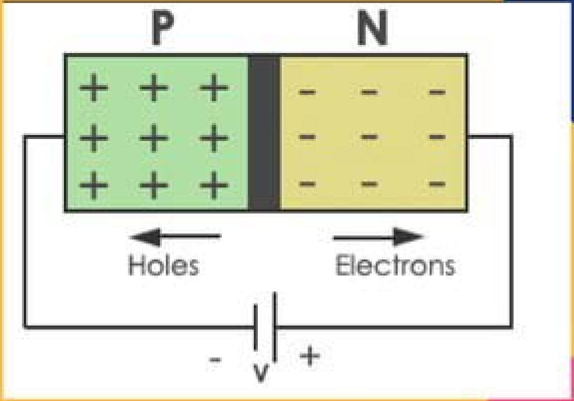
What is diode?

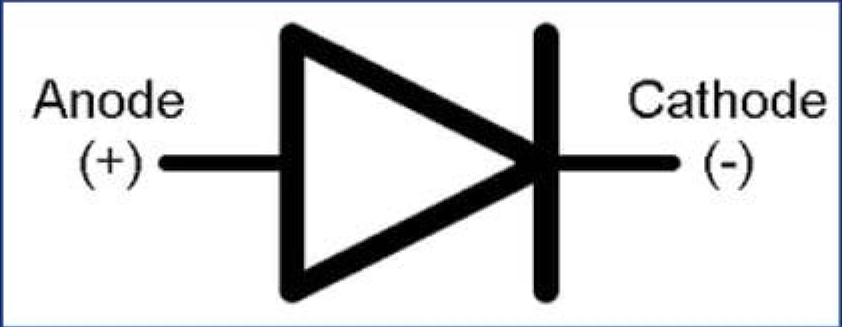
A diode is an electrical component designed to conduct electric current in only one direction.

It has two ends (or terminals), each with an electrode of a different charge.

