is connected by one wire to the bridge power supply node; at another end of the resistor there are two wires, the first of which is connected to the detector and the second is to the adjacent resistor of the bridge. Other arrangements are possible as well. The goal is to reduce the errors introduced by the long wires while measuring the remote resistor value.

threshold (1) the limiting value of some variable of interest.

(2) the condition under which the unsaturated round-trip gain in a laser is equal to the loss.

(3) that point at which the indication exceeds the background or ambient.

threshold coding a coding scheme in transform coding in which transform coefficients are coded only if they are larger than a selected threshold.

threshold current the current in an electrically pumped laser that is necessary for the unsaturated round-trip gain to be equal to the loss.

threshold decoding a special form of majority-logic decoding of block or convolutional codes.

threshold inversion population inversion that provides an unsaturated round-trip gain in a laser equal to the loss.

threshold sample selection in transform coders, quantization could be nonadaptive from block to block, where a percentage p of coefficients transmitted could vary according to spatial activity. To avoid large reconstruction errors as in coefficient reduction used by zonal selection, a threshold is chosen. Only the coefficients whose values are above the threshold are quantified and encoded.

threshold voltage when applied between the gate and source of a MOSFET, the voltage, VT, that results in an inversion of the charge carrier concentration at the silicon surface.

thresholding any technique involving decision making based on certain deliberately selected value(s) known as threshold(s). For an example, refer to threshold coding. These techniques are also often utilized in image segmentation: specifically, thresholding groups of pixels into black and white based on a numerical value; pixel levels below the value (threshold) become black, those above become white.

through via a via that connects the primary side and secondary side of a packaging and interconnecting structure.

through-reflect-line calibration a network analyzer two-port probe calibration technique. A TRL two-port calibration requires a thru standard, reflect (open circuit is preferred, short is optional), and one or more lines (transmission lines). It has the advantages of self-consistency and it requires electrically simple standards.

throughput the amount of flow per unit time. Generally refers to information flow.

thumper slang for a time-domain reflectometer used to detect and locate defects in buried electric power cables.

thyratron (1) gas-filled triode in which the voltage on the grid can trigger ionization of the gas in the tube. Once the gas is ionized, current flows from cathode to anode until the potential across the two falls below a certain level. In Linac (a linear accelerator), the thyratrons are used as high-voltage relays in the chopper power supplies and in the RF modulators to trigger the ignitrons.

(2) an electronic tube containing low pressure gas or metal vapor in which one or more electrodes start current flow to the anode but exercise no further control over its flow.

thyristor a controllable four-layer (pnpn) power semiconductor switching device that can only be on or off, with no intermediate operating states like transistors. *See also* silicon controlled rectifier.

thyristor rectifier a rectifier where the switches are thyristors. Thyristors are turned on by a gate trigger signal, and turned off by natural commutation. The output voltage is controllable by adjusting the firing angle α of the trigger signal. The direction of the power flow is reversible when an inductive load is used. When the average power flow is from DC to AC ($\alpha > \pi/2$), the rectifier is said to be operating in the line-commutated inverter mode.

thyristor-controlled phase angle regulator a phase shifting device used in transmission systems. The phase angle change is brought about by thyristor-based control.

thyristor-controlled series compensator a capacitor bank installed in series with an electric power transmission line in which each capacitor is placed in parallel with a thyristor device. Each capacitor may thus be switched in or out of the line for some variable portion of the AC cycle so as to maintain the line's maximum power-carrying ability under varying load conditions.

Ti sapphire laser laser in which the active medium is sapphire with titanium substituted for some of the aluminum atoms, important for its large bandwidth in the visible spectrum.

tie switch a disconnect switch used on feeders and laterals to reconfigure distribution circuits to allow for line maintenance.

tiepoint a point in an input image whose corresponding point in a transformed image is known. Tiepoints are often used to specify transformations in which the locations of transformed pixels change, as in geometric transformations and morphing. *See also* geometric transformation.

tier a group of cellular network cells of similar distance from some specific central cell. The tier number is the number of cell radii distant that the tier is from the central cell.

TIFF *See* tagged image file format.

tightly coupled multiprocessors a system with multiple processors in which communication between the processors takes place by sharing data in memory that is accessible to all processors in the system.

tilt angle the angle by which a surface slants away from the viewer's frontal plane.

time constant mathematically, the time required for the exponential component of a transient response (input as the step function) to decay to 37% $(1/e)$ of its initial value, or rise to 63% $(1 - 1/e)$ of its final value, where e is the mathematical constant 2.718281828 . . . .

In electronic circuits, the time constant is often related directly to the circuit RC value (i.e., the product of the resistance in ohms and the capacitance in farads) or to its L/R value (i.e., the ratio of the inductance in henrys to its resistance in ohms). *See also* settling time.

In a control system transfer function factor, T is the time constant and is equal to where f is the corner frequency in the bode plot. A closed-loop control system commonly has more than one time constant.

time correlation function a function characterizing the similarity of a received signal with respect to a shift in time. *See also* correlation.

time delay a time-current response characteristic, established by national standards, which means that a time-delay fuse is designed to carry five times rated current for 10 seconds before opening. *See also* envelope delay.

time diversity a way to try to obtain uncorrelated received signals to improve the performance of the system by transmitting the signals in different time instants. Interleaving is one way to implement time diversity.

time division duplexing (TDD) a technique for achieving duplex (i.e., two-way) communication. One direction of transmission is conducted within specific segments of time, and the reverse direction of transmission is conducted within different segments of time.

time division multiple access (TDMA) a technique for sharing a given communication resource amongst a number of users. The available communication resource is divided into a number of distinct time segments, each of which can then be used for transmission by individual users. Sometimes used in cellular and personal communications applications.

time division multiplexing (TDM) refers to the multiplexing of signals by taking rounds of samples from the signals. Each round consists of one sample from each signal, taken as a snapshot in time. *See also* time division multiple access.

time domain the specification of a signal as a function of time; time as the independent variable.

time domain analysis a type of simulation that allows the user to predict the circuit response over a specified time range. The result of the simulation is a graph of amplitude against time.

time domain storage an optical data storage technique in which time-dependent information is stored as a Fourier transform in an inhomogeneously broadened spectral hole burning material. This is usually accomplished with photon echoes or spin echoes. The maximum storage density is given by

the ratio of inhomogeneous to homogeneous widths of the absorption spectrum.

time frequency analysis any signal analysis method that examines the frequency properties of a signal as they vary over time.

time hopping a type of spread spectrum wherein the transmission of the signal occurs as bursts of pulses in time. Each burst has a random starting time and may have a fixed or random duration.

time invariance a special case of shift invariance, applying in the time domain. In particular, the impulse response of a system is independent of the time at which the impulse occurs. *See also* space invariance.

time invariant channel a communication channel for which the impulse response and transfer function are independent of time. Strictly time-invariant channels do not exist in practice, but many communication channels can be regarded as time invariant for observation intervals of practical interest.

time invariant system a system with zero initial conditions for which any input $f(t)$ applied at a time $t-\tau$ will simply result in a time shift of the output $y(t)$ to $y(t-\tau)$. For example, a RC circuit with relationship between loop current $f(t)$ and output voltage $y(t)$ described by

$$y(t) = Rf(t) + \frac{1}{C}\int_{-\infty}^{t} f(\tau)d\tau$$

is time invariant.

A system that is not time invariant is *time varying*, or *time variant*. For example, a system described by

$$y[k] = kf[k]$$

is time varying.

time overcurrent (TOC) relay an overcurrent relay that has intentional, selectable, time delay. The time delay is chosen so that the relay will operate more slowly than downstream relays or fuses, and more quickly than upstream relays or transformer fuses. Relay and fuse curves are generally displayed on time-current curves.

time response the system response in the time domain when a reference input signal is applied to a system. The time response of a control system is usually divided into two parts: the transient response and the steady-state response.

time shift for a signal $x(t)$ a displacement in time t_0. The time shift is given by $x(t-t_0)$.

time slot in time-division multiple access (TDMA), a time segment during which a designated user transmits, or control information is transmitted. In time-division multiplexing (TDM), each time slot carries bits associated with a particular call, or control information.

time stability the degree to which the initial value of resistance is maintained to a stated degree of certainty under stated conditions of use over a stated period of time. Time stability is usually expressed as a percent or parts per million change in resistance per 1000 hours of continuous use.

time variant channel a communication channel for which the impulse response and transfer function are functions of time. All practical channels are time-variant, providing the observation interval can be arbitrarily long. *See also* fading channel.

time variant system system in which the parameters vary with time. In practice, most physical systems contain time varying elements.

time varying system a system not exhibiting time invariance. In particular, one in which the impulse response varies as a function of the time at which the impulse occurs.

time–bandwidth product (1) in an acousto-optic deflector, the product of the acoustic-wave propagation time across the optical beam and the electrical bandwidth for optical diffraction; equivalent to the number of independent resolvable spots for the acousto-optic deflector. For coded signals such as chirp signals, the signal duration times the bandwidth of the signal; equivalent to the pulse compression ratio obtained in autocorrelation. *See also* pulse compression.

(2) the product of a signal's duration and bandwidth approximates the number of samples required to characterize the signal.

time-current characteristic curve (1) a relay time-current curve is a curve showing the time versus current characteristic of a time overcurrent (TOC) relay.

(2) a fuse time-current curve shows the melting and clearing times of a given fuse or family of fuses.

(3) a coordination time-current curve shows the relationship of the operating and clearing characteristics of coordinating devices (TOC relays and fuses) on a power system.

time-current curve *See* time-current characteristic curve.

time-delay fuse *See* dual-element fuse.

time-delay neural network a multilayer feed-forward network in which the output is trained on a sequence of inputs of the form $x(t), x(t-D), \ldots, x(t-mD)$, where $x(.)$ is, in general, a vector. By specifying the required output at sufficient times t, the network can be trained (using backpropagation) to recognize sequences and predict time series.

time-delay relay relay that responds with an intentional time delay.

1. in control circuits, time-delay relays are used to cause a time delay in the state of the relay when power is applied or removed to the relay actuator;

2. in power system protective relays, the response time usually depends on the magnitude of the measured value. If the measured value is a large multiple of the pickup value, then the relay operates or trips after a short time delay. For smaller multiples of pickup, the relay trips after a longer time delay.

time-dependent dielectric breakdown breakdown of a dielectric is marked by a sudden increase in current when an electric field is applied. The breakdown does not occur immediately upon application of the electric field, but at a period of time later that depends exponentially upon the magnitude of the field.

time-invariant system the system in which the parameters are stationary with respect to time during the operation of the system.

time-of-arrival the time instant of the arrival of the first signal component to the radio receiver. *See also* propagation delay.

time-to-close contact a contact in which the desired time to close the contactor could be set by the user.

time-to-open contact a contact in which the desired time to open the contactor could be set by the user.

timeout the concept of allowing only a certain specified time interval for a certain event. If the event has not occurred during the interval, a timeout has said to have occurred.

timer a circuit that records a time interval.

timing the temporal relationship between signals.

timing diagram a diagram showing a group of signal values as a function of time. Used to express temporal relationships among a series of related signals.

timing error an error in a system due to faulty time relationships between its constituents.

tin whisker a hairlike single crystal growth formed on the metallization surface.

tint the intensity of color. The name for a non-dominant color.

TLB *See* translation lookaside buffer.

TLM *See* transmission line measurement.

TM wave *See* transverse magnetic wave.

TMI refers to an accident at the Three Mile Island nuclear plant in 1979.

TOC relay *See* time overcurrent relay.

Toeplitz matrix a matrix with the property that it is symmetric and the i, jth element is a function of $(i - j)$. The Toeplitz nature of autocorrelation matrices of wide-sense stationary discrete time random processes is exploited extensively in minimum mean square error prediction/estimation algorithms.

toggle change of state from logic 0 to logic 1, or from logic 1 to logic 0, in a bistable device.

TOI point *See* third-order intercept point.

token device that generates or assists in generation of one-time security code/passwords.

token bus a method of sharing a bus-type communications medium that uses a token to schedule access to the medium. When a particular station has completed its use of the token, it broadcasts the token on the bus, and the station to which it is addressed takes control of the medium. Also called token ring.

token ring *See* token bus.

Tokomak an experimental power reactor that uses fusion, in which the hot plasma is contained and compressed with a magnetic field.

tolerance (1) the total amount by which a quantity is allowed to vary; thus the tolerance is the algebraic difference between the maximum and minimum limits.

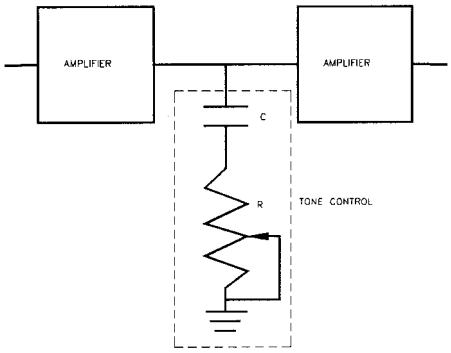
In the design of microwave component, it is important to perform a tolerance analysis in order to ascertain if a given component will also satisfy specifications when taking manufacturing tolerances into account.

(2) the amount of error allowable in an approximation.

Tomlinson precoding a transmitter precoding method that compensates for intersymbol interference introduced by a dispersive channel. The purpose is to move the feedback filter $F(z)$ of a decision-feedback equalizer to the transmitter. The purpose of the $\mathrm{mod} 2M$ operation is to satisfy the transmitted power constraint.

tomography the process of forming a cross-sectional view of an object by irradiating it from many directions and deducing from the transmitted energies the interior structure of the object. This latter process is known as reconstructing an image from its projections. Tomography can provide a very detailed map of the inside of an object and has revolutionized medical diagnostics. Also known as computed tomography (CT). *See also* projection, fan beam reconstruction, Radon transform.

tone control a resistance-capacitance network used to alter the frequency response of an amplifier by accentuating or attenuating the bass or treble portion of the audio-frequency spectrum. See figure.



tone control

tool space space of a 6×1 vector representing the positions and orientations of the tool or end effector of the robot.

top-down development an application development methodology that begins at a high level of abstraction and works through successively more detailed levels.

top antireflective coating (TAR) a thin film coated on top of the photoresist used to reduce reflections from the air–resist interface and thus reduce swing curves.

top hat transform a transform used in mathematical morphology. Let A be a structuring element centered about the origin, and for every pixel p, let A_p be its translate by p. The top hat transform measures the extent by which in a given gray-level image I the gray-levels of pixels in A_p are higher than those in the portion surrounding A_p. One way is to take the arithmetical difference $I - (I \circ A)$ between I and the opening $I \circ A$ of I by A; in a dual form, one takes the arithmetic difference $(I \bullet A) - I$ between the closing $I \bullet A$ of I by A and I. Another method considers a second structuring element B which forms a ring surrounding A, and at each pixel one computes the arithmetic difference between a "representitive" gray-level in A_p (either minimum, maximum, median, or average) and a "representitive" gray-level in B_p (either minimum, maximum, median, or average). *See* closing, opening, structuring element.

top surface imaging a resist imaging method whereby the chemical changes of exposure take place only in a very thin layer at the top of the resist.

topological map an organization of nodes in which the similarity of any two nodes is a function of their distance from each other on the map. For example, with a 2-dimensional grid, Euclidean distance can be used as the distance between two nodes. Used in the self-organizing map.

topology preserving skeleton result of an operation transforming a digital figure into a one-pixel wide skeleton having the same "topology," in other words, whose connected components and holes correspond in a one-to-one way with those of the figure. This is generally achieved by homotopic thinning. The medial axis transform or distance skeleton preserves the topology of a figure (binary image) in the Euclidean case, but not in the digital case; the same defect arises with the morphological skeleton. *See also* thinning, thickening.

tornadotron a gyrotron with a simple helical beam.

toroidal deflection yoke magnetic deflection yoke wound on a toroid core containing a split winding; one-half winding placed on opposite sides of the toroid. The yoke winding interconnection creates an opposing flux from each winding within the toroid and an aiding flux within the toroid inner diameter that causes the deflection of the electron beam. The toroid deflection yoke has a low inductance for compatibility with semiconductor deflection systems and permits precise control of the winding placement to obtain a uniform magnetic deflection field. A horizontal toroidal deflection yoke, in combination with the in-line electron gun, permits the construction of an inherent self-converging color TV display system.

torque the product of a force acting at a distance. The output of an electric motor.

torque angle the displacement angle between the rotor and rotating magnetic flux of the stator due to increases in shaft load in a synchronous machine. *See also* power angle.

torque pulsation oscillating torque produced by the interaction between the air gap flux, consisting mainly of the fundamental component, and the fluxes produced by harmonics in the rotor. Torque pulsations can stimulate complex mechanical vibrations that can flex and damage rotor and turbine elements.

torque ripple in variable speed motor drives, refers to the torque not being smooth as the rotor moves from one position to another. Torque ripple may be produced from space harmonics within the machine or time harmonics generated by the supply.

torque servo a servo where the output torque is the controlled variable and the operating speed depends on the load torque. *See also* servo.

torus a donut-shaped magnetic core used in electric transformers.

total demand distortion (TDD) an index that quantifies the amount of distortion in the voltage or current waveform with respect to the maximum 60-Hz demand load current I_{ML} over a 15–30 minute demand period.

$$\%TDDi = 100 \times \sqrt{\sum_{h \neq 1} \left(\frac{I_h}{I_{ML}} \right)^2}$$

total efficiency dimensionless ratio of the total RF power delivered to a load versus the total DC and RF incident power into the amplifier.

total harmonic distortion (THD) an index that quantifies the amount of distortion in the voltage or current waveform with respect to the fundamental component.

$$\%THDi = 100 \times \sqrt{\sum_{h \neq 1} \left(\frac{I_h}{I_1} \right)^2}$$

total harmonic distortion disturbance level an electromagnetic disturbance level due to all emissions from equipment in a system. This is expressed as a ratio of the RMS value of the harmonic content to the RMS of the fundamental and is calculated as a percentage of the fundamental component.

total internal reflection when light is incident on a boundary between two media from the one having the higher refractive index, n_1, then the angle of refraction is larger than the angle of incidence. At an angle of incidence times arc $\sin(n_2/n_1)$ the light is totally reflected and remains in the denser medium.

total reflection the phenomenon where a wave impinging on a certain medium interface is totally reflected without being damped by and without penetrating the boundary medium.

totem-pole output the standard output of transistor–transistor logic (TTL) gates consisting of two bipolar junction transistor in series between the source voltage and common. In normal operation, either one is driven into saturation while the other is at cutoff; alternating these conditions changes the output logic level.

touch input a means for selecting a location on the surface of the display unit using a variety of technologies that can respond to the placing of a finger or other pointing device on the surface. These are essentially data panels placed either on the display surface or between the user and the display surface.

touch screen a specialized type of video display where a control circuit is actuated when areas of the display are touched by ones finger or similar object. The types of touch screen technology include capacitive overlay, force vector, guided acoustic wave, resistive overlay, scanning infrared, strain gage and surface acoustic wave.

touch voltage used in power system safety studies, the voltage between any two conductive surfaces which can be touched simultaneously by a person.

tower a structure for elevating electric transmission lines, distinguished from a pole *cf* by its greater height and structural complexity.

