Encyclopedia of Electronics

2nd Edition

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Preface

The *Encyclopedia of Electronics—2nd Edition* is intended as a general reference in the rapidly expanding field of electronics. Where so comprehensive a subject as electronics is concerned it is inevitable that there should be an overlap with physics, mathematics, chemistry, and computer science. The introduction of new concepts and products into the field is being reflected in the language. Electronics-related words, phrases, acronyms, jargon, and even "buzz" words have kept pace with technology over the past five years, since the publication of the first edition.

Many words and phrases have migrated from the more forbidding lexicon of pure and applied science. People with little or no formal education in science and technology now regularly discuss products and concepts in terms that were heard only in the laboratory or seen only in professional journals a few years ago. High-technology terminology is entering the mainstream through the popular media—television, radio, newspapers, and general interest magazines. Some comprehension of advanced technology is needed to make sense of the copy in the ads for the latest TVs, VCRs, stereo systems, automobiles, and appliances—to say nothing of personal computers, cordless telephones, and facsimile machines.

Even those who profess to have no special interest in science and technology are now surrounded by products that contain such recent examples of high technology as LEDs, liquid crystals, integrated circuits, and microcontrollers. Products range from watches, calculators, and cameras to TV sets, stereos, VCRs, and microwave ovens. Traditional home appliances from telephones to washing machines have been improved with electronics. Many games and toys are now sophisticated electronics products. There may not be a personal computer in every home, but the numbers are rising.

Outside the home the impact of electronics is also conspicuous. Automobiles are now packed with electronic controls, safety devices, and entertainment products. The banks have computer-based automated tellers; service stations have computer-based test equipment; and the instruments and apparatus at the doctor's office have been updated with electronics. The new technology has been absorbed by business, industry, telecommunications, aviation, and even recreational boating. However, the most significant trend discernible over the past five years has been the ongoing merger between computers and communications.

Examples of words drawn from the electronics lexicon and not widely heard or seen just five years ago include *compact disks* (CDs), *cellular radio*, *communications satellites*, *dynamic memory* (D-RAM or DRAM), *facsimile* (FAX), *fiberoptic cable*, and *laser printers*. Those engaged in occupations within or related to the electronics field are sure to be aware of *ASIC*, *CMOS*, *VMEbus*, *Multibus*, *cache*, *emulation*, *coprocessor*, and *Ethernet*. There are frequent references to *CISC*, *RISC*, *SRAM*, *file servers*, *LANs*, *PLCCs*, and *PLDs*.

Despite the influx of new words and phrases, the classical vocabulary of electronics (largely adopted from electrical engineering) is still in wide circulation. These words are heard and written in the classroom, laboratory, repair shop, and factory. Some terminology has become obsolete and has disappeared along with the technology. There is little discussion these days of *triodes*, *pentodes*, *selenium rectifiers*, or even *germanium transistors*.

This encyclopedia was edited to fill a gap in reference sources between the dictionary (or dictionary of electronics) and formal textbooks or handbooks for the electronics engineering professional. It assumes that the average reader may want to know more about a subject than is given in a brief definition, yet may not be prepared to obtain that information from a professional-level text or handbook.

Even the reader with a formal background might not wish to take the time and make the effort to research the formal academic papers, journals, or texts just to find a simple, clear explanation of a topic in the field.

The articles in this encyclopedia are descriptive. They make fewer demands on the reader's educational background in electronics than do more academically rigorous references. Mathematics is used sparingly, and then only when necessary to explain a topic. Encyclopedias of science and technology cover many of the same subjects, but in ten or more volumes—and they may not be up to date on leading-edge subjects.

This encyclopedia does not call for minimum educational level, although a basic knowledge of high school physics and chemistry or practical electronics would be helpful. The single volume is intended to satisfy the reader's "need to know" with more than just a few sentences, any alternate meanings, and the correct spelling of the word or phrase. It is written to be a useful "stepping stone" or refresher for the reader wishing to delve deeper into specific subjects discussed in more advanced texts and papers.

This second edition has introduced many new articles and illustrations not found in the first edition. Some of the topics covered in the first edition that are considered obsolete have been deleted to make room for newer topics believed to be of more interest to a wider group of readers. The result is a book of about the same length as the first edition with more emphasis on coverage of the latest developments in electronics and computer hardware.

Because of its ongoing infiltration into all walks of human endeavor, even a fundamental knowledge of electronics is essential for an educated person. An otherwise well-informed person who has been "out of touch" with business and commerce for the past five years might have difficulty in reading and understanding some of today's popular articles without current knowledge. Articles on business, finance, and world economics now regularly cover the international electronics and computer industries, their products, and the politics of world trade.

Even persons with college degrees are finding it necessary to take formal courses on such recent subjects as word processing, computer graphics, computer-aided design, and desktop publishing because of the complex nature of those subjects.

This encyclopedia takes the view that computer science is a separate subject from, although it overlaps with, electronics. Thus the volume is neither a comprehensive encyclopedia of computers nor computer software; however, it contains many articles on topics in those fields. Selection was made on the basis of their relative importance to the wider field of electronics.

amplitude of the normal signal. The weaker the instantaneous amplitude of the signal, the greater the amplification factor.

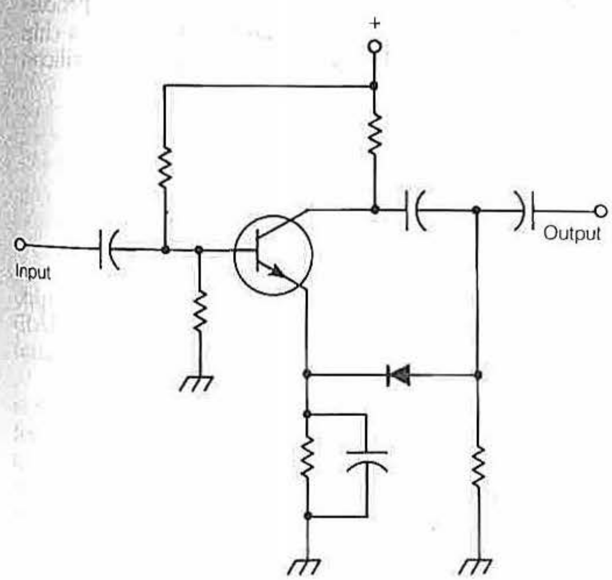
Compression is often used in communications systems to improve intelligibility under poor conditions. *See also* COMPRESSION CIRCUIT, SPEECH COMPRESSION.

