Electrical engineering

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Publication year: 2020

The branch of engineering that deals with electric and magnetic forces and their effects. *See also:* ELECTRICITY; ENGINEERING; MAGNETISM.

Scope

Electrical engineers design computers and incorporate them into devices and systems. They design two-way communications systems such as telephones and fiber-optic systems, and one-way communications systems such as radio and television, including satellite systems. They design control systems, such as aircraft collision-avoidance systems, and a variety of systems used in medical electronics. Electrical engineers are involved with generation, control, and delivery of electric power to homes, offices, and industry. Electric power lights, heats, and cools working and living space and operates the many devices used in homes and offices. Electrical engineers analyze and interpret computer-aided tomography data (CAT scans), seismic data from earthquakes and well drilling, and data from space probes, voice synthesizers, and handwriting recognition. They design systems that educate and entertain, such as computers and computer networks, compact-disk players, and multimedia systems. *See also:* CHARACTER RECOGNITION; COMMUNICATIONS SATELLITE; COMPACT DISK; COMPUTER; COMPUTERIZED TOMOGRAPHY; CONTROL SYSTEMS; DIGITAL COMPUTER; ELECTRIC HEATING; ELECTRIC POWER GENERATION; ELECTRIC POWER SYSTEMS; ELECTRIC POWER TRANSMISSION; ELECTRICAL COMMUNICATIONS; ILLUMINATION; MULTIMEDIA TECHNOLOGY; OPTICAL COMMUNICATIONS; OPTICAL FIBERS; RADIO; TELEPHONE SERVICE; TELEVISION; VOICE RESPONSE.

Early development

Early experimenters developed batteries, electromagnets, and electric motors. In 1832, M. Faraday showed that electric and magnetic effects are not separate, and combined the results of various observations into a single theory of electromagnetic induction. The first major commercial application of electromagnetism was the telegraph, demonstrated in 1844. *See also:* BATTERY; ELECTROMAGNET; ELECTROMAGNETIC INDUCTION; MOTOR; TELEGRAPHY.

The last quarter of the nineteenth century saw rapid developments in lighting, stemming from the invention of the incandescent lamp, and in electric power generation and delivery. During this period, lighting moved to homes, offices, and schools, and motors powered new forms of transportation and began to transform factories. A major technical debate in this period was whether to generate and distribute electric energy as direct current or alternating current. After the invention of the transformer in 1883, alternating-current generation and delivery quickly became the dominant system, because of its greater efficiency and versatility. *See also:* ALTERNATING CURRENT; DIRECT CURRENT; ELECTRIC ROTATING MACHINERY; INCANDESCENT LAMP; TRANSFORMER.

The latter nineteenth and early twentieth centuries saw the development of the telephone and wireless telegraphy. Telegraph wires provided communications for railroads and nearly instantaneous message capability for business, industry, and personal data, while the telephone industry grew rapidly. Wireless telegraphy linked continents with high-powered spark transmitters.

Electronics

The audion, invented in 1906 and later called the triode, was a vacuum tube (or valve) with three electrical elements. The triode was used to design and build amplifiers, a basic element in modern electronics. Amplifiers enable a weak information signal to control a local power source, yielding a more powerful output. Amplification and other applications of tubes enabled the rapid development of the electronics industry. The junction transistor, whose invention in 1948 followed that of the point-contact transistor in the previous year, became the dominant electronic device by the 1960s, replacing vacuum tubes. *See also:* AMPLIFIER; TRANSISTOR; VACUUM TUBE.

The integrated circuit, invented in 1959, quickly revolutionized electronics. This device or process enables designers to put many transistors and associated components into a single package. The number of electronic devices in a single integrated-circuit chip now routinely exceeds 1 million. These units have made the personal computer a reality, and are installed in home appliances, cars, offices, and factories. *See also:* ELECTRONICS; EMBEDDED SYSTEMS; INTEGRATED CIRCUITS; MICROCOMPUTER; MICROPROCESSOR.

Feedback

Electronic devices can produce, along with amplification, distorted output signals. An invention of the 1920s, called negative feedback, reduces this problem. A fraction of the amplifier output signal is subtracted from the input signal. While this subtraction reduces gain and signal level, it also reduces distortion. The idea illustrates the trade-offs that must be made throughout the design process, as competing requirements are balanced. While positive feedback can sometimes find application, it is often a serious problem in electronics. Positive feedback is responsible for the screeching sound in a public address system when a person inadvertently points a microphone at a loudspeaker. *See also:* DISTORTION (ELECTRONIC CIRCUITS); FEEDBACK CIRCUIT.

Control systems

Control systems use feedback. Common examples are thermostats that control furnaces or air conditioners. Automobile cruise controls and automatic pilots for aircraft are applications. Other examples are found in chemical processes and steel-rolling mills. In control systems, electronic circuits enable desired results to be compared with actual results, and the feedback enables the reduction of the error to nearly zero. Electrical engineers work with other engineers in the design and development of control systems. *See also:* AUTOPILOT; PROCESS CONTROL; THERMOSTAT.

Computers

Electrical engineers have a major role in the continuing development and application of computers, both large and small. They work with computer engineers, computer scientists, and other professionals. Electrical engineers design the data-storage systems, commonly called disks (floppy or hard), the central processing unit (CPU), and the display. The disks are magnetic storage devices, and proper operation of the disks requires a sophisticated control system. The CPU, which is the heart of the computer, includes very large scale integrated (VLSI) circuits for computations, for temporary storage during computation, and for control of printers, disk drives, and displays. The display may be a large vacuum tube with a phosphorescent screen, whose design requires knowledge of electromagnetic theory and materials, or it may be a liquid-crystal display, a technology that has developed rapidly. Computer capability continues to double every 18–24 months. *See also:* COMPUTER STORAGE TECHNOLOGY; ELECTRONIC DISPLAY.

The computer-communication system known as the internet or worldwide web is a linkage of computers around the world. The internet uses telephone lines, and in turn the telephone system uses satellites, microwave communications, wire communications, and radio. This system allows users to exchange data and ideas rapidly, reliably and at very low cost. *See also:* DATA COMMUNICATIONS.

Optics

In optical communications, another major contribution of electrical engineering, light pulses and waves carry data over very small strands of glass. The glass replaces copper wire, and the new systems are less expensive, more reliable, and in many respects safer to the user than those they replace. Fiber-optic networks provide two-way video and audio links for universities, colleges, public schools, libraries, hospitals, and court houses.

Challenges

The integration of communications equipment, control systems, computers, and other devices and processes into reliable, easily understood, and practical systems is a major challenge, which has given rise to the discipline of systems engineering. Electrical engineering must respond to numerous demands, including those for more efficient and effective lights and motors; better communications; faster and more reliable transfer of funds, orders, and inventory information in the business world; and the need of medical professionals for access to medical data and advice from all parts of the world. *See also:* INFORMATION SYSTEMS ENGINEERING; MEDICAL INFORMATION SYSTEMS; SYSTEMS ENGINEERING.

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Additional Readings

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