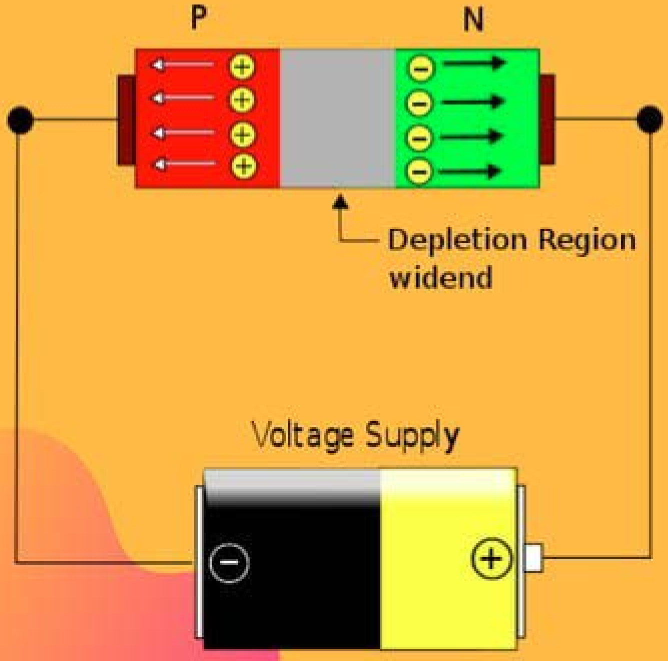


Symbol

DIODE



Constuction



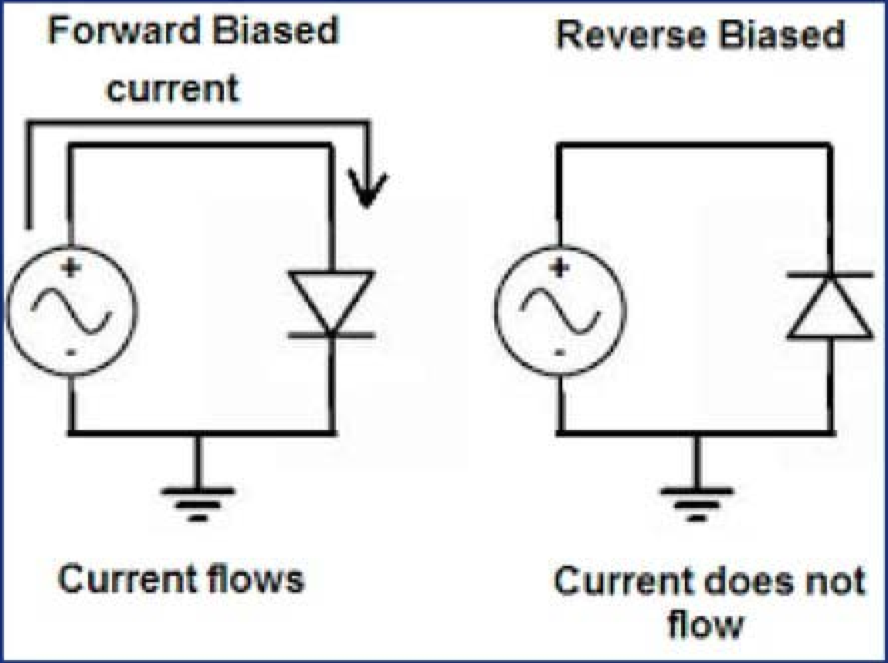
A diode is formed by joining two equivalently doped P-Type and N-Type semiconductor.

Biasing

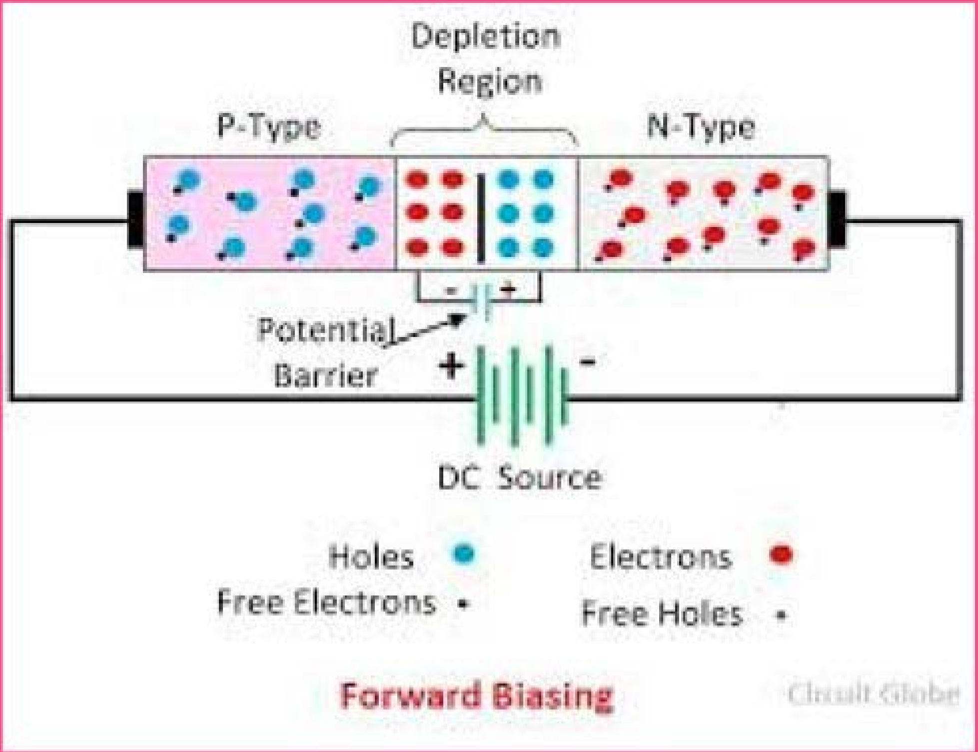
Biasing in electronics means establishing predetermined voltages or currents at various points of an electronic circuit for the purpose of establishing proper operating conditions in electronic components.