COMPRESSION CIRCUIT

A compression circuit is an amplifier that displays variable gain, depending on the amplitude of the input signal. The lower the input signal level, the greater the amplification factor. A compression circuit operates in a manner similar to an automatic-level-control circuit (*see* AUTOMATIC LEVEL CONTROL).

One method of obtaining compression is to apply a rectified portion of the signal to the input circuit of the amplifying device, changing the bias as the signal amplitude changes. This rectified bias should reduce the gain as the signal level increases. The time constant must be adjusted for the least amount of distortion. An example is shown in the diagram.

There is a practical limit to the effectiveness of compression. Too much compression will cause the system to emphasize acoustical noise. In a voice communications transmitter, several decibels of effective gain can be realized using audio compression. *See also* SPEECH COMPRESSION.



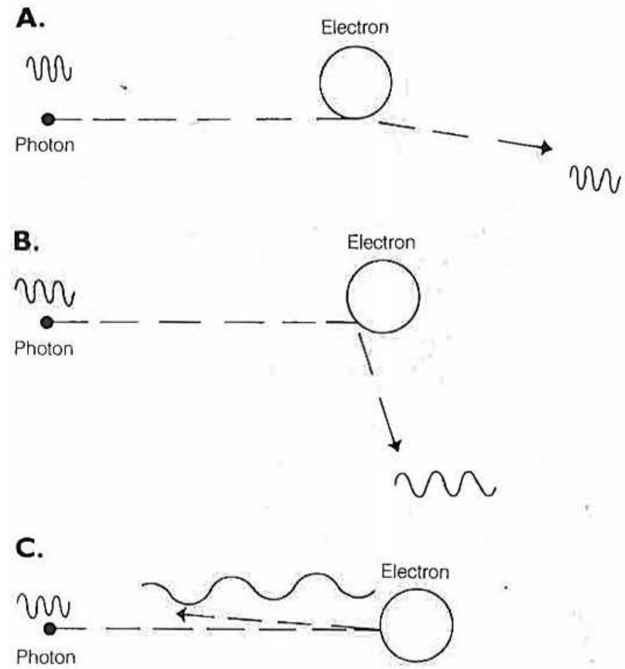
COMPRESSION CIRCUIT: A schematic for a compression circuit.

COMPTON EFFECT

When photons (particles of radiant energy) strike electrons, the wavelength of the photons changes because some of the photon energy is transferred to the electrons. The change in wavelength is called the Compton effect. The amount of change in the wavelength is a function of the scattering angle. Compton effect is generally observed with X rays.

At a grazing angle of collision, very little energy is transferred to the electron and the wavelength of the photon therefore increases only slightly (A in the illustration). At a sharper angle of collision (B), the photon loses more energy, and the change in wavelength is greater. At a nearly direct angle of collision, the wavelength change is the greatest, as shown at C.

Compton effect causes the wavelength of X rays to be spread out when the radiation passes through an obstruction. *See also* X RAY.



COMPTON EFFECT: Changes in emitted wavelength from photon-electron collisions (Compton effect) are diagrammed. At a shallow angle the effect is negligible (A), at a sharper angle the effect increases (B), and a direct hit produces the maximum effect.

COMPUTER

Any device that aids in computation, from an abacus or slide rule to a mechanical adding machine or an electronic calculator, can be called a computer. Some electromechanical machines based on gears, motors, clutches, and other mechanisms use in the performance of specialized calculations have also been referred to as computers. In the 1940s and 1950s, electronic equipment, based on potentiometers and vacuum-tube operational amplifiers, capable of performing a wide range of analog computations were referred to as computers. However, today, by common usage, the word *computer* has come to mean (and is used in this book) to mean a stored-program electronic digital computer. Figure 1 is a basic block diagram of a digital computer.

An electronic digital computer is distinguished from other computing devices by its speed, internal memory, and automatic execution of a program stored in its memory. The speed of an electronic computer is obtained with integrated circuit logic and memory devices.

The internal memory of an electronic stored-program computer stores both data and instructions. A sequence of instructions for input, processing and output is performed automatically, without human intervention. By contrast, an electronic calculator requires human direction from a keyboard at each step of the computation.

The difference between an electronic calculator and a computer is significant. Electronic calculators accept numbers that are entered on a keyboard, and these numbers are stored in registers. The calculator then performs arithmetic operations, one at a time, as the various function keys are pressed. The calculator does not have true memory for data storage. By contrast, a computer stores and executes a program entered on the keyboard or from a storage medium, such as a magnetic tape or magnetic disk drive.

Computer Types There are two basic types of electronic computers: analog computers and digital computers. Analog computers measure electrical or physical magnitudes, and digital computers count. *See* ANALOG COMPUTER.

