

# Appendixes

## APPENDIX A

# Glossary\*

---

**acceptable quality level (AQL).**—The fraction of defective items permitted in a group of parts (e.g., integrated circuits) that pass the statistical sampling tests agreed to by manufacturer and purchaser. An AQL of 0.01 percent, for instance, means that no more than 1 defect per 10,000 parts, on the average, is allowed.

**access time.**—The time required to retrieve the contents from a specified memory location in a computer system, commonly the average time to fetch a bit from an integrated circuit memory chip.

**active device.**—An electronic component that can control or regulate an electrical signal. Examples include most kinds of vacuum tubes, as well as transistors.

**actuator.**—Causes mechanical force or motion in response to an electrical signal. Examples include hydraulic cylinders (in conjunction with other control system components) and electric motors.

**A/D converter (analog/digital converter).**—A circuit that transforms analog electrical signals into the equivalent or proportional digital representation, commonly so that they can serve as inputs to a computer system.

**advance pricing (also termed forward pricing).**—Setting prices for manufactured goods below current costs in the expectation that these costs will fall as production experience accumulates and scale increases. A common pricing strategy for integrated circuits, where advance pricing has been used to gain early market share, sacrificing immediate profits for those in the somewhat longer term.

**analog.**—Refers to electrical signals that can vary continuously over a range, as compared to digital signals, which are restricted to a pair of nominally discrete values.

**architecture.**—The overall logic structure of a computer or computer-based system.

**binary.**—Number system in which all values are represented by combinations of a pair of symbols—e.g., “0” and “1.” In contrast, the familiar decimal or base 10 system represents all numbers by combinations of the 10 symbols “0” to “9.”

**bipolar.**—Transistors or integrated circuits in which electrical conduction takes place through the motion of both negative and positive charges.

The negative charges are electrons, while the positive consist of the absence of electrons where these negatively charged particles would ordinarily be (the electronic vacancy, or “hole,” leads to a net positive charge). Bipolar ICs are faster than unipolar (MOS) chips, but not as dense. They also dissipate more electrical power.

**bit.**—A binary digit, which can take on one of two values, typically written as “0” or “1.”

**bite (byte).**—A group of binary bits, usually 8.

**bubble memory.**—A solid-state microelectronic device in which binary data is stored in tiny magnetic domains (bubbles) given one of two possible polarities. Bubble memories are nonvolatile but not random access; to read or rewrite data in a given location, a string of bubbles must be moved past a detector to reach the desired memory location. Thus the access time depends on where in the string with respect to the detector that location happens to be.

**bus.**—Circuit path by which electrical signals move between components (e. g., microprocessor and memory chip) or between circuit boards.

**capacitor.**—Passive circuit element that stores electrical charge, creating a voltage differential. Capacitors can be fabricated within integrated circuits, as well as in the form of discrete components.

**captive.**—A semiconductor manufacturer whose output goes primarily for intracorporate consumption.

**chip.**—An integrated circuit, either partially or fully completed.

**circuit board.**—A card or board of insulating material on which components such as semiconductor devices, capacitors, and switches are installed.

**clock.**—An electronic circuit, often an integrated circuit, that produces high-frequency timing signals. A common application is synchronization of the operations performed by a computer or microprocessor-based system. Typical clock rates in microprocessor circuits are in the megahertz range, 1 megahertz equaling  $10^6$  cycles per second.

**core memory.**—Computer memory in the form of magnets that can have one of two states, thus enabling storage of binary data. Now largely obsolescent as a result of integrated circuit memory chips.

**CPU (central processing unit).**—The portion of a

\* Many of the technical terms included in this glossary are explained in more detail, often with examples, in chapter 3. See, in particular, appendixes 3A and 3B at the end of that chapter.

