Electrical and Electronics Engineering

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Electrical Quantities and Units: Charge

- Charge: Electric charge is the physical property of matter that causes it to experience a force when placed in an electromagnetic field.
- There are positive (ex: protons) and negative (ex: electron) charges.
- The unit of charge is coulomb (SI).
- The charge of a single proton or electron: 1.602×10^{-19} coulombs

(positive for proton and negative for electron).

- Denoted by Q.

Current

- It is the amount of electrical charge flowing across a surface in one second.
- The unit of current is Ampere (SI)
- Ampere is equivalent to one coulomb (roughly 6.241×10^{18} times the elementary charge of a proton or electron) per second.
- 1 Ampere=(1 coulomb/1 sec).
- Denoted by I.

Voltage

- **Voltage** is **electric potential difference** between any two points.
- Namely it is the difference in electric potential energy between two points per unit electric charge.
- Unit of Voltage is Volt (SI).
- 1 Volt=(1 joule/1 coulomb).
- Denoted by V.

Electric Field

- **Electric field** is defined as the **electric** force per unit charge.
- The direction of the **field** is taken to be the direction of the force it would exert on a positive test charge.
- The **electric field** is radially outward from a positive charge and radially in toward a negative point charge.
- The unit of electric field is Newton/coulomb=Volt/meter.
- $F=E_f \times Q$ (F is the force E_f is the electrical field Q is the charge).

Power

- **Electric power** is the rate at which electrical energy is transferred by an electric circuit.
- The SI unit of power is the Watt,
- Denoted by $P = V \times I$.
- 1 Watt=(1 joule/1 second)

Energy

- The ability of a system to perform work is called as the energy.
- Its unit is joule (SI)
- In electrical terms, it means moving a charged particle with 1 coulomb positive charge from a point whose potential is equal to 0 Volt to another point whose potential is equal to 1 Volt.
- Denoted by $E=V\times Q=P\times t$ (t is the time)

Capacitance

- **Capacitance** is the ability of a body to store an electrical charge.
- Its unit is Farad.
- 1 Farad=1 Coulomb/1 Volt=1 coulomb^2/1 joule.

What is Electrical and Electronics Engineering?

- Electrical engineering is a field of engineering that generally deals with the study and application of electricity, electronics and electromagnetism.
- The field first became an identifiable occupation in the late nineteenth century after commercialization of the telegraph and electrical power supply.

What is Electrical and Electronics Engineering?

- It now covers a range of subtopics and has deep relations with other engineering branches such as
  - power electronics,
  - control systems,
  - signal processing,
  - biomedical engineering,
  - robotics,
  - computer science, computer engineering,
  - mechatronics and
  - telecommunications.

- Electrical engineering may include electronic engineering.
- Electrical engineering is considered to deal with the problems associated with large-scale electrical systems such as
  - power transmission and
  - motor control,
- Electronic engineering deals with the study of small-scale electronic systems including
  - computers and
  - integrated circuits.

- Alternatively;
- Electrical engineers are usually concerned with using electricity to transmit energy,
- Electronic engineers are concerned with using electricity to process information.

- Recently, the distinction has become blurred by the growth of power electronics.

