CHAPTER 4

DIODE CIRCUIT ANALYSIS AND APPLICATION

Objectives

After completing this course, you will be able to:

- Determine the different types of diodes and use.
- Understand the flow of forward bias and reverse bias related to diodes.

Diode

- is a two-terminal electronic component that conducts current primarily in one direction (asymmetric conductance); it has low (ideally zero) resistance in one direction, and high (ideally infinite) resistance in the other.

Diode vacuum tube or thermionic diode

- is a vacuum tube with two electrodes, a heated cathode and a plate, in which electrons can flow in only one direction, from cathode to plate.

Semiconductor diode

- The most commonly used type today, is a crystalline piece of semiconductor material with a p–n junction connected to two electrical terminals. Semiconductor diodes were the first semiconductor electronic devices.
- The discovery of asymmetric electrical conduction across the contact between a crystalline mineral and a metal was made by German physicist Ferdinand Braun in 1874.
- Today, most diodes are made of silicon, but other semiconducting materials such as gallium arsenide and germanium are also used.
- The most common function of a diode is to allow an electric current to pass in one direction (called the diode's *forward* direction), while blocking it in the opposite direction (the *reverse* direction).
- As such, the diode can be viewed as an electronic version of a check valve.
- Semiconductor diodes begin conducting electricity only if a certain threshold voltage or cut-in voltage is present in the forward direction (a state in which the diode is said to be *forward-biased*). The voltage drop across a forward-biased diode varies only a little with the current, and is a function of temperature; this effect can be used as a temperature sensor or as a voltage reference.
- Diodes, both vacuum and semiconductor, can be used as shot-noise generators.
- Thermionic (vacuum-tube) diodes and solid-state (semiconductor) diodes were developed separately, at approximately the same time, in the early 1900s, as radio receiver detectors.
- Until the 1950s, vacuum diodes were used more frequently in radios because the early point-contact semiconductor diodes were less stable.
- In addition, most receiving sets had vacuum tubes for amplification that could easily have the thermionic diodes included in the tube (for example the 12SQ7 double diode triode), and vacuum-tube rectifiers and gas-filled

rectifiers were capable of handling some high-voltage/high-current rectification tasks better than the semiconductor diodes (such as selenium rectifiers) that were available at that time.

- In 1873, Frederick Guthrie observed that a grounded, white hot metal ball brought in close proximity to an electroscope would discharge a positively charged electroscope, but not a negatively charged electroscope.
- In 1880, Thomas Edison observed unidirectional current between heated and unheated elements in a bulb, later called Edison effect, and was granted a patent on application of the phenomenon for use in a dc voltmeter.
- Throughout the vacuum tube era, valve diodes were used in almost all electronics such as radios, televisions, sound systems and instrumentation.
- In 1874, German scientist Karl Ferdinand Braun discovered the "unilateral conduction" across a contact between a metal and a mineral. Jagadish Chandra Bose was the first to use a crystal for detecting radio waves in 1894.
- Point-contact diodes use a small diameter metal wire in contact with a semiconductor crystal, and are of either *non-welded* contact type or *welded contact* type.
- Non-welded contact construction utilizes the Schottky barrier principle.

Types of semiconductor diode

Avalanche diodes

These are diodes that conduct in the reverse direction when the reverse bias voltage exceeds the breakdown voltage. These are electrically very similar to Zener diodes (and are often mistakenly called Zener diodes), but break down by a different mechanism: the avalanche effect. Avalanche diodes are designed to break down at a well-defined reverse voltage without being destroyed.

Constant-current diodes

These are actually JFETs with the gate shorted to the source, and function like a two-terminal current-limiting analog to the voltage-limiting Zener diode. They allow a current through them to rise to a certain value, and then level off at a specific value.

Crystal rectifiers or crystal diodes

These are point-contact diodes.The 1N21 series and others are used in mixer and detector applications in radar and microwave receivers. The 1N34A is another example of a crystal diode.

Gunn diodes

These are similar to tunnel diodes in that they are made of materials such as GaAs or InP that exhibit a region of negative differential resistance. With appropriate biasing, dipole domains form and travel across the diode, allowing high frequency microwave oscillators to be built.

Light-emitting diodes (LEDs)

In a diode formed from a direct band-gap semiconductor, such as gallium arsenide, charge carriers that cross the junction emit photons when they recombine with the majority carrier on the other side. Depending on the material, wavelengths (or colors)from the infrared to the near ultraviolet may be produced.

