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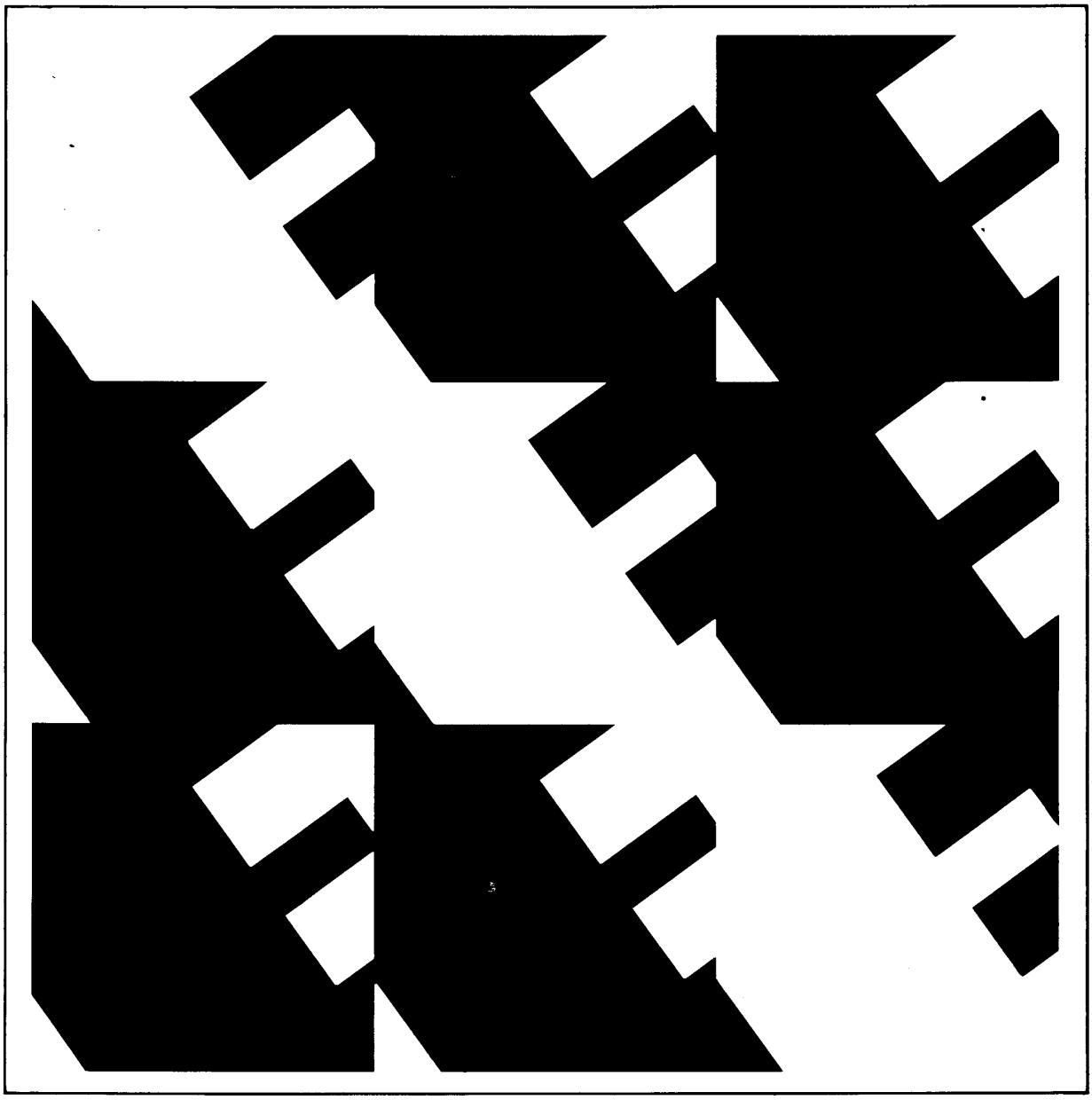
IEEE Standard Definitions of Terms for Analog Computers



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IEEE Standard Definitions of Terms for Analog Computers

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**Standards Committee of the
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**The Institute of Electrical and Electronics Engineers, Inc
345 East 47th Street, New York, NY 10017, USA**

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Foreword

(This Foreword is not part of IEEE Std 165-1977, Standard Definitions of Terms for Analog Computers.)