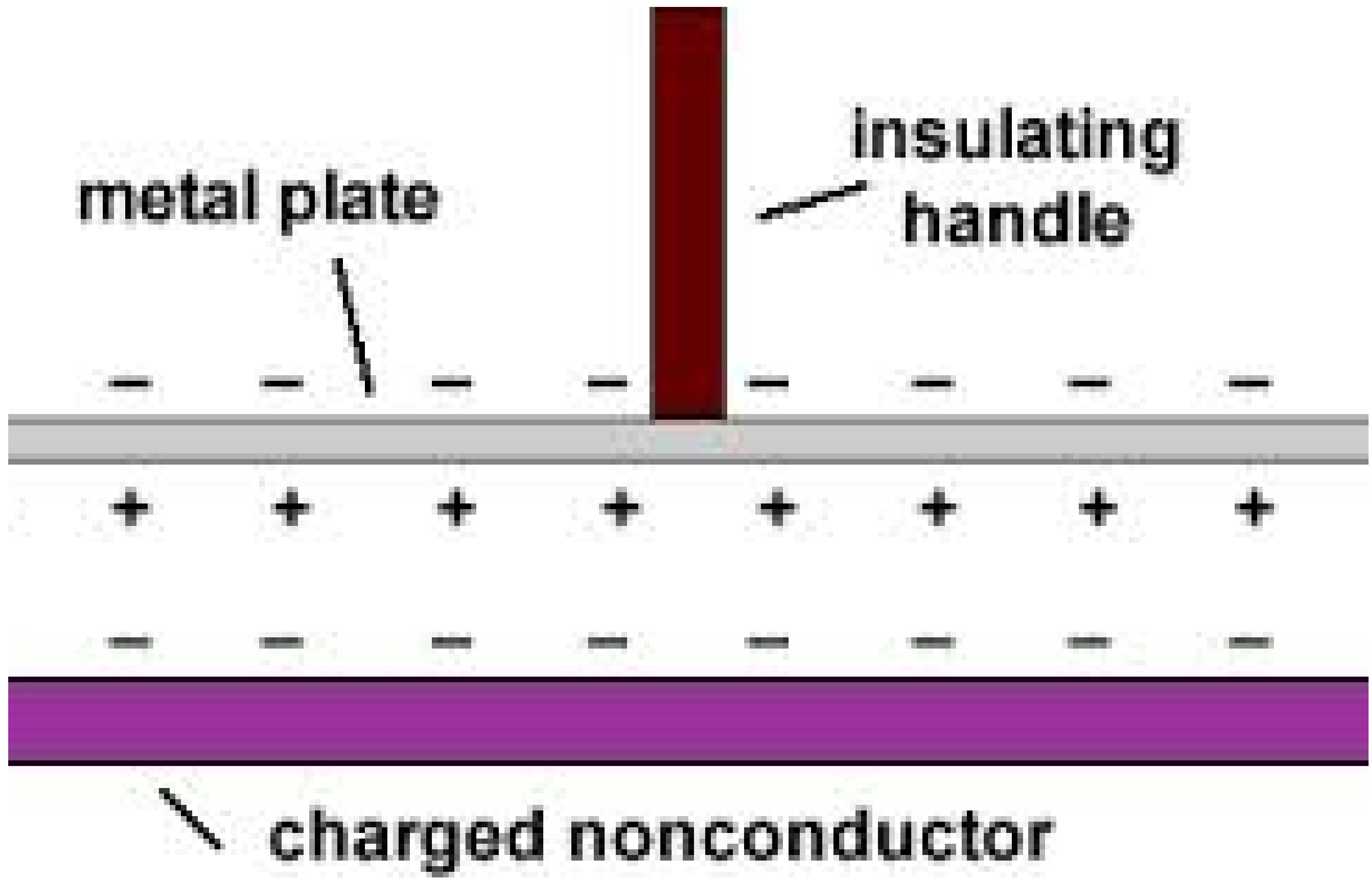
History

- Electricity has been a subject of scientific interest since at least the early 17th century.
- The first electrical engineer was probably **William Gilbert** who designed the **versorium:** a device that detected the presence of statically charged objects.
- **Versorium** is the first electrical measuring instrument.

History

- **William Gilbert** was also the first to draw a clear distinction between **magnetism** and **static electricity** and is credited with establishing the term electricity.
- In 1775 **Alessandro Volta's** scientific experimentations devised the **electrophorus**, a device that produced a static electric charge, and by 1800 Volta developed the **voltaic pile**, a forerunner of the **electric battery.**

Electrophorus



History

- It was not until the 19th century that research into the subject started to intensify.
- Notable developments in this century include the work of:
- George Ohm, who in 1827 quantified the relationship between the electric current and potential difference in a conductor,
- Michael Faraday, the discoverer of electromagnetic induction in 1831.

History

- **James Clerk Maxwell,** who in 1873 published a unified theory of electricity and magnetism in his treatise **Electricity and Magnetism.**
- From the 1830s, efforts were made to apply electricity to practical use in **telegraphy.**
- By the end of the 19th century the world had been forever changed by the rapid communication made possible by engineering development of land-line, underwater and, eventually, wireless telegraphy.