- digital computer where logical operations are performed under the direction of software—in other words, the portion of a computer system where the program is executed.
- CRT (cathode ray tube).—Displays an image on a screen—as in a TV set or a computer terminal—in response to electrical signals.
- D/A **converter (digital/analog converter)**.—An electrical circuit that changes a digital signal into equivalent or proportional analog form. See *A/D converter*.
- dedicated.—A piece of equipment—e.g., a computer processor—reserved for a single function, such as aircraft flight control or the operation of a microwave oven. Dedicated processors are often embedded within a more complex system so that they are invisible to casual users. This is the case, for example, with the computers used in electronic banking terminals.
- digital.—Refers to equipment or systems which operate on electrical signals that can be represented as strings of binary bits. In electronic circuitry, a pair of nominally discrete voltage levels commonly stand for the two possible values associated with each bit.
- disk drive.—Computer peripheral in which data is stored magnetically on a rigid or flexible (floppy) disk. In many cases, disks can be removed and replaced. A drive unit rotates the disk beneath magnetic heads for reading, erasing, and writing data; a typical drive also includes circuitry and control mechanisms for locating data and for interfacing with the processor.
- distributed processing.—Refers to computer systems in which two or more CPUs are interconnected, with processing (program execution) carried out—or distributed—among the linked CPUs under the control of system software.
- doping.—Adding to a semiconducting material small amounts of other elements (dopants) to change its electronic properties.
- electronic.—Refers to devices, components, or systems in which electrical signals are used primarily to convey and manipulate information.
- etching.—In semiconductor fabrication, surfaces are etched—e.g., with an acid—to selectively remove material.
- European Community (EC); European Economic Community (EEC).—The EEC, established in 1958 by the Treaty of Rome, joins Belgium, Denmark, France, West Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, and the United Kingdom in a Common Market. The European Community links EEC, the European Coal and Steel Community, and the European Atomic Energy Community. The Commission of the European Communities is EC's principal governing body.
- European Free Trade Association (EFTA).—A common market consisting of Austria, Finland, Iceland, Norway, Portugal, Sweden, and Switzerland.
- feedback control.—Use of a signal generated at the output of a process to vary one or more process inputs so that the measured output is maintained within a specified range.
- fiber-optics.—Use of glass fibers to transmit light for communicating information as an alternative to electrical signals. Typically, the light is generated by lasers.
- firmware.—Computer software stored in replaceable hardware components, generally integrated circuit memory chips such as ROMs (read-only memory circuits).
- floppy disk.—A thin, flexible disk made of a plastic such as mylar and magnetically coated to be used for computer memory and data storage. See *disk drive*.
- forward pricing.—See *advance pricing*.
- gallium arsenide.—Semiconductor devices made from this compound promise higher speeds than silicon-based devices.
- gate.—A simple electronic circuit that can implement a specified logical operation. In essence, gates act like switches. Computer processing units depend on large assemblies of gates, as do integrated circuit memory chips.
- GATT (General Agreement on Tariffs and Trade).—The nearly 90 nations which belong to GATT have agreed to work toward reduced barriers to international trade. The organization, the rules of which also have the name GATT, serves as a forum for multilateral trade negotiations and for dispute resolution.
- GDP (gross domestic product).—The value of goods and services generated *within* a national economy, generally on a yearly basis.
- GNP (gross national product).—The value of GDP adjusted for revenues that enter and leave the economy as a result of financial flows associated with foreign investments (payments to foreign investors are subtracted from GDP, revenues from overseas investments added).
- hard-wired.—Refers to an electrical circuit or system the operation of which is determined by the hardware elements—e.g., components and interconnections—and cannot be changed without changing the hardware configuration. In

contrast, the logical operations performed by a computer or a microprocessor-based system can be changed by loading a new software program.

input/output (I/O).—Refers to provisions for entering data into a computer system or for receiving output from the system. I/O devices are pieces of peripheral equipment with this purpose, notably terminals and printers.

instruction set.—The group of logical operations that a microprocessor or computer can carry out.

integrated circuit (IC).—An electronic circuit manufactured on a single substrate. Most ICs are produced on small chips of silicon and are monolithic—i.e., fabricated on and within the chip rather than assembled to it.

integrated optics.—Refers to devices in which information is manipulated in the form of light rather than electrical signals. Such devices might be interconnected by optical fibers (see *fiber-optic*).

**interface.—Circuitry**, and often software, that allows one piece of equipment to communicate with another, as in the interface between a pair of computers or between a computer and a disk drive.