Since 1958, when its Subcommittee on Analog Computers — Definitions and Symbols — initiated work on definitions for analog computer terms, the IEEE has been actively involved in the standardization of terminology relating to electronic computers. The need for standardized terminology in electrical and electronics technology was apparent from the earliest days of the IEEE's predecessor societies, and much of the significant standards contribution during the last eighty years has been in standard definitions.

The work was performed by the Standards Subcommittee on Analog and Hybrid Linkage Components, chaired by Arthur I. Rubin, who was the sole contributor. Many thanks are due to those who made helpful comments and suggestions for improving the definitions. These include A. Anuff, B. B. Barrow, G. S. Axelby, G. H. McAfee, and W. T. Wintringham. In addition, the Standards Committee of the Society for Computer Simulation also reviewed this standard.

The first edition of IEEE Std 165-1963 was approved in 1962 and published in the following year. That standard was reaffirmed in 1972, and work on the present revision was undertaken shortly thereafter. In addition to this revised standards document, the IEEE Computer Society has undertaken more than a dozen specialized computer definition standards projects which are in progress at the time this revision is published. It is hoped that this work will substantially improve communications between all those working within the technology.

IEEE Standard Definitions of Terms for Analog Computers

INTRODUCTORY NOTE: **Boldface** is used for alphabetical entries and in the body of the essay at the point where the boldface term is being defined.

Italics are used only where the meaning and context may not be clear and where the terms are defined elsewhere.

absolute-value circuit. A transducer or circuit that produces an output signal equal in magnitude to the input signal but always of one polarity.

accuracy. (1) Conformity of a measured value to an accepted standard value. (2) A measure of the degree by which the actual output of a device approximates the output of an ideal device nominally performing the same function.

accuracy, dynamic. Accuracy determined with a time-varying output.

accuracy, static. Accuracy determined with a constant output.

amplifier. A device that enables an input signal to control a source of power and thus is capable of delivering at its output a reproduction or analytic modification of the essential characteristics of the signal (see Ref [1]).

amplifier, buffer. An amplifier in which the reaction of the output-load-impedance variation on the input circuit is reduced to a constant for isolation purposes on the input circuit (see Ref [2]). See also *unloading amplifier.*

amplifier, high-gain dc. An amplifier that is capable of amplification substantially greater than required for a specified operation throughout a frequency band extending from zero to some maximum. Also, an operational amplifier without feedback circuit elements. See also *operational amplifier.*

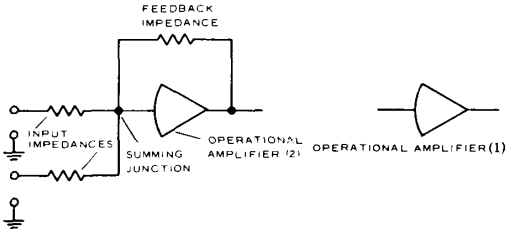
amplifier, integrating. An *operational amplifier* that produces an output signal equal to the time integral of a weighted sum of the input signals.

NOTE: In an analog computer, the term *integrator* is synonymous with *integrating amplifier.*

amplifier, inverting. An *operational amplifier* that produces an output signal of nominally equal magnitude and opposite algebraic sign to the input signal.