Standardization

- Practical applications and advances in such fields created an increasing need for standardized units of measure.
- It led to the international standardization of the units **ohm, volt, ampere, coulomb, and watt.**
- This was achieved at an international conference in Chicago 1893.
- The publication of these standards formed the basis of future advances in standardization in various industries
- During these years, the study of electricity was largely considered to be a subfield of physics.
- It was not until the late 19th century that universities started to offer degrees in electrical engineering.

- The Darmstadt University of Technology founded the first chair and the first faculty of electrical engineering worldwide in **1882**.
- In the same year, under Professor Charles Cross, the Massachusetts Institute of Technology began offering the first option of Electrical Engineering within a physics department.
- In 1883 Darmstadt University of Technology and Cornell University introduced the world's first courses of study in electrical engineering
- In 1885 University College London founded the first chair of electrical engineering in the United Kingdom.
- University of Missouri subsequently established the first department of electrical engineering in the United States in 1886.

Edison, Parsons, Tesla

- During this period, the work concerning electrical engineering increased dramatically.
- In 1882, **Edison** switched on the world's first **large-scale electrical supply network** that provided 110 volts **direct current** to fifty-nine customers in lower Manhattan.
- In 1884 **Sir Charles Parsons** invented the **steam turbine** which today generates about 80 percent of the electric power in the world using a variety of heat sources.
- In 1887, **Nikola Tesla** filed a number of patents related to a competing form of power distribution known as **alternating current**.

War of Currents

- In the following years a bitter rivalry between **Tesla and Edison**, known as the "**War of Currents"**, took place over the preferred method of distribution.
- **AC eventually replaced DC for generation and power distribution, enormously extending the range and improving the safety and efficiency of power distribution.**

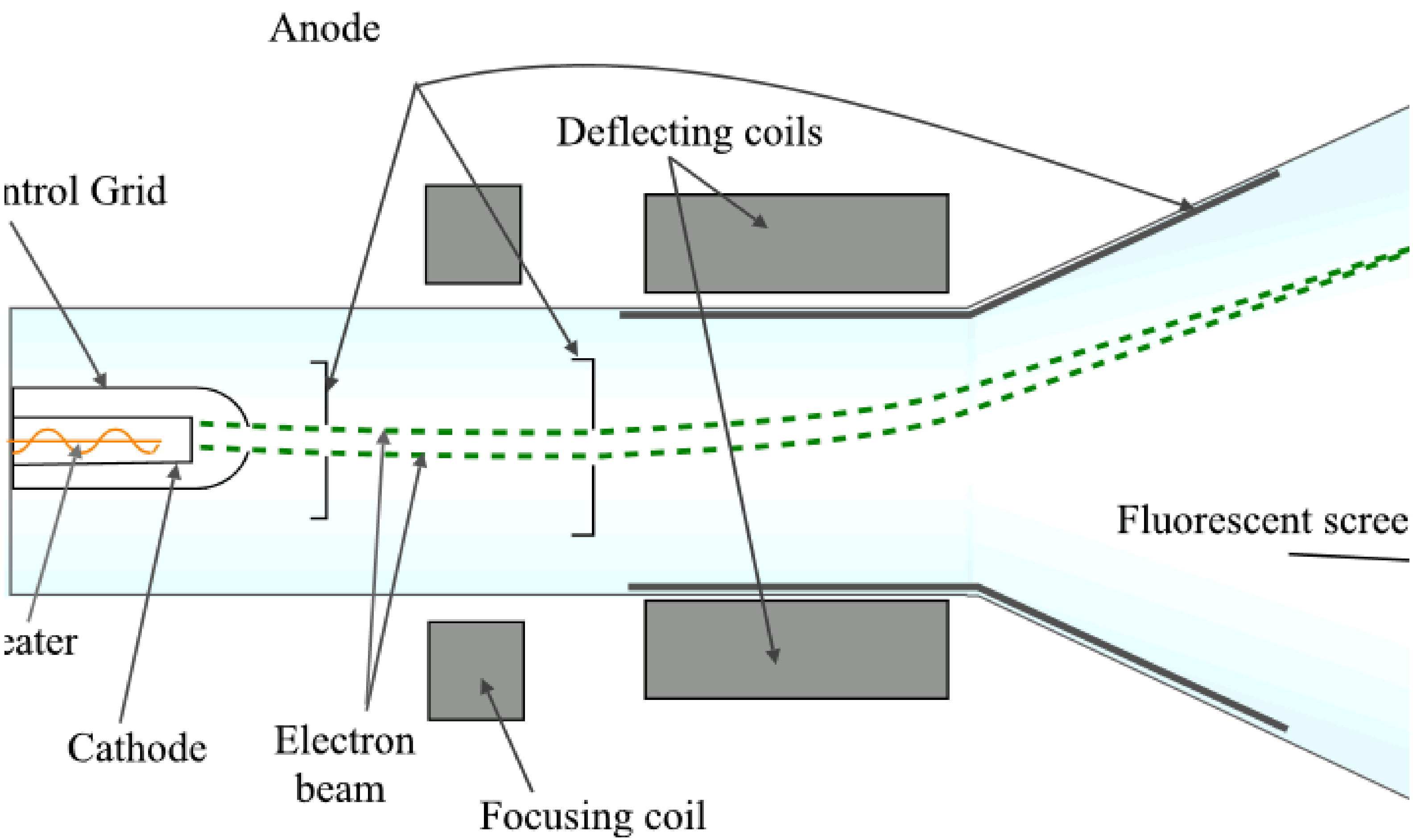
- The efforts of Edison and Tesla did much to further developments of electrical engineering.
- Tesla's work on induction motors and polyphase systems influenced the field for years to come.
- Edison's work on telegraphy and his development of the stock ticker proved profitable for his company, which ultimately became General Electric.