TPBVP in optimal control two-point boundary value problem resulting from necessary conditions for control optimality given by the Pontryagin maximum principle. For continuous-time control systems described by the state equation in the form

$$\dot{x} = f(x, u, t); x(t_0) = x_0$$

with performance index defined as

$$J = \int_{t_0}^{t_f} L(x, u, t)dt + q\left(x\left(t_f\right), t_f\right)$$

where x, u are respectively state and control vectors, $[t_0, t_f]$ is an optimization horizon and f, L, q are sufficiently smooth functions of appropriate dimensions, the TPBVP is given by the state equation and costate equation defined as follows:

$$\dot{p} = -\frac{\partial H(x, u, p, t)'}{\partial x};$$
$$p\left(t_f\right) = \frac{\partial q\left(x\left(t_f\right), t_f\right)'}{\partial x}$$

where $H(x, u, p, t) = L(x, u, t) + p'(t) f(x, u, t)$ is a Hamiltonian, p is a costate vector, u should be found by minimizing the Hamiltonian with x found from the state equation driven by the optimal u.

trace length the physical distance between electronic components connected by a circuit path.

trace loading the electronic load on a circuit path.

tracing in software engineering, the process of capturing the stream of instructions, referred to as the trace, for later analysis.

track a narrow annulus or ring-like region on a disk surface, scanned by the read/write head during one revolution of the spindle; the data bits of magnetic and optical disks are stored sequentially along these tracks. The disk is covered either with concentric rings of densely packed circular tracks or with one continuous, fine-pitched spiral track. *See also* magnetic disk track, optical disk track, magnetic tape .

track buffer a memory buffer embedded in the disk drive. It can hold the contents of the current disk track.

trackball the earliest version of an input device using a roller ball, differing from the mouse in that the ball is contained in a unit that can remain in a fixed position while the ball is rotated. It is sometimes referred to as an upside-down mouse, but the reverse is more appropriate, as the trackball came first.

tracking conduction along the surface of an insulator and especially the establishment of a carbonized conduction path along the surface of a polymer insulator.

tracking bandwidth *See* lock range.

traffic channel a channel in a communication network that is used to carry the main information or service, which is typically voice, data, video, etc. *Compare with* control channel.

traffic decomposition the decomposition approximates the steady-state behavior of the

traffic by "decomposing" it into long- and short-term behavior.

trailing edge when a pulse waveform switches from high to low, it is called a trailing edge.

trailing-edge triggered a device that is activated by the trailing edge of a signal.

trainability the property of an algorithm or process by which it can be trained on sample data and thus rendered adaptable to different situations. *See also* training procedure, supervised learning, unsupervised learning.

training algorithm of self-generating neural network given as follows:

1. Initially, the network contains nothing. When the first training example comes in, the system creates a neuron for it.

2. When a new training example comes in, the neurons in the hierarchy are examined for similarity to the training example, hierarchically from the root(s). Each time, the last winner and all the neurons in its child networks are examined to find a new winner. If the new winner is the old winner, the examination stops and the old winner is the final winner; otherwise, the new winner and its child network are examined until a leaf node is found to be the winner. During this process, the weights of all the winners and their neighbors should be updated according to the same rule as that of self-organizing network. After the final winner is found, the network structure should be updated according to the following rules:

3. If the winner is a terminal node (i.e., it has no child network(s)), generate two new neurons, and copy the training vector and the original winner into them, respectively. Make them as two neurons in a new child network of the updated winner.

If the winner is a nonterminal node (i.e., it has a child network), generate only one neuron, copy the training vector into it, and put it in the child network of the updated winner.

4. Repeat the above process until all the training examples are exhausted. One training epoch has been completed at this point, and more than one epoch may be required for the network of neural networks to reach an equilibrium. *See also* self-generating neural network.

training procedure the method of calculating the set of free parameters of a function given a set of training data.

training sequence a sequence of transmitted symbols known at the receiver, which is used to train an adaptive equalizer or echo canceller.

training set data used as the basis for determining the best set of free parameters. Typically used in iterative training algorithms.

trajectory a path on which a time law is specified for instance in terms of velocities and/or accelerations at each point.

trajectory planning a trajectory planning algorithm is the path description, the path constraints imposed by manipulator dynamics as inputs and position, velocity, and accelerations of the joint (end-effector) trajectories as the outputs. *See also* path.

transceiver a device that can serve as both transmitter and receiver.

transco contraction of "transmission company," a firm which owns electric power transmission lines but does not engage in power generation or distribution.

transconductance a quantity used to specify a field-effect transistor, defined as the differential change in drain current upon a differential change in gate voltage.

transducer a device that converts a physical quantity into an electrical signal. Typically, transducers are electromechanical en-

ergy conversion devices used for measurement or control. Transducers generally operate under linear input-output conditions and with relatively small signals. Examples include microphones, pickups, and loudspeakers.

transducer gain ratio of the power delivered to the load to the power available from the source.

transducer power gain *See* transducer gain.

transfer characteristic curve one of a set of device curves derived from the expression for the output current as a function of the input voltage.

transfer function (1) a mathematical model that defines the relationship between the output and the input of a linear system. It is usually expressed as the ratio of the Laplace transform of the output function divided by the Laplace transform of the input function. A typical transfer function model has the form

$$g(s) = \frac{b_0 + b_1 s + b_2 s^2 + b_3 s^3 + \cdots + b_m s^m}{a_0 + a_1 s + a_2 s^2 + a_3 s^3 + \cdots + a_m s^m}$$

without deadtime, or

$$g(s) = \frac{b_0 + b_1 s + b_2 s^2 + b_3 s^3 + \cdots + b_m s^m}{a_0 + a_1 s + a_2 s^2 + a_3 s^3 + \cdots + a_m s^m} e^{-s\tau}$$

with deadtime. The numerator and denominator polynomials are co-prime and the coefficients are real constants. For causality, the order of the numerator polynomial must not exceed that of the denominator ($m \leq n$). For larger systems with multiple inputs and outputs, the concept is generalized to a transfer function matrix in which each (i, j) element is a simple transfer function that defines how output (i) is affected by input (j). Although not uniquely defined, it is possible to transform any transfer function or transfer function matrix to a state space model having the same input–output behavior. *See also* state space model. Equivalent pulse transfer function models exist for digital (discrete-time) systems:

$$g(z) = \frac{b_0 + b_1 z + b_2 z^2 + b_3 z^3 + \cdots + b_m z^m}{a_0 + a_1 z + a_2 z^2 + a_3 z^3 + \cdots + a_m z^m}$$

where the polynomials are based on the z-transform. Though not as common, these can also be collected into matrices for MIMO systems to form pulse transfer function matrices. *See also* z-transform and modified z-transform.

(2) the Fourier transform of the output signal divided by the Fourier transform of the input signal. Alternatively, the Fourier transform of the impulse response function.

transfer matrix of linear stationary continuous time dynamical system, $K(s)$ represents controllable and observable part of dynamical system and is defined by the equality

$$K(s) = C(sI - A)^{-1}B + D$$

for systems with m inputs and q outputs $K(s)$ is $q \times m$ dimensional matrix.

transfer rate a measure of the number of bits that can be transferred between devices in a unit of time.

transfer time in a hierarchical memory system, the time required to move a block between two levels.

transform the process of converting data from one form into another. Often used to signify a system that rotates the coordinate axes. Examples of transforms include the Fourier transform and the discrete Fourier transform. A discrete linear transform can be described as a product of the input vector with a transform matrix. *See also* transform kernel.

transform coding a method for source coding similar to subband coding. The input signal is transformed into an alternative representation, using an invertible transform (e.g., the Fourier transform), and the quantization is then performed in the transform domain. The method utilizes the fact that enhanced compression can then be obtained by focusing (only) on "important" transform parameters.

transform kernel a function that is multiplied with an input function: the result of which is integrated or summed to form a transformed output. For example in the definition of the continuous Fourier transform the kernel is $e^{-j\omega t}$ and in the definition of the discrete Fourier transform the kernel is $e^{-j2\pi nm/N}$.

transform vector quantization the generalization of scalar transform coding to vector coding. *See also* transform coding.

transform VQ *See* transform vector quantization.

transform-based heirarchical coding use of heirarchically compacted image energies to allow recognizable reconstruction with a relatively small amount of data.

transformation ratio dimensionless ratio of the real parts of the load and source impedance.

transformed circuit an original circuit with the currents, voltages, sources, and passive elements replaced by transformed equivalents.

transformer a device that has two or more coils wound on an iron core. Transformers provide an efficient means of changing voltage and current levels, and make the bulk power transmission system practical. The transformer primary is the winding that accepts power, and the transformer secondary is the winding that delivers power. The primary to secondary voltages are related by the turns ratio of the coils. The corresponding currents are related inversely by the same ratio.

transformer differential relay a differential relay specifically designed to protect transformers. In particular, transformer differential relays must deal with current transformer turns ratio error and transformer inrush and excitation current.

transformer fuse a fuse employed to isolate a transformer from the power system in the event of a transformer fault or heavy overload.

transformer vault a fireproof enclosure in which power transformers containing oil must be mounted if used underground or indoors.

transient (1) the behavior exhibited by a linear system that is operating in steady state in moving from one steady state to another. For stable systems, the transient will decay while for unstable system it will not, and thus the latter never reach another steady-state operation. *See also* settling time and time constant.

(2) any signal or condition that exists only for a short time.

(3) an electrical disturbance, usually on a power line.

(4) refers to momentary overvoltages or voltage reductions in an electric power system due to lightning, line switching, motor starting, and other temporary phenomena.

transient current the fault current that flows during the transient period when the machine apparent impedance is the transient impedance.

transient fault a fault that can appear (e.g., caused by electrical noise) and disappear within some short period of time.

transient impedance the series impedance that a generator or motor exhibits fol-

lowing the subtransient period but prior to the steady-state situation.

transient open-circuit time constant *See* quadrature-axis transient open-circuit time constant and direct-axis transient open-circuit time constant.

transient operation a power system operating under abnormal conditions because of a disturbance.

transient reactance the reactance offered for the transient currents in synchronous machines. Referred to by the symbol X'_s, the transient reactance is a function of the stator frequency and the transient inductance. X'_s is comparatively smaller in comparison to the steady-state inductive reactance of the machine.

transient short-circuit time constant *See* quadrature-axis subtransient short-circuit time constant and direct-axis transient short-circuit time constant.

transient stability the ability of a power system to remain stable following a system disturbance.

transient suppressor a device connected to a piece of sensitive electrical equipment to reduce the amplitude of transient voltage excursions, thus protecting the equipment.

transistor–transistor logic (TTL) a transistor technology in which the output of a logic gate is amplified in going from 0 to 1 as well as from 1 to 0.

transit time the average time in seconds required for an electron to move between two specified surfaces.

transition band the portion of the frequency spectrum where a filter changes from a stop filter to a pass filter or vice versa. The steepness of the transition band is often a measure of the quality of a filter, where the pass and stop bands are critical. A longer filter length generally implies that the filter can have a steeper transition band to a similarly shaped shorter length filter.

transition lifetime coefficient representing the time after which a population of atoms in an excited state may be expected to fall to $1/e$ of its initial value due to stimulated and spontaneous processes as well as inelastic collisions. *See also* spontaneous lifetime, transition rate.

transition matrix of 2-D Fornasini–Marchesini model for

$$x_{i+1,j+1} = A_1 x_{i+1,j} + A_2 x_{i,j+1} + B_1 u_{i+1,j} + B_2 u_{i,j+1}$$

$i, j \in Z_+$ (the set of nonnegative integers) is defined as follows:

$$T_{ij} = \begin{cases} I_n \text{ for } i = j = 0 \\ A_1 T_{i,j-1} + A_2 T_{i-1,j} \\ \text{for } i, j \in Z_+ \ (i + j \neq 0) \\ 0 \text{ for } i < 0 \text{ or/and } j < 0 \end{cases}$$

where $x_{ij} \in R^n$ is the local state vector, $u_{ij} \in R^m$ is the input vector, A_k, B_k $(k = 1, 2)$ are real matrices.

transition matrix of 2-D general model for

$$x_{i+1,j+1} = A_0 x_{ij} + A_1 x_{i+1,j} + A_2 x_{i,j+1} + B_0 u_{ij} + B_1 u_{i+1,j} + B_2 u_{i,j+1}$$

$i, j \in Z_+$ (the set of nonnegative integers) is defined as follows:

$$T_{ij} = \begin{cases} I \text{ for } i = j = 0 \\ A_0 T_{i-1,j-1} + A_1 T_{i,j-1} + A_2 T_{i-1,j} \\ \text{for } i, j \in Z_+ \ (i + j \neq 0) \\ 0 \text{ for } i < 0 \text{ or/and } j < 0 \end{cases}$$

The transition matrix of the first 2-D Fornasini–Marchesini model is defined in the same way.

transition matrix of 2-D Roesser model denoted T_{ij},

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

$i, j \in Z_+$ (the set of nonnegative integers) is defined as follows:

$$T_{ij} = \begin{cases} I_n \text{ for } i = j = 0 \\ \begin{bmatrix} A_1 & A_2 \\ 0 & 0 \end{bmatrix} \text{ for } i = 1,\ j = 0 \\ \begin{bmatrix} 0 & 0 \\ A_3 & A_4 \end{bmatrix} \text{ for } i = 0,\ j = 1 \text{ and} \\ T_{10}T_{i-1,j} + T_{01}T_{i,j-1} \\ \text{for } i, j \in Z_+ \ \ (i + j \neq 0) \\ 0 \ \text{ for } i < 0 \text{ or/and } j < 0 \end{cases}$$

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, A_1, A_2, A_3, A_4, B_1, B_2 are real matrices.

transition rate rate at which atoms undergo transitions from one level to another due to stimulated and spontaneous processes as well as inelastic collisions; reciprocal of transition lifetime.

transition region the region of the I-V curve(s) of a device between the ohmic region and the current source region, in which the slope of the I-V curve(s) is rapidly changing as it transitions from the resistance region to the current source region.

translation a geometric transformation which simply adds an offset to the pixel coordinates of an image.

translation lookaside buffer (TLB) essentially a small fully associative address-cache used to provide fast address translation for the most used virtual addresses. The TLB is associatively searched on a virtual address, and in the event of a hit, it returns the corresponding real address. In the event of a miss, if the addressed page is in main memory, then a TLB entry is made for it; otherwise the page is first brought in after a page fault and then the TLB entry is made. In either case, the TLB eventually returns a real address. The TLB may be fully associative, set associative, or hashed.

translator an unattended television or FM broadcast repeater that receives a distant signal and retransmits the picture and/or audio locally on another channel.

transmission (1) the act of sending information from one location to another.

(2) transformation of an optical wave incident on a surface that passes a portion of the wave to the medium behind the surface.

(3) that class of electric power system work which is concerned with the transport of electric power from the generator to the area of consumption. The circuits of interest typically extend at the generating station and terminate at the local substation.

transmission coefficient a number that describes the relative amplitude and phase of the transmitted wave with respect to the incident wave. The term is usually used in the context of wave transmission at a material interface or transmission line.

transmission grating a diffraction grating that operates in transmission, i.e., the diffracted light is obtained by shining light through the grating.

transmission line (1) an arrangement of two or more conductors used to convey electromagnetic energy from one point to another.

(2) conductive connections that guide signal power between circuit elements.

transmission line coupler passive coupler composed of two or more transmissions spaced closely together where the proximity of the transmission lines allows signals to be coupled or transferred in part from one line to the other. The electrical length of the transmission lines is usually one quarter of a wavelength.

transmission line filter a microwave device that is made up of sections of transmission lines so as to act as a filter in the microwave frequency range.

transmission line measurement (TLM) an experimental technique to measure the specific contact resistance of a metal ohmic contact on a semiconductor with a set of variable spaced transmission lines.

transmission line parameters parameters that describe the electrical response of a transmission line. These consists of one describing the characteristic impedance (ζ) and another describing the complex propagation constant (γ). The complex propagation constant is sometimes defined independently in terms of two separate parameters, one defining the real part (α) and a second one defining the imaginary part (β) of the complex constant.

transmission line resonator resonator formed by a transmission line.

transmission matrix for a microwave network, a matrix that gives the output quantities in terms of the input quantities, when the input/output quantities are linearly dependent. When voltages and currents are chosen, it is called voltage–current transmission matrix. If incident and reflected waves are chosen, it is called wave amplitude transmission matrix.

transmission system a transmission system transfers the motion from the actuator to the joint.

transmissivity a property that describes the transmitted energy as a function of the incident energy of an EM wave and a material body. The property may be quantified in terms of the magnitude of the transmission coefficient or the ratio of the incident to the transmitted field.

transmit/receive (T/R) switch a single-pole double-throw (SPDT) switch, connected to the antenna feed. It is used to prevent destruction of the receiver from the transmit RF power.

transmittance ratio of the complex amplitude of a transmitted wave to the complex amplitude of the corresponding incident wave at a transmitting surface.

transmitter equipment used to generate an RF carrier signal, modulate this signal and radiate it into space.

transparent code a code in which the complement of every codeword also is a codeword.

transparent mode a mode of a bistable device where an output responds to data input signal changes.

transposition (1) the practice of twisting a three-phase power line so that, for example, phase A takes the place on the tower formerly occupied by phase B, phase B takes the place of phase C, and phase C occupies the former position of phase A.

(2) a point on a three-phase electric power line where the conductors are physically transposed for purposes of improving circuit balance

transputer a class of CPU designed and manufactured by Inmos Corporation. The transputer was specifically designed to be used in arrays for parallel processing.

transverse electric (TE) referring to fields or waves in which the electric field has nonzero vector components only in the plane perpendicular (transverse) to a specified axis, usually a coordinate axis.

transverse electric mode mode having no longitudinal component of the electric field (no component in the direction of propagation). Generally referred to as TE mode.

transverse electric polarization polarization state of a transverse electric (TE) mode. Also called TE polarization.

transverse electric wave electromagnetic waves polarized so that the electric field intensity vector is perpendicular to the direction of propagation. The wave solutions have zero electric field component in the direction of propagation. Also known as TE-wave or H-mode.

transverse electromagnetic (TEM) referring to fields or waves in which both the electric and magnetic fields have nonzero vector components only in the plane perpendicular (transverse) to a specified axis, usually a coordinate axis. In a TEM wave, the electric and magnetic fields are perpendicular to each other and to the direction of propagation.

transverse electromagnetic mode electromagnetic wave propagation mode in which electric and magnetic fields are transverse to the direction of propagation (i.e., no radial field components). TEM mode propagation is a characteristic of antenna radiation in the far-field and of transmission-line propagation below the cutoff frequency of the higher order modes.

transverse electromagnetic wave the electric and magnetic field components along in the direction of propagation are zero. Abbreviated TEM wave.

transverse excitation laser pumping process in which the pump power is introduced into the amplifying medium in a direction perpendicular to the direction of propagation of the resulting laser radiation.

transverse magnetic (TM) referring to fields or waves in which the magnetic field has nonzero vector components only in the plane perpendicular (transverse) to a specified axis, usually a coordinate axis.

transverse magnetic wave the wave solutions with zero magnetic field component in the direction of propagation. Also known as TM wave and E-modes.

transverse mode term (somewhat misleading) used in referring to the transverse structure or indices of the mode of a laser oscillator.

transverse mode-locking forcing the transverse modes of a laser to be equally spaced in frequency and have a fixed phase relationship; useful for obtaining a scanning output beam oscillator.

transverse resonance a technique used in order to find the modes of closed waveguides.

transverse-excitation-atmospheric (TEA) laser high pressure (sometimes atmospheric pressure or higher) gas laser excited by a discharge in which the current flow is transverse to the direction of propagation of the laser beam; useful for very high power pulsed applications.

trap (1) in microelectronics, an imperfection in a semiconducting material that can capture a free electron or hole.

(2) in computers, a machine operation consisting of a hardware-generated interrupt or subroutine call that is invoked in the case of some error condition, for example, encountering an unimplemented instruction code in the instruction stream. *See also* exception.

TRAPATT diode acronym for trapped plasma avalanche transit time, a microwave diode that uses a high field generated electron-hole plasma and the resulting diffusion of these carriers to the contacts to create a microwave negative resistance, used as high power, high efficiency RF power sources.

trapezoidal pattern a signal produced on an oscilloscope by applying an amplitude modulated signal to the horizontal input and the modulating signal to the vertical input.

By measuring the maximum and minimum height of the resulting trapezoid, the modulation index may be obtained.

trapped wave *See* bound mode.

traveling wave an electromagnetic signal that propagates energy through space or a dielectric material.

traveling wave amplifier the principle of traveling-wave amplification is a technique for increasing the gain-bandwidth product of an amplifier. The input and output capacitances of discrete transistors are combined with lumped inductors and form artificial transmission lines, coupled by the transductances of the devices. The amplifier can be designed to give a flat, lowpass response up to very high frequencies. Sometimes called a traveling wave tube amplifier (TWTA).

traveling wave excitation a method of pumping in which the excitation travels along the lasing axis at or near the velocity of light in order to pump short-lived transitions just prior to stimulation.

traveling wave tube amplifier (TWTA) *See* traveling wave amplifier.

tree (1) a connected subgraph of a given connected graph G which contains all the vertices of G but no circuits.