NOTE: In an analog computer, the term *inverter* is synonymous with *inverting amplifier.*

amplifier, operational. (1) An amplifier, usually a *high-gain dc amplifier,* designed to be used with external circuit elements to perform a specified computing operation or to provide a specified transfer function. (See Fig 1.) (2) An amplifier, usually a *high-gain dc amplifier,* with external circuit elements, used for performing a specified computing operation. (See also *integrating amplifier, summing amplifier,* and *inverting amplifier.*)



OPERATIONAL AMPLIFIER (1), TYPICAL ARRANGEMENT

Fig 1

NOTES:

(1) The gain and phase characteristics are generally designed to permit large variations in the feedback circuit without instability.

(2) The input terminal of an *operational amplifier* (1) is the *summing junction* of an *operational amplifier* (2) and is generally designed to draw current that is negligibly small relative to signal currents in the *feedback impedance.*

amplifier, relay. An amplifier that drives an electromechanical relay.

amplifier, servo. An amplifier, used as part of a servomechanism, that supplies power to the electrical input terminals of a mechanical actuator.

amplifier, summing. An *operational amplifier* that produces an output signal equal to a weighted sum of the input signals.

NOTE: In an analog computer, the term *summer* is synonymous with *summing amplifier.*

amplifier, unloading. An amplifier that is capable of reproducing or amplifying a given voltage signal while drawing negligible current from the voltage source.

NOTE: In an analog computer, the term *buffer amplifier* is sometimes used as a synonym for *unloading amplifier,* in an incorrect sense, since a buffer amplifier draws *significant* current, but at a constant load impedance (seen at the input).

analog (ADJ). Pertaining to representation by means of continuously variable physical quantities, for example, to describe a physical quantity, such as voltage or shaft position, that normally varies in a continuous manner, or devices such as potentiometers and synchros that operate with such quantities.

analog computer. An automatic computing device that operates in terms of continuous variation of some physical quantities, such as electrical voltages and currents, mechanical shaft rotations, or displacements, and which is used primarily to solve differential equations. The equations governing the variation of the physical quantities have the same or very nearly the same form as the mathematical equations under investigation and, therefore, yield a solution analogous to the desired solution of the problem. Results are measured on meters, dials, oscillograph recorders, or oscilloscopes (see also *simulator*).

analog computer, ac. An analog computer in which electrical signals are of the form of amplitude-modulated suppressed carrier signals where the absolute value of a computer variable is represented by the amplitude of the carrier and the sign of a computer variable is represented by the phase (0 to 180 degrees) of the carrier relative to the reference ac signal.

analog computer, dc. An analog computer in which computer variables are represented by the instantaneous values of voltages.

attenuator. A device for reducing the amplitude of a signal without introducing appreciable distortion.

automatic component interconnection matrix (see also *problem board*). A hardware system for connecting inputs and outputs of parallel computing components according to a predetermined program. This system, which may consist of a matrix of mechanical or electronic switches, or both, replaces the manual program *patch panel* and patch cords on analog computers.

autopatch (see *automatic component interconnection matrix*).

automatic control. In an analog computer, a method of computer operation using auxiliary automatic equipment to perform *computer-control state* selections, switching operations, or component adjustments in accordance with previously selected criteria. Such auxiliary automatic equipment usually consists of programmable digital logic which is part of the analog, a separate digital computer, or both. The case of the digital computer controlling the analog computer is an example of a *hybrid computer.*

balance check. The *computer-control state* in which all amplifier *summing junctions* are connected to the computer zero reference level (usually signal ground) to permit zero balance of the *operational amplifiers.* Integrator capacitors may be shunted by a resistor to permit the zero balance of an *integrator.* This control state may not be found in some analog computers.

balancing of an operational amplifier. The act of adjusting the output level of an *operational amplifier* to coincide with its input reference level, usually ground or zero voltage, in the *"balance check"* computer-control state. This operation may not be required in some amplifiers, and there may be no provision for performing it.

bandwidth. (1) Of a signal, the difference between the limiting frequencies encountered in the signal. (2) Of a device, the range of frequencies within which performance in respect to some characteristic falls within specific limits.

bridge limiter (see *limiter circuit*).