by the end of the 19th century, other key figures in the progress of electrical engineering were beginning to emerge.

Modern Developments

- During the development of radio, many scientists and inventors contributed to **radio technology and electronics.**
- In his classic **UHF** experiments of 1888, **Heinrich Hertz** transmitted (via a spark-gap transmitter) and detected radio waves using electrical equipment.
- In 1895, Nikola Tesla was able to detect signals from the transmissions of his New York lab at West Point (a distance of 80.4 km).
- In 1897, **Karl Ferdinand Braun** introduced the **cathode ray tube as part of an oscilloscope,** a crucial enabling technology for **electronic television.**
- John Fleming invented the first **radio tube, the diode**, in 1904.
- Two years later, **Robert von Lieben and Lee De Forest** independently developed the **amplifier tube**, called **the triode**.

Cathode Ray Tube



- In 1895, **Guglielmo Marconi** furthered the art of **Hertzian wireless** methods.
- Early on, he sent wireless signals over a distance of one and a half miles.
- In December 1901, he sent wireless waves that were not affected by the curvature of the Earth.
- Marconi later transmitted the wireless signals across the Atlantic between Poldhu, Cornwall, and St. John's, Newfoundland, a distance of 2,100 miles (3,400 km).

- In 1920 **Albert Hull** developed the magnetron which would eventually lead to the development of the **microwave oven** in 1946 by **Percy Spencer.**
- In 1934 the British military began to make strides toward radar (which also uses the magnetron) under the direction **of Dr Wimperis**, culminating in the operation of the **first radar station** at Bawdsey in August 1936.
- In 1941 **Konrad Zuse** presented the Z3, the world's first fully functional and programmable computer.
- In 1946 the ENIAC (Electronic Numerical Integrator and Computer) of **John Presper Eckert and John Mauchly** followed, beginning the computing era.

- The arithmetic performance of these machines allowed engineers to develop completely new technologies and achieve new objectives, including the Apollo missions and the NASA moon landing.
- The invention of the **transistor** in 1947 by **William B. Shockley, John Bardeen and Walter Brattain** opened the door for more compact devices and led to the development of **the integrated circuit** in 1958 by **Jack Kilby** and independently in 1959 **by Robert Noyce**.
- Starting in 1968, **Ted Hoff** and a team at Intel invented the first **commercial microprocessor,** which presaged the personal computer.
- The Intel 4004 was a 4-bit processor released in 1971, but in 1973 the Intel 8080, an 8-bit processor, made the first personal computer, the Altair 8800, possible.

