

Semiconductors Devices

Lecturers: Prof. K . Thamilmaran

OBJECTIVES

This course deals with an introduction to semiconductor Devices.

SYLLABUS

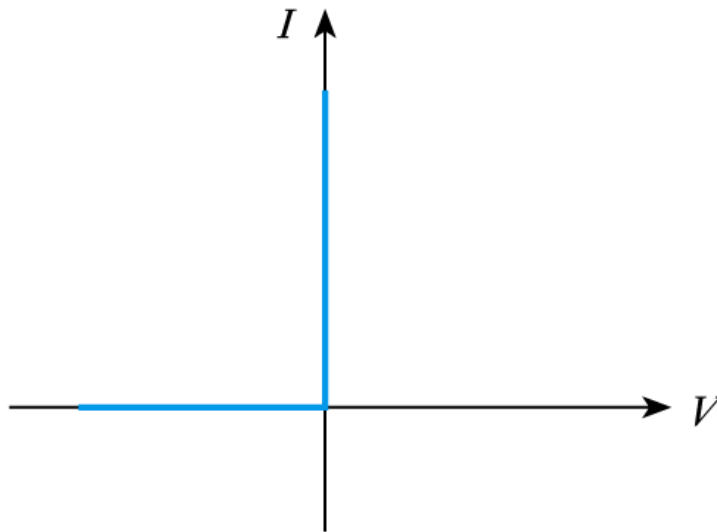
Semiconductors Devices: Metal - Semiconductor contacts (Ohmic and Schottky) - Schottky barrier diode – Zener diode – Varactor diode – Tunnel diode.

Semiconductor Diodes

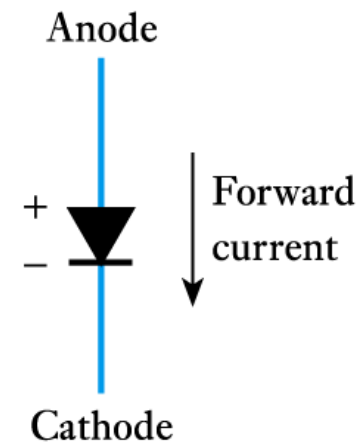
- ❖ **Diodes**
- ❖ **Semiconductors**
- ❖ ***pn* Junctions**
- ❖ **Semiconductor Diodes**
- ❖ **Special-purpose Diodes**