(2) a form of microscopic cracking which forms in flexible cable insulation. It is typically a precursor of insulation failure. *See* water tree, electrical tree.

tree code a code produced by a coder that has memory.

tree coding old name for *convolutional coding.*

tree network limited connection of subscriber nodes to a central control or distribution unit via other subscriber nodes in the network.

tree structure robots a set of rigid bodies connected by joints forming a topological tree is called a tree structure robot.

tree structured vector quantization scheme to reduce the search processes for finding the minimum distortion codevector using a tree structured codebook, where each node has m branches and there are $p = \log_m N_c$ levels of the tree. Abbreviated tree structured VQ.

tree structured VQ *See* tree structured vector quantization.

tree wire a thinly-insulated conductor used in distribution work along tree-lined streets. The insulation is sufficient to withstand a brush from a tree branch.

tree-search algorithms for searching through a tree-structured problem based on a certain cost function, or metric, increment associated with each branch of the tree.

trellis code a (channel) coding scheme in which the relation between information symbols and coded symbols is determined by a finite-state machine. The current block of information symbols and the state (in the finite-state machine) uniquely determine the block of coded output symbols as well as the next state. Thus, trellis coding can be viewed as generalized block coding for which the encoder function depends on the current as well as previous blocks of nonoverlapping information symbols. In the class of trellis codes we, for example, find convolutional codes, trellis-coded modulation and continuous-phase modulation. *See also* convolutional code.

trellis coded modulation a forward error control technique in which redundancy is introduced into the source stream through an increase in number of symbol values rather than an increase in the number of symbols. Developed by G. Ungerboeck in the late 1970s,

this approach has found widespread use in systems with limited bandwidth.

trellis coding *See* trellis code.

trellis diagram in convolutional codes and trellis coded modulation, a graphical depiction of all valid encoded symbol sequences, and the basis for the Viterbi decoding algorithm.

trellis search an algorithm for searching through a trellis-structured problem based on a certain cost function, or metric, increment associated with each branch of the trellis.

trellis vector quantization a method for structured vector quantization, where the input signal is classified and coded in a manner described by a mathematical structure known as a "trellis." Abbreviated trellis VQ.

trellis VQ *See* trellis vector quantization.

trench isolation condition in which parasitic MOSFETs are formed between transistors sharing a common substrate when polysilicon or metal layers run between the two.

tri-state circuit a logic circuit that can assume three output states, corresponding to ZERO, ONE, and OFF. Tri-state circuits are used to place signals on a bus where only one signal source is allowed to be active at a time. Using this type of device, there may be several sources that have the ability to send signals to the same receiver, at different times.

tri-state logic *See* tri-state circuit.

triac a power switch that is functionally a pair of converter-grade thyristors connected in anti-parallel. Triacs are mainly used in phase control applications such as dimmer switches for lighting. Because of the integration, the triac has poor reapplied dv/dt, poor gate current sensitivity at turn-on, and longer turn-on time. They are primarily used for AC power control with resistive loads, such as in light dimmers.

triangle function a binary operation τ on distance distribution functions that is commutative, associative, and nondecreasing in each place, i.e., satisfying the following relationships:

$$\begin{aligned} \tau(F, G) &= \tau(G, F)\ ; \\ \tau(F, G) &\le \tau(H, K) \\ &\Leftarrow F \le H, G \le K\ ; \\ \tau(\tau(F, G), H) &= \tau(F, \tau(G, H)); \\ \tau(F, \mathbf{1}) &= F; \end{aligned}$$

for any distance distribution functions F, G, H, K and the unit step function $\mathbf{1}$. The triangle functions defines a triangle inequality in the given probabilistic metric space. The most important triangle functions are defined by convolutions or are induced by triangular norms.

triangular co-norm denoted $\dot{+}$, is a two place function from $[0, 1] \times [0, 1]$ to $[0, 1]$. The most used triangular co-norm is the union $\vee$ defined as

$$\mu_{A \vee B} = \max\{\mu_A(x), \mu_B(x)\},$$

where A and B are two fuzzy sets in the universe of discourse X.

The triangular co-norm is used as disjunction in the approximate reasoning, and reduces to the classical OR, when applied to two crisp (nonfuzzy) sets.

See also approximate reasoning, fuzzy set.

triangular norm (1) in fuzzy systems, denoted $\star$, a two place function from $[0, 1] \times [0, 1]$ to $[0, 1]$. The most used triangular norms are the intersection $\wedge$ and the algebric product $\cdot$ defined as

$$\begin{aligned} \mu_{A \wedge B} &= \min\{\mu_A(x), \mu_B(x)\}, \text{ and} \\ \mu_{A \cdot B} &= \mu_A(x)\mu_B(x), \end{aligned}$$

where A and B are two fuzzy sets in the universe of discourse X.

The triangular norm is used as conjunction in the approximate reasoning, and reduces to the classical AND. when applied to two crisp (nonfuzzy) sets.

See also approximate reasoning, fuzzy set.

(2) in control, a function T from the closed unit square into the closed unit interval endowed with the following properties:

$$T(a,b) = T(b,a); T(a,b) \leq T(c,d) \Leftarrow a \leq c, b \leq d ;$$
$$T(a,1) = a; T(T(a,b),c) = T(a,T(b,c)) ;$$

for all $a, b, c, d \in [0,1]$. The most important triangular norms (t-norms) are defined by product of two numbers, operation of taking the smaller one of two numbers and a family of T_s given by

$$T_s(a,b) = \log_s \left(1 + \frac{(s^a - 1)(s^b - 1)}{s - 1}\right)$$

t-norms are used to define a triangle inequality in the family of probabilistic metric spaces called statistical metric spaces, which may be considered as uncertain counterparts of metric spaces. Different triangular norms are used as composition operators in fuzzy systems, although the standard operation is defined by minimum.

triangular window *See* Bartlett window.

trigger in oscilloscopes and logic analyzers, the "trigger" signal is used to notify the system that a certain event has occurred, and data acquisition should commence.

trim condition *See* set point.

trinocular vision a vision model in which points in a scene are projected onto three different image planes.

triode region *See* ohmic region.

trip coil a solenoid in a circuit breaker that initiates breaker opening when energized.

triple transit echo (TTE) a multiple transit echo received at three times the main SAW signal delay time. The echo is caused due to the bidirectional nature of SAW transducers and the electrical and/or acoustic mismatch at the respective ports. This is a primary delay signal distortion which can cause filter distortion, especially in bidirectional transducers and filters.

triplen harmonics the frequency components which have a frequency of multiple of three times the frequency of the fundamental. These voltages are in phase in all three windings of a three-phase transformer and peak simultaneously. Delta connection on the other side provides a closed path for the flow of triple harmonic currents.

triplex cable a cable used for residential or commercial service drops consisting of two or three insulated conductors spiralled around a bare neutral wire which provides support for the cable.

tristimulus value one value in tristimulus color theory. Tristimulus color theory stems from the hypothesis that the human eye has three types of color receptors (cones) that have peak sensitivity in the red, green and blue visible light wavelengths respectively. The tristimulus color values are a set of three values X, Y, and Z which replace the red, green, and blue intensities with a weighted integral which calculates a spectral energy over the range of visible wavelengths of light for each value; the integrals allow for colors to be represented purely additively, while representing colors via red, green and blue intensities often requires a subtractive interaction between the "primaries."

troposphere the region of the atmosphere within about 10 km of the Earth's surface. Within this region, the wireless radio channel is modified relative to free space conditions by weather conditions, pollution, dust particles, etc. These inhomogeneities act as point scatterers, which deflect radio waves down-

ward to reach the receiving antennas, thereby providing tropospheric scatter propagation.

trouble ticket a complaint made by a customer regarding service. Its origins trace back to a paper work request which was given to the service representative.

true complement in a system that uses binary (base 2) data negative numbers, the true complement can be represented as 1's complement of the positive number. This is also called a radix complement.

true concurrency *See* concurrency. *Compare with* apparent concurrency.

true data dependency the situation between two sequential instructions in a program when the first instruction produces a result that is used as an input operand by the second instruction. To obtain the desired result, the second instruction must not read the location that will hold the result until the first has written its results to the location. Also called a read-after-write dependency and a flow dependency.

true efficiency *See* total efficiency.

truncation for a function $x(t)$, truncation is another function, usually denoted $x_T(t)$, defined as follows:

$$x_T(t) = \begin{cases} x(t) & t \leq T \\ 0 & t > T \end{cases}$$

See also extended space.

truncation error when numerically solving the differential equations associated with electrical circuits, approximation techniques are used. The errors associated with the use of these methods are termed truncation error. Controlling the local and global truncation errors is an important part of a circuit simulator's task. Limits on these errors are often given by the user of the program.

trunk a communication line between two switching nodes.

truth model a very detailed mathematical description of a process to be controlled. The truth model is also called the *simulation model*, since it is used in simulation studies of the process. *See also* design model.

truth table a listing of the relationship of a circuit's output that is produced for various combinations of logic levels at the inputs.

TS fuzzy model *See* Takagi–Sugeno–Kang fuzzy model.

TSK fuzzy model *See* Takagi–Sugeno–Kang fuzzy model.

TTE *See* triple transit echo.

TTL *See* transistor–transistor logic.

tube leak a crippling mishap in a steam power plant. High-pressure steam leaks from a cracked boiler tube with sufficient energy to cut adjacent tubes.

tunable laser laser in which the oscillation frequency can be tuned over a wide range.

tuned-circuit oscillators *See* LC-oscillator.

tuner a circuit or device that may be set to select one signal from a number of signals in a frequency band.

tuning elements generally lossless elements (probes, screw, etc.) of adjustable penetration extending through the wall of the waveguide or cavity resonator. By changing their position the reflection coefficient is adjusting. *See also* matching elements.

tunnel diode a PN diode structure that uses band to band tunneling to produce a terminal negative differential resistance, also called an Esaki diode after its inventor L. Esaki.

tunneling a physical phenomenon whereby an electron can move instantly through a thin dielectric.

tunneling modes in an optical fiber, modes that are intermediate in attenuation between propagating modes and cladding modes and may be sustained between 10's to 100's of meters.

turbidity inverse of the length over which the energy of the light transmitted in the forward direction decays to e^{-1} times its incidence value.

turbo code the parallel concatenated convolutional coding technique introduced by Berrou, Glavieux, and Thitimajshima in 1993. These codes achieve astonishing performance through parallel encoding of the source symbol sequence and iterative serial decoding of the demodulated symbol sequence.

turbogenerator a generator driven by a steam-turbine engine.

turn-off snubber an auxiliary circuit or circuit element (consisting of a resistor and capacitor) used in power electronic systems to reduce the dv/dt during turn off.

turn-on snubber an auxiliary circuit or circuit element (usually an inductor) used in power electronic systems to reduce the rate of rise or fall of the turn-on or turn off current to protect the power electronic device.

turns ratio the ratio of the number of turns between two coupled windings, e.g., for a transformer, it is the ratio of number of turns of the primary winding to the number of turns of the secondary windings. For an induction machine, it is the ratio of the number of turns of the stator winding to the number of turns of the rotor winding.

twelve-pulse converter the combination of two 6-pulse converters connected through a Y-Y and a delta-Y transformer in order to cancel the characteristic 5th and 7th harmonics of the 6-pulse converters. The lowest characteristic harmonics with twelve-pulse converters under balanced conditions are the 11th and 13th harmonics. The converters are connected in parallel on the AC side and in either series or parallel on the DC side, depending on the required DC output voltage.

twenty-six connected *See* voxel adjacency.

twin-T bridge represents a parallel connection of two T-shape two-ports. Each such two-port includes three impedances: two impedances are connected in series between input and output of the two-port, and the third impedance is connected between ground and the common point of two series impedances. The most important in applications is a twin-T bridge where one two-port is a series connection of two resistors and a capacitor is connected between their common point and ground; the other two-port is a series connection of two capacitors and a resistor is connected between their common point and ground. This circuit is used as a passive rejection filter, and as a feedback circuit of some active filters and oscillators.

twin-T bridge oscillator an oscillator where the twin-T bridge is used as a feedback circuit of an amplifier. The twin-T bridge has a very steep phase-frequency response in the vicinity of the bridge rejection frequency, and, with proper design, this may provide high indirect frequency stability. The most problem-free design requires that the bridge transfer function has complex-conjugate zeros slightly shifted from $j\omega$-axis into the right half of s-plane. The amplifier should have a negative gain compensating the bridge losses at the oscillation frequency, which is close to the bridge rejection frequency.

twisted nematic the alignments of the nematic planes are rotated through 90 degrees

across the crystal by constraining alignments to be orthogonal at the boundaries.

twisted nematic liquid crystal layered electro-optic material that can be switched between an electric-field-aligned state and the natural state with progressive rotation of polarization direction between layers, used in thicknesses to rotate light polarization by 90 degrees between polarizers, to produce light modulation.

two-address computer one of a class of computers using two or fewer address instructions.

two-address instruction a class of assembly language ALU instruction in which the two operands are located in memory by their memory addresses. One of the two addresses is also used to store the result of the ALU operation.

two-and-a-half-D sketch a representation of the input image which is augmented at every position by information relating to 3-D structure and which is deemed to constitute a significant step on the way to human image interpretation. The name arises as the basic representation is still 2-D, whereas it is tagged with all available 3-D information: it is important in forming a bridge between early (i.e., low level) visual processes and high level vision. It is strongly associated with the name of its developer, the late David Marr.

two-antenna gain measurement method technique based on Friis transmission formula in which the gain of each of two assumed to be identical antennas is calculated from a measurement of the insertion loss between the two antennas and the calculated propagation loss.

two-band filter bank *See* two-channel filter bank.

two-beam coupling any of several nonlinear optical processes involving two optical beams in which energy is transferred from one beam to the other.

two-channel coding a coding scheme in which a signal is decomposed into two parts: low frequency and high frequency components. The low frequency component is undersampled and the high frequency component is coarsely quantized, thus saving data. It can be viewed as a special example of subband coding.

two-channel filter bank a filter bank that has one high frequency band and one low frequency band in both analysis and synthesis filters.

two-degree-of-freedom system a linear robust controller can consist of two independent parts. The feedback part's transfer function G_{fb} is typically chosen so that disturbances acting on the process are attenuated and the closed-loop system is insensitive to process variations. The feedforward part's transfer function G_{ff} is then chosen to the desired response to command signals. Such a system is called a two-degree-of-freedom system because the controller has two transfer functions that can be chosen independently.

two-dimensional acousto-optic processor an acousto-optic signal processing system typically utilizing the two orthogonal dimensions (e.g., x and y) of Cartesian space to implement space and/or time based integration.

two-dimensional correlator a correlator where both input signals are two-dimensional, such as images.

two-dimensional Fourier transform an operation performed optically by a lens on an image placed at the front focal plane of the lens; the complex Fourier transform output

is represented by the light at the back focal plane.

two-dimensional joint transform correlator a type of optical correlator that employs two parallel paths, one for the input image and one for the reference image, instead of an in-line cascade. *See also* joint transform correlator.

two-dimensional memory organization memory organization in which the arrangement on a single chip reflects the logical arrangement of memory. In the most straightforward case, each address is presented at once in its entirety and decoded by a single decoder. However, to reduce the number of pins required for addressing, the address may be split into two parts that are then sent in sequence on the same lines. Then during the row access strobe, one part is used to select a "row" of the memory, and during the column access strobe the other part is used to select a "column" of the selected "row." The "row" output may be held in a buffer and the "column" access then applied to the contents of the buffer.

In a two-and-a-half dimensional organization, the bits of each word are spread across several chips — one bit per chip in the most extreme case. Each chip is then equipped with two decoders, each of which decodes part of a split address in order to carry out a selection on the chip.

two-lamp synchronizing the process to connect two three-phase power systems in parallel using the same procedure as for three-lamp synchronizing except that lamps are placed across only two phases of the switch. *See also* three-lamp synchronizing.

two-pass assembler an assembler program that makes two passes through the source code to produce its output. The first pass determines all the referenced addresses and the second pass produces the assembled code. A two-pass assembler can produce directly loadable object code because all the label values are determined in the first pass.

two-phase clock having two separate clock signals, one high while the other is low, and vice-versa.

two-photon absorption a nonlinear optical process in which two photons are removed simultaneously from a laser beam as an atom makes a transition from its ground to its excited state. The rate at which such events occur is proportional to the square of the intensity of the laser beam.

two-port a network with four accessible terminals grouped in pairs, for example, input pair, output pair.

two-port memory a memory system that has two access paths; one path is usually used by the CPU and the other by I/O devices. This is also called dual port memory.

two-quadrant a drive that can operate as a motor as well as a generator in one direction.

two-quadrant operation operation of a motor with a controller that can provide power to run the motor and absorb power from the motor during deceleration (regenerative braking). Two quadrant operation provides improved efficiency if the motor is started and stopped frequently.

two-scale relation in general, a linear combination of the scaling functions of a wavelet. It shows clearly how the function behaves at different resolutions. A general two-scale relation could be expressed as

$$\psi\left(\frac{t}{2}\right) = \sum_{k=-\infty}^{+\infty} h_k \psi(t-k)$$

where ψ is the scaling function and the h are the coefficients that define the wavelet.

two-terminal a network with two accessible terminals.

two-wave mixing a nonlinear optical process in which two beams of coherent light interact inside nonlinear media or photorefractive crystals. When two beams of coherent electromagnetic radiation intersect inside a nonlinear medium of a photorefractive crystal, the periodic variation of the intensity due to interference will induce a volume refractive index grating. The presence of such a refractive index grating will then affect the propagation of these two beams. This may lead to energy coupling. The coupling of the two beams in nonlinear media is referred to as two-wave mixing.

two-way channel two terminal channel in which both terminals simultaneously transmit and receive using the same channel, thus disturbing each other's transmissions.

two-way interleaved in memory technology, a technique that provides faster access to memory values by interleaving memory values in two separate modules.

TWTA traveling-wave tube amplifier. *See* traveling wave amplifier.

type-N connector named after P. Neill of Bell labs, this coaxial connector has both a male and female version. The outer diameter of the female connector is approximately 5/8 inch with an upper frequency range of about 18 GHz.

typical sequence for a given probability mass function $p(x)$, a particular sequence of length n chosen i.i.d. according to $p(x)$ is typical if its empirical distribution is deemed close to the true distribution. This notion is also generalized to include the comparison of functions of the true and empirical distributions. For example, entropy–typical sequences are used in proving coding theorems in information theory.

U

UART *See* universal asynchronous receiver/transmitter.

ubitron a millimeter wave high-power quasiquantum generator with relativistically high-speed electron beam. Millimeter waves are generated due to quantum transition between two energy states of electrons and amplified due to the velocity modulation and kinetic energy transfer principles.

UCA *See* uniform circular array.

UDT *See* unidirectional transducer.

UEESLA *See* uniformly excited equally spaced linear array.

UEP code *See* unequal error protection code.

Ufer ground a term, named for engineer Herb Ufer, used to describe concrete-encased earth electrodes (e.g., rebars in a building's foundation footers).

UHF *See* ultra-high frequency.

UHF power in television, the band of frequencies ranging from 300MHz to 3 GHz.

UL *See* Underwriters Laboratory.

ULA *See* uniform linear array.

UL classes a classification system established by Underwriters Laboratory (UL) for the purpose of defining certain operating characteristics of low voltage fuses. UL classes include G, J, L, CC, T, K, R, and H.

ULSI *See* ultra-large-scale integration.

ultimate boundedness the property of the solutions of a system equation, guaranteeing that for "small" perturbations in the equation, the solution will eventually be "small" in time.