1. **Forward Biasing**
2. **Reverse Biasing**

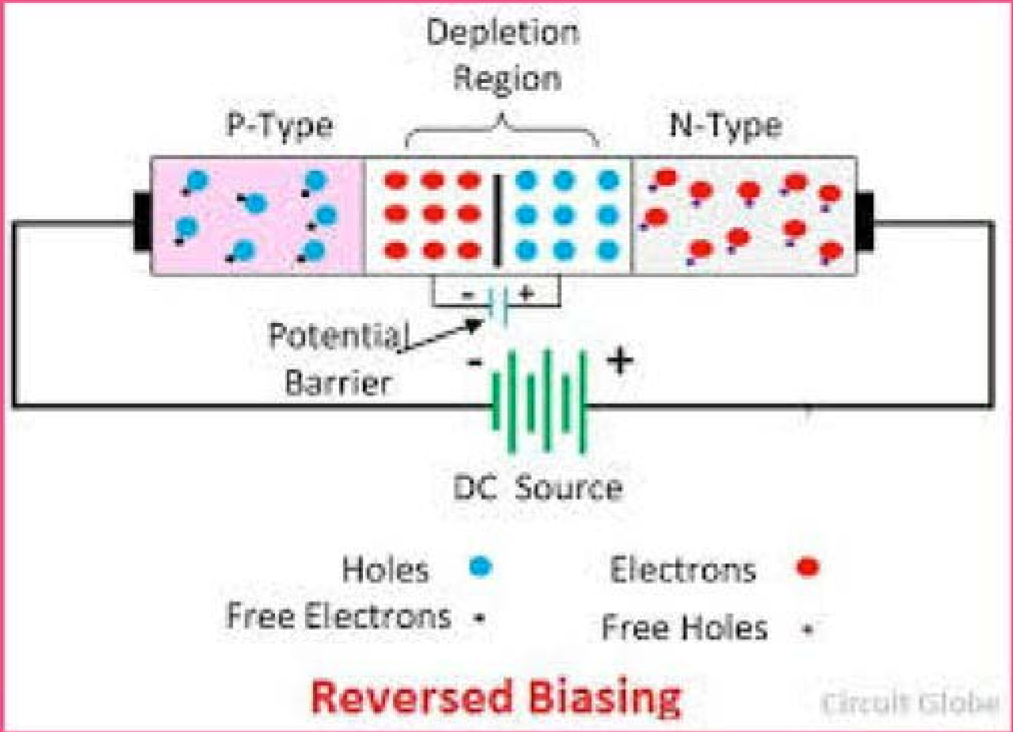
Forward and Reverse Bias



FORWARD BIAS



REVERSE BIAS

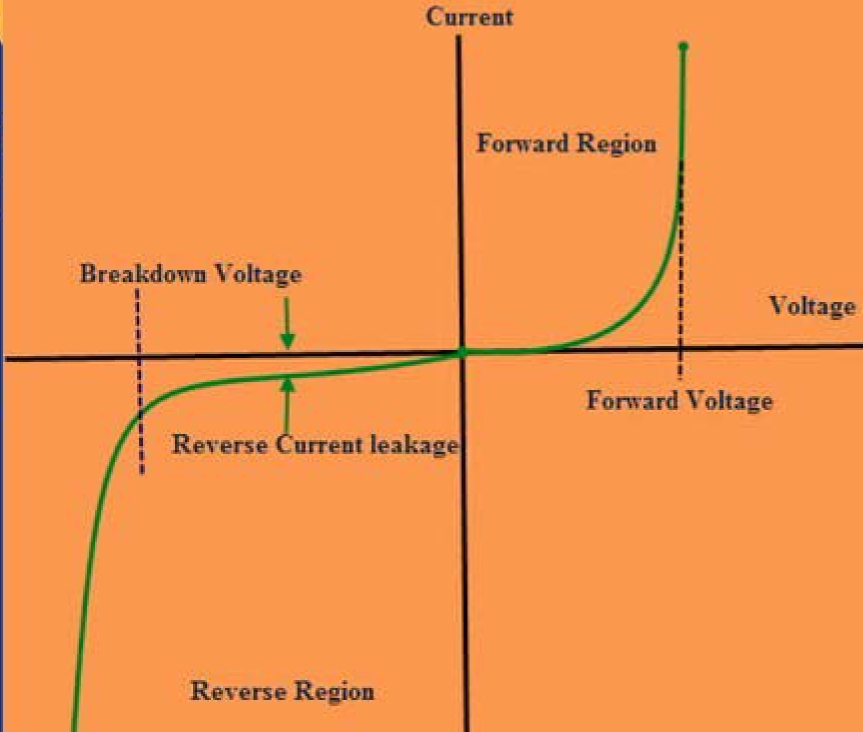


FORWARD AND REVERSE BIAS

Forward biasing means putting a voltage across a diode that allows current to flow easily, while reverse biasing means putting a voltage across a diode in the opposite direction.