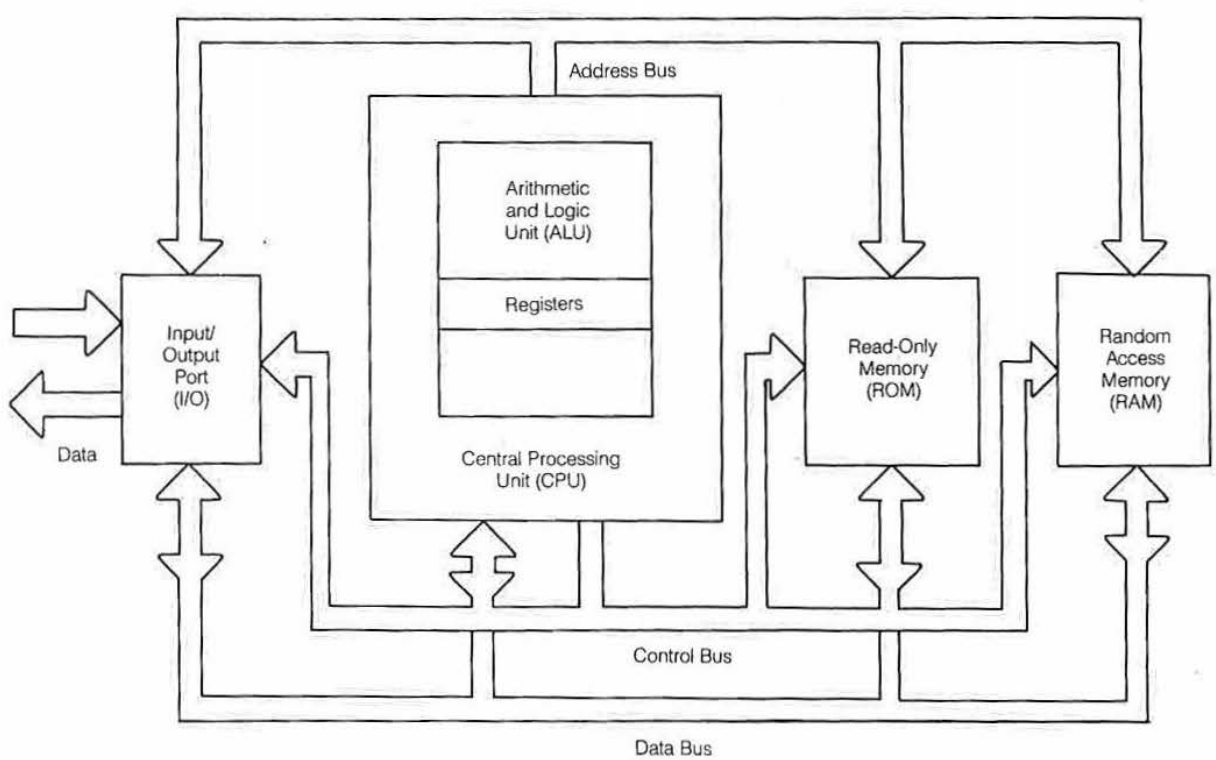
There is still a need for analog computation in science and engineering. This is being met with hybrid computers combining an analog computer with a digital computer. The digital section performs counting and data processing.

Many different digital computers are available to meet the very wide requirements for computation, graphics generation, word processing, accounting, process control, and data processing. There are significant differences in capabilities, performance, size, form factor, and price in available digital computers today. New computers are becoming available with significant differences from the traditional or Von Neumann architecture. *See* COMPUTER ARCHITECTURE.

There are also differences in input/output (I/O) peripheral devices in use. Printers and plotters are used to produce hard copy printed pages. The CRT displays transactions and also is an interactive device. Other interactive devices include keyboards, light pens, the mouse, and data entry tablets.

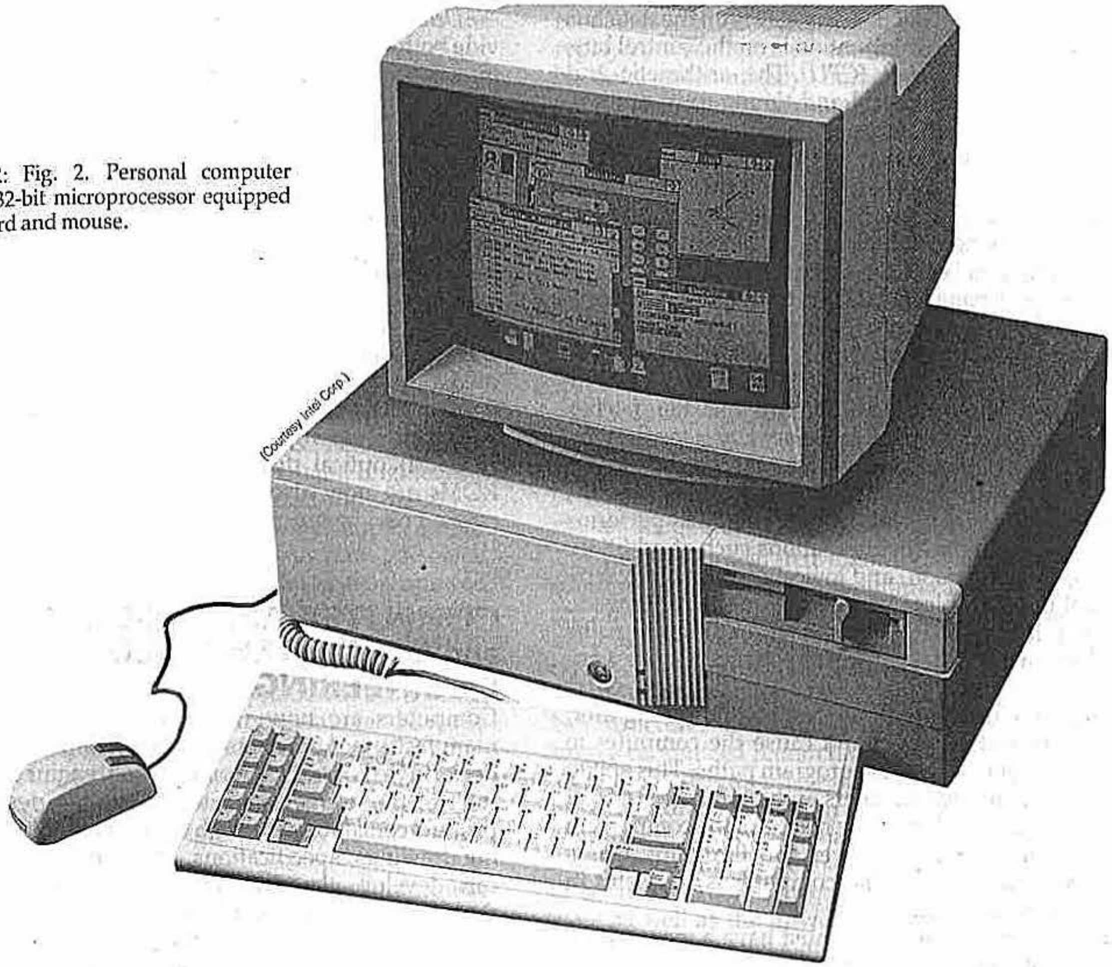
At the low end of the computer hierarchy are the simple, low-cost microcomputers for playing electronic games on home television sets or carrying out routine process control duties. At the next higher level there are the personal computers that offer a wide range of options and performance. At an even higher performance level are the minicomputers and the computer-aided design (CAD) graphics workstations. At the highest levels are the high-speed supercomputers used in making extensive scientific and engineering calculations. Figure 2 shows a personal computer.