A solution $x : [t_0, \infty] \rightarrow R^n; x(t_0) = x_0$ is said to be uniformly ultimately bounded with respect to a given set S if there exists a nonnegative constant time $T(x_0, S), \infty$ independent of t_0 such that $x(t) \in S$ for all $t \geq t_0 + T(x_0, S)$. In other words, ultimate uniform boundedness guarantees that the state of the system enters and remains in the given neighborhood of the origin after a finite time interval.

ultra-high frequency (UHF) electromagnetic spectrum with frequencies between 300 MHz and 3000 MHz or wavelengths between 10 cm and 100 cm. Also called as decimetric waves.

ultra-large-scale integration (ULSI) an integrated circuit made of millions of transistors.

ultrasonic memory obsolete form of memory, in which data was stored as ultrasonic sound recirculating through a column of mercury. Also called mercury delay-line memory.

ultrasound an imaging modality that uses reflected high-frequency sound energy to image the interface between materials with different acoustic impedances.

ultraviolet a term referring to wavelengths shorter than 400 nm, but longer than 30 nm. The region 400–300 nm is the near ultraviolet, 300–200 is the middle ultraviolet; and 200–30 nm is the far ultraviolet or vacuum.

ultraviolet laser laser producing its output in the ultraviolet region of the spectrum.

umbra transform a morpohological transform used for visualization of operations

on gray-level images. Let the gray-level image F be a function $E \to T$, where E is the set of points and T the set of gray-levels. The umbra of F is the set

$$U(F) = \{(h, v) \in E \times T \mid v \leq F(h) \text{ and } v \neq \pm\infty\}.$$

The behavior of a morphological operator on gray-level functions can be visualized by applying the corresponding operator for sets to the umbras of the gray-level functions. *See* morphological operator.

umbrella cell a cell that covers the same geographical area as a number of micro- or picocells, and is aimed at supplying seamless service to subscribers with high mobility in these areas.

unary operation an operation a computer performs that involves only one data element. The complement and increment operations are examples of such an operation while ADD is an example of an operation that requires two data elements.

unbalanced line refers to a signal carrying line where one of the conductors is connected to ground. *Contrast with* balanced line.

unbalanced magnetic pull a phenomenon in electric machines arising from the rotor not being symmetrical with respect to the stator or the axis of the rotor and stator not being coincident. Results in a higher pulling force on the side with the smaller airgap, resulting in additional bearing stresses.

unbalanced operation in an n-phase system ($n > 1$), a condition in which the phase voltages (currents) are either

1. not equal-amplitude sinusoids or

2. have phase angles displaced by a value other than that specified for balanced operation.

The term "unbalanced" is also used to describe a machine that has unsymmetrical phase windings. *See also* balanced operation.

unbiased estimate an estimate $\hat{\boldsymbol{x}}$ of $\boldsymbol{x}$ which is not subject to any systematic bias; that is,

$$E\left[\hat{\boldsymbol{x}} - \boldsymbol{x} = 0\right].$$

See also expectation, bias.

unbundling a feature of utility deregulation in which services which were formerly bundled together are sold separately to the customer.

uncertain dynamical system model a mathematical model of a dynamical system that includes the system's uncertainties or disturbances. A possible tool to model an uncertain system is to use a *differential inclusion*,

$$\dot{\mathbf{x}} \in \mathbf{F}(t, \mathbf{x}) .$$

Another example of an uncertain dynamical system model is

$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u} + \mathbf{h}(t, \mathbf{x}, \mathbf{u}) ,$$

where the vector function $\mathbf{h}$ models the system's uncertainties. *See also* matching condition and unmatched uncertainty.

unconditional branch an instruction that causes a transfer of control to another address without regard to the state of any condition flags.

uncontrolled rectifier a rectifier circuit employing switches that do not require control signals to operate them in their "on" or "off" states.

underexcited a condition of operating a synchronous machine, in which the current to the DC field winding is insufficient to establish the required magnetic flux in the airgap. As a result, the machine requires reactive power from the AC system. An underexcited synchronous motor operates at a lagging power factor, as it appears as an inductive load to the AC system. An underexcited synchronous generator operates with

a leading power factor, since it must deliver power to a leading (capacitive) system.

underflow a condition in a floating-point system where the result of an operation is nonzero yet too small in absolute value to be properly represented in the system.

underfrequency relay a protection device that curtails loads in an area that is deficient in generation. Lower generation compared to load demands give rise to lower frequency and a frequency threshold can be used by the relay to initiate load shedding in order to balance generation and demand.

underground distribution a class of electric power distribution work, typically used in densely-populated urban business districts, in which conductors are carried in conduits under streets between manholes and submersible distribution transformers are mounted in underground vaults.

underground residential distribution practices involved in the underground distribution of electric power to residential subdivisions through direct-buried cables and pad mound transformers.

underlay in a wireless communication system this refers to a system where a transmitter which covers a small area (small cell) transmits a signal that occupies the same spectrum as the main system. Such an underlay cell may block out coverage of the main system service in the small cell.

undervoltage a voltage that is less than nominal for a time greater than 1 minute.

undervoltage relay a protective relay that operates on low voltage or loss of voltage.

Underwriters Laboratory an insurance industry testing agency that establishes standards for and conducts testing of electrical equipment.

undetected error probability in a linear block code, the probability that a receiver will not be able to detect the presence of transmission errors in received codewords. The transmission of codewords from a linear block code, C, via a communication channel can be expressed as follows:

$$\overline{x} = \overline{y} + \overline{e}$$

with $\overline{y}$ codewords from the code C and $\overline{x}$ words received via the channel. $\overline{e}$ denotes error words generated by the channel during transmission of the codewords. The receiver will only detect the presence of errors if $\overline{x} \notin C$, i.e., if the received words are not codewords from the code C. Undetected errors occur only if $\overline{e} \in C$, in which case the linearity property of the codes causes $\overline{x} \in C$ although $\overline{x} \neq \overline{y}$. The undetected error probability is, therefore, strongly related to the nature of errors in the communication channel as well as the particular block code used. *See also* block code.

unequal error protection (UEP) code a code in which certain digits of a codeword are protected against a greater number of errors than other digits in the codeword.

unfolding the technique of transforming a program that describes one iteration of an algorithm to another equivalent program that describes iterations of the same algorithm.

unforced system a dynamic system where all of the external sources of excitation are identically zero.

ungrounded system an electrical distribution system in which there is no intentional connection between a current-carrying conductor and ground.

uniaxial medium a medium whose permittivity and/or permeability is characterized by a 3×3 diagonal matrix where two of the three elements are the same.

Unibus bus standard used by Digital Equipment Corporation for its PDP and VAX computers.

unidirectional bus a group of signals that carries information in one direction. Example: The address bus of the microprocessor is unidirectional; it carries address information in one direction — from the microprocessor to memory or peripheral.

unidirectional laser ring laser in which either the clockwise or counter-clockwise circulating wave is negligible.

unidirectional resonator ring resonator in which the electromagnetic waves circulate in either the clockwise or counter-clockwise direction but not both.

unidirectional transducer (UDT) a transducer capable of launching energy from primarily one acoustic port over a desired bandwidth of interest.

unified cache a cache that can hold both instructions and data. *See also* cache.

unified power flow controller a device for both series and shunt reactive compensation, brought about by thyristor-based control.

unified transaction a transaction, which can be a hardware instruction or a program segment, that performs a read-modify-write operation, that is allowed to complete without interruption by other processes.

uniform array an array where the antenna elements that make up the array are uniformly spaced. Typical examples of this are the linear array and circular array.

uniform boundedness a property of dynamical systems possessing solutions of state equations uniformly bounded.

The solutions of $\dot{\mathbf{x}} = \mathbf{f}(t, \mathbf{x})$ are uniformly bounded if for any given $d > 0$, there exists a $b = b(d) < \infty$ so that for each solution $\mathbf{x}(t)$ starting from the initial condition $\mathbf{x}(t_0)$ such that $\|\mathbf{x}(t_0)\| \leq d$,

$$\|\mathbf{x}(t)\| \leq b \quad \text{for all} \quad t \geq 0$$

where $\|\cdot\|$ is any Hölder norm on $\mathbb{R}^n$.

uniform chromaticity scale a chart, which allows for the quick calculation of the X, Y, and Z tristimulus values of the CIE colorimetry system.

uniform circular array (UCA) in array processing, an array with evenly spaced sensors placed on the perimeter of a circle.

uniform controllability a dynamical where it is controllable in any time interval $[t_0, t_1]$.

uniform distribution a probability distribution in which all events are equiprobable, i.e., $p(x) = k$ subject to $\int_{-\infty}^{\infty} p(s)ds = 1$.

uniform length coding a coding scheme that assigns the same number of bits to different messages no matter what probabilities the messages assume.

uniform linear array (ULA) in array processing, an array with evenly spaced sensors placed on a straight line.

uniform memory access refers to a class of shared memory multiprocessor systems in which accesses to all parts of the shared memory take the same time independently of which processor makes the access.

uniform plane wave a special class of electromagnetic problems where the E and H field are locally contained in a plane, and in each local plane, the E and H fields have a constant value over all that plane.

uniform sampling the sampling of a continuous signal at a constant sampling frequency.

uniform scalar quantization a structured scalar quantizer where the distance between reproduction levels is a given fixed number. Also known as uniform SQ.

uniform SQ *See* uniform scalar quantization.

uniform stability the constant equilibrium solution $\mathbf{x}_{eq} \in \mathbb{R}^n$ of $\dot{\mathbf{x}} = \mathbf{f}(t, \mathbf{x})$ or $\mathbf{x}(k+1) = \mathbf{f}(k, \mathbf{x})$ is uniformly stable, in the sense of Lyapunov, if for any $\varepsilon > 0$, $t_0 \geq 0$, there corresponds $\delta = \delta(\varepsilon)$ independent of t_0 such that

$$\left\| \mathbf{x}(t) - \mathbf{x}_{eq} \right\| < \varepsilon$$

for $t \geq t_0$ whenever

$$\left\| \mathbf{x}(t_0) - \mathbf{x}_{eq} \right\| < \delta \ ,$$

where $\| \cdot \|$ is any Hölder norm on $\mathbb{R}^n$.

uniform ultimate boundedness the solutions of $\dot{\mathbf{x}} = \mathbf{f}(t, \mathbf{x})$, $\mathbf{x} \in \mathbb{R}^n$, are uniformly ultimately bounded, or practically stable, with respect to the ball

$$B_r = \{\mathbf{x} : \|\mathbf{x}\| \leq r\} \ ,$$

if for every $d > 0$, there exists $T(d) > 0$ such that for each solution $\mathbf{x}(t)$ starting from the initial condition $\mathbf{x}(t_0)$ such that $\|\mathbf{x}(t_0)\| \leq d$,

$$\mathbf{x}(t) \in B_r \ \text{ for } \ t \geq T(d) \ ,$$

where $\| \cdot \|$ is any Hölder norm on $\mathbb{R}^n$. *See also* uniform boundedness.

uniform variate pseudo-random variate generated by computer that is equally likely to be any place within a fixed interval, usually [0, 1].

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

uniformly convergent state the equilibrium state of a dynamic system described by a first-order vector differential equation where there exists a δ, independent of the t_0, such that

$$\| x(t_0) - x_e \| < \delta \Rightarrow \lim_{t \to \infty} x(t) = x_e$$

See also convergent state.

uniformly excited equally spaced linear array (UEESLA) an antenna array in which all the centers of the antennas are collinear and equally spaced and each antenna has a constant harmonic value but each antenna can have a unique phasing.

uniformly stable equilibrium an equilibrium point of a nonautonomous system where the solutions that start "sufficiently close," stay "close" in time irrespective of the choice of initial time.

uniformly stable state the equilibrium state of a dynamic system described by a first-order vector differential equation where if given $\epsilon > 0$ there exists a $\delta = \delta(\epsilon)$, independent of the initial t_0, such that

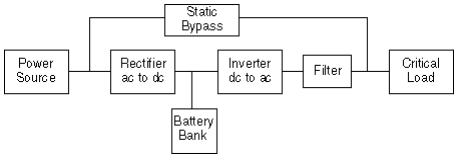
$$\| x(t_0) - x_e \| < \delta \Rightarrow \| x(t) - x_e \| < \epsilon$$
$$\forall t \geq t_0$$

See also stable state.

unilateral gain special case of the transducer power gain of a 2-port network. The transducer power gain is the ratio of the power delivered to the load to the power available from the source. The unilateral gain is the nonreciprocal case of transducer power gain ($S_{12} = 0$).

unilateral transducer power gain a special case of transducer power gain, G_{Tu}, where $S_{12} = 0$.

unimplemented instruction (1) a numeric pattern in an instruction stream that does not correspond to any defined machine instruction.



A typical UPS.

2) a type of trap operation executed by a processor when an unimplemented instruction is encountered.

uninterrupted power supply (UPS) (1) a power supply designed to charge an energy storage medium, while providing conditioned output power, during the presence of input power and to continue providing output power for a limited time when the input to the supply is removed. These power supplies are typically used in critical applications to prevent shut-down of these systems during power failures, power surges, or brownouts.

(2) a device that provides protection for critical loads against power outages, overvoltages, undervoltages, transients, and harmonic disturbances. A typical UPS is a rectifier supplied battery bank for energy storage, and a PWM inverter-filter system to convert a DC voltage to a sinusoidal AC output. UPS systems can be on-line, as shown in the figure, where the UPS inverter powers the load continuously, or off-line where the load is connected directly to the utility under normal operation and emergency power is provided by the UPS.

union *See* union operator.

union of fuzzy sets the fuzzy analogy to set the set-theoretic union.

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 union $A \cup B$, for all $x \in X$, is

$$\mu_{A\cup B}(x) = \max\{\mu_A(x), \mu_B(x)\}$$

See also fuzzy set, membership function.

union operator a logical OR operator.

In a crisp (nonfuzzy) system, the union of two sets contains elements which belongs to either one or both of the sets. In fuzzy logic, the union of two fuzzy sets is the fuzzy set with a membership function which is the larger of the two. *See also* union of fuzzy sets.

unipolar neuron neuron with output signal between 0 and +1.

uniprocessor *See* single-instruction stream, single data stream.

uniquely decodeable a channel code where the correct message sequence can always be recovered uniquely from the coded sequence as observed through the channel. Of particular interest for multiple access channels. *See also* multiple access channel, zero-error capacity.

uniqueness of solution to generalized 2-D model the generalized 2-D model with variable coefficients

$$\begin{aligned} E_{i+1,j+1}x_{i+1,j+1} &= A^0_{ij}x_{ij} + A^1_{i+1,j}x_{i+1,j} \\ &+ A^2_{i,j+1}x_{i,j+1} + B^0_{ij}u_{ij} \\ &+ B^1_{i+1,j}u_{i+1,j} + B^2_{i,j+1}u_{i,j+1} \end{aligned}$$

$i, j \in Z_+$ (the set of nonnegative integers) has the unique solution in the rectangle $[0, N_1] \times [0, N_2]$ for any sequence u_{ij} for $0 \le i \le N_1, 0 \le j \le N_2$ and any boundary conditions x_{i0} for $0 \le i \le N_1$ and x_{0j} for $0 \le j \le N_2$ if and only if the matrix F' is nonsingular, where $x_{ij} \in R^n$ is the local semistate vector, $u_{ij} \in R^m$ is the input vector E_{ij}, A^k_{ij}, B^k_{ij} $(k = 0, 1, 2)$ are real matrices with E_{ij} possibly singular (rectangular), $F^{'}$ is defined by the equation $F^{'}x^{'} = Gu + Hx_0$ which follows from the model for $i = 0, 1, \ldots, N_1 - 1$;

$$\begin{aligned} j &= 0, 1, \ldots, N_2 - 1, \\ x^{'} &:= \left[x^T_1, x^{'T}_2, \ldots, x^{'T}_{N_1}\right]^T , \\ x^{'}_i &:= \left[x^T_{i1}, x^T_{i2}, \ldots, x^{'T}_{iN_2}\right] , \end{aligned}$$

$$u = \left[u_0^T, u_1^T, \ldots, u_{N_1}^T\right]^T ,$$
$$u_i := \left[u_{i0}^T, u_{i1}^T, \ldots, u_{iN_2}^T\right]^T ,$$
$$x_0 := \left[x_{00}^T, x_{01}^T, \ldots, x_{0N_2}^T, x_{10}^T, x_{20}^T, \ldots, x_{N_10}^T\right]^T$$

uniqueness theorem of electromagnetics a theorem stating that the solutions to Maxwell's equations are unique, given certain boundary conditions (for the differential form of the equations) or certain initial conditions (for the integral form of the equations). As an example, if the electric field and magnetic field satisfy Maxwell's equations in some volume V of lossy material and if the tangential fields satisfy a prescribed set of boundary conditions on the surface S that defines V, then the solution for the electric and magnetic fields is the only one (i.e., the unique one). *Note:* The uniqueness theorem only requires one of the following three conditions:

1. knowledge of the tangential electric field on all of S,

2. knowledge of the tangential magnetic field on all of S, or

3. knowledge of the tangential electric field on part of S and the tangential magnetic field on the remaining part of S.

unit commitment problem the task of minimizing the cost of production by deciding which of several thermal generating plants in a power system should be kept generating, on hot reserve or on cold reserve.

unit delay in discrete time systems the delay of a signal by a single sample interval, i.e., $x(n-1)$. Under the z-transform, $z^{-1}X(z)$.

unit impulse function a very short pulse such that its value is zero for $t \neq 0$ and the "force" of the pulse is 1.

In discrete time: $\delta(n) = 1$ for $n = 0$, $\delta(n) = 0$ for $n \neq 0$. *See also* Kronecker delta function. In continuous time: $\delta(t) = 0$ for $t \neq 0$ and $\int_\epsilon^\epsilon \delta(s)ds = 1$ for $\epsilon > 0$. *See also* Dirac's delta function.

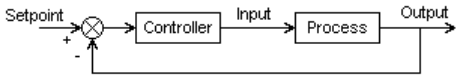
unit step *See* unit step function.

unit step function a mathematical function whose amplitude is zero for all values of time prior to a certain instant and unity for all values of time afterwards. The unit step signal is the integral of the unit impulse function. That is, the function $u(t)$ which is 1 for all $t \geq t_0$ and 0 for all $t < t_0$.

unitarity in scattering law expressing the conservation of energy from the incident light to that scattered and absorbed by an inhomogeneous medium.

unitary transform a transform whose inverse is equal to the complex conjugate of its transpose.

unity feedback the automatic control loop configuration shown in the figure.



Unity feedback configuration.

universal asynchronous receiver/transmitter (UART) a standard interface often used in small computer systems, to buffer and translate between the parallel word format used by the CPU and the aynchronous serial format used by slow I/O devices.

universal coding coding procedure that does not require knowledge of the source statistics and yet is asymptotically optimal. A typical example is Ziv–Lempel coding.

universal function approximation property uniform approximation of any real continuous nonlinear function to arbitrary level of accuracy in a compact set. It has been demonstrated that some relevant model of

soft-computing (such as multilayer perceptrons, radial basis functions networks, and fuzzy systems) hold this property.

See also fuzzy system, multilayer perceptron, radial basis function network.

universal fuzzy approximator a fuzzy system approximator in a sense that it can approximate any nonlinear function to any degree of accuracy on any compact set.

universal fuzzy controller a fuzzy controller in a sense that it can control any nonlinear plant as long as the plant can be controlled by a smooth nonlinear control law.

universal source coding refers to methods for source coding that do not rely on explicit knowledge of the source statistics. One important method for universal lossless source coding is Ziv–Lempel coding.

universal synchronous/asynchronous receiver/transmitter (USART) a logic device that performs the data link layer functions, such as serializing, deserializing, parity generation and checking, error checking, and bit stuffing, of a serial transmission protocol for either synchronous or asynchronous transfer modes.

universe of discourse term associated with a particular variable or groups of variables, it is the total problem space encompassing the smallest to the largest allowable nonfuzzy value that each variable can take.

unloaded Q dimensionless ratio of the average over any period of time (T = 1/frequency) of the ratio of the maximum energy stored (Umax) to the power absorbed or dissipated in a passive component or circuit, discounting any external effects. An ideal resistor has an unloaded Q of zero, and ideal capacitors or inductors have an uloaded Q of infinity. For most applications, the higher the unloaded Q the better the part.

unmatched uncertainty a dynamical system model in which the vector function that models uncertainties in the system does not satisfy the *matching condition* as, for example, in the system model

$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u} + \mathbf{h}(t, \mathbf{x}, \mathbf{u}) \ ,$$

where the function **h** may model system uncertainties such as modeling uncertainties, input connection uncertainties, or additive disturbances.

unmodeled dynamics in control systems design, it is often assumed that the true process is compatible with the model used in parameter estimation. However, it frequently happens that the true process is more complex than the estimated model. This is often referred to as unmodeled dynamics. The problem is complex, and a careful analysis is lengthy. If a controller is able to control processes with unmodeled dynamics and/or disturbances, we say that the controller is robust.

unpolarized if the amplitude of the wave in plane perpendicular to the direction of propagation appears to be oriented in all directions with equal probability, the wave is said to be unpolarized. Unpolarized electromagnetic waves are generated by atomic processes.

unprivileged mode one of two CPU modes, the other being privileged mode. Sometimes called user mode, this mode prohibits access to certain instructions, data, and registers.

unsharp masking an edge enhancement technique that subtracts a blurred version of an image from the input image. *See also* edge enhancement.

unsigned integer an integer numeric representation in which only positive numbers are represented. For example, a 16-bit unsigned integer has a range of 0 to 65535.

unstable (1) a circuit or circuit element that is likely to change state spontaneously within a short period of time.