Diodes

- An **ideal diode** passing electricity in one direction but not the other

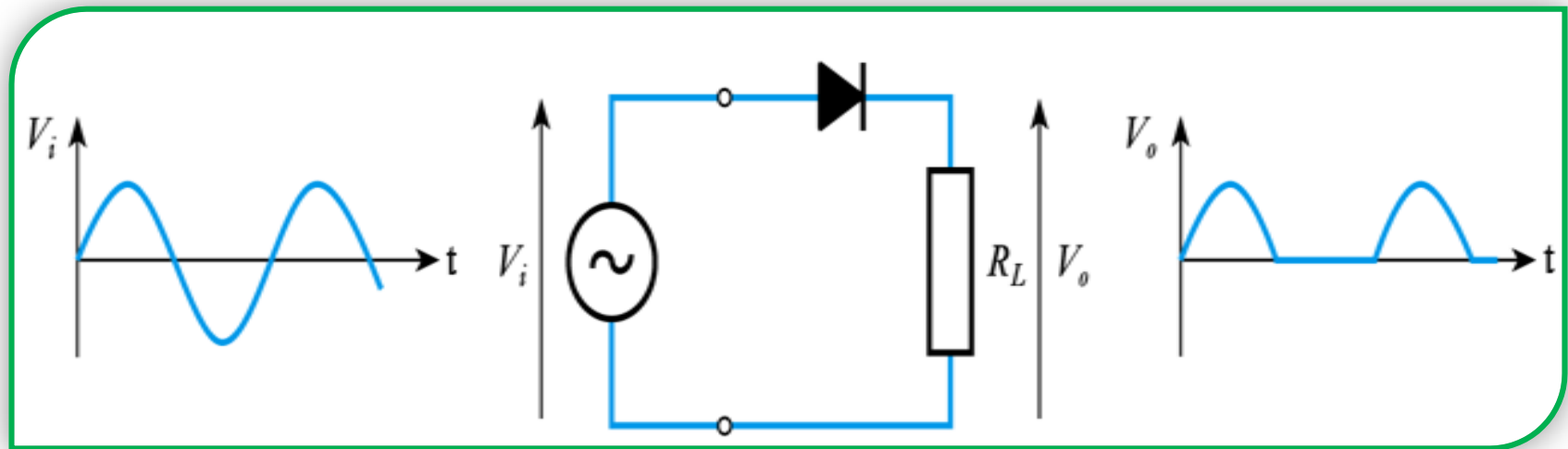


(a) I–V characteristic



(b) Diode circuit symbol

- ❖ One application of diodes is in **rectification**
The example below shows a **half-wave rectifier**
- ❖ In practice, no real diode has ideal characteristics but semiconductor **pn junctions** make good diodes
- ❖ To understand such devices we need to look at some properties of materials



Electrical Properties of Solids

Conductors

- ❖ If an electric field is applied electrons will flow causing an electric current (at all temperatures above absolute zero).
e.g. copper or aluminium

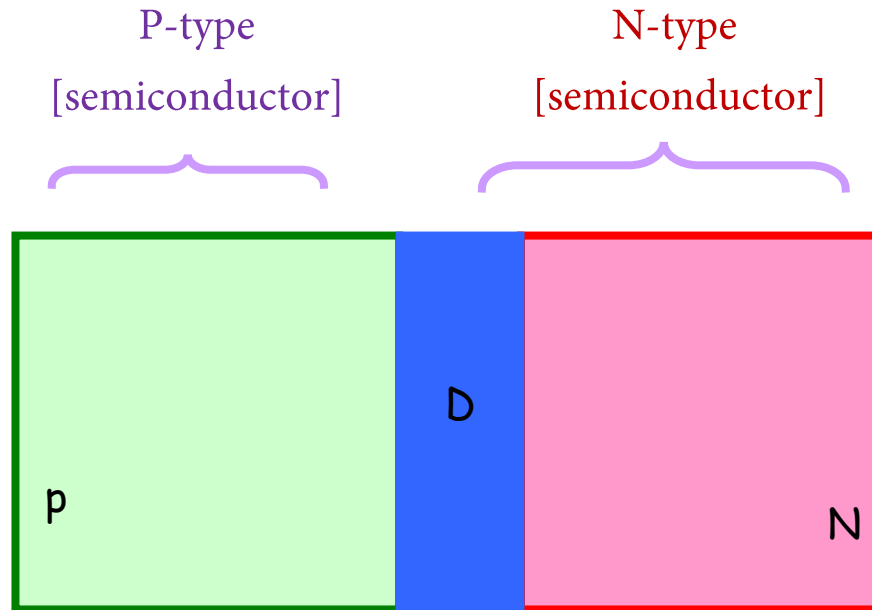
Insulators

- ❖ Electrons are tightly bound to atoms so few can break free to conduct electricity
e.g. Glass, Wood, polythene

Semiconductors

- ❖ Semiconductors have several properties that make them distinct from conductors and insulators
e.g. silicon ($V_B = 0.7\text{volts}$) or germanium ($V_B = 0.3\text{ volts}$)
- ❖ At very low temperatures these have the properties of insulators
- ❖ The material warms up some electrons break free and can move about, and it takes on the properties of a conductor.