Josephson junction, Josephson device.—Made from superconducting materials (which must be held at very low temperatures), these offer the possibility of logic gates with very high switching speeds, hence very fast computers.

learning curve, experience curve.—Graphical depiction of declines in manufacturing costs with time or with accumulated production volume. While often attributed to learning by factory personnel and engineers, the curves—which tend to show rapid cost decreases for semiconductor manufacturing, leading to competitive strategies based on advance pricing—also depend on many other factors, including product design changes.

lithography.—Processes related to photography and printing by which patterns are formed on silicon wafers during the fabrication of integrated circuits.

LSI (large-scale integration).—Refers to integrated circuits which contain of the order of  $10^4$  devices.

main memory, primary memory.—The portion of computer memory that the processor can address directly (as opposed to mass or peripheral storage equipment such as disk drives). The main memory normally holds the program being executed as well as the data being manipulated.

mainframe computer.—A system, normally intended for general-purpose data processing, characterized by high performance and versatility.

Mainframes have grown steadily in capability as smaller and less expensive machines have progressed.

mask.—Stencil-like grid used in creating lithographic patterns on semiconductor chips.

mass storage.—Refers to peripheral equipment for computer memory suitable for large amounts of data or for archival storage. Typical mass storage devices are disk and tape drives.

mean time to failure, mean time between failures.—The common measure of reliability—average time between malfunctions that disable a system or substantially degrade its performance. Normally determined through statistical estimating procedures.

microcomputer.—Refers to integrated circuits that contain a microprocessing unit plus memory, as well as to computers designed around microprocessors or single-chip microcomputers.

microprocessor.—An integrated circuit of which the major portion is a digital processing unit. Microprocessor *families* consist of groups of similar chips each intended for a somewhat different class of applications.

minicomputer.—A small computer system, intermediate in cost, size, and processing power between a microcomputer and a mainframe.

MOS (metal oxide semiconductor).—Oxide layers grown on semiconducting substrates are used to form transistors and other circuit elements. MOS integrated circuits are unipolar rather than bipolar—i.e., electrical currents are carried by either positive or negative charges but not both.

packing density.—VLSI circuits are packed more densely than LSI circuits by making the individual circuit elements and their interconnections physically smaller. This has required steady improvements in manufacturing equipment—e.g., for lithography—and careful control of the production process.

passive devices.—Circuit elements, such as resistors, whose characteristics affect electrical signals but which cannot be used to regulate or control those signals.

peripheral.—Equipment used in conjunction with a computer processor. Typical peripherals include keyboards and terminals, mass storage devices, and printers.

peripheral chips.—Integrated circuits designed to be used in conjunction with particular microprocessors or single-chip microcomputers. Common types include clock circuits, A/D converters, and keyboard interfaces.

PROM (programmable read-only memory).—An

integrated circuit chip that stores data permanently. A PROM can be programmed with this data after the chip has been manufactured; in contrast, data is stored in a ROM as part of the manufacturing process.

**OEM (original equipment manufacturer).**—OEMs incorporate computers and other system components into their own end products. As an OEM, General Motors purchases microprocessors to be used in engine control systems and dashboard computers.

**quality.**—Measures the extent to which products meet specifications dealing with performance and other functional parameters, and often appearance as well. Quality is determined at a point in time—generally before the product enters service—in contrast to reliability, which is a measure of the ability to continue meeting specifications over time. In most cases, quality is determined by statistical sampling procedures based on data from testing and inspection that accompany or follow manufacturing.

**RAM (random access memory).**—Most commonly, an integrated circuit that stores data in such form that it can be read, erased, and rewritten under the control of a computer processor. Any memory location in a RAM can be addressed directly (random access) as opposed to sequentially or serially.

**real time.**—Refers to computer operations that parallel (in time) related external phenomena, as in real time control of industrial processes (see *feedback control*). Real time processing often makes heavy demands on the hardware elements of a system, as well as the software.

**register.**—Location in a computer processor where binary information is manipulated. Programs are executed by operating on strings of bits brought to the registers.

**reliability.**—Measure of the extent to which a product or system functions satisfactorily in service, commonly quantified as the time between failures that impair operation or degrade performance.