V-I Charecteristics

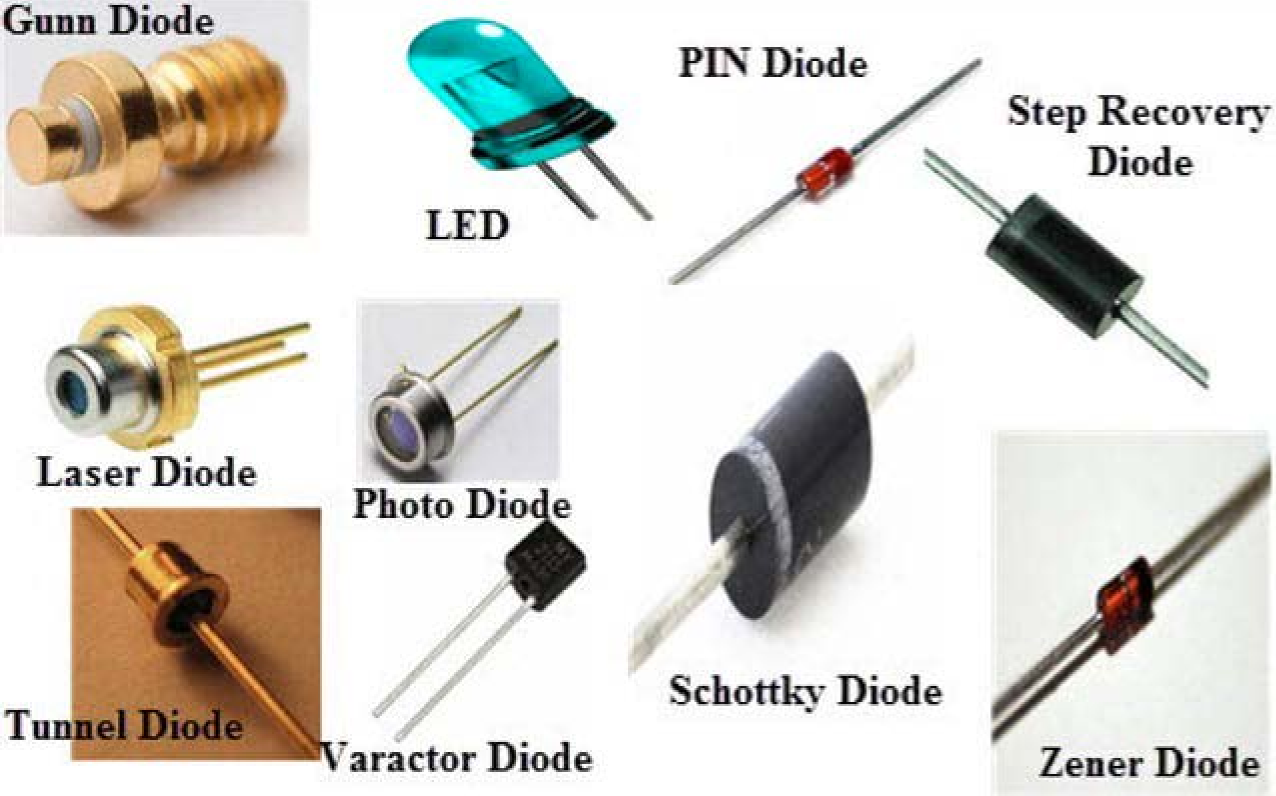
Using V-I characteristics of the diode, it is easy to find the voltage and current in the circuit which contains the diode.