Laser diodes

When an LED-like structure is contained in a resonant cavity formed by polishing the parallel end faces, a laser can be formed. Laser diodes are commonly used in optical storage devices and for high speed optical communication.

Thermal diodes

This term is used both for conventional p–n diodes used to monitor temperature because of their varying forward voltage with temperature, and for Peltier heat pumps for thermoelectric heating and cooling. Peltier heat pumps may be made from semiconductor, though they do not have any rectifying junctions, they use the differing behaviour of charge carriers in N and P type semiconductor to move heat.

Photodiodes

All semiconductors are subject to optical charge carrier generation. This is typically an undesired effect, so most semiconductors are packaged in light blocking material. Photodiodes are intended to sense light (photodetector), so they are packaged in materials that allow light to pass, and are usually PIN (the kind of diode most sensitive to light).

PIN diodes

A PIN diode has a central un-doped, or intrinsic, layer, forming a p-type/intrinsic/n-type structure. They are used as radio frequency switches and attenuators. They are also used as large-volume, ionizing-radiation detectors and as photodetectors. PIN diodes are also used in power electronics, as their central layer can withstand high voltages.

Schottky diodes

Schottky diodes are constructed from a metal to semiconductor contact. They have a lower forward voltage drop than p–n junction diodes. Their forward voltage drop at forward currents of about 1 mA is in the range 0.15 V to 0.45 V, which makes them useful in voltage clamping applications and prevention of transistor saturation.

Super barrier diodes

Super barrier diodes are rectifier diodes that incorporate the low forward voltage drop of the Schottky diode with the surge-handling capability and low reverse leakage current of a normal p–n junction diode.

Gold-doped diodes

As a dopant, gold (or platinum) acts as recombination centers, which helps a fast recombination of minority carriers. This allows the diode to operate at signal frequencies, at the expense of a higher forward voltage drop.

Snap-off or Step recovery diodes

The term step recovery relates to the form of the reverse recovery characteristic of these devices. After a forward current has been passing in an SRD and the current is interrupted or reversed, the reverse conduction will cease very abruptly (as in a step waveform). SRDs can, therefore, provide very fast voltage transitions by the very sudden disappearance of the charge carriers.

Stabistors or Forward Reference Diodes

The term stabistor refers to a special type of diodes featuring extremely stable forward voltage characteristics. These devices are specially designed for low-voltage stabilization applications requiring a guaranteed voltage over a wide current range and highly stable over temperature.

Transient voltage suppression diode (TVS)

These are avalanche diodes designed specifically to protect other semiconductor devices from high-voltage transients.Their p–n junctions have a much larger cross-sectional area than those of a normal diode, allowing them to conduct large currents to ground without sustaining damage.

Tunnel diodes or Esaki diodes

These have a region of operation showing negative resistance caused by quantum tunneling,allowing amplification of signals and very simple bistable circuits. Because of the high carrier concentration, tunnel diodes are very fast, may be used at low (mK) temperatures, high magnetic fields, and in high radiation environments. Because of these properties, they are often used in spacecraft.

Varicap or varactor diodes

These are used as voltage-controlled capacitors. These are important in PLL (phase-locked loop) and FLL (frequency-locked loop) circuits, allowing tuning circuits, such as those in television receivers, to lock quickly on to the frequency.

Zener diodes

These can be made to conduct in reverse bias (backward), and are correctly termed reverse breakdown diodes. This effect, called Zener breakdown, occurs at a precisely defined voltage, allowing the diode to be used as a precision voltage reference.

Video links:

Diodes - What Are Diodes - PN Junction - Forward Bias - Reverse Bias - Zener Diodes

- ***https://www.youtube.com/watch?v=n0SiQIaitHk***

What Is a Diode?

- ***https://www.youtube.com/watch?v=g54vURe47gM***

Diodes Explained - The basics how diodes work working principle pn junction

- ***https://www.youtube.com/watch?v=Fwj_d3uO5g8***

Reference:

- ***Tooley, Mike (2013). Electronic Circuits: Fundamentals and Applications, 3rd Ed. Routledge. p. 81. ISBN 978-1-136-40731-4.***
- ***Crecraft, Filip Mincic; Stephen Gergely (2002). Analog Electronics: Circuits, Systems and Signal Processing. Butterworth-Heinemann. p. 110. ISBN 0-7506-5095-8.***
- ***Horowitz, Paul; Winfield Hill (1989). The Art of Electronics, 2nd Ed. London: Cambridge University Press. p. 44. ISBN 0-521-37095-7.***