check solution. A solution to a problem obtained by independent means to verify a computer solution.

chopper. A mechanical, electrical, or electromechanical device that converts dc into a square wave. As applied to a direct-coupled *operational amplifier,* it is a modulator used to convert the dc at the *summing junction* to ac for amplification and reinsertion as a correcting voltage to reduce *offset.*

coefficient potentiometer (see *parameter potentiometer*).

comparator. A circuit, having only two logic output states, for comparing the relative amplitudes of two analog variables, or of a variable and a constant, such that the logic signal output of the comparator uniquely determines which variable is the larger at all times.

computer. (1) A machine for carrying out calculations. (2) By extension, a machine for carrying out specified transformations on information.

computer component. Any part, assembly, or subdivision of a computer, such as resistor, amplifier, power supply, or rack.

computer-control state. One of several distinct and selectable conditions of the computer-control circuits. See also *balance check, hold, operate, potentiometer set, reset,* and *static test.*

computer diagram. A functional drawing showing interconnections between computing elements, such interconnections being specified for the solution of a particular set of equations. (See also *computer program* and *problem board.*)

computer equation (machine equation). An equation derived from a mathematical model for use on a computer (see also *scale factor*) which is equivalent or proportional to the original equation.

computer program. That combination of *computer diagram, potentiometer list, amplifier list, trunk list, switch list, scaled equations,* and any other documentation that defines the analog configuration for the particular problem to be solved. This term sometimes is used to include the *problem patch board* as well, and, in some loose usage, the *computer program* may be (incorrectly) used to refer solely to the *program patch panel.*

computer time (see *time*).

computer variable (machine variable) (see *scale factor*).

computing element. A computer component that performs a mathematical operation required for problem solution. It is shown explicitly in *computer diagrams,* or *computer programs.*

conformity. As applied to a potentiometer, the accuracy of its output; used especially in reference to a *function potentiometer.*

correction (see *error*).

curve follower (see *curve-follower function generator*).

differential analyzer. A computer designed primarily for the convenient solution of differential equations.

differentiator. A device producing an output proportional to the derivative of one variable with respect to another, usually time.

digital coefficient attenuator (see under *hybrid computer linkage components* Ref [4]).

digital differential analyzer (DDA). A special-purpose digital computer consisting of many computing elements, all operating in parallel, that performs integration by means of a suitable integration code on incremental quantities and that can be programmed for the solution of differential equations in a manner similar to an analog computer.

digital logic elements. In an analog computer, a number of digital functional modules, consisting of logic gates, registers, flip-flops, timers, etc, all operating in parallel, either synchronously or asynchronously, and whose inputs and outputs are interconnected, according to a "logic program," via *patch cords,* on a *patch board.*

divider. (1) A device capable of dividing one variable by another. (2) A device capable of attenuating a variable by a constant or adjustable amount, as an *attenuator.*

drift. In an analog computer, a slowly varying error in an integrator, caused by the integration of offset errors at the inputs, capacitor leakage, or both. Also, any slowly varying error in a computer component.

drift, zero. Drift with zero input.

dynamic check (see *problem check*).

dynamic computer check (see *problem check*).

dynamic problem check (see *problem check*).

dynamic range. The ratio of the specified maximum signal level capability of a system or component to its noise or resolution level, usually expressed in decibels. Also, the ratio of the maximum-to-minimum amplitudes of a variable during a computer solution.

error. (1) In science, the difference between the true value and a calculated or observed value. A quantity (equal in absolute magnitude to the error) added to a calculated, indicated, or observed value to obtain the true value is called a **correction.** (2) In a computer or data processing system, any incorrect step, process, or result. In the computer field, the following terms are commonly used: a machine malfunction is a "machine error" (or "computer error"); an incorrect program is a "program error"; and a human mistake is a "human error" (or "operator error"). Frequently it is helpful to distinguish among these errors as follows: an **error** results from approximations used in numerical methods or imperfections in analog components; a **mistake** results from incorrect programming, coding, data transcription, manual operation, etc; a **malfunction** results from a failure in the operation of a machine component such as a gate, a flip-flop, or an amplifier.