VARIOUS DIODES

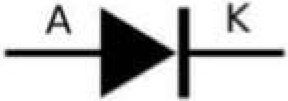
a Backward diode,
BARITT diode,
Gunn Diode,
Laser diode,
Light emitting diodes,
Photodiode,
PIN diode,
PN Junction,
Schottky diodes,
Step recovery diode,
Tunnel diode,
Varactor diode and a
Zener diode.

VARIOUS DIODES



Application of Diodes

Power Diode



Rectifying power supply circuit
(Rectifier = penerus)

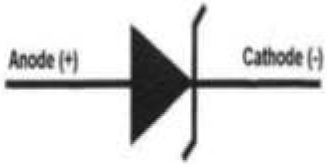
Application of Diodes

Signal Diode

signal sensor in radar

Application of Diodes

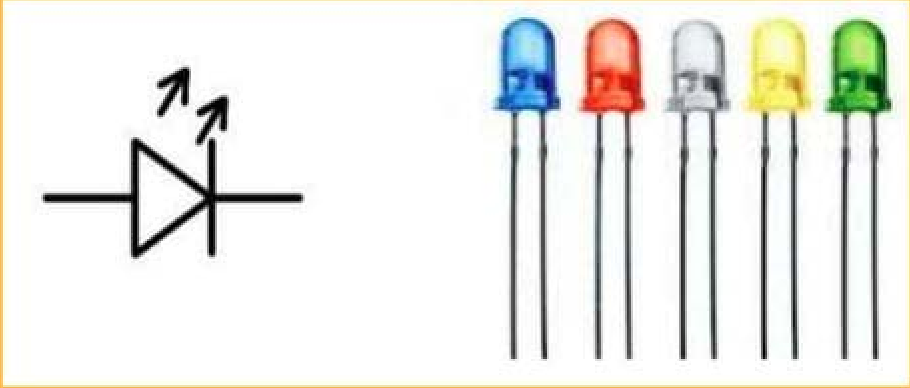
Zerner Diode



Voltage regulator in power supply circuit.
Voltage clipper in power supply circuit

Application of Diodes

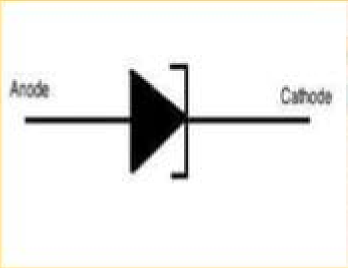
Light Emitting Diode (LED)