(2) a system that is not stable.

unstable resonator resonator in which an axial light ray is unstable with respect to perturbations, and ray trajectories become unbounded; does not imply unstable modes (unstable resonators have stable modes); high-loss resonator.

unstable state the equilibrium state of a dynamic system described by a first-order vector differential equation is said to be unstable if it is not stable. *See also* stable state.

unstructured uncertainty high-order variations or unknown disturbances characterized usually by a set of norm-bounded perturbations introduced into a fixed nominal plant.

For linear systems with a model in frequency domain, an uncertain system is represented by a class of plants composed of a nominal known rational matrix and unknown but stable one whose norm is bounded by an absolute value of known rational function.

unsupervised learning (1) learning from unlabeled data. The learning system seeks to identify structure in the data by clustering similar input patterns.

(2) a training technique in statistical pattern recognition or artificial neural networks in which the training set does not include a predefined desired output.

unsupervised neural network neural network that does require predetermined output to form the interconnection weight matrix of a network. If no input–output pairs are known and a number of inputs are available, we can only memorize them in an organized order. Similar inputs are memorized in locations close to each other and different inputs are stored in locations far from each other. The network is able to recognize an input that has already appeared before. If the input has never appeared, it will be stored in an appropriate location, which is close to similar inputs and far from different inputs. An example of unsupervised neural network is the Kohonen self-organizing map, which can be implemented using an adaptive correlator. A correlator has been long used in optical processing for measuring the similarity between two inputs.

unsymmetrical fault a fault on a three-phase power line in which the fault current is not equal in all three phases, e.g., a single-line-to-ground, double-line-to-ground or line-to-line fault.

unsymmetrical load a load which forces the currents in the three-phase power line which supplies it to be unequal.

up-down converter *See* buck-boost transformer.

up-down counter a register that is capable of operating like a counter and can be either incremented or decremented by applying the proper electronic signals.

up-down transformer *See* buck-boost transformer.

upconversion a nonlinear optical process in which a beam of light is shifted to higher frequency, for instance, through the process of sum-frequency generation.

upconverter special type of microwave mixer that outputs the sum frequency signals of the input microwave RF frequency and the LO frequency. The up-conversion is useful if the microwave carrier frequency needs to be altered.

uplink in a cellular system, the communication link from the mobile to the central base station. *See also* downlink. Also called reverse link.

upper frequency band edge the upper cutoff frequency where the amplitude is equal to the maximum attenuation loss across the band.

upper side frequency the sum frequency that is 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 upper side frequency is 501 kHz.

UPS *See* uninterrupted power supply.

upsampling a system that inserts $L-1$ zeros between the samples of an input signal to form an output signal. An L-fold upsampler followed by an appropriate lowpass filter produces an output signal that is an interpolated form of the input signal, at L times the sampling rate. Upsampling also often refers to the operation of the upsampler and the lowpass filter together.

URD *See* underground residential distribution.

USART *See* universal synchronous/asynchronous receiver/transmitter.

use bit in a paging system, a bit associated with a page entry in a lookup table which indicates that the page has been referenced since the last time the bit was reset. The bit is reset when it is read.

user mode in a multitasking processor, the mode in which user programs are executed. In user mode, the program is prevented from executing instructions that could possibly disrupt the system and also from accessing data outside the user's specified area.

user state a computer mode in which a user program is executing rather than a systems program.

Some computers have two modes of operation: the system state is used when parts of the computer's operating system are executing and the user state is used when the computer is executing application programs.

user-visible register an alternative name for general purpose registers, emphasizing the fact that these registers are accessible to the instructions in user programs. The counterpart to user-visible registers are registers that are reserved for use by privileged instructions, particularly within the operating system.

utility interface the interface of the utility with power electronic systems. Utility interface issues include maintaining power quality with the proliferation of large power electronic loads in power system networks and the utility applications of power electronics for flexible AC transmission systems (FACTS).

UV cure a post-development process by which the resist patterns are exposed to deep-UV radiation (and often baked at the same time) in order to harden the resist patterns for subsequent pattern transfer. The UV cure is a replacement for the hard bake step.

utilization factor the ratio of the maximum demand on the system vs the rated capacity of the system.

utilization voltage the voltage across the power input terminals of a piece of electrical equipment.

UVPROM *See* erasable programmable read-only memory.

V

V parameter describes the number of modes M in an optical fiber.

$$V = 2\ pi \frac{a}{\lambda_o} NA$$

where a is the fiber core radius, λ is the wavelength, and NA is the fiber's numerical aperture. $V < 2.405$ for single-mode operation. Often referred to as normalized frequency.

V system *See* vee system.

$V_{IN_{p-p}}$ common notation for peak-to-peak input voltage in volts.

$V_{OUT_{p-p}}$ common notation for the peak-to-peak output voltage in volts.

V_{DS} common notation for the FET drain-to-source voltage.

V_{GD} common notation for the FET gate-to-drain voltage.

V_{GS} common notation for the FET gate-to-source voltage.

V-curves the characteristic curves that show the variation of the armature current versus the field current in synchronous motors.

V-V transformer *See* open-delta transformer.

vacuum capacitor a capacitor with a vacuum between its plates.

vacuum circuit breaker a power circuit breaker where a vacuum chamber is used as an insulating and arc clearing medium.

vacuum insulation any insulation scheme which depends upon the dielectric capabilities of a high vacuum.

vagueness a property indicating the lack of specifics and clarity and which is allied to imprecision and fuzziness.

valence band the lower of the two partially filled bands in a semiconductor. *See also* conduction band.

valid bit a bit used in caches and virtual memories that records whether the cached item or page contains valid data.

validation (1) in electronic active and passive device modeling, the pass/fail process in which a completed, ready to use model is used in a simulation, then compared to an intended application, and is determined to suitably predict reality.

(2) a review to establish the quality of a software product for its operational purpose.

validation set the set of data to evaluate the performance of a system that was trained on a separate set of data.

valuation in electronic active and passive device modeling, valuation is a measure of the intrinsic value of a model in predicting a new application, condition or change in the device. The most valuable model (assigned a valuation coefficient of 1.0) would be a complete omnipotent physical based model that could be utilized to predict exact circuit response. The least valuable model (assigned a valuation coefficient of 0.0) such as a lookup table, would only be able to predict a circuit response to a specific set of conditions for a very specific device excited in a specific way.

van de Graf generator a high-voltage device that generates high static voltages on a sphere. It is driven by a mechanical belt, which delivers the charges.

van der Pol oscillator an oscillator or oscillating system described by the equation

$$\frac{d^2x}{dt^2} - \mu\left(1 - \epsilon x^2\right)\frac{dx}{dt} + x = 0$$

This equation is mentioned in almost any book on oscillators or on nonlinear mechanics. The reason is that this equation is relatively simple, yet it successfully lumps together two rather complex processes associated with oscillators, namely, the process of generation of periodic waveform and the process of automatically stabilizing the amplitude of this wave. The attempts to improve the solutions of the van der Pol equation and to apply to design of low-distortion oscillators can be traced to recent publications.

Vander Lugt filter encoded optical mask for representing, in the Fourier-transform domain, the reference or library functions needed in an image correlator; encoding is performed holographically.

vanishing point the point in the perspective projection plane in which a system of 3-D parallel lines converge.

Vapnik–Chervonenk (VC) dimension a measure of the expressive power of a learning system with binary or bipolar outputs. For neural networks it is closely related to the number of weights in the network. For single-layer networks it is simply equal to the number of weights (including biases) but for multilayer and other networks, analytic expressions for VC dimension are not available.

vapor cooling a cooling technique for power vacuum tubes utilizing the conversion of hot water to steam as a means of safely conducting heat from the device and to a heat sink.

VAR *See* volt-ampere-reactive.

varactor a reverse biased PN or Schottky diode that uses the voltage variable depletion region as a tuning element or as a nonlinear frequency multiplier.

varactor diode a diode designed to have a repeatable and high capacitance vs. reverse voltage characteristic. A two terminal semiconductor device in which the electrical characteristic of primary interest is the voltage dependent capacitance.

varactor tuner a tuning circuit at the input of a television receiver that uses a varactor diode. The tuning capability comes from the characteristic of a varactor, or varicap, to function as a voltage-sensitive capacitance.

variable bit rate (VBR) describes a traffic pattern in which the rate at which bits are transmitted varies over time; such patterns are also referred to as bursty. VBR sources often result from compressing CBR sources, for example, a 64 kbps voice source in its raw form has a constant bit rate; after compression by removing the silence intervals, the source becomes VBR.

variable frequency drive electric drive system in which the speed of the motor can be varied by varying the frequency of the input power.

variable length code to exploit redundancy in statistical data, and to reduce average number of bits per word luminance levels having high probability are assigned short code words and those having low probability are assigned longer code words. This is called variable length coding or entropy coding. *See also* entropy coding.

variable loss machine loss that changes with a change in the mode of machine operation such as loading, temperature and current. For example, in a transformer, the winding losses are a function of the load current, while the core losses are almost independent of the load current.

variable polarity plasma arc welding (VPPAW) a welding process that produces coalescence of metals by heating them with a constricted variable polarity arc between an electrode and the parts to be joined (transferred arc) or between the electrode and the constricting nozzle (transferred arc). Shielding is obtained from the hot, ionized gas issuing from the torch as well as from a normally employed auxiliary shielding gas source. Pressure is not applied and filler metal may or may not be added.

variable reflectivity mirror mirror in which the reflection profile varies across the mirror surface; useful for discriminating against high-order transverse modes in a resonator. *See also* tapered mirror.

variable reluctance machine salient pole machine consisting of stators having concentrated excitation windings and a magnetic rotor devoid of any windings, commutators, or brushes. The machine operates on the principle of varying reluctance along the length of the air gap. Torque is produced by the tendency of the rotor to align itself with the stator produced flux waves in such a way that the stator produced flux-linkages are maximized. The motor operates continuously in either direction of rotation with closed loop position feedback.

variable resolution hierarchy an approach where images corresponding to the levels of the hierarchy vary in spatial resolution. This results in a pyramid structure where the base of the pyramid represents the full resolution and the upper levels have lower resolution.

variable speed AC drive an AC motor drive that is capable of delivering variable frequency AC power to a motor to cause it to operate at variable speeds. Induction motors and synchronous motors are limited to operation at or near synchronous speed when a particular frequency is applied. Variable speed drives rectify the incoming AC source voltage to create a DC voltage that is then inverted to the desired frequency and number of phases.

variable speed DC drive a DC motor controller that allows the DC motor to operate over a wide speed range. A common type of variable speed DC drive uses a separately excited DC motor. Armature voltage control is used to provide operation below base speed, and field weakening is used to provide operation above base speed.

variable speed drive *See* variable speed AC drive or variable speed DC drive.

variable structure system a dynamical system whose structure changes in accordance with the current value of its state. A variable structure system can be viewed as a system composed of independent structures together with a switching logic to switch between each of the structures. With appropriate switching logic, a variable structure system can exploit the desirable properties of each of the structures the system is composed of. A variable structure system may even have a property, such as asymptotic stability, that is not a property of any of its structures.

variable-length instruction the fact that the machine language instructions for a computer have different numbers of bits with the length dependent on the type of instruction.

variance the mean-squared variability of a random variable about its mean:

$$\sigma^2 = \int_{-\infty}^{\infty} (x - \mu)^2 p(x) dx$$

where σ^2 is the variance, μ is the mean and $p(x)$ is the probability density function. *See also* covariance, correlation.

variational formula a formula that provides the sought unknown quantity a in terms of another unknown quantity b. The advantage is in the fact that, for variational formulas, an error in b provide only a modest error

in a. Hence, by approximating b we can get a fairly good estimate of a.

variational problem a problem in which solving a differential equation is equivalent to seeking a function that minimizes an integral expression.

variational similarity between two vectors $x = (x_1, \ldots, x_n)$ and $y = (y_1, \ldots, y_m)$ is the match score in the following dynamic matching procedure:

Suppose the current point is (x_i, y_j). The next point to match should be selected from (x_{i+1}, y_j), (x_{i+1}, y_{j+1}), and (x_{i+1}, y_{j+2}). If there is one match only among them, take it as the current match point and go on in the same manner. If there is no match, select (x_{i+1}, y_{j+1}). If there is more than one match including (x_{i+1}, y_{j+1}), select (x_{i+1}, y_{j+1}), otherwise, select (x_{i+1}, y_{j+2}). This process continues until at least one of the vectors is exhausted.

During the above procedure, if there is at least one match in one step increase the match score by 1.

Varsharmov–Gilbert bound the lower bound on the minimum distance of linear (n, k) code asymptotically satisfies

$$\frac{d_{\min}}{n} \geq \alpha$$

where α is given by

$$\frac{k}{n} = 1+\alpha \log_2 \alpha+(1-\alpha) \log_2 \alpha \quad 0 \leq \alpha \leq \frac{1}{2}$$

vault *See* transformer vault

VBR *See* variable bit rate.

VC dimension *See* Vapnik–Chervonenk dimension.

VCO *See* voltage-controlled oscillator.

VCO gain the ratio of the VCO output frequency to the DC control input level. This is usually expressed in units of radians per second per volt.

VCP *See* visual comfort probability.

VDS *See* drain-to-source voltage.

VDSL *See* very high-speed digital subscriber line.

vector a quantity having both magnitude and direction.

vector controlled induction motor a variable speed controller and motor in which the magnetizing and torque producing components of current are controlled separately. Some vector drives requires rotor position sensors. Vector controlled induction motors can operate over a wider speed range, and may produce rated torque even at zero speed, much like a DC motor. Thus, vector controlled induction motors are often used for applications that might otherwise require a DC motor drive.

vector field when the field needed to describe some physical phenomenon has several components, it is customary to represent such a field by a vector function $\mathbf{V}(x, y, z)$ which depends on the space coordinates x, y, z.

vector image an image consisting of mathematical descriptions of the objects in the scene, e.g., equations for lines and curves. The image is independent of resolution so it can be stretched, rotated and skewed with no degradation. Vector images are often used in CAD applications. *See also* bitmapped image, CAD, image.

vector network analyzer a microwave receiver designed to measure and process the magnitude and phase of transmitted and reflected waves from the linear network under test.

vector operation a hardware instruction that performs multiple similar operations on data arranged in one or more arrays.

vector processor a computer architecture with specialized function units designed to operate very efficiently on vectors represented as streams of data.

vector quantization (VQ) quantization applied to vectors or blocks of outputs of a continuous source.

Each possible source block is represented by a reproduction vector chosen from a finite set (the "codebook"). According to rate-distortion theory, vector quantization (VQ) is able to perform arbitrarily close to the theoretical optimum if the lengths of the input blocks are permitted to grow without limit. The method was suggested by Claude Shannon in his theoretical work on source coding (during the late 1940s and the 1950s), but has found practical importance first in recent years (during the 1980s and 1990s) because of the relatively high complexity of implementation and design compared to scalar methods. Also referred to as "block source coding with a fidelity criterion."

vector quantization encoding an encoding scheme whereby an image is decomposed into n dimensional image vectors. Each image vector is compared with a collection of representative template or codevector from a previously generated codebook. The best match codevector is chosen using a minimum distortion rule. Then the index of the codevector is transmitted. At the receiver this is used with a duplicate codebook to reconstruct the image. Usually called VQ encoding.

vector quantizer (VQ) a device that performs vector quantization.

vector space an algebraic structure comprised of a set of elements over which operations of vector addition and scalar multiplication are defined. In a linear forward error control code, code words form a vector space when addition and multiplication are defined in terms of element-wise operations from the finite field of code symbol values.

vector stride the number of consecutive memory addresses from the beginning of one element to the next of a vector stored in memory. Also used to refer to the difference in vector index between two consecutively accessed vector elements.

vector wave wave that cannot be adequately described in terms of a single field variable.

vector wave equation an equation (or more specifically, a set of scalar equations) governing the various components of a vector wave, the Maxwell–Heaviside equations, for example.

vectored interrupt an interrupt request whereby the processor is directed to a predetermined memory location, depending on the source of the interrupt, by the built-in internal hardware. In the X86 processors, the addresses are stored in an array in memory (a mathematical vector) and indexed by the interrupt number. In the 8080 and Z80, the interrupt number becomes part of a CALL instruction with an implied address that is executed on an interrupt cycle.

vectorscope an oscilloscope-type device used to display the color parameters of a video signal. A vectorscope decodes color information into R-Y and B-Y components, which are then used to drive the X and Y axis of the scope. The total lack of color in a video signal is displayed as a dot in the center of the vectorscope. The angle, distance around the circle, magnitude, and distance away from the center indicate the phase and amplitude of the color signal.

vee system a 3-level system in which the highest two energy states are coupled by electromagnetic fields to a common, intermediate, lower state. This system is so named

because schematic representations of it often look like a capital letter V.

velocity error the final steady difference between a ramp 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 velocity. *See also* acceleration error and position error.

velocity error constant a gain K_v from which the velocity error e_v is readily determined. It is a concept that is useful in the design of unity feedback control systems since it transforms a constraint on the final error to a constraint on the gain of the open loop system. The relevant equations are

$$e_v = \frac{1}{K_v} \text{ and } \quad K_v = s \lim_{\to} \infty \, sq(s)$$

where $q(s)$ is the transfer function model of the open loop system, including the controller and the process in cascade. *See also* acceleration error constant and position error constant.

velocity filtering means for discriminating signals from noise or other undesired signals because of their different apparent velocities.

velocity flow field the velocity field calculated in optical flow computation.

velocity manipulability ellipsoid an ellipsoid that characterizes the end-effector velocities that can be generated with the given set of joint velocities, with the manipulator in a given posture.

Consider a set of generalized joint velocities $\dot{q}$ of constant, unit norm $\dot{q}^T \dot{q} = 1$. Taking into account the differential kinematics J and properties of the pseudo-inverse of the geometrical Jacobian, the unit norm can be rewritten as follows: $v^T (J J^T)^{-1} v = 1$, which is the equation of the points on the surface of an ellipsoid in the end-effector velocity space.

velocity of light in vacuum, a constant equal to 2.997928×10^8 meters/second. In other media, equal to the vacuum value divided by the refractive index of the medium.

velocity saturation a physical process in a semiconductor where the carrier velocity becomes constant independent of the electric field due to high energy scattering and energy loss, compared to low electric field transport where the velocity is linearly related to the field by the mobility.

verification the process of proving that the implementation of hardware or software meets the published system requirements.

verification kit known impedance standards traced to NIST, other than calibration standards, used to verify the calibrated performance of a vector network analyzer system.