For many years, digital computers were simply classed as microcomputers (because of their use of microprocessors—MPUs—as central processing units or CPUs), minicomputers, and mainframe computers. The term microcomputer has a dual meaning today. For some it means any computer with a microprocessor as a central processor (as opposed to a discrete component processor); for others it has come to mean a computer-on-a-chip or a microcontroller (MCU). An MCU is an LSI silicon



COMPUTER: Fig. 1. Block diagram of the organization of a digital computer.

COMPUTER: Fig. 2. Personal computer based on a 32-bit microprocessor equipped with keyboard and mouse.



chip containing a CPU, limited random access memory (RAM) and read-only memory (ROM), and on-chip (I/O) functions. *See* MICROPROCESSOR.

Today the term *personal computer* (or PC) is understood to mean a general purpose desktop (or laptop) unit for computation, process control, word processing and even desktop publishing. It can also function as a smart video data terminal or VDT (*See* VIDEO DISPLAY TERMINAL). Most personal computers in use are based on 8-bit and 16-bit microprocessors, but designs on 32-bit units are available.

Workstations are a new classification of computers specialized for computer-aided design (CAD) and computer-aided engineering (CAE) with heavy emphasis on graphics capability. (*See* COMPUTER-AIDED DESIGN AND COMPUTER-AIDED ENGINEERING.) Current generation workstations are based on 16-bit and 32-bit microprocessors.

The term *minicomputer* is still in use, but it is now defined more in terms of word length capability than its former industrial control specialty. Most minicomputers are based on 32-bit, custom-designed microprocessors. The term *mainframe* computer today is ambiguous. It has been replaced by such terms as supercomputer, super minicomputer, and mini supercomputer.

Computer Organization All digital computers, regardless of size or complexity—from personal computers to supercomputers—have the same functional components as shown in Fig. 1. This arrangement is named sequential machine architecture and it dates back to the World War II period of 1942 to 1945. From this diagram it can be seen that the computer reads or inputs data from sources such as keyboards, modems, or secondary memory devices such as disk or tape drives. It writes or outputs to the CRT monitor and other devices such as printers.

The computer has two kinds of memory to store program instructions as well as the data that are being processed. The computer is under the direction of a program and it has a CPU (central processing unit) that interprets the program instructions and supervises their execution.

The computer also has a section that performs addition, division, and other arithmetic operations called the

ALU (arithmetic logic unit). The ALU can also perform logical operations such as comparing the magnitude of two numbers. The flow of data in Fig. 1 is on the data bus and the flow of control information is on the control bus.

Central Processing Unit (CPU). The arithmetic and logic unit (ALU), the control and timing unit, and the registers are integrated into a single physical unit called the central processing unit or CPU. The CPU is the brain or nerve center of a computer. It controls the operation of the computer through the control and timing unit and performs arithmetic and logical operations through the arithmetic and logic unit. *See* ARITHMETIC LOGIC UNIT.

Control and Timing Unit. The control and timing unit supervises all operations of the computer under direction of a stored program. First the control and timing unit determines which instruction is to be executed next by the computer. The control and timing unit then fetches the instruction from the main memory and interprets the instruction. The instruction is then executed by other computer units, under the direction of the control unit.

The Arithmetic Logic Unit (ALU). The ALU performs computations and data manipulations such as addition, subtraction, comparison, and logical operations. A typical logical operation involves comparing two numbers, and then selecting one of two (or more) program paths depending on the result of the comparison. *See* ARITHMETIC LOGIC UNIT.

Acting in harmony with the control and timing unit, the ALU can test numbers and cause the computer to branch to one of two possible program paths. This ability to test or compare two numbers and to branch to one of several paths depending on the results of the comparison gives the computer great power and flexibility. It is a major reason why the digital computer is so useful in many different applications.

Main Memory. A computer must have a memory for storage of data and instructions. This memory can be in three levels: primary, secondary, and tertiary. The computer main memory consists of arrays of semiconductor memory devices. Data and instructions are stored in areas called locations. Each location in main memory has an address so that data can be located. The capacity of main memory is determined by the size and application of the computer.

The computer central processing unit (CPU) can only operate on the data from the main memory, and only instructions from the main memory can control the computer. The basic building block of a computer main memory is the integrated circuit semiconductor memory. Each memory IC (integrated circuit) contains thousands of transistors that function as switches in representing the binary digits zero and one. (*See* SEMICONDUCTOR MEMORY.) In most computers, main memory is divided into sections. For example, there is often a division between random access memory (RAM) and read-only memory (ROM) as shown in the figure.

Main memory is usually supplemented by secondary storage mass memory which includes floppy-disk drives, rigid-disk drives (typically Winchester type). These memory devices are random access memories that can read and write data rapidly, making them virtual main memories. *See* DISK DRIVE.

Demand-Paged. Demand-paged memory systems divide both disk and RAM (virtual and physical) memories into fixed-sized pages. In moving from disk to RAM, blocks of information are switched into the same number of pages. Demand-paged virtual memory permits multiple users and multiprocessing. Segmented memory systems impose partitions on RAM. This segmentation must accommodate the longest program or data construct needed.

Many computer systems also have tertiary memory that serve as backup, long-term, or archival data and program storage. The most commonly used tertiary memories are magnetic tape drives with the memory media in the form of tape cassettes or tape reels (streaming tape). Tape drives are serial-access memories with relatively long access times. Write-once, read-many (WORM) optical disk drives and compact disk (CD) ROMs are now also being used for data storage. *See* COMPACT DISK, OPTICAL DISK DRIVE.

COMPUTER-AIDED DESIGN and COMPUTER-AIDED ENGINEERING

Computers are now widely used in the design and manufacture of products and systems. Computer-aided design (CAD) and computer-aided engineering (CAE) refer to the use of computers to aid the designer from product conception through the preparation of engineering drawings, specifications, and parts lists. Computers can develop elevation views and three-dimensional drawings of engineering structures, analyze those structures, and prepare manufacturing drawings. They can also perform interference checking, tool-path definition, parts listing, and numerical control (NC) tape preparation.

Computer-aided manufacturing (CAM) refers to the use of computers in inventory and quality control as well as the supervision and direct control of manufacturing machines and processes. Ideally design concepts originated at the CAD/CAE level are transferred directly into instructions for the manufacture of products because they share a common database. The same database can be used for testing, quality control, inventory control and production scheduling.