Indicator light in electronic circuit

Application of Diodes

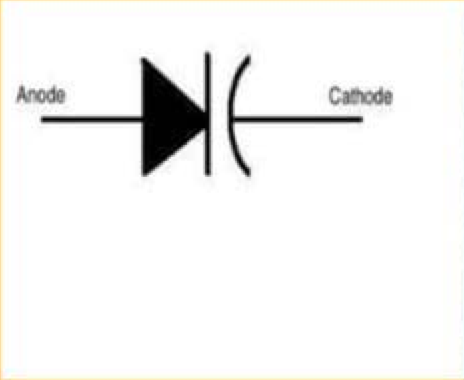
Tunnel Diode

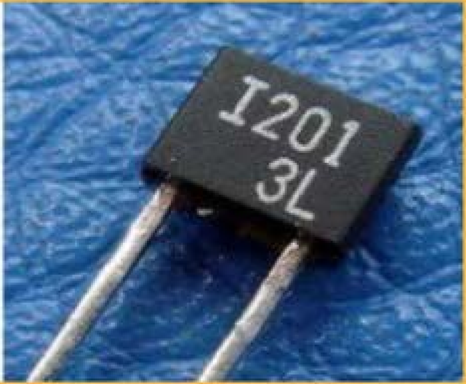


Oscillator circuit in an oscilloscope

Application of Diodes

Varactor Diode

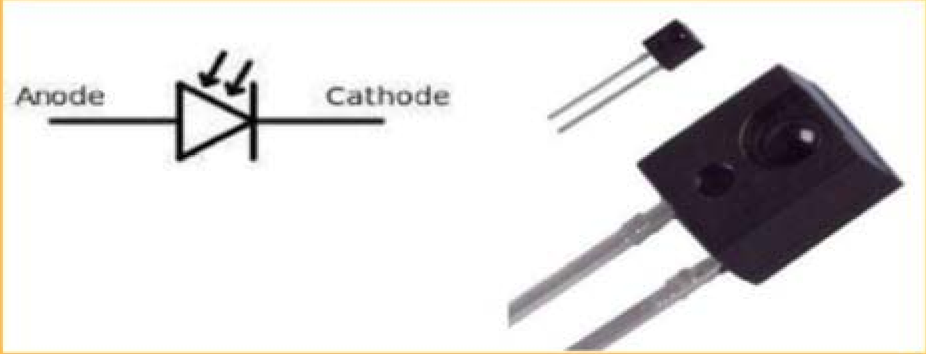




Variable capacitor in a tune circuit

Application of Diodes

Photo Diode



Light sensor in a remote control unit

Application of Diodes

Laser Diode

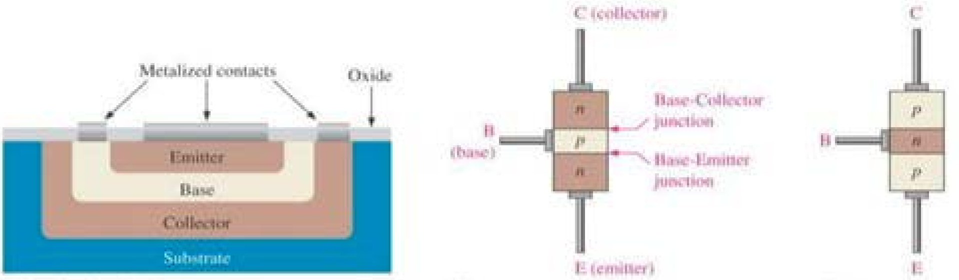
- Focused single colour light source in compact disc player

Transistor

- Transistor is a combination of two words i.e. transfer and resistor. It is because a transistor is basically a resistor that amplifies electrical impulses as they are transferred through it from its input to output terminal.

Architecture of a Transistor

- A transistor has three doped regions.
- The bottom region is called the **emitter**
- The middle region is the **base**
- And the top region is the **collector.**
- In an actual transistor, the base region is much thinner as compared to the collector and emitter regions.
- The transistor Shown in figure (b) is an *npn device* because there is a *p* region between two *n* regions. Recall that the majority carriers are free electrons in *n*-type material and holes in *p*-type material.
- Transistors shown in figure (c) is an pnp. A *pnp* transistor has an *n* region between two *p* regions. To avoid confusion between the *npn* and the *pnp* transistors, our early discussions will focus on the *npn* transistor.



(a) Basic epitaxial planar structure (b) *npn* (c) *pnp*

Architecture of a BJTs

- There are two types of BJTs, the *npn* and *pnp*.
- The two junctions are termed the *base-emitter* junction and the *base-collector* junction
- The term bipolar refers to the use of both holes and electrons as charge carriers in the transistor structure
- In order for the transistor to operate properly, the two junctions must have the correct dc bias voltages
  - the base-emitter (BE) junction is forward biased(>=0.7V for Si, >=0.3V for Ge)
  - the base-collector (BC) junction is reverse biased

Parts of a Transistor

Emitter

It is the most heavily doped part of the transistor. Its major function is to supply the majority charge carriers to base.

Base

It is the smallest part of the transistor with 10.6mm area and it is lightly doped.

Collector

It is physically the largest part of the transistor. Its major function is to collect the charge carriers.

Basic Circuit of a BJT

The minus signs represent free electrons.

The heavily doped emitter has the following job: to emit or inject its free electrons into the base.

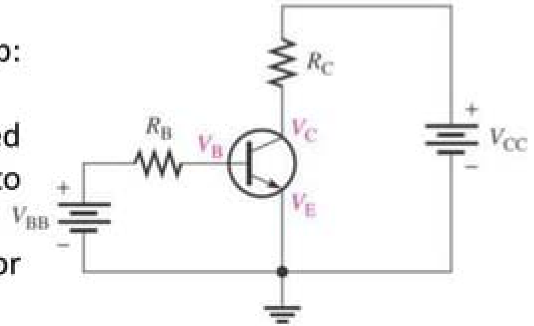
The lightly doped base also has a well-defined purpose: to pass emitter-injected electrons on to the collector.