Versa Module Europe bus (VME bus) a standardized processor backplane bus system originally developed by Motorola. The bus allows multiple processors to share memory and I/O devices.

vertical cavity laser semiconductor laser in which the electromagnetic fields propagate in a direction perpendicular to the amplifying plane (the vertical direction).

vertical deflection the direction of an entity is caused to move by some physical action; commonly describes the vertical movement of an electron beam caused by electrostatic or magnetic forces applied to produce a required scan. Magnetic deflection is frequently used with a CRT video display and requires a large deflection angle.

vertical microinstruction a field that specifies one microcommand via its op code. In practice, microinstructions that typically contain three or four fields are called vertical.

vertical 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 vertically polarized EM wave is one with its electric field vector aligned perpendicular to the local horizontal.

vertical roll in television, the apparent continuous upward or downward movement of the picture, resulting from the lack of synchronization between the transmitter and receiver.

vertical sync pulse a signal interval of the NTSC composite video signal provided for the synchronization of the vertical deflection system; the vertical sync interval has a duration of three horizontal lines and is serrated with six pulses. The vertical sync interval starts after six equalizing pulses (3 horizontal line periods) that identify the beginning of the vertical blanking interval. The vertical serration preserves the horizontal line synchronization information during the vertical sync pulse interval with the one-half horizontal line time-signal transition from the composite video blanking signal level to the sync signal level. The serrated vertical pulse duration is at the blanking level for $7 \pm 1\%$ of the horizontal line time.

vertically integrated utility a utility in which generation, transmission, and distribution divisions are all owned by a single entity.

very high-speed digital subscriber line (VDSL) a digital subscriber line (DSL) that provides very high rates (13 Mbps, 26 Mbps, and 52 Mbps) through short subscriber loops (1 to 3 kft). A VDSL may support asymmetric rates between the customer premise and the central office.

very-large-scale-integration (VLSI) (1) a technology that allows the construction and interconnection of large numbers (millions) of transistors on a single integrated circuit.

(2) an integrated circuit made of tens of thousands to hundreds of thousands of transistors.

very long instruction word (VLIW) a computer architecture that performs no dynamic analysis on the instruction stream and executes operations precisely as ordered in the instruction stream.

very small aperture terminal (VSAT) a small earth station suitable for installation at a customer's premises. A VSAT typically consists of an antenna less than 2.4 m, an outdoor unit to receive and transmit signals, and an indoor unit containing the satellite and terrestrial interface units.

vestigial sideband (1) a portion of one sideband in an amplitude modulated signal, remaining after passage through a selective filter.

(2) Amplitude modulated signal in which one sideband has been partially or largely suppressed.

(3) The small amount of energy emitted in the unused sideband in a single-sided transmitter.

VGA *See* video graphics adapter.

VHF very high frequency. See VHF power.

VHF power in television, the band of frequencies ranging from 30MHz to 300MHz.

VHSIC acronym for very high speed integrated circuit.

via a hole in the insulator between two metal layers on a multilayer integrated circuit that is etched and filled with a conducting material so that the two metal layers are electrically connected. Via resistance is typically less than 10 ohms.

via hole hole chemically etched from the back of a MMIC wafer and filled with metal

in such a way as to allow an electrical connection between the backside of a wafer and the topside of the wafer.

vibration damper any of a number of devices mounted on a power line to reduce vibrations caused by wind.

vibrational transition transition between vibrational states of a molecule.

video (1) representation of moving images for storage and processing. Often used interchangeably with television. In particular, "video signal" and "television signal" are synonyms.

(2) a particular stored sequence of moving images, e.g., on a tape or within a database.

video amplifier (1) in television, the wideband stage (or stages) that amplifies the picture signal and presents it to the picture tube.

(2) A similar wideband amplifier, such as an instrument amplifier or preamplifier having at least a 4-MHz bandwidth.

video coding compression of moving images. Coding can be done purely on an Intraframe (within-frame) basis, using a still image coding algorithm, or by exploiting temporal correlations between frames (interframe coding). In the latter case, the encoder estimates motion between the current frame and a previously-coded reference frame, encodes a field of motion vectors that describe the motion compactly, generates a motion-compensated prediction image and codes the difference between this and the actual frame with an intraframe residue coder — typically the 8×8 discrete cosine transform. The decoder receives the motion vectors and encoded residue, constructs the prediction picture from its stored reference frame and adds back the difference information to recover the frame. *See also* MPEG.

video compression *See* video coding.

video graphics adapter (VGA) a video adapter proposed by IBM in 1987 as an evolution of EGA. It is capable of emulating EGA, CGA, and MDA. In graphic mode, it allows to reach 640×480 pixels (wide per high) with 16 colors selected from a pallet of 262144, or 320×240 with 256 colors selected from a pallet of 262144.

video RFI undesired radio-frequency signals that compete with the desired video signal.

video signal the video signal in the U.S. is defined by the NTSC standard. *See* National Television System Committee.

video signal processing The area of specialization concerned with the processing of time sequences of image data, i.e., video.

video transmission the combined amplitude-modulated carrier, sync, and blanking pulses that make up a video signal.

virtual address (1) an address that refers to a location of virtual memory.

(2) the address generated by the processor in a paging (virtual memory) system. *Compare with* real address.

virtual channel a concept used to describe unidirectional transport of ATM cells associated by a common unique identifier value.

virtual circuit an abstraction that enables a fraction of a physical circuit to be allocated to a user. To a user, a virtual circuit appears as a physical circuit; multiple virtual circuits can be multiplexed onto a single physical circuit.

virtual connection a representation of the circuit between the input leads of an ideal op-amp. The voltage across and the current through a virtual connection are both zero. If one input lead of an ideal op-amp is con-

nected to ground, the virtual connection is often termed a virtual ground.

virtual DMA DMA in which virtual addresses are translated into real addresses during the I/O operation.

virtual instrument an instrument created through computer control of a collection of instrument resources with analysis and display of the data collected.

virtual machine a process on a multitasking computer that behaves as if it were a stand-alone computer and not part of a larger system.

virtual memory main memory as seen by the processor, i.e., as defined by the processor-generated addresses, in contrast with real memory, which is the memory actually installed or that is immediately addressable.

The virtual memory corresponds to the secondary storage, and data is automatically transferred to and from real memory as needed. In paged virtual memory, secondary memory is divided into fixed-size pages that are automatically moved to and from page frames of real memory; the division is not logical and is usually invisible to the programmer. In segmentation, the divisions (known as segments) are logical and of variable-sized units that are much larger than pages. Segments are generally much larger than pages: 16–24 KB versus 0.5–4 KB. Many machines combine both paging and segmentation.

Since secondary memory is much larger than main memory, virtual memory presents the programmer with the view of a main memory that appears to be larger than it actually is. Virtual memory also facilitates automatic transfer of data, protection, accommodation of growing structures, efficient management of main-memory, and long-term storage.

virtual memory interrupt interrupt that occurs when an attempt is made to access an item of virtual memory that is not loaded into main memory.

virtual page number in a paged virtual memory system, this is the part of the memory addresses that points to the page that is accessed, while the rest of the address points to a particular part of that page.

virtual path a concept used to describe the unidirectional transport of virtual channels that are associated by a common identifier value.

virtual reality three or more dimensionality of computer-generated images, which gives the user a sense of presence (i.e., a first-person experience) in the scene.

virtual register one of a bank of registers used as general purpose registers to hold the results of speculative instruction execution until instruction completion. Virtual registers are used to prevent conflicts between instructions that would normally use the same registers. *See also* speculative execution.

virtually addressed cache a cache memory in which the placement of data is determined by virtual addresses rather than physical addresses. This scheme has the advantage of decreasing memory access times by avoiding virtual address translation for most accesses. The disadvantage is that data stored in the cache may have different virtual addresses in different processes (aliasing).

visible associated with the wavelength region that can be seen by the human eye; often considered to range from about 400 to 700 nanometers.

visible light electromagnetic radiation in the visible portion of the spectrum, roughly 400 to 700 nanometers.

visual comfort probability (VCP) this rating is based in terms of the percentage of people who will be expected to find the given lighting system acceptable when they are seated in most undesirable locations.

visual display unit a common means of input/output to/from a computer. Consists of a CRT and a keyboard.

visual perception the perception of a scene as observed by the human visual system: it may differ considerably from the actual intensity image because of the nonlinear response of the human visual system to light stimuli.

visual space the complete set of all possible images on a specific set of sampling and quantization parameters. Any specific image would be a member of this large space. For a 2×2 bi-level image, the space contains 16 members. Allowing all 3×3 bi-level images increases the size of the space to 512 (number of quantized levels raised to the power M, where M is the total number of pixels in the image).

Viterbi algorithm an algorithm for finding the most probable sequence given that data can be modeled by a finite-state Markov model. For example, used in maximum likelihood decoding of trellis codes and in equalization.

VLIW *See* very long instruction word.

VLSI *See* very-large-scale-integration.

voice means for enabling a computer or data processing system to recognize spoken commands and input data and convert them into electrical signals that can be used to cause the system to carry out these commands or accept the data. Various types of algorithms and stored templates are used to achieve this recognition.

voice activity stimuli that can be used to optimize channel capacity. The human voice activity cycle is typically 35%. The rest of the time we are either listening or pausing. In a multiple access scenario such as CDMA, all users are sharing the same radio channel. When users assigned to the channel are not talking, all other users on the same channel benefit with less interference. Thus, the voice activity cycle reduces mutual interference by 65%, tripling the true channel capacity. CDMA is not the only technology that takes advantage of this phenomenon.

voice coil the bobbinless coil transducer element of a dynamic microphone.

voice compression *See* speech compression.

voicing classification of a speech segment as being voiced (i.e., produced by glottal excitation), unvoiced (i.e., produced by turbulent air flow at a constriction), or some mix of those two.

volatile pertaining to a memory or storage device that loses its storage capability when power is removed.

volatile device a memory or storage device that loses its storage capability when power is removed.

volatile memory memory that loses its contents when the power supply is removed. Examples include most types of RAM.

volt-ampere-reactive (VAR) a unit of power equal to the reactive power in a circuit carrying a sinusoidal current when the product of the root-mean-square value of the voltage (expressed in volts), the root-mean-square value of the current (expressed in amperes), and the cosine of the phase angle between the voltage and the current, equals one; the unit of reactive power in the International System. Also expressed as megavars and kilovars.

voltage collapse the rapid and uncontrollable drop of bus voltage due to a slight increase in load at the bus, generally characterized by inadequate reactive support in a high-load area.

voltage variation — long duration a change of voltage RMS value from nominal for a time period greater than 1 minute, and can be used with the words showing a magnitude change such as overvoltage, or undervoltage.

Volta, Alessando (Corte) (1745–1827) Born: Como, Italy

Volta is best known for the invention of a number of practical devices including the first battery (voltaic pile), a simple electrometer for measuring current and electrophorus. Volta was not a theoretical physicist, but a good researcher. He was able to follow up Benjamin Franklin's early work and that of Luigi Galvani by devising devices and experiments that allowed him to explore the physics. Volta is honored by having his name used as the unit of electromotive force, the volt.

voltage the potential to do work, voltage is the ratio of the energy available to the charge, expressed in volts.

voltage coefficient of resistance the change in resistance per unit change in voltage, expressed as a percentage of the resistance at 10% of rated voltage.

voltage and current transmission matrix a matrix representation for a two port network that provides the voltages and current at one port as a function of the voltages and current at the other port. Also known as chain matrix.

voltage change a deviation of the peak or RMS voltage between two levels that are of some fixed duration.

voltage controlled oscillator *See* voltage-controlled oscillator.

voltage dip *See* sag.

voltage distortion a change from a nominal clean sinusoidal waveform.

voltage drop the difference in potential between the two ends of the resistor measured in the direction of flow current. The voltage drop is $V = IR$, where V is voltage across the resistor, I is the current through the resistor, and R is the resistance.

voltage fed inverter *See* voltage source inverter.

voltage feedback op-amp an op-amp in which the output voltage is controlled by the differential input voltage multiplied by the open-loop gain. A voltage feedback op-amp has very high input resistance (the current in either input is ideally negligibly small), low output resistance, and large open loop gain. Ideally, the bandwidth would be infinite; in practice, the finite bandwidth leads to a gain–bandwidth tradeoff in the closed loop performance of amplifiers using voltage feedback op-amps. Thus increasing the closed-loop gain causes a proportional decrease in the closed-loop bandwidth.

voltage fluctuation refers to a series of voltage variations.

voltage gain dimensionless ratio of the peak-to-peak RF output voltage versus the peak-to-peak RF input voltage.

voltage instability proximity index an index that gives an indication of the amount of real or reactive power margin available in the system before a voltage collapse occurs.

voltage interruption the removal of the supply voltage from any phase, which is of momentary, sustained, of temporary duration.

voltage multiplier an electronic device or circuit for multiplying the peak DC value of an input AC signal. A rectifying circuit that produces a direct voltage whose amplitude is approximately equal to a multiple of the peak amplitude of the applied alternating voltage. Voltage doublers are commonly used in consumer electronic products that are designed for use in both U.S. and European markets.

voltage protection the output voltage is limited to protect the load from an overvoltage condition. This can be accomplished by shunting the power-supply output or shutting down the drive circuit for the active switches in a switching supply if the output voltage exceeds a preset value.

voltage rating the maximum voltage that may be applied to the resistor.

voltage reference a functional block that ideally provides a constant output voltage independent of external influences such as supply voltage, loading, or temperature. Commonly used voltage references are based on the bandgap voltage of silicon (bandgap reference) or the reverse breakdown of a zener diode.

voltage regulating relay a voltage regulating relay senses RMS voltage level and issues commands to devices such as load tap changers, which then adjust the tap position to bring the voltage back to the desired level.

voltage regulation the change in delivered voltage from a generator or transformer from no-load to full-load. Voltage regulation is usually expressed as a percentage of the no-load voltage. For a DC generator, the voltage will always drop as the load increases and the voltage regulation will be a positive quantity. For AC generators and transformers, voltage regulation is the difference in the magnitude of the no-load and full-load voltages (ignoring phase angles). For capacitive (leading power factor) loads, the full-load voltage may have a higher magnitude than the no-load voltage, resulting in negative voltage regulation. Such a condition may lead to instability and is undesirable.

voltage regulator similar to a voltage reference, but provides more output current at a less precisely controlled voltage. Primarily used to "clean up" (regulate) a varying input voltage to provide circuitry with a constant power supply voltage.

voltage source inverter a power converter that takes a DC voltage from a battery or the output of a rectifier and supplies a voltage of controllable and variable frequency and magnitude to a single or multiphase load. *See also* current source inverter.

voltage spread the difference between a power system's specified maximum and minimum voltages.

voltage stability a measure of power system stability which considers the system's capacity to support a given load.

voltage standing wave ratio (VSWR) another way of expressing impedance mismatch resulting in signal reflection. With respect to reflection coefficient G, the VSWR may be expressed mathematically as

$$\text{VSWR} = \frac{1+\mid G \mid}{1-\mid G \mid}$$

See also reflection coefficient.

voltage transfer function any function of input to output voltage in ratio form, expressed as a dimensionless ratio. The input voltage may be the source voltage or the input voltage, which differ due to mismatch. The output voltage may be the load voltage or maximum output voltage, which also differ due to mismatch. Other voltages could also be ratioed, such as the input and output voltages of a MESFET. The voltage gain of a device is a specific case of a voltage transfer function. Regardless of the voltages used,

they should be explicitly specified or confusion will result.

voltage transformer an instrument transformer specially designed and optimized for voltage measurement and power metering applications. The primary winding is rated to match the system voltage and the secondary is typically rated at a standard value to match common meters and display units. Also called a potential transformer.

voltage unbalance refers to the greatest change of the polyphase voltages from the average polyphase voltage divided by the average polyphase voltage.

voltage unit a protective unit (in protective relaying) whose operation depends exclusively on the magnitude of voltage.

voltage variation – short duration a change of the voltage RMS value from nominal for a time period from 0.5 cycles to 1 minute, and can be used with the words sag, swell, and interruption for magnitude changes, and the words instantaneous, momentary, of temporary for showing duration.

voltage-behind-reactance model a representation of a machine in which the stator voltage equations are modeled as a voltage source in series with a reactance (and typically a resistance). The voltage source represents the back emf present on the stator windings due to the coupling between the stator and rotor circuits. In synchronous machine modeling, several different voltage-behind-reactance models have historically been used, wherein approximations are used to represent the machine in various detail.

voltage-controlled bus in power-flow analysis of an electric power system, a bus at which the real power, voltage magnitude, and limits on reactive power are specified. A bus connected to a generator will be so represented.

voltage-controlled oscillator (VCO) (1) an oscillator where the frequency can be controlled by an external voltage. These oscillators can be divided into three categories:

1. Oscillators based on analog computer simulation of an oscillating system with quasi-static variable frequency.

2. Oscillators based on quasi-static variation of frequency using voltage-controlled capacitance of semiconductor diodes or varactors.

3. Oscillators based on control of charge–discharge currents in current-controlled multivibrators with further nonlinear waveshaping of the triangular wave.

(2) an oscillator whose frequency is designed to be controlled primarily by the amplitude of the applied voltage. The VCO is one of the building blocks making up the phase-locked-loop circuit.

voltage-source inverter (VSI) an inverter with a DC voltage input.

Volterra integral equation a linear integral equation wherein the limits of integration are functions of position.

Volterra series a series expansion of a nonlinear function around a point. The Volterra series method is a generalization of the power-series method useful for analyzing harmonic and intermodulation distortion due to frequency-dependent nonlinearities in a device.

voltmeter an instrument for measuring a potential difference between different points of an electrical circuit. Units are volts.

volts/hertz control a method of speed control of induction machines, used below rated speed. When the volts/hertz ratio is kept constant, the current through the stator windings remains almost the same, except for very low speeds; hence, the available torque remains constant, but the speed changes due to change in frequency.

volume plasmon a volume polariton in a plasma medium.

volume polariton a polariton that propagates in unbounded medium, also referred to as a bulk mode, wave by 180 degrees.

volume scattering the reflection of electromagnetic waves from a collection of particles or transitions in media properties distributed throughout a three-dimensional region. Particles may or may not be immersed or imbedded in a dielectric medium. *See also* surface scattering.

volumetric scattering *See* volume scattering.

von Neumann architecture a stored program computer design in which data and instructions are stored in the same memory device and accessed similarly. *See also* Princeton architecture. *See* single-instruction stream, single data stream.

von Neumann, John (1903–1957) Born: Budapest, Hungary

von Neumann is best known for his role in the development of the theory of stored program flexible computers. He is honored by the reference to von Neumann machines as a theoretical class of computers. von Neumann also invented the idea of game theory. As a mathematician, von Neumann published significant work on logic, the theory of rings, operators, and set theory. His work, *The Mathematical Foundations of Quantum Mechanics*, was significant in the mathematical justification of that field. von Neumann was a brilliant mathematician and physicist whose theoretical contributions are fundamental to modern physics and electrical engineering. He was the youngest member of the Institute of Advanced Studies at Princeton, and did important work on the Manhattan project.

voting circuit a circuit that provides fault-tolerance by comparing its inputs and taking a majority vote in case of disagreement.

vowel diagram the articulation of different vowels is strongly based on the position of the tongue, which can be high/low and front/back. The diagram defined by these two dimensions is called vowel diagram.

voxel the 3-D analogue of a pixel; abbreviation of Volumetric Picture Element. Mathematically it is a point in 3-D space having integer coordinates; concretely, it can also be interpreted as a cube of unit size centered about that point. *See* pixel.

voxel adjacency one of three types of adjacency relations defined on voxels:

1. 6-adjacency: two voxels are 6-adjacent if they differ by 1 in one coordinate, the other two coordinates being equal; equivalently, the two unit cubes centered about these voxels have one face in common.

2. 18-adjacency: Two voxels are 18-adjacent if they differ by 1 in one or two coordinates, the remaining coordinates being equal; equivalently, the two unit cubes centered about these voxels have one face or one edge in common.

3. 26-adjacency: Two voxels are 26-adjacent if they differ by 1 in one, two, or three coordinates, the remaining coordinates being equal; equivalently, the two unit cubes centered about these voxels have one face, one edge, or one vertex in common. In these definitions, the numbers 6, 18, and 26 refer to the number of voxels that are adjacent to a given voxel. *See* pixel adjacency, voxel.

VP-PAW *See* variable polarity plasma arc welding.

VQ *See* vector quantization or vector quantizer.

VQ encoding *See* vector quantization encoding.

VSAT *See* very small aperture terminal.

VSI *See* voltage-source inverter.

VSWR *See* voltage standing wave ratio.

VT *See* potential transformer.