error, dynamic. An error in a time-varying signal resulting from imperfect dynamic response of a transducer.

error, linearity. An error which is the deviation of the output quantity, from a specified linear reference curve.

error, loading. An error due to the effect of a load impedance upon the transducer or signal source driving it.

error, resolution. The error due to the inability of a transducer to manifest changes of a variable smaller than a given increment.

error, static. An error independent of the time-varying nature of a variable. Also known as the dc error.

feedback limiter (see *limiter circuit*).

full scale. In an analog computer, the nominal maximum value of a computer variable or the nominal maximum value at the output of a computing element. Also sometimes used to indicate the entire computing voltage range, such as 20V is *full scale* for a computer whose voltage ranges from +10V to −10V. The latter definition is generally used in manufacturers' specifications, that is, 0.01 percent of *full scale.*

function generator. A computing element whose output is a specified nonlinear function of its input or inputs. Normal usage excludes *multipliers* and *resolvers.*

function generator, card set. A *diode function generator* whose values are stored and set by means of a punched card and a mechanical card-reading device.

function generator, curve-follower. A function generator that operates by automatically following a curve $f(x)$ drawn or constructed on a surface, as the input x varies over its range.

function generator, digitally controlled. A hybrid component using DAC's and DAM's to insert the linear segment approximation values to the desired arbitrary function. The values are stored in a self-contained digital core memory, which is accessed by the DAC's and DAM's at digital-computer speeds (microseconds).

function generator, diode. A function generator that uses the transfer characteristics of resistive networks containing biased diodes. The desired function is approximated by linear segments whose values are manually inserted by means of potentiometers and switches.

function generator, multi-variable. A function generator with more than one input.

function relay. In an analog computer, a relay used as a computing element, generally driven by a comparator.

function switch. In an analog computer, a manually operated switch used as a computing element; for example, to modify a circuit, to add or delete an input function or constant, etc.

ground loop. A potentially detrimental loop formed when two or more points in an electrical system that are nominally at ground potential are connected by a conducting path such that either or both points are not at the same ground potential.

hard limiting (see *limiter circuit*).

hold. In an analog computer, the *computer control state* in which the problem solution is stopped and held at its last values usually by automatic disconnect of integrator input signals.

hybrid computer. A computer which consists of two main computers, one a dc analog computer, and the other a digital computer, with appropriate control and signal interface, such that they may simultaneously operate or solve, or both, upon different portions of a single problem. (See also *hybrid computer linkage components* [4].)

impedance, feedback. In an analog computer, a passive network connected between the output terminal of an *operational amplifier* and its *summing junction.*

impedance, input. In an analog computer, a passive network connected between the input terminal or terminals of an *operational amplifier* and its *summing junction.*

impedance, output. The impedance presented by the transducer to a load (see Ref [3]).

implicit computation. Computation using a self-nulling principle in which, for example, the variable sought is first assumed to exist, after which a synthetic variable is produced according to an equation and compared with a corresponding known variable and the difference between the synthetic and the known variable driven to zero by adjusting the assumed variable. Although the term applies to most analog circuits, even to a single *operational amplifier,* it is restricted usually to computation performed by (1) circuits in which a function is generated at the output of a single *high-gain dc amplifier* by inserting an element generating the inverse function in the feedback path, (2) circuits in which combinations of computing elements are interconnected in closed loops to satisfy implicit equations, or (3) circuits in which linear or nonlinear differential equations yield the solutions to a system of algebraic or transcendental equations in the steady state.

initial condition. The value of a variable at the start of computation. (See also *reset.*) A more restricted definition refers solely to the initial value of an *integrator.* Also used as a synonym for the *computer-control state* **"reset."**

input limiter (see *limiter circuit*).