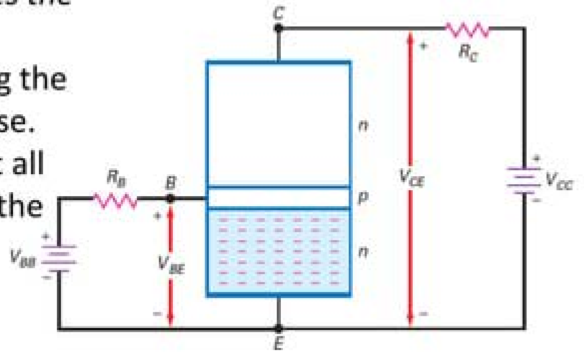
The collector is so named because it collects or gathers most of the electrons from the base.

The left source V_{BB} *of* forward-biases the emitter diode, and the right source V_{CC} *reverse-biases the collector Diode.*

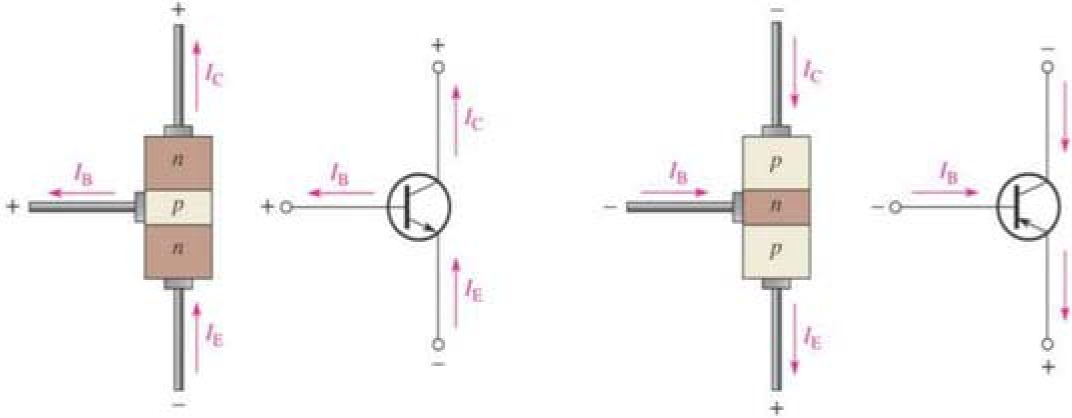
V_{BB} *forward-biases* the emitter diode, forcing the free electrons in the emitter to enter the base.

The thin and lightly doped base gives almost all these electrons enough time to diffuse into the collector. These electrons flow through the collector, through R_C, *and into* the positive terminal of the V_{CC} *voltage source.*





Symbolic Representation



(a) *npn* (b) *pnp*

DC Analysis of BJTs (Transistor Currents)

- Recall Kirchhoff's current law. It says that the sum of all currents into a point or junction equals the sum of all currents out of the point or junction. When applied to a transistor, Kirchhoff's current law gives us this important relationship:

$$I_E = I_C + I_B$$

$$I_C >> I_B$$

$$I_E = I_C$$

- **alpha** (α_{DC})

$$I_C = \alpha_{DC} I_E$$

- **beta** (β_{DC})

$$I_C = \beta_{DC} I_B$$

  – β_{DC} typically has a value between 20 and 200.

Examples

A transistor has a collector current of 10 mA and a base current of 40 μA. What is the current gain of the transistor?

SOLUTION Divide the collector current by the base current to get:

$$\beta_{dc} = \frac{10 \text{ mA}}{40\ \mu\text{A}} = 250$$

A transistor has a current gain of 175. If the base current is 0.1 mA, what is the collector current?