Computer-aided design has evolved from automatic drafting. The computer-based video workstation terminal displayed the end product as a two-dimensional representation of a conventional engineering drawing. Information on the third dimension was obtained from orthogonal views.

However, in the design of circuit boards and integrated circuits, the third dimension could be introduced by displaying layers positioned and registered on one another. Design work can be done on individual layers and a composite presentation can distinguish each layer by means of color coding. By following sets of rules programmed into the computer, wiring runs and interconnects can be made without overlap or interference.

Computer solids modeling was developed for the design of more complex objects such as machines, ships, and aircraft. The object can be represented on the screen as a three-dimensional line drawing that can be moved about in space. These presentations suggested isometric drawings. With further developments these wire-frame images could be filled in to achieve solids modeling and surface modeling in shades of gray or colors.

Finite element analysis (FEA) was a CAD development that enabled a complex solid structure is broken down into a large number of simple elements so each simple element could be analyzed. For example, the forces on the structure or loading of building, ship, or aircraft structures could be analyzed.

Computer-aided engineering is an outgrowth of computer-aided design, and it becomes increasingly difficult to distinguish the difference between them. Engineering software has been developed to permit the solution of problems other than stress analysis. For example, electrical and electronic circuit problems can now be solved with programs that analyze the specific circuits displayed in schematic form. Data and design rules on the physical and electrical characteristics of components are stored in memory to be called up as needed.

CAE systems permit circuit simulation at the abstract symbolic level. Substitution of components can be made in the models to determine their effect on circuit performance. This simulation saves on the cost of completing drawings and building hardware prototypes. CAE seeks to analyze and optimize designs in many fields of engineering.

Computer-aided testing (CAT) is another outgrowth of computer-aided design and engineering. The electrical characteristics of devices, components, and subsystems can be stored in computer memory for comparison with actual measured characteristics with the computer-aided test equipment. CAT systems speed up the testing of complex integrated circuits in wafer form or as packaged devices. They can also test complete circuit boards and subsystems. CAT systems can provide printed records of product testing and can even direct the marking and ejection of failures from production lines.

Computer-aided manufacturing is an outgrowth of the numerical control (NC) of machines. NC machines were designed for digital control of the machine by a program introduced on a punched and coded paper tape. Computers can now control banks of NC machining centers, milling machines, or lathes in a hierarchical organization known as computer numerical' control (CNC). They can also manage tool wear and replacement, scheduling, parts resupply, productivity, and other administrative details.

Robots are example machines that are directly controlled by computers. General-purpose robots are modified by the installation of special tooling to perform a range of specific tasks such as arc welding, spot welding, painting, gluing and assembly. The robot can be taught by manually leading it through the task so that the robot memory will store a record of the movements of each robot axis in three dimensions. The robot controller then replays the sequence on command when the work is to be done automatically. Some robots can also be programed off line by writing programs based on assembling standardized sequences without tying up the robot for teaching. *See* ROBOT.

Many kinds of specialized machines that do not qualify as robots such as automatic pick-and-place machines for inserting or positioning electronic component on circuit boards may also be controlled by a computer. Separate programs are prepared giving the location of each leaded or surface mount component and this information is stored in a computer memory library as in the case of robots.

Computer vision (CV) systems can be programed to recognize specific objects in a field of similar objects for sorting. They can also be used to inspect parts for quality or completeness by comparing their images against a master image stored in memory. *See* COMPUTER VISION.

Computer integrated manufacturing (CIM) seeks to combine and standardize communications among different kinds of workstations and different software to permit a totally integrated factory. Basic design information can be developed off line at a laboratory or factory and be transmitted over compatible communications lines and bus structures to permit the organization of factories from a centralized hierarchical computer.

Under CIM, all phases of design engineering, planning, manufacture, and inventory control can be under centralized control. This activity is in its early stages. Adherents of the concept are encountering the problems of communication between disparate systems and software as well as the unwillingness of many suppliers of embedded computers and software to subordinate their products to an overall supervisory control system.

COMPUTER-AIDED MEDICAL IMAGING

Computer-aided medical imaging refers to a number of different techniques that permit physicians and surgeons to view the inside of the human body without intrusive surgery. Signals obtained from X rays, nuclear magnetic resonance, ultrasonic waves, and radioactive isotopes, for example, are organized by computers and applications software to present views of living human beings unobtainable with earlier X ray and sonogram methods. The views are typically presented on a cathode ray tube (CRT). (*See* CATHODE RAY TUBE.) These scans permit doctors to watch vital organs at work, identify blockages and growths, detect disease, and even detect warning signs of diseases not yet present—all without exploratory surgery.

Five different computerized body scanning techniques are discussed in this section. All are based on the ability of the computer to enhance or construct more detailed images than those that could be derived directly

Microphones are available in a wide variety of sizes and input impedances, and with various frequency-response characteristics. Some microphones are omnidirectional, while others have a cardioid or unidirectional response. The optimum choice of a microphone is important in any audio-frequency system. Specialized microphones are made for communications, high-fidelity, and public-address applications.

MICROPHONICS

Mechanical vibration can cause unwanted modulation of a radio-frequency oscillator circuit or an audio- or radio-frequency amplifier circuit. This can occur in a transmitter, resulting in over-the-air noise in addition to the desired modulation; it can take place in a receiver, causing apparent noise on a signal. This unwanted modulation is known as microphonics.

In fixed-station equipment, microphonics are not usually a problem because mechanical vibration is not severe. However, in mobile applications equipment must be designed for minimum susceptibility to microphonics. Microphonics can, if severe, result in out-of-band modulation in a transmitter. It can also make a signal unintelligible.

For immunity to microphonics, equipment circuit boards must be firmly anchored to the chassis, and component leads must be kept short. Especially sensitive circuits, such as oscillators, can be encased in wax or some other shock-absorbing potting compound.