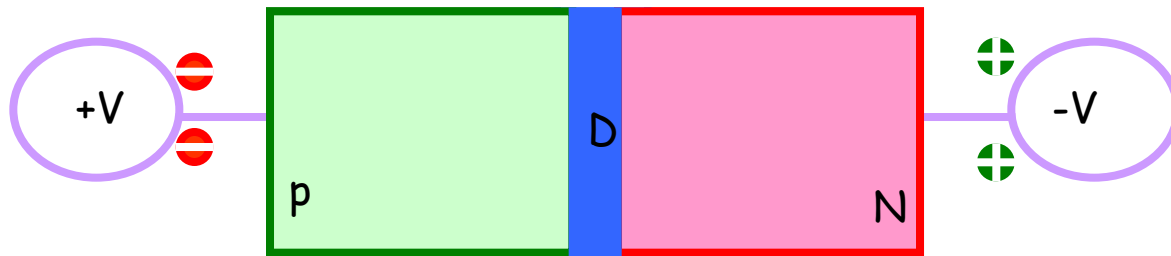
PN Junction



Depletion region, barrier to free flow of current from P to N → insulator

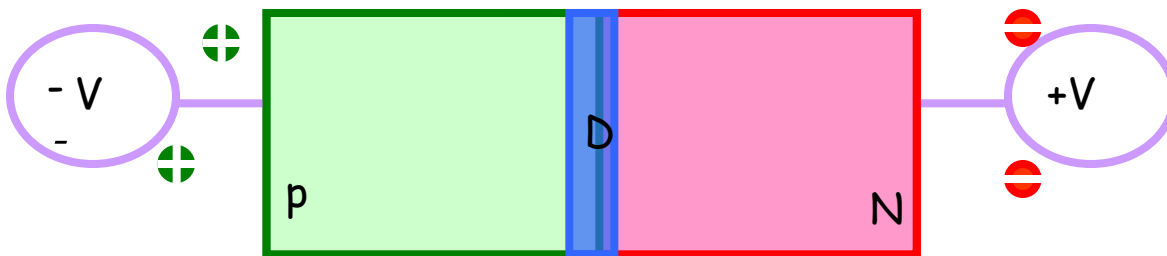
PN Junction

Forward Bias: Shrink depletion region, current dragged through the barrier



Once the difficulty of getting through the depletion region has been overcome, current can rise with applied voltage (Ohm's law)

Reverse Bias: Grow depletion region, current finds it more and more difficult to get through the barrier

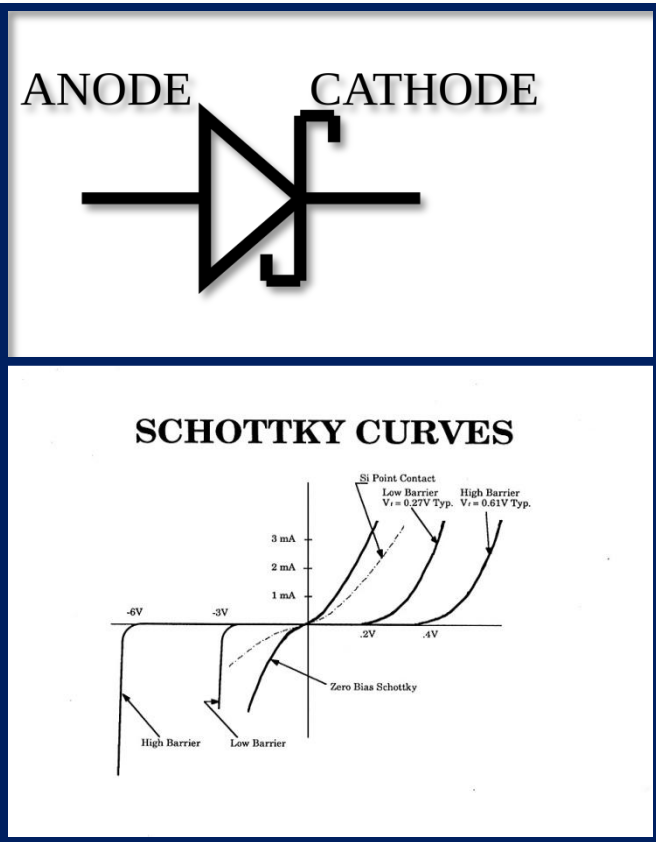


- ❖ Little current flows because barrier too high
- ❖ However increasing voltage further → high electric field
- ❖ Depletion region eventually breaks down → reverse current