**resist, photoresist.**—Chemicals used in lithographic processing of integrated circuits which, much like photographic emulsions, can be exposed by light, X-rays, or other radiation to form patterns.

**ROM (read-only memory).**—Computer memory, typically consisting of integrated circuit chips, the contents of which can be retrieved at any time but which cannot be changed by erasing or rewriting. Often used for program storage in microprocessor-based systems.

**second-sourcing, alternate sourcing.**—When one firm designs and develops a product that others begin to manufacture, the latter are referred to as second sources or alternate sources. Both military and commercial customers often insist on multiple sources for critical components such as integrated circuits. An IC produced by a second-source supplier may be identical to the original design or it may differ in detail while remaining functionally interchangeable. Popular chips are sometimes produced by a dozen or more firms. Second-source manufacturers commonly negotiate licenses or purchase technology from the originator.

**semiconductors.**—Materials from which semiconductor devices are made—e.g., silicon, germanium, gallium arsenide—so called because their electrical conductivities are lower than for good conductors such as metals but higher than for insulators such as glass. The devices themselves are also called semiconductors. Discrete transistors and integrated circuits are the most common types of semiconductor devices.

**sensor.**—Converts a pressure, temperature, or other physical parameter into an electrical signal, often for use in a control system. A digital speedometer for an automobile transforms the output of a sensor into a miles-per-hour reading, as does an airplane's air speed indicator. In the case of the automobile speedometer, rotary motion is converted into an electrical signal, while an air speed indicator depends on the pressure created by the motion of the airplane.

**smart terminal, smart machine.**—In essence, a smart terminal is a small computer intended primarily for communicating with other, more powerful computers. It can perform some processing itself, in contrast to a dumb terminal which can communicate with a computer but cannot execute programs. A smart machine—e.g., a numerically controlled lathe—contains one or more computer processors; these might be microprocessors or minicomputers.

**software.**—Computer programs. More generally, instructions or procedural descriptions.

**solid state.**—Refers to electronic components such as transistors or integrated circuits in which the functions are carried out within a solid material (as opposed to a vacuum tube), or to systems (e.g., TV receivers) made with such components.

**supercomputer.**—At a given time, machines at the upper limit of computing power—as measured by computations per second or related measures of performance—are called supercomputers.

**system development.**—Software generation for

- microprocessor-based systems is often referred to as system development. Commercially available microprocessor development systems are frequently used to help in the preparation of programs that will implement the desired functions. Software accounts for a major portion of the engineering effort for systems that use embedded or dedicated microprocessors or computers.
- terminal.—Generally includes a keyboard for data entry, along with a display such as a video screen for showing the input data, as well as output from the computer(s) that the terminal communicates with.
- transistor.—A solid-state electronic device which can control or regulate an electrical signal in response to a second signal, thus enabling amplification of the first signal.
- TTL (transistor-transistor logic).—Most common of the families of bipolar logic circuits.
- VLSI (very large-scale integration).—Refers to integrated circuits with of the order of  $10^5$  devices. 64K RAMs are at the lower end of the VLSI range.
- VCR (video cassette recorder).—Records and plays back TV images on magnetic tape. Common consumer models can record off the air or from video cameras. Also called VTRs (video tape recorders).
- video disk.—TV images mechanically encoded on spinning disks can be played back using a stylus or laser beam. Current models cannot be used for recording.
- wafer.—A disk of silicon (or other semiconducting material) on which integrated circuit chips are fabricated. Today, wafers may be 4 inches or more in diameter and accommodate hundreds of chips.
- Winchester disk.—A hard disk for computer memory which rotates within a sealed enclosure and thus cannot be removed. Compared to removable disks of the same diameter, Winchester drives can store more data; however, they are not suited for archival storage.
- word.—The basic unit of information—having the form of a string of binary bits—that a computer processor works with. Typical word lengths range from 4 to 64 bits; more powerful machines are generally designed to use longer words.
- yield.—In the production of microelectronic devices, the fraction that survive all tests and inspection, function correctly, and can be sold or incorporated into the manufacturer's own end products. Production costs depend heavily on yields, which themselves depend on circuit design, fabrication equipment, and control of the manufacturing process.