W

wafer a thin slice of semiconductor material on which semiconductor devices are made. Also called a slice or substrate.

wafer fab the facility (building) in which semiconductor devices are fabricated. Also called a semiconductor fabrication facility.

wafer scale integration most integrated circuits are cut from a large slice of material called a wafer. With wafer scale integration, the entire slice of material is used to create a complex circuit.

wafer sort a preliminary electrical test of each die while still on the wafer to eliminate most of the bad die before they are assembled.

wait state a bus cycle during which a CPU waits for a response from a memory or input-output device.

wall clock a device providing the time of day; contrast processor clock. Elapsed wall clock time for a process does not correspond with processor time because of time used in system functions.

Walsh cover mutually orthogonal sequences used in direct-sequence code division multiple access, obtained from the rows of a Hadamard matrix. *See also* Hadamard matrix.

Walsh transform *See* Walsh–Hadamard transform.

Walsh–Hadamard transform (WHT) a transform that uses a set of basis functions containing values that are either $+1$ or -1, and are determined from the rows of the Hadamard matrices. This has a modest decorrelation capability and is simple to implement.

Waltz filtering also termed "Boolean constraint propagation"; a method of simplifying certain tree-search problems. It was originally developed to solve the computer vision problem of labeling each edge of a line drawing in order to give a 3-D description of the represented object.

WAN *See* wide-area network.

Ward–Leonard drive an adjustable voltage control drive system for the speed control of DC machines, whereby variable voltage is supplied to the armature, while maintaining constant voltage across the shunt or separately excited fields. The variable voltage is obtained from a motor-generator set. The Ward–Leonard drive was frequently used in elevators.

warm start (1) reassumption, without loss, of some processes of the system from the point of detected fault.

(2) the restart of a computer operating system without going through the power-on (cold) boot process.

watchdog processor a processor that observes some process and signals an alert if a certain event happens or fails to happen.

watchdog timer a simple timer circuitry that keeps track of proper system functioning on the basis of time analysis. If the timer is not reset before it expires, a fault is signaled, e.g., with an interrupt.

water resistivity a measure of the purity of cooling liquid for a power tube, typically measured in megohms per centimeter.

water tree a microscopic cracking pattern which forms in the insulation of cables which are immersed in water or direct-buried in the earth. *See* tree.

watercourse a line on a surface $f(x, y)$ which represents a watershed of the inverted surface $-f(x, y)$. The line of steepest descent from a saddle point to a minimum is a watercourse. Watercourses meet watersheds at saddle points.

watershed a line on a surface $f(x, y)$, typically an image, which divides it into "catchment areas." Within a catchment area, lines of descent all connect to the same minimum point. The line of steepest ascent from a saddle point to a maximum is a watershed. Watersheds often correspond to ridges.

Watson, Thomas J., Jr. Watson is best known as the president of IBM who led the company into a dominant position in the computer industry. Watson took over his father's company, changed the structure, and moved the company away from the card tabulating business in which they held a dominant position. Watson Jr. oversaw the development of the IBM System/360 machines, which were to give the company a dominant position in computing.

Watson, Thomas J., Sr. (1874–1956) Born: Cambell, New York, U.S.A.

Watson is best known as the president of IBM (International Business Machines). While Watson was not a technical person, his position as head of IBM put him in a position of supporting the development of a number of devices, both electronic and mechanical, leading to the development of the modern computer industry.

Watson-Watt, Robert Alexander (1892–1973) Born: Brechin, Angus, Great Britain

Watson-Watt is most famous for his pioneering work in the development of radar. Watson-Watt's work is based on the principles elucidated by Faraday, Maxwell, and Hertz. A German physicist, Christian Hulsmeyer had filed a patent in 1904 for an earlier device. Lack of enthusiasm from the German government and the governments in France and the United States gave the English, who supported Watson-Watt, a clear edge in this field. Watson-Watt filed his patent application in 1919. His device proved invaluable to the Allies in World War II.

watt unit of power in the SI system of units.

Watt, James (1736–1819) Born: Greenock, Scotland, U.K.

Watt is best known for his work in the development of efficient steam power. Watt began his career as an instrument maker. When asked to fix a troublesome Newcomen engine, he began to make improvements. Watt eventually partnered with industrialist Matthew Boulton to form a steam engine company. Watt is credited with having devised the horsepower system. The unit of power, the watt, is named in his honor.

watt-VAR meter meter capable of simultaneously measuring the real and reactive power delivered to an AC load.

wattmeter an instrument for measuring electric power in watts. A wattmeter requires connections to measure both the current through and the voltage across the load being measured.

wave equation equation governing the evolution of a wave; in electromagnetics any of several equations or equation sets starting from the most general, nonlinear multivariable differential Maxwell–Heaviside equations and ranging down to the simplest first-order rate equations.

wave impedance the ratio of the transverse electric and magnetic fields inside a waveguide.

wave optics formalism for optics in which the fields are represented as wave phenomena, in contrast to other ray or particle optics models.

wave plate transparent anisotropic medium that introduces polarization-dependent phase shifts on an optical wave.

wave polarization a description of the time-varying behavior of the electric field vector as some fixed point in space. Elliptical polarization is the most general polarization and special cases include linear and circular polarizations.

wave propagation the transfer of energy by electromagnetic radiation.

wave winding an armature winding on a DC machine in which the two ends of each coil are connected to bars on opposite sides of the commutator ring. The wave winding provides two parallel paths through the armature winding, regardless of the number of poles in the machine.

waveform coding refers to the class of signal compression methods that are based on a criterion where the input waveform is to be resembled as closely as possible according to some criterion, e.g., minimum squared error, by the reproduced coded version. Waveform coding contrasts parametric coding techniques.

waveform distortion refers to a deviation from a steady-state clean sine waveform.

waveform interpolation coding parametric speech coding method where a characteristic waveform, a prototype waveform, is extracted from the speech signal at regular time instants and the intermediate signal is interpolated. Waveform interpolation coding is mostly used in low bit rate speech coding.

wavefront front of a wave; often a surface of constant phase.

waveguide a system of conductive or dielectric materials in which boundaries and related dimensions are defined such that electromagnetic waves propagate within the bounded region of the structure. Although most waveguides utilize a hollow or dielectric filled conductive metal tube, a solid dielectric rod in which the dielectric constant of the rod is very much different from the dielectric constant of the surrounding medium can also be used to guide a wave. Waveguides rapidly attenuate energy at frequencies below the waveguide lower cut-off frequency, and are limited in bandwidth at the upper end of the frequency spectrum due to wave attenuation as well as undesired mode propagation.

waveguide interconnect interconnect that uses a waveguide to connect a source to a detector. A waveguide is used for implementing a bus. The merits are large bandwidth, high speed of propagation, and compatibility with integrated optics and optoelectronics.

waveguide laser a laser in which amplification occurs within a waveguide that is confining the laser modes in the transverse direction.

wavelength a constant that describes the distance a periodic wave must travel in order to repeat itself. For example, if $v(z, t)$ is a periodic wave and if the wave travels a distance λ, then $v(z + \lambda, t) = v(z, t)$.

wavelength division multiplexing (WDM) a technique to increase capacity and throughput of systems by using a number of wavelength channels simultaneously.

wavelet a basis function that is obtained by translating and dilating a mother wavelet; it has such properties as smoothness, time-frequency localization, orthogonality, and/or symmetry.

wavelet coding coding a signal by coding the coefficients of the wavelet transform of the signal. The discrete wavelet transform is often used in image compression.

wavelet packet a family of scaling functions and wavelets by translation and dilation of a mother wavelet and a scaling function following a binary tree structure.

wavelet shrinkage a non-parametric estimation method to remove noise from a signal by shrinking wavelet coefficients of a signal towards zero.

wavelet transform a computational procedure that to represent a given function $x(t)$ by basis function ϕ, calculates

$$x(a,b) = \frac{1}{\sqrt{|a|}} \int_{-infty}^{infty} x(t)\phi(\frac{t-b}{a})dt,$$

where a and b are real numbers. *See also* inverse wavelet transform.

wavenumber a constant that relates the spatial rate of change of phase for a propagating wave. The wavenumber is mathematically equal to $2\pi/\lambda$, where λ is the wavelength. SI units are radians per meter. *See also* phase constant.

WDM *See* wavelength division multiplexing.

weak interconnection a connection between two power systems which has a high impedance and thus allows local disturbances at either end to threaten the synchronization of the two systems.

weak localization the name given to a process of self-interference of carriers in a mesoscopic system in which the transport is quasi-ballistic. A significant fraction of the carriers can be scattered by impurities back to their initial position in phase space, at which point they interfere with each other leading to an additional resistance. Since the scattering path can be traversed in either direction (which are time reversed paths of one another), it is said that the additional resistance is made up of continual interference between the two time-reversed paths. A small magnetic field breaks up this equivalence of the two paths and eliminates the weak localization contribution to the resistance.

weak localization of light enhanced backscattering; sometimes also called opposition effect.

weak SPR function *See* weak strictly positive real function.

weak strictly positive real function a rational function $H(s) = n(s)/d(s)$ of the complex variable $s = \sigma + \jmath\omega$ that satisfies the following properties:

1. $a(s)$ is a Hurwitz polynomial.

2. $Re[H(\jmath\omega)] > 0$ for all $\omega \geq 0$.

3. The degrees of the numerator and denominator polynomials differ by, at most, one.

4. If $\partial(b) > \partial(a)$, then $\lim_{\omega\to\infty}[H(\jmath\omega)]/\jmath\omega > 0$, where $\partial(b)$ denotes the degree of the polynomial b and similarly for a.

wearout failure failure mechanism caused by monotonic accumulation of incremental damage beyond the endurance of the product.

Weber, Wilhelm (1804–1891) Born: Wittenberg, Germany

Weber is best known as the person who deduced that electricity consists of charged particles. Weber held several university appointments including professorships at Gottingen, where he had a very productive collaboration with Karl Gauss. Weber insisted on precision in his mathematical and experimental work. He developed a number of very precise measurement instruments. His efforts helped establish a sound foundation for the study of electricity and magnetism. He is honored by having his name used as the SI unit of magnetic flux density, the weber.

Weber's law an experimental result that states that the smallest luminance increment ΔL at which a region of luminance $L + \Delta L$ is just discernible from a background of lu-

minance L is such that the ratio $\Delta L/L$ is constant. *See also* brightness constancy, simultaneous contrast.

wedge ring detector a special photodetector structure consisting of wedge elements and annular half-ring shaped elements, each set covering a semicircle. This structure detects feature without regard to scale with the wedges, and without regard to rotational orientation with the annuli.

weight decay a technique employed in network training that aims to reduce the number of interconnections in the final, trained network. This is achieved by penalizing the weights in some way such that they have a tendency to decay to zero unless their values are reinforced.

weight initialization the choosing of initial values for the weights in a neural network prior to training. Most commonly small random values are employed so as to avoid symmetries and saturated sigmoids.

weight sharing a scheme under which two or more weights in a network are constrained to maintain the same value throughout the training process.

weighted Euclidean distance for two real valued vectors $x = (x_1, x_2, \ldots, x_n)$ and $y = (y_1, y_2, \ldots, y_n)$, defined as

$$D_\psi(x, y) = \sqrt{(x - y)^T \psi (x - y)} \ ,$$

where ψ is the inverse of the covariance matrix of x and y, and T denotes the transpose. *See also* Mahalanobis distance.

weighted mean squared error (WMSE) a generalization of the mean squared error.

weighted residual a different form of the moment method. *See also* moment method.

weighted similarity *See* weighted Euclidean distance.

weighting filter a standardized filter used to impart predetermined characteristics to noise measurements in an audio system.

weightless network networks that are trained, not by changing weight values, but by modifying the contents of a memory device, usually a RAM.

Welch bound lower bound on the total squared cross correlation of a multi-set of sequences. For N complex–valued sequences s_i, $i = 1, 2, \ldots, N$, each of energy $s_i^* . s_i = L$,

$$\sum_{i=1}^{N} \sum_{j=1}^{N} \left| s_i^* . s_j \right|^2 \geq K^2 L \ .$$

Westinghouse, George (1846–1914) Born: Central Bridge, New York, U.S.A.

Westinghouse is best known as a financier and industrialist during America's age of great commercial expansion. What is less known today is that Westinghouse's fortune was based on his early inventions in the railroad industry. His braking system was eventually adopted in most rail cars. Westinghouse went on to secure over 400 patents in the rail and the gas distribution industries. Before hiring Tesla and buying his patents, Westinghouse had been a champion of alternating current for power distribution. His company provided illumination for the great Chicago Exposition of 1893. Before his death, Westinghouse was to lose control of the companies that bear his name. Undaunted, he returned to the laboratory for a number of additional years of invention.

wet etching a process that uses liquid chemical reactions with unprotected regions of a wafer to remove specific layers of the substrate.

wet withstand test a withstand test that is conducted under conditions which include simulated rain or fog.

Weyl identity an expansion of a spherical wave in terms of plane waves is known as the Weyl identity and may be written as

$$\frac{e^{-jkr}}{r} = -\frac{j}{2\pi}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\frac{e^{-j(k_x x+k_y y)-jk_z|z|}}{k_z}\,dk_x\,dk_y$$

Wheatstone bridge a bridge circuit where all arms are resistors. The condition of balance in the circuit is used for precise measurement of resisors. In this case, one of the arms is an unknown resistor, another arm is a standard resistor (usually a variable resistor box), and two other arms (called ratio arms) are variable resistors with a well determined ratio. When the condition of balance is achieved, one can calculate the unknown resistor multiplying the standard resistor value by the ratio of ratio arms resistors. The precision of measurements is 0.05% for the range 10 ohms to 1 megohm. The Wheatstone bridge is used for resistor measurements at DC and AC (in the universal impedance bridges).

Moreover, the Wheatstone bridge is widely used in resistive transducers where one or more arms is substituted by resistors the resistance of which depends on a physical variable (temperature, pressure, force, etc.). In these applications, the deflection from balance is used for measurement of the physical variable.

whetstone the speed of a processor as measured by the Whetstone benchmark.

Whetstone benchmark a benchmark test program for scientific computers originally written in Fortran at Whetstone Laboratories, England.

whisker contact diode a technique for mounting very high frequency diodes in a waveguide that involves a thin pointed wire or whisker that acts as both an antenna into the guide and as a bias contact.

white noise the noise that in its spectrum contains constant energy per unit bandwidth independent of frequency. *See also* thermal noise.

whitening filter a filter that whitens noise, i.e., one that brings noise whose power spectrum is not white into this condition, e.g., by means of a frequency dependent filter. Noise whitening is a vital precursor to matched filtering.

WHT *See* Walsh–Hadamard transform.

wide band property of a tuner, amplifier, or other device that can pass a broad range of frequencies.

wide band FM frequency modulation scheme where the ratio of peak frequency deviation to the frequency of modulating signal is larger than 0.2.

wide sense stationary uncorrelated scattering (WSSUS) channel a randomly time-variant channel whose first- and second-order statistics (means and correlation functions) are independent of time and frequency. The frequency independence translates into the uncorrelated scattering requirement. In a WSSUS multipath channel, the random process pertaining to a signal caused by any resolvable scatterer (reflector) is:

1. wide sense stationary, i.e., its mean and correlation functions are independent of time, and

2. uncorrelated with any other scatterer's contribution.

wide-area network (WAN) a computer communication network spanning a broad geographic area, such as a state or country.

wide-sense stationary process a stochastic process $x(t)$ for which the mean $m(t) = m =$ constant and the covariance $C(t_1, t_2)$ is a function of only $|\, t_1 - t_2 \,|$. In this case, we write $C(t_1, t_2) = C(T)$ where $T = t_1 - t_2$.

Widrow-Hoff learning rule a gradient descent learning rule for calculating the weight vector $\vec{w}$ for a linear discriminant which minimizes the squared error objective function. The vector $\vec{w}$ is modified as

$$\vec{w}(n+1) = \vec{w}(n) + \alpha(n)(d - \vec{w}^T(n)\vec{x})\vec{x}$$

where $\vec{x}$ is an input vector, d is the desired output, and $\vec{w}(n)$ is the weight vector at iteration n.

Wien bridge a bridge circuit where one arm is a series connection of a resistor and capacitor, another arm is a parallel connection of a resistor and capacitor (these two arms are called reactance arms), and two other arms (called ratio arms) are resistors. The balance detector is connected between the common point of ratio arms and the common point of reactance arms, a sinusoidal voltage source is connected to another bridge diagonal. The Wien bridge was initially designed as a frequency measuring circuit; now the main part of its application is the Wien bridge oscillator.

Wien bridge oscillator (1) an oscillator where the Wien bridge is used in the amplifier feedback. The frequently used circuit includes equal resistors and equal capacitors in reactance branches of the bridge; this arrangement provides easy continuous tuning of the oscillation frequency. Tuning of the bridge providing high indirect frequency stability of oscillations is easily combined with application of an operational amplifier as oscillator active element. The circuit of amplitude control is also easily attached. All these advantages provide wide spread of Wien bridge oscillators in high and low radio frequency ranges of applications.

(2) a form of feedback oscillator that uses a noninverting amplifier along with a feedback path that produces a phase shift of zero degrees at the operating frequency. The feedback network contains only two reactive elements of the same type.

Wiener, Norbert (1894-1964) mathematician whose contributions include Brownian motion, stochastic processes, generalized functions, harmonic analysis, control theory, and optimal filtering. Established the field of cybernetics, author of "Cybernetics: or Control and Communication in the Animal and the Machine."

Wiener filter filter that attempts to reduce signal noise by separating and suppressing the power spectrum of the noise from the power spectrum of the signal. The uncertainty in the estimation of the noise power spectrum will cause the signal to be smoothed. Also known as the least-mean square filter.

Wilkinson coupler a coupler that splits a signal into a number of equiphase and equiamplitude parts. It provides isolation between output terminals by connecting resistors between each output terminal and a common junction. A coaxial type coupler was first proposed by Dr. Wilkinson. In recent years, not only coaxial type but also MIC (microwave integrated circuit) type Wilkinson couplers are practically used for various kinds of microwave circuits.

Williams tube memory a memory device based on electric charges being stored on the screen of a cathode ray tube. Now obsolete.

Wilson central terminal reference point for forming most of the standard ECG leads. It is the average of the right arm, the left arm, and the left potentials. It is a time-varying reference.

Winchester disk a type of magnetic disk for data storage. Its characteristic property is that the disk and the read-write head are placed in a hermetically sealed box. This allows higher recording density as the read-write head can be moved closer to the disk surface. *See also* disk head.

wind–electric conversion the process by which wind (mechanical) energy is converted to electrical energy, usually by the use of wind turbine.

wind farm a plot of land on which several power-generating windmills are placed.

wind power generator a system that utilizes the energy in the wind to generate electricity. The energy in the wind drives a wind turbine which acts as the prime mover for the generator. A wind turbine operates at a variable speed, and an appropriate electric machine and controller converts the mechanical energy into electrical energy and pumps it into a utility grid.

winding a conductive path, usually wire, inductively coupled to a magnetic core or cell.

winding factor a design parameter for electric machines that is the product of the pitch factor and the distribution factor.

window any appropriate function that multiplies the data with the intent to minimize the distortions of the Fourier spectra.

window operation an image processing operation in which the new value assigned to a given pixel depends on all the pixels within a window centered at that pixel location.

windowing the process of opening a window.

In signal processing, it is common to open only a certain restricted portion of the available data for processing at any one time: such a portion is called a window or sometimes a mask or neighborhood. For instance, in *FIR* filter design, a technique known as windowing is used for truncation in order to design an FIR filter. The design of window becomes crucial in the design.

In image processing, it is a common practice that a square window of (for example) 3×3 pixels is opened centered at a pixel under consideration. In this window operation, the gray level of the pixel is replaced by a function of its original gray level and the gray levels of other pixels in the window. Different functions represent different operations: in particular, they will be suitable for different filtering or shape analysis tasks. *See also* median filter, thinning.

Windscale incident a nuclear power plant accident at the Windscale plant in Great Britain.

winner-take-all network a network in which learning is competitive in some sense; for each input a particular neuron is declared the "winner" and allowed to adjust its weights. After learning, for any given input, only one neuron turns on.

wiped joint a fused joint used in splicing lead-sheathed cables.

wipe system in television, a system that allows the fading in of one channel of video as a second channel of video is faded out without loss of sync.

wired OR a circuit that performs an OR operation by the interconnection of gate outputs without using an explicit gate device. An open collector bus performs a wired OR function on active-low signals.

wireframe (1) 3-D object representation containing only edge and vertex information. It may produce ambiguous images (e.g., the Necker cube).