Reverse

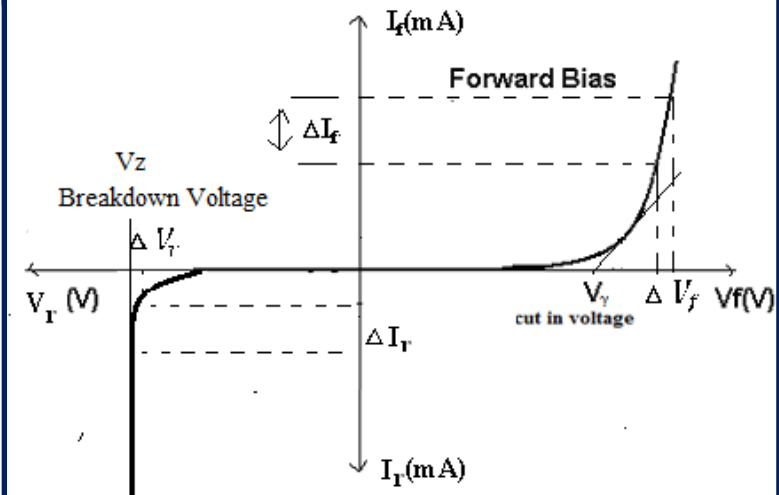
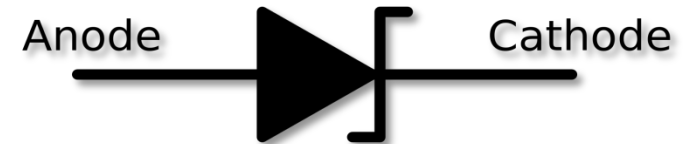
Schottky diode

- ❖ Junction between a layer of metal (e.g. aluminium) and a semiconductor
- ❖ Action relies only on majority charge carriers
- ❖ Much faster in operation than a *pn* junction diode
- ❖ A low forward voltage drop of about 0.25 V
- ❖ Used in the design of high-speed logic gates



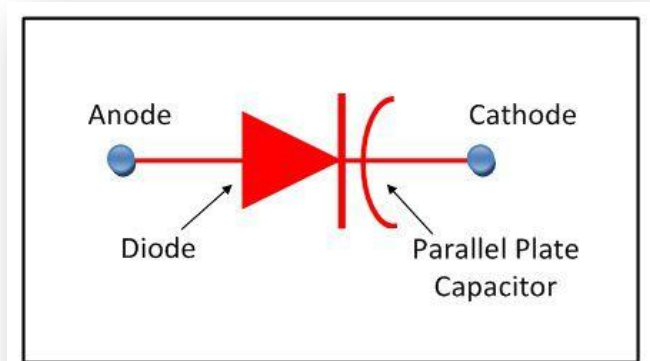
Zener diodes

- The relatively constant reverse breakdown voltage to produce a voltage reference
- Breakdown voltage is called the Zener voltage, V_Z
- Output voltage of circuit shown is equal to V_Z despite variations in input voltage V
- A resistor is used to limit the current in the diode