integrator. A device producing an output proportional to the integral of one variable or of a sum of variables, with respect to another variable, usually time. (See also *amplifier, integrating.*)

integrator, gain. For each input, the ratio of the input to the corresponding time rate of change of the output. For fixed input resistors, the "time constant" is determined by the integrating feedback capacitor.

inverter (see *amplifier, inverting*).

iterative operation (see *repetitive operation*).

leakage. (1) Undesirable conductive paths in certain components; specifically, in capacitors, a path through which a slow discharge may take effect; in *problem boards,* interaction effects between electrical signals through insufficient insulation between patch bay terminals. (2) Current flowing through such paths.

limiter circuit. A circuit of nonlinear elements that restrict the electrical excursion of a variable in accordance with some specified criteria. (See also *stop.*) **Hard limiting** is a limiting action with negligible variation in output in the range where the output is limited. **Soft limiting** is a limiting action with appreciable variation in output in the range where the output is limited. A **bridge limiter** is a bridge circuit used as a *limiter circuit.* In an analog computer, a **feedback limiter** is a *limiter circuit* usually employing biased diodes shunting the feedback component of an *operational amplifier;* an *input limiter* is a *limiter circuit* usually employing biased diodes in the amplifier input channel that operates by limiting the current entering the *summing junction.*

linear system or element. A system with the properties: if y_1 is the response to x_1 and y_2 is the response to x_2, then (i) $(y_1 + y_2)$ is the response to $(x_1 + x_2)$ and (ii) ky_1 is the response to kx_1.

linearity. A property of a component describing a constant ratio of incremental cause and effect. **Proportionality** is a special case of linearity in which the straight line passes through the origin. **Zero-error reference** of a linear transducer is a selected straight-line function of the input from which output errors are measured. **Zero-based linearity** is transducer linearity defined in terms of a *zero-error reference* where zero input coincides with zero output.

linearity of a multiplier. (1) The ability of an electromechanical or electronic multiplier to generate an output voltage that varies linearly with either one of its two inputs, provided the other input is held constant. (2) The accuracy with which the above requirement is met. **Linearity of a potentiometer** is the accuracy with which a potentiometer yields a linear but not necessarily a proportional relationship between the angle of rotation of its shaft and the voltage appearing at the output arm, in the absence of loading errors.

machine time (see *time*).

malfunction (see *error*).

mathematical model. A set of equations used to represent a physical system.

mistake (see *error*).

multiple. A junction into which patch cords may be plugged to form a common connection.

multiplier. In an analog computer, a device capable of multiplying one variable by another.

multiplier, constant. A computing element that multiplies a variable by a constant factor.

multiplier, four-quadrant. A multiplier in which operation is unrestricted as to the sign of both of the input variables.

multiplier, two-quadrant. A multiplier in which operation is restricted to a single sign of one input variable only.

multiplier, servo. An electromechanical multiplier in which one variable is used to position one or more ganged potentiometers across which the other variable voltages are applied.

noise. Unwanted disturbances superimposed upon a useful signal, which tend to obscure its information content. **Random noise** is the part of the noise that is unpredictable, except in a statistical sense.

noise generator. In an analog computer, a computing element used purposely to introduce noise of specified amplitude distribution, spectral density, or rms value, or appropriate combination thereof into other computing elements.

offset. In a transducer, the component of error that is constant and independent of the inputs, often used to denote bias.

operate. In an analog computer, the *computer-control state* in which input signals are connected to all appropriate computing elements, including integrators, for the generation of the solution.

operational relay. A relay that may be driven from one position or state to another by an *operational amplifier* or a *relay amplifier.* (See also *function relay.*)

oven. An enclosure and associated sensors and heaters for maintaining components at a controlled and usually constant temperature.

overload. In an analog computer, a condition existing within or at the output of a computing element that causes a substantial computing error because of the voltage or current saturation of one or more of the parts of the computing element. Similar to an overflow of an accumulator in a digital computer.