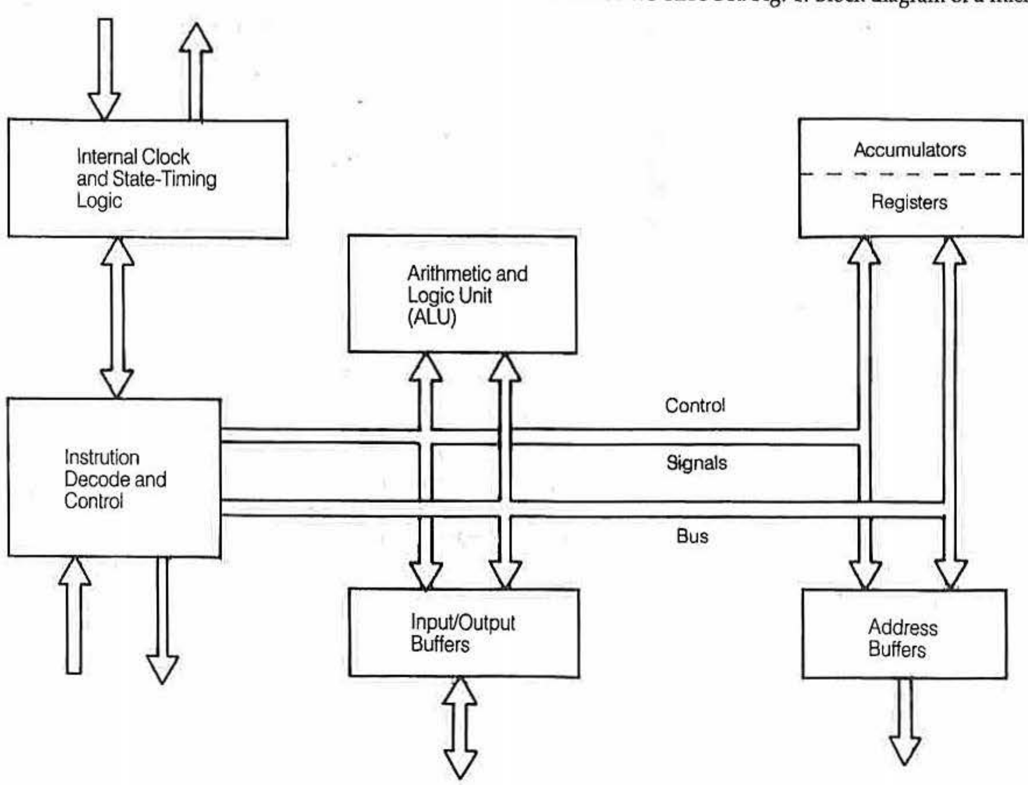
MICROPROCESSOR

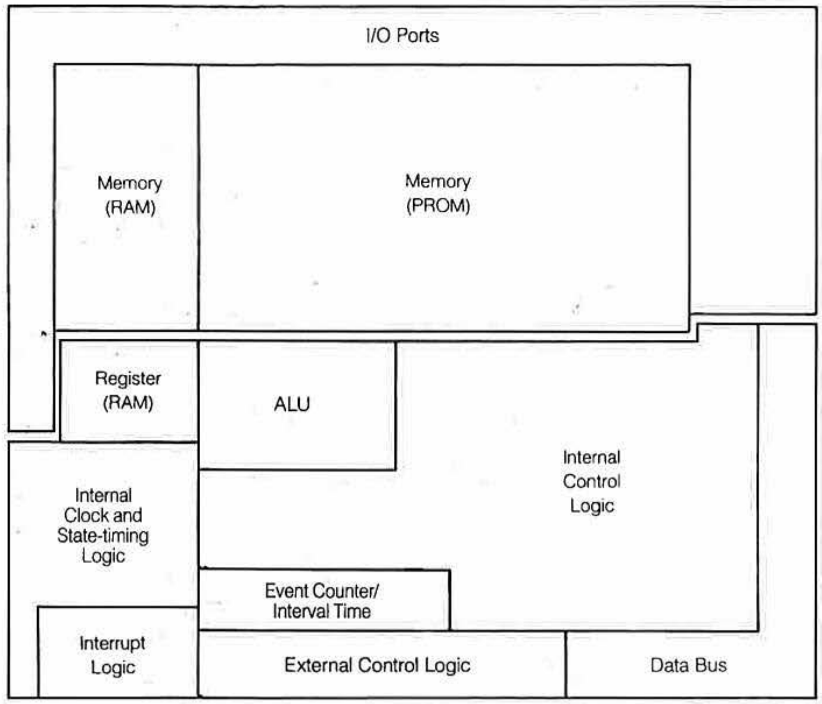
A microprocessor (MPU) is a large-scale monolithic integrated (LSI) circuit that performs the functions of a central processing unit (CPU) of a computer. The MPU is the principal computing element in many personal computers, CAD and graphics workstations, and new generations of parallel or hierarchical computers incorporating many microprocessors. Figure 1 shows the principal functional blocks of an MPU: the arithmetic-logic unit (ALU), instruction decode and control, timing, accumulators and registers, and input/output and address buffers. *See* ARITHMETIC LOGIC UNIT, COMPUTER.

Instructions from the stored program are decoded by the decode-and-control unit. The ALU performs arithmetic and logic operations. The registers are easily accessible memory for frequently used data. The accumulators are special registers that serve the ALU as sources of data and immediate destinations for results. Address buffers supply the control memory with the address of the next instruction. The buffers also give the read/write memory the address for reading or writing the next data block. Input/output buffers read instructions or data into the MPU and send data out.

The integration of the principal functions of a stored-program digital computer on a single silicon chip is one of the outstanding technical accomplishments of the twentieth century. Figure 2 shows the layout of the MPU functions on a chip indicating the relative areas occupied by each function.

MICROPROCESSOR: Fig. 1. Block diagram of a microprocessor.





MICROPROCESSOR: Fig. 2. Functional layout of a single-chip 8-bit microprocessor.

The MPU is a universal LSI circuit capable of replacing many standard logic ICs (integrated circuits) and a smaller number of more costly custom LSI circuits. In other cases, MPUs are performing functions that could not have been built in the form of hard-wired logic. The MPU can perform a wider variety of different functions more reliably than arrays of logic devices.

The MPU is the computing component in a microcomputer and it can be coupled by suitable input/output (I/O) circuits to many different external devices which both provide its input signals and are controlled by its output. The microprocessor responds to inputs and produces outputs determined by the program or sequence of instructions which are stored in some form of memory connected to the MPU. In even the simplest microcomputer-based system, the MPU requires additional read-only memory (ROM) to handle instructions, read/write memory (RAM) to handle data, input/output (I/O) ports, and a clock oscillator and timer. *See* SEMICONDUCTOR MEMORY.