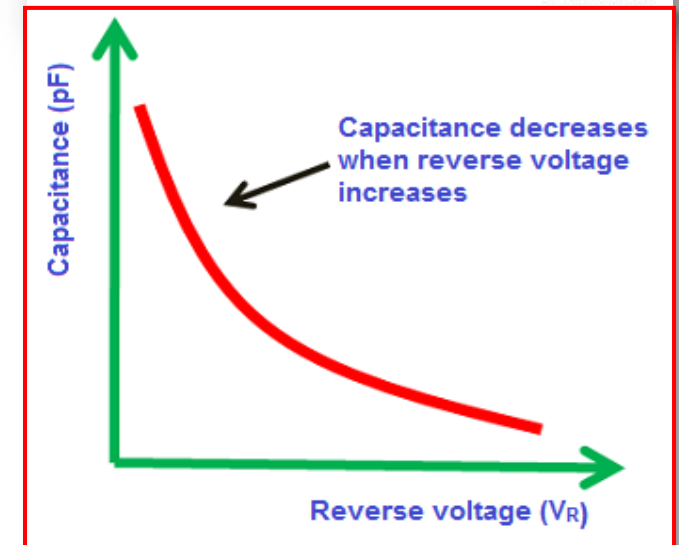


Varactor diode (Varicap Diode)

- A reversed-biased diode has two conducting regions separated by an insulating depletion region
- Variations in the reverse - bias voltage change the width of the depletion layer and hence the capacitance
- This produces a **voltage - dependent capacitor**
- These are used in applications such as **automatic tuning circuits**

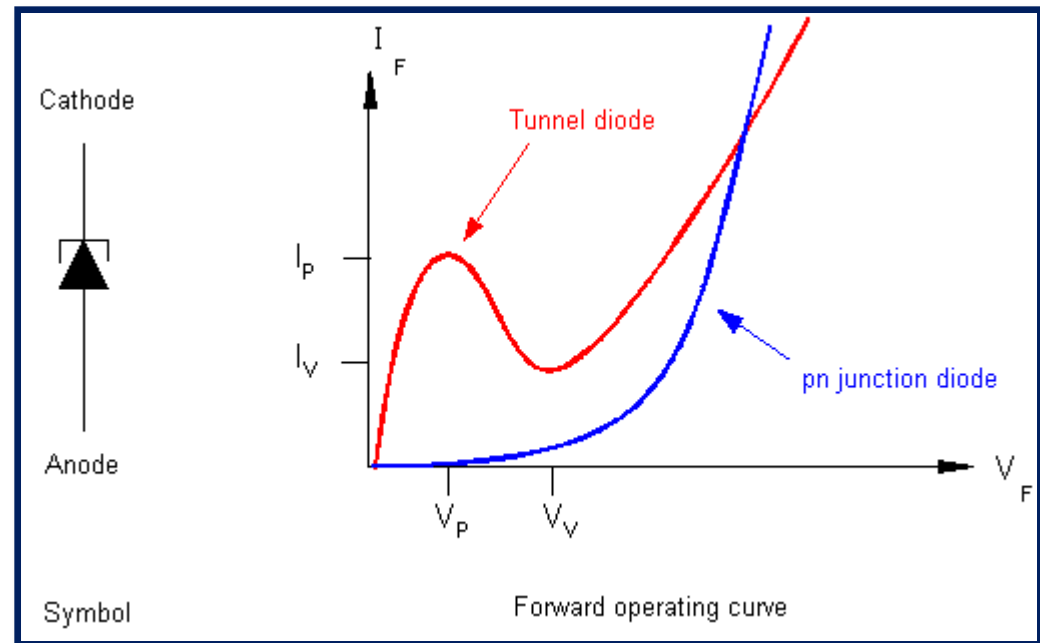


Circuit Globe



Tunnel diodes

- ❖ High doping levels produce a very thin depletion layer which permits 'tunnelling' of charge carriers
- ❖ Results in a characteristic with a **negative resistance** region



- ❖ Used in high - frequency oscillators, where they can be used to 'cancel out' resistance in passive components

Key Points

- ❖ Diodes allow current to flow in only one direction
- ❖ At low temperatures semiconductors act like insulators
- ❖ At higher temperatures they begin to conduct
- ❖ Doping of semiconductors leads to the production of p -type and n -type materials
- ❖ A junction between p - type and n - type semiconductors has the properties of a diode
- ❖ Silicon semiconductor diodes approximate the behaviour of ideal diodes but have a conduction voltage of about 0.7 V and germanium 0.3 V
- ❖ There are also a wide range of special purpose diodes
- ❖ Diodes are used in a range of applications