Transistor

Tools and Works

- From the Global Positioning System to electric power generation, electrical engineers have contributed to the development of a wide range of technologies.
- They design, develop, test and supervise the deployment of electrical systems and electronic devices.
- They may work on the design of
  - telecommunication systems,
  - the operation of electric power stations,
  - the lighting and wiring of buildings,
  - the design of household appliances or
  - the electrical control of industrial machinery.

- Fundamental to the discipline are the sciences of physics and mathematics as these help to obtain both a qualitative and quantitative description of how such systems will work.
- Today most engineering work involves the use of computers and it is common place to use computer-aided design programs when designing electrical systems.

- Although most electrical engineers will understand **basic circuit theory** (that is the interactions of elements such as resistors, capacitors, diodes, transistors and inductors in a circuit), the theories employed by engineers generally depend upon the work they do.
- For example, quantum mechanics and solid state physics might be relevant to an engineer working **on VLSI** (the design of integrated circuits), but are largely irrelevant to engineers working with **macroscopic electrical systems.**

Perhaps the most important technical skills for electrical engineers are reflected in university programs, which emphasize

strong numerical skills,

computer knowledge and

the ability to understand the technical language and concepts

that relate to electrical engineering.

Resistor

- For many engineers, technical work accounts for only a fraction of the work they do.
- A lot of time may also be spent on tasks such as discussing proposals with clients, preparing budgets and determining project schedules.
- Many senior engineers manage a team of technicians or other engineers and for this reason **project management** skills are important.
- Most engineering projects involve some form of documentation and written communication skills are therefore very important.

Sub-Disciplines

- Electrical engineering has many sub-disciplines, the most popular of which are listed in this presentation.
- Although there are electrical engineers who focus exclusively on one of these sub-disciplines, many deal with a combination of them.
- Sometimes certain fields, such as electronic engineering and computer engineering, are considered separate disciplines in their own right.