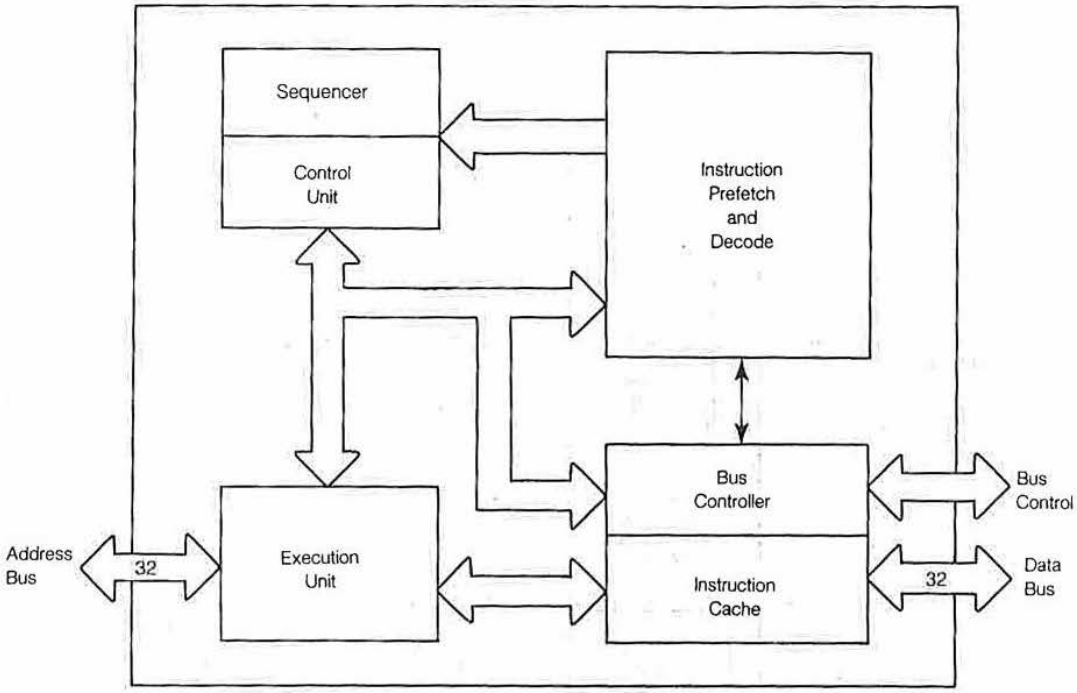
Microprocessors are optimized for software-intensive applications involving numerical computations and data processing. They are the principal computing devices in personal computer, graphics and CAD workstations, and the new-generation parallel computers. MPUs are available with 8-, 16-, and 32-bit architecture. They should be distinguished from microcontrollers (MCU) or single-chip microcomputers available with 4-, 8-, and 16-bit architectures. Both classes of device have similar origins, but different architecture and applications. The microcontroller has more of the functional elements of a complete computer on a single monolithic chip than does the microprocessor, but the microcontroller has lower performance. Microcontrollers are optimized for real-time, hardware-intensive applications such as those in automobile engine controls, motor controls, and keyboards. *See* MICROCONTROLLER.

The most advanced MPUs available have 32-bit internal architecture (32-bit internal address bus and 32-bit internal data bus) and 32-bit external data bus. However, some have 32-bit internal architecture, 16-bit external data buses and 24-bit address lines. Driven by intense competition, manufacturers are continually improving their existing MPUs because of the perceived customer demand for even higher speeds and more features for operation in a parallel-system bus, large-memory environment. Figure 3 is a block diagram of a single-chip 32-bit microprocessor.

The newer 32-bit microprocessors feature instruction and data caches, relatively high-speed, on-chip memory for holding the most recently used instructions and data for future re-use by the CPU. A memory management unit (MMU) provides protection by allowing programmers to use system resources without considering the actual size of the memory in megabytes. The MMU also allows multiple programs and operating systems to be used simultaneously.

The electronics industry has accepted 8-, 16-, and 32-bit microprocessors. The most concentrated efforts relate to finding new applications for the 32-bit devices. MPUs designed and built by Motorola Semiconductor and Intel Corporation dominate in the world marketplace. These are the 68000 family processors from Motorola (68020 and 68030) and the iAPX 286 and 386 from Intel (80286 and 80386).

The process of selecting a microprocessor for a new product is complicated by a lack of compatibility between the leading 32-bit products. Because of its compatibility with software developed for earlier and very popular



MICROPROCESSOR: Fig. 3. Block diagram of a single-chip 32-bit microprocessor.

Intel 8- and 16-bit microprocessors, many users are persuaded to stay with the Intel MPUs. However, the Motorola microprocessors have been successful in the important workstation marketplace and are compatible with the more versatile Unix operating system. They are attracting many users wishing to take advantage of this operating system that has benefits in intercomputer communications, graphics and multiprocessing (the sharing of a task by several machines). Efforts are underway to resolve differences between the processors and make them universally compatible. *See* OPERATING SYSTEM.

The first-generation microprocessors were able to manipulate 4-bit words and the next generation was able to handle 8-bit words. The ability of an MPU to handle longer 8-bit words or bytes made them more adaptable to communications applications where characters and symbols are encoded with 8-bits or bytes. The more advanced 8-bit MPUs require fewer supporting peripheral chips than the earlier models because more support functions have been integrated into the MPU. The early MPUs were fabricated with NMOS technology.

Sixteen-bit MPUs were introduced to handle two 8-bit words (bytes) at a time. The transition from NMOS technology to CMOS technology was made at the 16-bit level. In the next evolutionary step, 32-bit MPUs were introduced with 32-bit internal architecture. The first ones had a 16-bit external data bus, but they now have 32-bit external buses. The latest 32-bit MPUs have achieved the performance levels formerly attained only by CPUs in mainframe computers. Some 32-bit MPUs are capable of 25 MHz cycle times.

New MPUs under development are incorporating reduced instruction set (RISC) architecture. (*See* REDUCED INSTRUCTION SET COMPUTER). Multiple MPUs are being installed in new hierarchical computer designs for parallel operation to shorten computing time. *See* COMPUTER ARCHITECTURE.