patch bay. In an analog computer, a concentrated assembly of the inputs and outputs of computing elements, control elements, tie points, reference voltages, and ground points that offers a means of electrical connection.

patch board (see *problem board*).

polar mode (see *resolver*).

potentiometer. A resistive element with two end terminals and a movable contact. (See also *attenuator.*)

potentiometer, digital coefficient (see under *digital coefficient potentiometer—hybrid computer linkage component,* Ref [4]).

potentiometer, grounded. A potentiometer with one end terminal attached directly to ground.

potentiometer, linear. A potentiometer in which the voltage at a movable contact is a linear function of the displacement of the contact. (See also *linearity.*)

potentiometer, manual. A potentiometer which is set by hand, also known as a *hand-set potentiometer.*

potentiometer, multiplier. Any of the ganged potentiometers of a *servo multiplier* that permit the multiplication of one variable by a second variable.

potentiometer, parameter (scale-factor potentiometer or **coefficient potentiometer).** A potentiometer used in an analog computer to represent a problem parameter such as a coefficient or a scale factor.

potentiometer, servo. A potentiometer driven by a positional servomechanism.

potentiometer, ungrounded. A potentiometer with neither end terminal attached directly to ground.

potentiometer granularity. The physical inability of a potentiometer to produce an output voltage that varies in other than discrete steps, due either to contacting individual turns of wire in a wire-wound potentiometer or to discrete irregularities of the resistance element of composition or film potentiometers.

potentiometer set. A *computer-control state* that supplies the same operating potentiometer loading as under computing conditions, and thus allows correct potentiometer adjustment. (See also *problem check.*)

precision. Exactly or sharply defined or stated. A measure of the precision of a representation is the number of distinguishable alternatives from which it was selected, which is sometimes indicated by the number of significant digits it contains. (See also *accuracy.*)

problem board (patch board, patch panel, prepatch panel). In an analog computer, a removable frame of receptacles for *patch cords* and plugs that, through a *patch bay,* offers a means for interconnecting the inputs and outputs of computing elements, etc, according to the *computer diagram.*

problem check. One or more tests used to assist in obtaining the correct machine solution to a problem. **Static check** consists of one or more tests of computing elements, their interconnections, or both, performed under static conditions. **Dynamic check** consists of one or more tests of computing elements, their interconnections, or both, performed under dynamic conditions. **Rate test** is a test that verifies that the time constants of the integrators are those selected. This term also refers to the computer-control state that implements the rate test previously described. **Dynamic problem check** is any dynamic check used to ascertain the correct performance of some or all of the computer components. (See also *computer-control state.*)

problem variable (see *scale factor*).

proportionality (see *linearity*).

rate test (see *problem check*).

recorder. A device that makes a permanent record, usually graphic, of varying signals.

recorder, strip chart. A recorder in which one or more records are made simultaneously as a function of time.

recorder, $x-y$ (plotting board). A recorder that makes a record of any one voltage with respect to another.

rectangular mode (see *resolver*).

reference voltage. In an analog computer, a voltage used as a standard of reference, usually the nominal *full scale* of the computer.

repeatability. A quantitative measure of the agreement among repeated operations.

repetitive operation. In an analog computer, a condition in which the computer operates as a repetitive device; the solution time may be a small fraction of a second or as long as desired, after which the problem is automatically and repetitively cycled through *reset, hold,* and *operate.*

iterative operation. Similar in many respects to *repetitive operation,* except that the automatic recycling of the computer is controlled by programmed logic circuits, which generally include a program change for a parameter(s), variable(s), or combinations of these between successive solutions, resulting in an iterative process which tends to converge on desired values of the parameter(s) or variables(s) that have been changed.