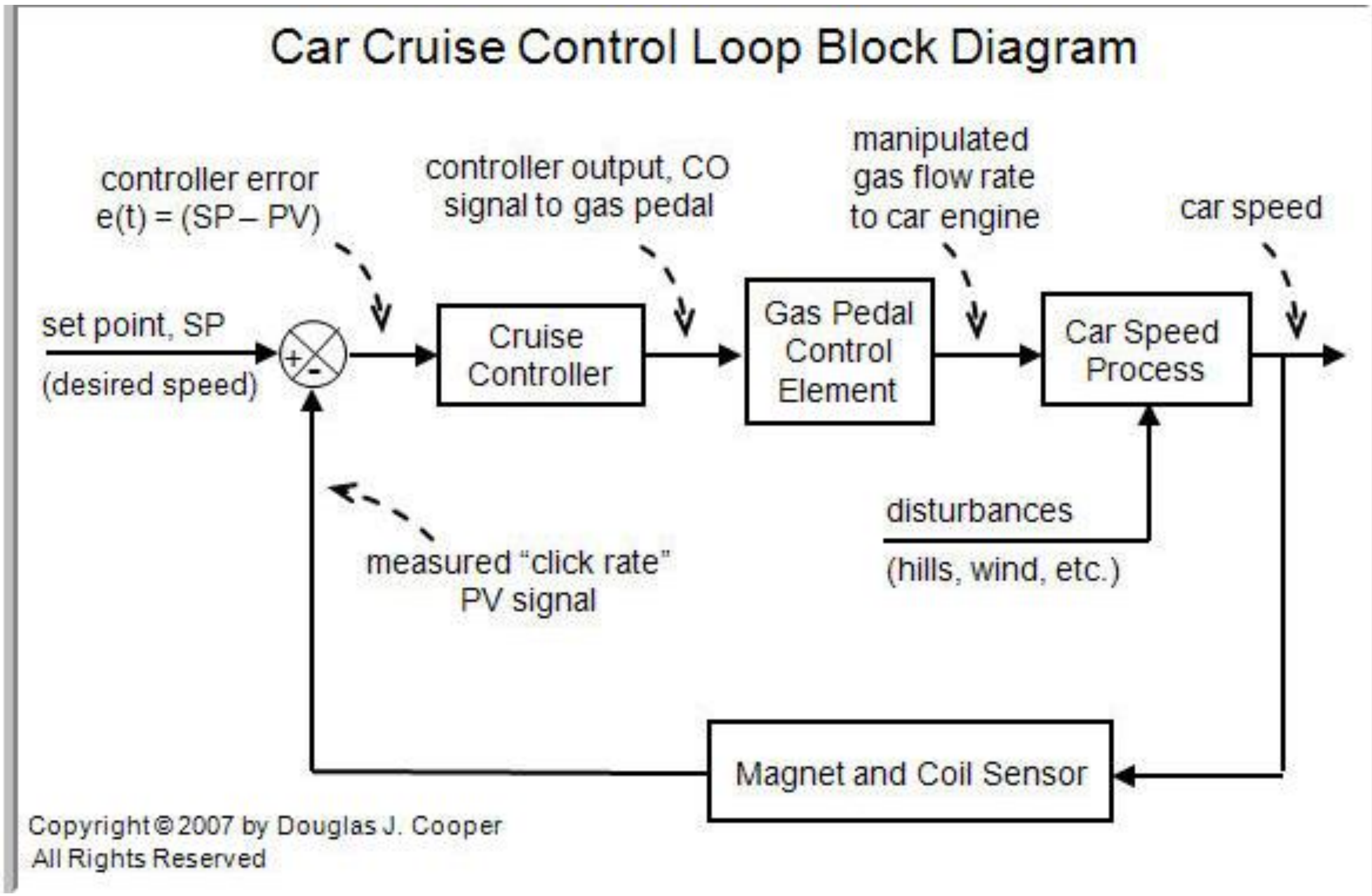
Control

- Control engineering focuses on the modeling of a diverse range of dynamic systems and the design of controllers that will cause these systems to behave in the desired manner.
- To implement such controllers electrical engineers may use electrical circuits, digital signal processors, microcontrollers and PLCs (Programmable Logic Controllers).
- Control engineering has a wide range of applications from the flight and propulsion systems of commercial airliners to the cruise control present in many modern automobiles.

Control

- It also plays an important role in industrial automation.
- Control engineers often utilize feedback when designing control systems. For example, in an automobile with cruise control the vehicle's speed is continuously monitored and fed back to the system which adjusts the motor's power output accordingly.
- Where there is regular feedback, control theory can be used to determine how the system responds to such feedback.

A Control Diagram



Electronics

- Electronic engineering involves the design and testing of electronic circuits that use the properties of components such as resistors, capacitors, inductors, diodes and transistors to achieve a particular functionality.
- The tuned circuit, which allows the user of a radio to filter out all but a single station, is just one example of such a circuit.
- Prior to the second world war, the subject was commonly known as *radio engineering* and basically was restricted to aspects of communications and radar, commercial radio and early television.
- Later, in post war years, as consumer devices began to be developed, the field grew to include modern television, audio systems, computers and microprocessors. In the mid-to-late 1950s, the term *radio engineering* gradually gave way to the name *electronic engineering*.

Electronics

- Before the invention of the integrated circuit in 1959, electronic circuits were constructed from discrete components that could be manipulated by humans.
- These discrete circuits consumed much space and power and were limited in speed, although they are still common in some applications.
- By contrast, integrated circuits packed a large number (often millions) of tiny electrical components, mainly transistors, into a small chip around the size of a coin.
- This allowed for the powerful computers and other electronic devices we see today.

