Unit 5

Basics of electronics

Introduction to Semiconductors and Diodes

Electronic devices play a crucial role in our daily lives, making tasks simpler and more efficient. These devices, which include everything from mobile phones to medical imaging equipment, rely heavily on semiconductors and diodes to function.

1. Semiconductors

Conductors, Insulators, and Semiconductors

- **Conductors**: Materials that allow electricity to flow easily due to the presence of free electrons. Examples include metals like copper and aluminum.
- **Insulators**: Materials that do not conduct electricity because their electrons are tightly bound to their atoms. Examples include plastic, wood, and rubber.
- **Semiconductors**: Materials with electrical conductivity between that of conductors and insulators. Examples include silicon and germanium.

Lattice Structure of Semiconductors

- **Atomic Structure**: Semiconductors like silicon have a nucleus surrounded by electrons. The outermost electrons are involved in bonding.
- **Covalent Bonds**: Each atom in a semiconductor shares electrons with neighboring atoms, forming covalent bonds. This creates a stable lattice structure.

Types of Charge Carriers: Electrons and Holes

- **Electrons**: Negatively charged particles that can move freely in a semiconductor when energy is provided.
- **Holes**: Represent the absence of an electron in the lattice structure and behave as positively charged particles.

2. Types of Semiconductors

Intrinsic Semiconductors

- Made of pure material (like silicon or germanium) without any added impurities. These are also called undoped semiconductors.

Extrinsic Semiconductors

- Formed by adding impurities to an intrinsic semiconductor, a process called **doping**. This significantly increases the material's conductivity.

N-type Semiconductors

- **Doping with Group V elements**: Adding elements like phosphorus or arsenic, which have more electrons than silicon, results in extra free electrons, leading to conduction primarily through electron flow. These dopants are called **donor atoms**.

P-type Semiconductors

- **Doping with Group III elements**: Adding elements like boron or aluminum, which have fewer electrons than silicon, creates holes (positive charge carriers). These dopants are known as **acceptor atoms**.

3. Diodes and Their Functions

P-N Junction Diode

- **Formation**: When an N-type semiconductor is joined with a P-type semiconductor, a P-N junction diode is formed.
- **Depletion Region**: At the junction, electrons from the N-type region combine with holes from the P-type region, creating a depletion region where no free charge carriers exist.

Biasing of P-N Junction Diode

Forward Bias

- **Connection**: The positive terminal of a battery is connected to the P-type semiconductor, and the negative terminal is connected to the N-type.
- **Behavior**: The depletion region narrows, allowing current to flow through the diode.

Reverse Bias

- **Connection**: The positive terminal of a battery is connected to the N-type semiconductor, and the negative terminal is connected to the P-type.
- **Behavior**: The depletion region widens, preventing current from flowing.

I-V Characteristics of a Diode

- **Forward Bias**: The current remains low until the applied voltage exceeds the cut-in voltage (0.7V for silicon, 0.3V for germanium), after which the current increases rapidly.
- **Reverse Bias**: A small leakage current flows until the reverse voltage reaches a critical point, called the **breakdown voltage**, where the current increases sharply.

This understanding of semiconductors and diodes is fundamental to grasping how electronic devices operate.

5.3 Rectification

Rectification is the process of converting an alternating current (AC) voltage supply into a unidirectional (DC) voltage. This conversion is done using a **rectifier**, an electric circuit that typically involves a P-N junction diode. A P-N junction diode conducts electricity when forward biased and blocks it when reverse biased, making it essential for rectification.

Types of Rectifiers:

1. **Half-Wave Rectification**:
   - A **half-wave rectifier** allows only one half-cycle (either positive or negative) of an AC voltage to pass, blocking the other half-cycle.
   - It consists of a diode and a load resistor connected in series. During the positive half-cycle, the diode is forward biased and conducts current, developing a voltage across the load resistor. During the negative half-cycle, the diode is reverse biased and does not conduct, resulting in no current flow.
   - The output is a pulsating DC voltage, where only the positive half of the AC input is converted to DC.
2. **Full-Wave Rectification**:
   - A **full-wave rectifier** addresses the disadvantage of the half-wave rectifier by using the entire AC waveform.
   - It uses four diodes arranged in a bridge configuration. During the positive half-cycle, two of the diodes conduct, allowing current to flow through the load resistor. In the negative half-cycle, the other

    - two diodes conduct, ensuring the current through the load resistor flows in the same direction as during the positive half-cycle.
    - The result is a smoother DC output, utilizing both halves of the AC waveform.