reset. The *computer-control state* in which integrators are held constant and the proper initial condition voltages or charges are applied or reapplied. (See also *initial condition.*)

resolver. A device or computing element used for vector resolution or composition. The **rectangular mode** is the mode of operation that produces a transformation from polar to rectangular coordinates or a rotation of rectangular coordinates. The **polar mode** is the mode of operation that produces a transformation from rectangular to polar coordinates.

scale factor. The multiplication factor necessary to transform problem variables to computer variables. A **problem variable** is a variable appearing in the mathematical model of the problem. A **computer variable** is a dependent variable as represented on the computer. (See also *time.*)

simulation. The representation of an actual or proposed system by the analogous characteristics of some device easier to construct, modify, or understand.

simulation, mathematical. The use of a model of mathematical equations generally solved by computers to represent an actual or proposed system.

simulator. A device used to represent the behavior of a physical system by virtue of its analogous characteristics. In this general sense, all computers are, or can be, simulators. However, in a more restricted definition, a simulator is a device used to interact with, or to train, a human operator in the performance of a given task or tasks.

soft limiting (see *limiter circuit*).

stabilization, drift. Any automatic method used to minimize the drift of a dc amplifier.

stabilization network. As applied to *operational amplifiers,* a network used to shape the transfer characteristics to eliminate or minimize oscillations when feedback is provided.

static check (see *problem check*).

static test. The computer-control state which applies a predetermined set of voltages and conditions to the analog computer, which al-

lows the *static check* to be executed.

summing junction. The junction common to the input and feedback impedances used with an *operational amplifier.*

time, real. Using an ordinary clock as a time standard, the number of seconds measured between two events occurring in a physical system. By contrast, **computer time** is the number of seconds measured, with the same clock, between corresponding events in the simulated system. The ratio of the time interval between two events in a simulated system to the time interval between the corresponding events in the physical system is the **time scale.** *Computer time* is eual to the product of *real time* and the *time scale.* **Real-time computation** is computer operation in which the *time scale* is unity. **Machine time** is synonymous with *computer time.* (See also *scale factor.*)

time delay. The time interval between the manifestation of a signal at one point and the manifestation or detection of the same signal at another point.

NOTES:

(1) Generally, the term *time delay* is used to describe a process whereby an output signal has the same form as an input signal causing it, but is delayed in time; that is, the amplification of all frequency components of the output are related by a single constant to those of corresponding input frequency components but each output component lags behind the corresponding input component by a phase angle proportional to the frequency of the component.

(2) **Transport delay** is synonymous with *time delay* but usually is reserved for applications that involve the flow of material.

time scale (see *time*).

time skew (see under *hybrid computer linkage components—converters, analog to digital* Ref. [4]).

track store. In an analog computer, a component, controlled by **digital logic** signals, whose output equals the input, when in the "track" mode, and whose output becomes constant and is held (stored) at the value it possessed at the instant its mode was switched to the "store" mode.

transport delay (see *time delay*).

trunk. A connecting line between one analog computer and another, or between an analog computer and an external point, allowing the input (or output) of an analog component to communicate directly with the output (or input) of another component which is located outside of the analog computer.

unloading circuit. In an analog computer, a computing element or combination of computing elements capable of reproducing or amplifying a given voltage signal while drawing negligible current from the voltage source, thus eliminating any possible loading errors. (See also *unloading amplifier.*)

zero-based linearity (see *linearity*).

zero-error reference (see *linearity*).

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[1] IRE Std 3.S1-1958, IRE Standards on Audio Techniques: Definitions of Terms, 1958, Proceedings of the IRE, vol 46, pp 1928-1934, December 1958.

[2] IRE Std 2, 11, 15-S1-1948, IRE Standards on Antennas, Modulation Systems, and Transmitters: Definitions of Terms, 1948, Separate Report.

[3] IEEE Std 151-1965, Standard Definitions of Terms for Audio and Electroacoustics, p 7.

[4] IEEE Std 166-1977, Standard Definitions of Terms for Hybrid Computer Linkage Components.