Microelectronics

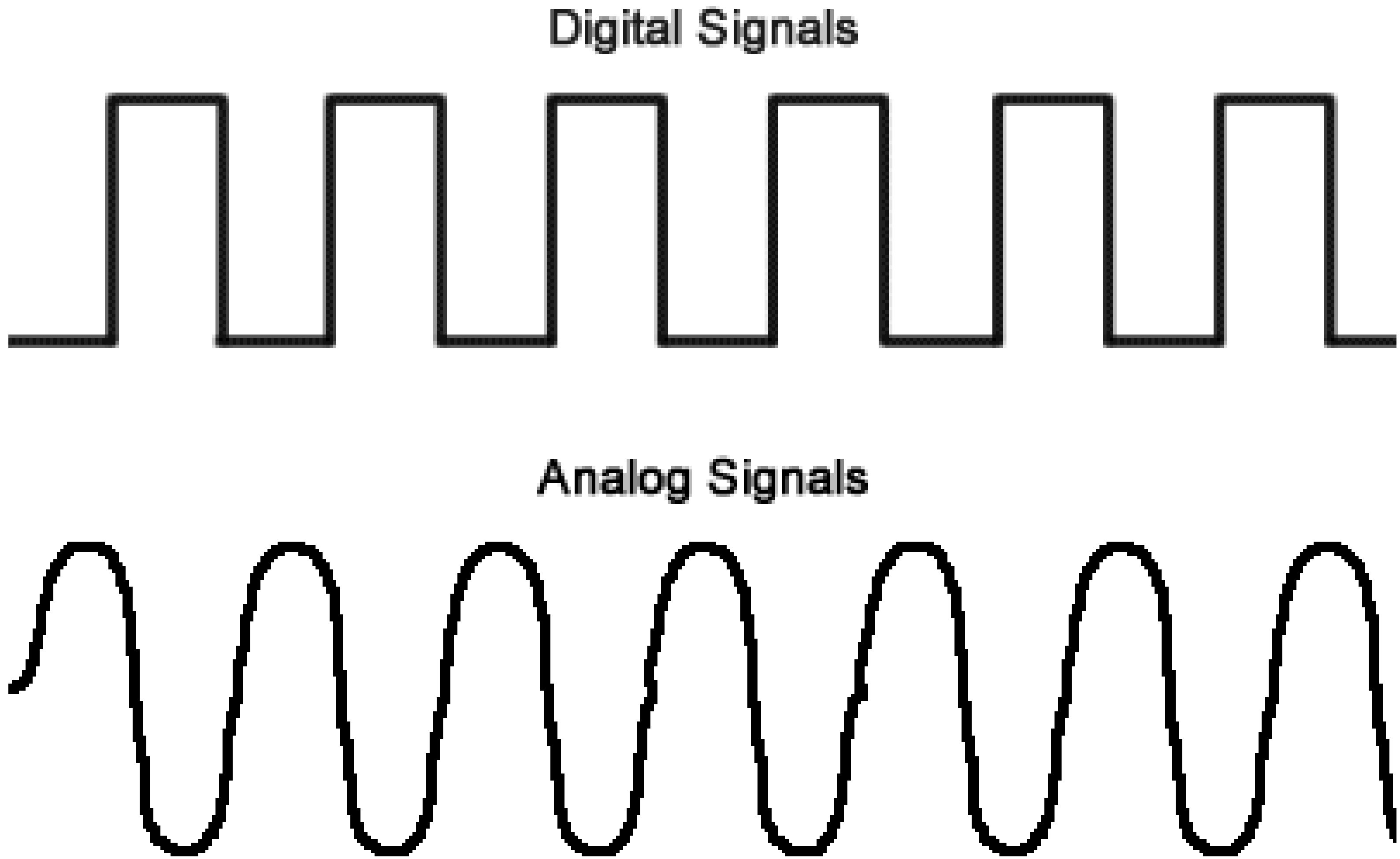
- Microelectronics engineering deals with the design and microfabrication of very small electronic circuit components for use in an integrated circuit or sometimes for use on their own as a general electronic component.
- The most common microelectronic components are semiconductor transistors, although all main electronic components (resistors, capacitors, inductors) can be created at a microscopic level.
- Nanoelectronics is the further scaling of devices down to nanometer levels.

- Microelectronic components are created by chemically fabricating wafers of semiconductors such as silicon (at higher frequencies, compound semiconductors like gallium arsenide and indium phosphide) to obtain the desired transport of electronic charge and control of current.
- The field of microelectronics involves a significant amount of chemistry and material science and requires the electronic engineer working in the field to have a very good working knowledge of the effects of quantum mechanics.