Smoothing with Capacitors:

- A **capacitor** is used in rectifier circuits to smooth the pulsating DC voltage. It charges during the peak of the voltage and discharges when the voltage drops, providing a more consistent output.

5.4 Transistors and Their Applications

Transistors are semiconductor devices used to amplify or switch electronic signals. They come in two types: **Bipolar Junction Transistors (BJT)** and **Field Effect Transistors (FET)**. Here, we focus on BJTs.

BJT Structure:

- A BJT consists of three layers of alternately doped semiconductor material, forming two P-N junctions. Depending on the arrangement, a BJT can be an **NPN** or **PNP** transistor.
    - **NPN Transistor**: Consists of a P-type material sandwiched between two N-type materials.
    - **PNP Transistor**: Consists of an N-type material sandwiched between two P-type materials.
- The three regions of a transistor are:

    1. **Emitter (E)**: Supplies charge carriers (electrons or holes). It is heavily doped.
    2. **Collector (C)**: Collects charge carriers. It is moderately doped and larger in size.
    3. **Base (B)**: Controls the flow of charge carriers between the emitter and collector. It is lightly doped and very thin.

Transistor Operation:

- In an **NPN transistor**, the emitter is connected to the negative terminal of a battery, making the emitter junction forward biased. The collector is connected to a positive terminal, making the collector junction reverse

biased. Electrons from the emitter cross the base (a thin, lightly doped region) and reach the collector, resulting in current flow.
- In a **PNP transistor**, the biasing is reversed. The emitter is connected to the positive terminal of the battery, and the collector to the negative terminal. The operation is similar but with holes as the majority carriers.

Transistor Configurations:

- **Common-Collector (CC)**: Input is applied between base and collector; output is taken between emitter and collector. This configuration provides good current gain but no voltage gain.
- **Common-Base (CB)**: Input is applied between emitter and base; output is taken between collector and base. This provides voltage gain but no current gain.
- **Common-Emitter (CE)**: Input is applied between base and emitter; output is taken between collector and emitter. This configuration provides both current and voltage gain, making it the most commonly used configuration.

Transistor Applications:

- **Amplification**: Transistors amplify weak electrical signals, making them stronger.
- **Switching**: They are used as switches in electronic devices, including computers and communication systems.
- **Logic Gates**: Transistors are fundamental in creating logic gates, which are the building blocks of digital circuits.
- **Integrated Circuits (ICs)**: Transistors are the core components in ICs, found in nearly all modern electronic devices.

Integrated Circuits (ICs)

Overview:
Integrated Circuits (ICs) are crucial components in modern electronics, enabling the miniaturization and efficient functioning of devices like computers, mobile phones, and other digital gadgets. ICs integrate multiple electronic components, such as transistors, diodes, resistors, and capacitors, into a single small chip, typically made of silicon.

Importance of Integrated Circuits:
ICs have revolutionized the electronics industry by significantly reducing the size, power consumption, and cost of electronic devices. This invention, credited to

Jack Kilby and Robert Noyce, has enabled the development of compact and powerful digital technologies, from calculators to advanced computing systems.

Components of an Integrated Circuit:
An IC comprises a set of interconnected electronic components, including:

- **Transistors**: Act as switches or amplifiers.
- **Diodes**: Allow current to flow in one direction.
- **Resistors**: Control the flow of current.
- **Capacitors**: Store and release electrical energy.

These components are integrated onto a small silicon chip, making ICs compact and efficient.

Advantages and Disadvantages of ICs:
Advantages:

- **Small Size:** ICs are incredibly compact, allowing for miniaturization of electronic devices.
- **Low Power Consumption:** ICs consume less power compared to older technologies.
- **High Reliability:** The internal components of ICs are permanently connected, reducing the chance of errors and increasing reliability.
- **Cost-Effective:** ICs reduce the number of parts needed, lowering manufacturing costs.
- **High-Speed Operation:** Due to direct connections within the chip, ICs operate at higher speeds.

Disadvantages:

- **Limited Current and Voltage Handling:** ICs cannot manage high currents or voltages, as excessive heat or voltage can damage the device.
- **Non-Repairable:** ICs cannot be repaired since their internal components are inseparable.

Logic Gates and Circuits

Digital and Analog Signals:

- **Analog Signal:** A continuous signal that varies smoothly over time, like a sinusoidal wave.
- **Digital Signal:** A discrete signal that represents data as a sequence of values, typically 0s and 1s. These are binary signals, with only two possible states: low (0) or high (1).