(2) a model that approximately represents a solid object by using several hundreds of triangles. It is used in applications such as facial coding, facial recognition and industrial component mensuration.

wireless local area network (WLAN) a computer network that allows the transfer of data without wired connections.

wireless local loop a wireless connection (using a radio link) between a subscriber terminal (for example, a telephone) and the local exchange of the public switched network.

withstand rating the maximum voltage that electrical equipment can safely withstand, without failure, under specified test conditions.

withstand test a test of an insulator's ability to withstand a high voltage of some specified waveform.

WLAN *See* wireless local area network.

WMSE *See* weighted mean squared error.

word parallel processing of multiple words in the same clock cycle.

wordspotting detection or location of keywords in the context of fluent speech.

work flow management the process to monitor work progress through any number of departments.

work function amount of energy necessary to take out an electron from a material.

working set the collection of pages, $w(t, T)$, referenced by a process during the time interval $(t - T, t)$.

working-set policy a memory allocation strategy that regulates the amount of main memory per process, so that the process is guaranteed a minimum level of processing efficiency.

workstation a computer system designed for engineering design calculations, characterized by (comparatively) large main memory, high floating point computational speed, and a high resolution graphic display system. It is used primarily in engineering and scientific applications.

world modeling describes the geometric and physical properties of the object (including the robot) and represents the state of the assembly of objects in the workspace. World modeling makes it possible to implement many of the features of a task-level programming system. *See also* object-oriented programming.

WORM *See* write once read many.

worst-case design a family of control design algorithms in which parameter perturbations and/or disturbances are estimated to behave in the most unfavorable way from control objective point of view. This assumption leads usually to various min-max control algorithms based on static min-max, noncooperative game theory or H infinity design. Since the worst-case estimates are conservative, the resulting controllers, although robust, may be in some sense too pessimistic. *See also* robust controller design.

worst-case measure of sensitivity for the multiparameter sensitivity row vector with components x_i having tolerance constants ϵ_i (these are considered to be positive numbers), i.e.,

$$x_{i0}\,(1 - \epsilon_i) \le x_i \le x_{i0}\,(1 + \epsilon_i)$$

we have

$$M_W = \int_{\omega_1}^{\omega_2} \left(\sum_{i=1}^{n} \left| \mathrm{Re}\mathbf{S}_{x_i}^{F(j\omega,\mathbf{x})} \right| \epsilon_i \right) d\omega$$

wound rotor induction motor an induction motor in which the secondary circuit consists of a polyphase winding or coils connected through a suitable circuit. When provided with slip rings, the term slip-ring induction motor is used.

wraparound (1) a phenomenon in signal processing that occurs in the discrete case when signals are not properly manipulated. For instance, in circular convolution, if the length of signals is not properly chosen, i.e.,

there are not sufficient zeros appended at the end of the signals, the so-called wraparound error will take place, that is, the contributions from different periods will overlap.

(2) the returning to a zero state when a register or pointer at its maximum value is incremented or one at its minimum value is decremented.

(3) a condition code or indicator that may be set, or a program segment that is executed when a register wraps around.

wraps pre-formed wire grips or ties for mechanically joining overhead conductors to insulators.

Wratten filter a light filter for separating colors. It is available in transparent sheets of various colors and is useful in photography and in several phases of electronics, including the operation of color meters and color matchers.

wrist for a manipulator, refers to the joints in the kinematic linkage between the arm and hand (or end-effector). Usually, wrist allows an orienting the manipulator. Therefore, the main role of the wrist is to change the orientation of the hand (or end-effector). *See also* spherical wrist.

write allocate part of a write policy that stipulates that if a copy of data being updated is not found in one level of the memory hierarchy, space for a copy of the updated data will be allocated in that level. Most frequently used in conjunction with a write-back policy.

write broadcast a protocol for maintaining cache coherence in multiprocessor systems. Each time a shared block in one cache is updated, the modification is broadcast to all other caches. Also referred to as write update.

write buffer a buffer that stores memory write requests from a CPU. The write request in the buffer are then served by the memory system as soon as possible. Reduces the number of processor wait cycles due to long latency write operations.

write instruction a processor instruction that stores information into memory from a processor register or a higher level cache.

write invalidate a protocol for maintaining cache coherence in multiprocessor systems. Each time a shared block in one cache is updated, a message is sent that invalidates (removes) copies of the same block in other cache memories. This is a more common alternative than write broadcast protocols.

write once read many (WORM) used to refer for memory devices that allow data to be written once after device fabrication, and to be read any number of times. A typical example is PROM.

write policy determines when copies of data are updated in a memory hierarchy. The two most common write policies are write through and write back (copy back).

write through a write policy that stipulates that when a copy of data is updated at one level of a memory hierarchy, the same data are also updated in the next outer level. Write through is usually only used in low-level caches. Its advantages are that it is fast and simple to implement, and that it always guarantees that the next level of the memory hierarchy has a valid copy of all data. Its main disadvantage is that it generates much data traffic to the next level.

write update *See* write broadcast.

write-after-read hazard *See* anti-dependency.

write-after-write hazard *See* output dependency.

write-back *See* copy-back.

write-back cache *See* copy-back.

write-through cache when a location in the cache memory is changed, the corresponding location in main memory is also changed.

written-pole motor a single-phase motor that uses a coil to write poles on the magnetic rotor. The advantage of the written-pole motor is that it draws much lower starting current, allowing much larger single-phase motors. The development of this motor has been sponsored by the Electric Power Research Institute.

Wronskian matrix whose determinant is used to test the linear independence of solutions to differential equations (such as Maxwell's equations).

WSSUS channel *See* wide sense stationary uncorrelated scattering channel.

wye connection *See* Y connection.

wye-connection a three phase source or load connected in the form of Y.

wye-delta starter a motor starter that starts a three-phase AC motor in wye or star configuration so that the motor starts on approximately 58% of normal voltage, with a two-thirds reduction in starting current. As the motor approaches operating speed, the windings are reconfigured in delta configuration so that full voltage is applied for normal operation. The transition from star to delta is performed with the help of timer settings and contactors.

wye-delta transformer a connection of a three-phase transformer with one primary and one secondary which can be considered as three similar single-phase transformers. The primary is connected in wye, that is one terminal from each phase is connected to neutral and one to a line voltage. The secondary is connected in delta, with each phase connected between two line voltages.

wye-wye transformer a three-phase transformer with both the primary and secondary coils connected in wye. This connection is considered undesirable, due to the triple harmonics in the exciting current. To maintain balance load voltages under varying loads, it is necessary to solidly connect the primary and secondary neutrals to ground. This may allow some secondary current to flow on the primary neutral and may also cause interference with parallel communication lines.

wye-wye-delta transformer a three-phase transformer in which the primary and secondary coils are connected in wye. In order to overcome the problems with the wye-wye connection, a set of tertiary coils are connected in delta to provide a path for the triple harmonic components of the exciting current to circulate.

X

X-raser *See* X-ray laser.

X-ray short wavelength electromagnetic radiation; often considered to range from about 0.1 to 100 $\mathring{A}$.

X-ray image a digital image whose pixels represent intensities of x-rays. The x-rays may come from artificial sources (medical images) or arise naturally (astronomy). Also important in modern inspection systems. *See also* imaging modalities, medical imaging.

X-ray laser a laser that has emission shorter than 30 nm (soft X-rays) or shorter than ≈ 1 $\mathring{A}$ (hard X-rays); laser producing its output in the X-ray region of the spectrum. Also called an X-raser.

X-ray lithography lithography using light of a wavelength in the range of about 0.1 to 5 nm, with about 1 nm being the most common, usually taking the form of proximity printing.

XOR *See* exclusive OR.

XOR gate a logic gate that performs the exclusive-OR function. Exclusive OR is defined for two inputs as one or the other being true but not both.

Y

Y connection a three-phase source or load which is connected such that the elements are connected in parallel and are thus represented in a schematic diagram in a Y or star–shaped configuration.

Y-bus a matrix which contains the admittance of each element in an electric power system.

y-parameters the input and output admittances that are used to characterize a two port device (network).

YAG *See* yttrium aluminum garnet.

Yagi–Uda array a wire antenna array consisting of three key components:

1. a dipole antenna (roughly a half wavelength in length) that connects the antenna to a source or load,

2. a reflector element (slightly longer than the dipole antenna), which is a wire that is placed behind, but not connected to, the dipole antenna, and

3. director elements (slightly shorter than the dipole antenna), which are wires that are placed in front of, but not connected to, the dipole antenna. The Yagi–Uda array is commonly used in the reception of television signals.

yield percentage of acceptably good chips to the total chips considered at a certain level of a MMIC process. High yield is one of the most important parameters of a cost-efficient process. DC yield refers to the percentage of chips that behave appropriately to the application of DC biasing voltages and currents (*See also* bias voltage or current). RF yield refers the percentage of chips that properly process RF/microwave signals.

YIG *See* yttrium iron garnet.

YIG filter *See* yttrium iron garnet filter.

YIG resonator *See* yttrium iron garnet resonator.

YIQ the standard format used in U.S. color television. In this standard the image is coded as; Y (luminance), I(phase) and Q (quadrature phase) can be calculated from RGB values as follows: $Y = 0.30R + 0.59G + 0.11B$, $I = 0.28G + 0.59R - 0.32B$ and $Q = -0.53G + 0.21R + 0.31B$.

yttrium aluminum garnet (YAG) host material for rare-earth ions, such as neodymium, used for laser systems. Basis for important laser media when doped with appropriate ions, especially neodymium; output frequencies mostly in the near infrared. Also written YAlG.

yttrium iron garnet (YIG) a ferrite often used in microwave devices. This material ($Y_3Fe_5O_{12}$) has a complicated cubic crystal structure with eight formula units per cell. The five Fe ions per formula unit are distributed between antiparallel sublattices, giving the material its ferrimagnetic structure.

yttrium iron garnet filter a tunable filter employing externally biased YIG and operating near its ferrimagnetic resonance.

yttrium iron garnet resonator a tunable resonator employing externally biased YIG and operating near its ferrimagnetic resonance.

Z

Z *See* impedance.

$\mathbf{Z}_L$ common symbol for load impedance.

$\mathbf{Z}_S$ common symbol for source impedance.

Z-bus a matrix which contains the impedance of each element in an electric power system.

z-parameters the input and output impedances that are used to characterize a two port device (network).

z-transform a mathematical transformation that can be applied to a differential equation of a system in order to obtain the system's transfer function. The z-transform is defined as

$$Z\{f(n)\} = F(Z) = \sum_{n=0}^{\infty} f(n)z^{-n}$$

where n is the series of discrete samples, $f(n)$ is the series of sample values corresponding to the discrete samples.

The z-transform can also be written in terms of the Laplace transform variable (s) and the sampling period (T) as

$$z = e^{Ts}$$

ZCS *See* zero current switching.

Zeeman broadening inhomogeneous spectral broadening of a transition in a laser medium due to Zeeman shifts that vary among the laser atoms or molecules in the medium.

zener breakdown the electrical breakdown occurring on the reverse biasing of a zener diode. Zener breakdown occurs when the electric field in the depletion layer increases to the point where it can break covalent bonds and generate electron-hole pairs.

zener diode a pn-junction diode that has an abrupt rise in current at a reverse-bias voltage V_z, which is usually between 3 to 6 volts. Zener diodes are deliberately fabricated to operate in the reverse breakdown region at a specified voltage and are often used in voltage reference or voltage regulator circuits.

zero the values of a complex function which cause the value of the function to equal zero. The zeros are all natural frequencies of vibration, or resonances of the circuit described by the equation. They are influenced by all elements in the circuit, and will move with any circuit element change (susceptible to load pulling).

zero coprimeness of 2-D polynomial matrices 2-D polynomial matrices $A \in F^{p\times m}[z_1, z_2]$, $B \in F^{q\times m}[z_1, z_2]$ $(p + q \geq m \geq 1)$ are called zero right coprime if there exists a pair (z_1, z_2) that is a zero of all $m \times m$ minors of the matrix

$$\begin{bmatrix} A \\ B \end{bmatrix}$$

2-D polynomial matrices $A \in F^{m\times p}[z_1, z_2]$, $B \in F^{m\times q}[z_1, z_2]$ are called zero left coprime if the transposed matrices A^T, B^T are zero right coprime.

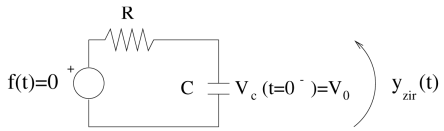
zero crossing a point where a function changes sign; in a digital image I, a point $\mathbf{x}$ for which $I(\mathbf{x}) > 0$ and $I(\mathbf{x} + \Delta\mathbf{x}) < 0$ for some $\Delta\mathbf{x}$, or vice versa.

zero current switching (ZCS) the control of converter switches such that the switch is turned on or off only when the current through it is zero at the switching instant. This is typically achieved through the use of some form of LC resonance.

zero divide *See* divide by zero.

zero flag a bit in the condition code register that indicates whether the result of the last arithmetic or logic instruction is zero (1 for zero, 0 for not zero).

zero input response (ZIR) the response of a system to initial conditions (i.e., to the initial energy present in the system) only. For example, the zero input response (ZIR) of the RC circuit shown in the figure is the signal $y_{zir}(t)$, $t \geq 0$ to the initial voltage across the capacitor, with zero voltage applied at the source.



RC circuit zero input response.

zero of 2-D transfer matrix a pair of complex numbers (z_1^0, z_2^0)

$$T(z_1, z_2) = \frac{N(z_1, z_2)}{d(z_1, z_2)},$$
$$N(z_1, z_2) \in R^{p \times m}[z_1, z_2]$$

that satisfy the condition that the rank of the matrix $N(z_1^0, z_2^0)$ drops below the normal rank of the polynomial matrix $N(z_1, z_2)$, i.e.,

$$\text{rank } N\left(z_1^0, z_2^0\right) < \min(m, p)$$

where $R^{p \times m}[z_1, z_2]$ is the set $p \times m$ polynomial matrices in z_1 and z_2 with real coefficients.

zero of generalized 2-D linear system a pair of complex numbers (z_1^0, z_2^0)

$$Ex_{i+1,j+1} = A_0 x_{ij} + A_1 x_{i+1,j} + A_2 x_{i,j+1} + B_0 u_{ij} + B_1 u_{i+1,j} + B_2 u_{i,j+1}$$
$$y_{ij} = Cx_{ij} + Du_{ij}$$

with the system matrix

$$S(z_1, z_2) = \begin{bmatrix} G(z_1, z_2) & -B(z_1, z_2) \\ C & D \end{bmatrix}$$

$$G(z_1, z_2) := Ez_1z_2 - A_0 - A_1z_1 - A_2z_2$$
$$B(z_1, z_2) := B_0 + B_1z_1 + B_2z_2$$
$$\text{if rank } S\left(z_1^0, z_2^0\right) < n + \min(m, p)$$

where $x_{ij} \in R^n$ is the semistate vector, $u_{ij} \in R^m$ is the input vector, $y_{ij} \in R^p$ is the output vector, A_k, B_k $(k = 0, 1, 2)$, C, D are real matrices with E possibly singular. A zero of 2-D transfer matrix. (*See also* zero of 2-D transfer matrix) is always zero of the system.

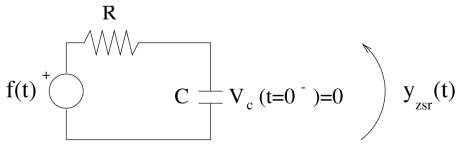
zero order hold (ZOH) a procedure that samples a signal $x(t)$ at a given sampling instant and holds that value until the succeeding sampling instant.

zero padding technique where a discrete finite length signal is padded by adding some number of zeros at the end of the signal. The discrete Fourier transform of a zero padded signal has more frequency samples or components than that of a nonzero padded signal, although the frequency resolution is not increased. Zero padding is also sometimes used with the discrete Fourier transform to perform a convolution between two signals.

zero phase filter a filter whose Fourier transform is purely real. In this way the phase response is zero. A filter considered as a signal has zero phase if it is an even signal.

zero sequence the set of in-phase components used in symmetrical component analysis. Zero sequence currents are closely associated with ground current in a grounded wye system, and do not directly flow in an ungrounded delta system.

zero state response (ZSR) the response of a system with zero initial conditions (i.e., zero initial energy present in the system) to an applied input. For example, in the following circuit, the zero state response (ZSR) is the signal $y_{zsr}(t)$, $t \geq 0$ when the input voltage $f(t)$ is applied, and there is zero initial voltage across the capacitor.



RC circuit zero state response.

zero voltage switching (ZVS) the control of converter switches such that the switch is turned on or off only when the voltage across it is zero at the switching instant. This is typically achieved through the use of some form of LC resonance.

zero-address computer a class of computer based on zero-address instructions. Stack-based calculators use zero-address computers and can be programmed using postfix notation.

zero-address instruction a class of assembly language ALU instruction in which the operands are kept on a first-in-first-out stack in the CPU, and thus require no explicit addresses.

zero-coefficient sensitivity analysis technique used for evaluation of circuit functions strongly dependent on zero locations (some bridge circuits and bridge oscillators). Zero-coefficient sensitivity is introduced in a way similar to pole-coefficient sensitivity.

zero-error capacity for a given channel, the highest information transmission rate, such that there exists channel codes with decoding error probability identically zero. *See also* capacity region.

zero-sequence reactance the reactive component of the zero sequence impedance. *See also* symmetrical component.

zero-sum game one of a wide class of noncooperative two-person games in which the sum of the cost functions of the decision makers is identically zero. In the zero-sum games, cooperation between players is impossible because the gain of one player is a loss of the other one. Thus, the game is characterized by only one cost function, which is minimized by the first player and maximized by the second one. To the zero-sum game one could also transform a constant-sum game in which the sum of the cost functions is constant. The solution in the zero-sum games has a form of saddle-point equilibrium, and roughly speaking it exists for problems in which max and min operations on the cost function commute. In zero-sum games without equilibrium in pure strategies it is possible to find saddle point in mixed strategies if the game is played many times in the same conditions. The resulting outcomes are average gains or losses of the players.

zig-zag ground (1) a grounding arrangement which is used to supply single phase grounded circuits from an ungrounded three-phase delta connected electric power line.

(2) the winding arrangement within a grounding transformer.

zinc oxide arrester a lightning arrester that consists of a stack of ZnO disks stacked within a vented porcelain tube. *See* gapless arrester.

zip a file format and a set of data compression algorithms used to store one or more files in a single file. Originally devised by Phil Katz and placed in the public domain.

ZIR *See* zero input response.

Ziv–Lempel (ZL) coding a method for lossless source coding, due to J. Ziv and A. Lempel (1977). ZL coding is capable of achieving the bound given by the source coding theorem. Commonly used to compress computer files. *See also* LZ77, LZ78, and Lempel-Ziv-Welch coding.

ZL coding *See* Ziv–Lempel coding.

ZOH *See* zero order hold.

zonal coding a coding scheme in transform coding in which only those transform

coefficients located in a specified zone in the transform domain are coded. For its counterpart, refer to threshold coding.

zonal sampling in threshold sample selection it is difficult to transmit to the receiver which coefficients were sent and which were not. In zonal coding, all coefficients are transmitted in order of increasing spatial frequency or some other predetermined order and a end-of-block code-word is sent when all code words are below the threshold. *See also* threshold sample selection.

zone of protection the area of a power system for which a particular set of protective relays has primary protection responsibility. In typical cases, operation of any of these relays will open circuit breakers which will isolate this zone. Each major power system component (line, transformer, bus, generator) has a separate zone of protection.

zone plate a Fresnel optical circular grating that produces the spatial frequencies to measure the resolution and the performance of telephoto- graphic or television systems. A moving Fresnel zone plate can measure the performance of line- or frame-based comb filters, the performance of scan converters, and the scan aperture of television images.

zone recording a technique that allows the number of sectors per track on a magnetic disk to vary with the radius of the track. The tracks are divided into several zones, such that the number of sectors per track is determined by the maximum possible bit density on the innermost track in each zone.

ZSR *See* zero state response.

ZVS *See* zero voltage switching.