Signal Processing

- Signal processing deals with the analysis and manipulation of signals.
- Signals can be either analog, in which case the signal varies continuously according to the information, or digital, in which case the signal varies according to a series of discrete values representing the information.
- For analog signals, signal processing may involve the amplification and filtering of audio signals for audio equipment or the modulation and demodulation of signals for telecommunications.
- For digital signals, signal processing may involve the compression, error detection and error correction of digitally sampled signals.

Analog and Digital Signals



- Signal Processing is a very mathematically oriented and intensive area forming the core of digital signal processing
- It is rapidly expanding with new applications in every field of electrical engineering such as communications, control, radar, TV/Audio/Video engineering, power electronics and bio-medical engineering as many already existing analog systems are replaced with their digital counterparts.
- Analog signal processing only provided a mathematical description of a system to be implemented by the analog hardware engineers.
- Digital signal processing both provides a mathematical description of the systems to be designed and also implements it in the software of a processor.

- DSP (Digital Signal Processing) processor and Integrated Circuits are found in every type of modern electronic systems and products.
- Examples:
  - SDTV (Standard Definition Television),
  - HDTV (High Definition Television) sets,
  - GSM (Global System for Mobile Communication)
  - Intelligent missile guidance,
  - Radar,
  - GPS (General Positioning System).

Telecommunications

- Telecommunications engineering focuses on the transmission of informatin across a channel such as a coax cable, optical fiber or free space.
- Transmissions across free space require information to be encoded in a carrier wave in order to shift the information to a carrier frequency suitable for transmission, this is known as modulation.
- Popular analog modulation techniques include amplitude modulation (AM) and frequency modulation (FM).
- The choice of modulation affects the cost and performance of a system and these two factors must be balanced carefully by the engineer.

Telecommunications

- Once the transmission characteristics of a system are determined, telecommunication engineers design the transmitters and receivers needed for such systems.
- These two are sometimes combined to form a two-way communication device known as a transceiver.
- A key consideration in the design of transmitters is their power consumption as this is closely related to their signal strength.
- If the signal strength of a transmitter is insufficient the signal's information will be corrupted by noise.

Instrumentation

- Instrumentation engineering deals with the design of devices to measure physical quantities such as pressure, flow and temperature.
- The design of such instrumentation requires a good understanding of physics that often extends beyond electromagnetic theory.
- For example, flight instruments measure variables such as wind speed and altitude to enable pilots the control of aircraft analytically.

Instrumentation

- Similarly, thermocouples use the Peltier-Seebeck effect to measure the temperature difference between two points.
- Often instrumentation is not used by itself, but instead as the sensors of larger electrical systems.
- For example, a thermocouple might be used to help ensure a furnace's temperature remains constant. For this reason, instrumentation engineering is often viewed as the counterpart of control engineering.

Computer Engineering

- Computer engineering deals with the design of computers and computer systems.
- This may involve the design of new hardware, the design of PDAs (Personal Digital assistant) and supercomputers or the use of computers to control an industrial plant.
- Computer engineers may also work on a system's software. However, the design of complex software systems is often the domain of software engineering, which is usually considered a separate discipline.
- Desktop computers represent a tiny fraction of the devices a computer engineer might work on, as computer-like architectures are now found in a range of devices including video game consoles and DVD (Digital Video Disk) players.

Related Disciplines

- Mechatronics is an engineering discipline which deals with the convergence of electrical and mechanical systems.
- Such combined systems are known as electromechanical systems and have widespread adoption.
- Examples include automated manufacturing systems, heating, ventilation and air-conditioning systems and various subsystems of aircraft and automobiles.

Related Disciplines

- The term *Mechatronics* is typically used to refer to macroscopic systems but futurists have predicted the emergence of very small electromechanical devices.
- Already such small devices, known as Microelectromechanical systems (MEMS), are used in automobiles to tell airbags when to deploy, in digital projectors to create sharper images and in inkjet printers to create nozzles for high definition printing.

Related Disciplines

- In the future it is hoped the devices will help build tiny implantable medical devices and improve optical communication.
- Biomedical engineering is another related discipline, concerned with the design of medical equipment.
- This includes fixed equipment such as ventilators, MRI (Magnetic resonance Imaging) scanners and electrocardiograph monitors as well as mobile equipment such as cochlear implants, artificial pacemakers and artificial hearts.