Positive and Negative Logic:

- **Positive Logic:** 1 represents a high voltage (e.g., 5V), and 0 represents a low voltage (0V).
- **Negative Logic:** 1 represents a low voltage (0V), and 0 represents a high voltage (5V).

Logic Gates:

Logic gates are the basic building blocks of digital circuits. They perform logical operations on one or more inputs to produce a single output based on Boolean expressions.

1. **OR Gate:**
   - **Boolean Expression:** $y=A+B$
   - **Operation:** Outputs 1 if at least one input is 1.
   - **Application:** Used in circuits where the output is triggered if any input is active, like a light switch at either end of a corridor.
2. **AND Gate:**
   - **Boolean Expression:** $y=A\cdot B$
   - **Operation:** Outputs 1 only if both inputs are 1.
   - **Application:** Used in systems where all conditions must be met, like indicating if both airplane toilets are occupied.
3. **NOT Gate:**
   - **Boolean Expression:** $y=A^{-}$
   - **Operation:** Inverts the input; outputs 1 if input is 0, and vice versa.
   - **Application:** Automatically turning on a water pipe when the soil is dry using a moisture sensor.
4. **NOR Gate:**
   - **Boolean Expression:** $y=A+B^{-}$
   - **Operation:** Outputs 1 only if both inputs are 0.
   - **Application:** Combining OR and NOT functions, useful in specific digital circuits.
5. **NAND Gate:**
   - **Boolean Expression:** $y=A\cdot B^{-}$

- **Operation:** Outputs 1 if any input is 0.
- **Application:** Combining AND and NOT functions, used in various digital applications for control and timing functions.

Conclusion:
Integrated circuits and logic gates are fundamental to modern electronics. They enable complex functionalities in a wide range of devices while being compact, efficient, and reliable. Understanding how these components work is essential for grasping the principles of digital electronics.

5.7 Application of Electronics

Electronics play a crucial role in simplifying our work and solving problems across various fields. From everyday gadgets to complex systems, electronics are integral to modern life. Here's a clear breakdown of some key applications:

1. **Aerospace Industry**
   - Electronics are essential in aerospace for managing power in space shuttles and satellites. In commercial airlines, electronics measure vital physical factors like temperature, pressure, and elevation.
2. **Medical Field**
   - The advancement of electronics has revolutionized medicine. Devices like X-rays, MRIs, and robotic check-up machines are all based on electronics and physics. These innovations enhance medical care and allow for more precise diagnoses and treatments.
3. **Automobile Industry**
   - Modern vehicles rely heavily on electronics, from controlling engine functions (engine control units) to providing in-car entertainment and navigation systems. Electronics ensure better safety, comfort, and efficiency in vehicles.
4. **Agriculture**
   - Electronics are used to monitor and improve crop growth. Devices like e-Agri sensors measure moisture levels, nutrient content, and soil salinity, helping farmers manage their crops more effectively in the face of climate change.
5. **Communication**
   - Electronics are the backbone of communication systems. They handle the processing, storage, and transfer of information, enabling everything from phone calls to data transfer.
6. **Residential Applications**
   - Electronic devices like air conditioners, computers, and mobile phones have become essential in everyday life, making tasks easier and more efficient.
7. **Military Applications**

  - In the military, electronics are used in drones, night vision devices, and other sophisticated gadgets to enhance surveillance and combat capabilities. These tools help soldiers with targeting and monitoring during operations.

Key Electronic Components and Concepts

- **Junction Diode**: A device formed by joining N-type and P-type materials, with a depletion region acting as a barrier to charge carriers.
- **Biasing**: Applying a DC voltage to a diode.
- **Rectification**: Converting AC voltage to DC; can be done using half-wave or full-wave rectifiers.
- **Capacitors**: Used in rectifiers to smooth voltage fluctuations.
- **LED (Light-Emitting Diode)**: Emits light when electricity passes through it.
- **Transistor**: A semiconductor device with three layers (emitter, base, and collector). It can amplify signals or act as a switch.
- **Integrated Circuits**: Composed of components like diodes, transistors, resistors, and capacitors, these circuits handle complex tasks in small packages.
- **Logic Gates**:
  - **AND Gate**: Outputs 1 when all inputs are 1.
  - **OR Gate**: Outputs 1 if any input is 1.
  - **NOT Gate**: Inverts the input.
  - **NAND and NOR Gates**: Combinations of AND/OR and NOT gates for specific logic functions.

These applications and components demonstrate the wide-ranging impact of electronics on various industries and everyday life.