Variable word length computers are being built by what is known as bit-slice architecture. In this design, the microprocessor consists of a common control section made up of read-only memory for decoding instructions and controlling the microprocessor and a functional unit called registers and an arithmetic and logic unit (RALU) consisting of separate monolithic chips called bit slices. The bit slices are identical 2-bit or 4-bit units connected in parallel so the processors may have different word lengths. The modular bit-slice approach permits the formation of processors with from 4 to 32 bits. Bit-slice architecture is used for bipolar microprocessors because of the improved heat dissipation for these high-density bipolar circuits.

MICROPROGRAM

A microprogram is a set of microinstructions at the machine-language level. It results in the execution of a specific function, independent of the functions of the program being run. The microprograms implement routine operating functions in a computer. Microprograms can be permanently placed in a computer or microcomputer in the form of firmware. *See also* FIRMWARE.

MICROSTRIP

Microstrip is a form of unbalanced transmission line. A flat conductor is bonded to a ground-plane strip by

They will also be easier and less expensive to mold than the thermoset plastics such as diallyl phthalate widely used to make military-grade and test sockets. Standard sockets have an inserted height of 0.25 inch above the PC (printed-circuit) board, while low-profile sockets have a height of 0.16 inch.

DIP sockets can have stamped or machined contacts. The two basic styles of stamped contact are single beam (or single leaf) and dual beam (or dual leaf), a reference to the way the internal contacts are bent and formed. Stamped contacts are usually stamped from phosphor-bronze, brass, or beryllium copper. A wide choice of contact plating and thickness is available: nickel, tin, lead-tin, and gold. Two-piece machined socket contacts have internal springs that grip the inserted DIP pin in as many as four places. The inner contacts are usually machined from beryllium copper, and outer sleeves are usually machined from phosphor bronze. Gold plating is widely specified as a finish.

SOFTWARE

In a computer system, the programs are called software. Software can exist in written form, as magnetic impulses on tapes or disks, or as electrical or magnetic bits in a computer memory. Software also includes the instructions that tell personnel how to operate the computer.

There are many types of computer-programming languages, each with its own special purpose. The most basic form of software language is called machine language. It consists of the actual binary information used by the electronic components of the computer.

Software can be programmed temporarily into a memory, or it can be programmed permanently by various means. When software is not alterable (that is, it is programmed permanently), it is called firmware. *See also* ASSEMBLER AND ASSEMBLY LANGUAGE, COMPUTER, COMPUTER PROGRAMMING, FIRMWARE, HIGHER-ORDER LANGUAGE, MACHINE LANGUAGE, MICROPROCESSOR, SEMICONDUCTOR MEMORY.

SOLAR CELL

A solar cell or solar energy converter is a large photovoltaic photodiode designed to function as a power source. Low-current solar cells used as sensors or to power light loads such as pocket calculators can be packaged in metal cases with glass windows or in transparent plastic packages. However, those cells intended as solar energy converters require larger surface areas to provide maximum current capacity. The figure shows the construction of a typical power solar cell used as an energy converter.

The surface layer of P-type material is thin so that light can penetrate to the junction. Solar power cells are also available in flat strip form for efficient coverage of available surface areas. The circuit symbol for the photovoltaic cell is also shown in the figure. *See* PHOTOCELL.

SOLAR ENERGY

The sun radiates a large amount of energy across the electromagnetic spectrum. Most of this energy occurs at visible wavelengths, but significant energy occurs in the infrared and ultraviolet ranges. Relatively little energy is radiated by the sun at radio, X ray, and gamma-ray wavelengths.

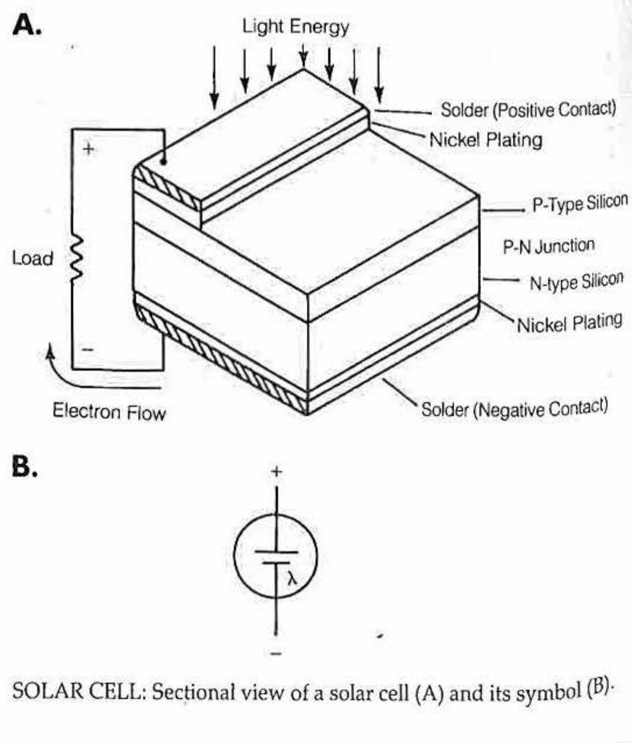
Because of the large amount of energy received from the sun, much thought has been given in recent years to harnessing this radiant energy. Solar energy can be converted directly into electricity with solar cells (*see* SOLAR CELL). A large set of solar cells can provide enough electricity for the needs of an average residence.

SOLAR FLARE

A solar flare is a violent storm on the surface of the sun. Solar flares can be seen with astronomical telescopes equipped with projecting devices to protect the eyes of observers. A solar flare appears as a bright spot on the solar disk, thousands of miles across and thousands of miles high. Solar flares also cause an increase in the level of radio noise that comes from the sun (*see* SOLAR FLUX).

Solar flares emit large quantities of high-speed atomic particles. These particles travel through space and arrive at the earth a few hours after the occurrence of the flare. Since the particles are charged, they are attracted toward the geomagnetic poles. Sometimes a geomagnetic disturbance results (*see* GEOMAGNETIC FIELD, GEOMAGNETIC STORM). An aurora can be seen at night and there is a sudden, dramatic deterioration of ionospheric radiopropagation conditions. At some frequencies, communications can be completely cut off. Wire communications circuits and power lines can be affected.

Solar flares can occur at any time, but they take place most often near the peak of the 11-year sunspot cycle.



SOLAR CELL: Sectional view of a solar cell (A) and its symbol (B).