SOLUTION Multiply the current gain by the base current to get:

$$I_C = 175(0.1 \text{ mA}) = 17.5 \text{ mA}$$

Determine the dc current gain β_{DC} and the emitter current I_E for a transistor where $I_B = 50\ \mu\text{A}$ and $I_C = 3.65$ mA.

Solution

$$\beta_{DC} = \frac{I_C}{I_B} = \frac{3.65 \text{ mA}}{50\ \mu\text{A}} = 73$$

$$I_E = I_C + I_B = 3.65 \text{ mA} + 50\ \mu\text{A} = 3.70 \text{ mA}$$

THE MOSFET

ABOUT MOSFET

MOSFET

(metal oxide semiconductor field-effective transistor) is another category of field-effective transistor. The MOSFET , different from the JFET, has no pn junction structure; instead , the gate of the MOSFET is insulated from the channel by a silicon dioxide(SIO_2).

The two basic types of MOSFETs are:

1. **E**nhancement (E).
2. **D**epletion (D).

E-MOSFET

The Enhancement MOSFET operates only in the enhancement mode and has no depletion mode.

- It has no structural channel.
- The conductivity of the channel is enhanced by increasing the gate-to-source voltage and thus pulling more electrons into the channel area.

D-MOSFET

The drain and source are diffused into the substrate material and connected by a narrow channel adjacent to the insulated gate.

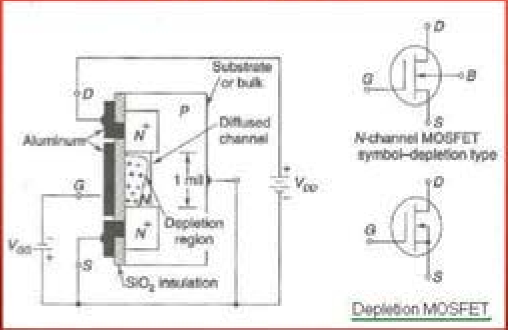
- The n-channel device to describe the basic operation.
- The p-channel operation is same, except the voltage polarities are opposite those for the n-channel.

DIFFERENCE B/W

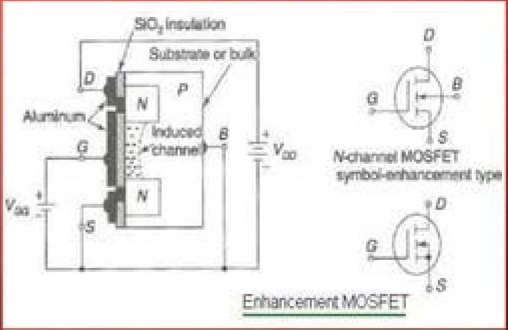
E-MOSFET	D-MOSFET
It also mentions circuit symbol of N-channel MOSFET of enhancement type. Here continuous channel does not exist from source to drain. Hence no current flows at zero gate voltage.	Due to its construction if offers very high input resistance (about 10^{10} to 10^{15}). Significant current flows for given V_{DS} at V_{GS} of 0 volt.
When positive voltage is applied to the gate, it will induce a channel by flowing minority carriers(i.e. electrons) from P-type bulk into the concentrated layer.	When gate(i.e. one plate of capacitor) is made positive, the channel((i.e. the other plate of capacitor) will have positive charge induced in it.
Enhancement MOSFET does not conduct at 0 volt, as there is no channel in this type to conduct. Depletion MOSFET conducts at 0 volt.	When positive cut-off gate voltage is applied to depletion MOSFET, hence it is less preferred.

SHAPE DIFFERENCE

D-MOSFET



E-MOSFET



COMPARISON OF N- AND P-TYPE MOSFETS

Parameter	nMOSFET	pMOSFET
Source/drain type	n-type	p-type
Channel type (MOS capacitor)	n-type	p-type
Gate type (poly Si)	n+ poly-Si	p+ poly-Si
Gate type (metal)	ϕ_m ~ Si CB	ϕ_m ~ Si VB
Well type	p-type	n-type
Threshold voltage, V_{th}	positive (enhancement) negative (depletion)	negative (enhancement) positive (depletion)
Band-bending	Downwards	Upwards
Inversion layer carriers	electrons	holes
Substrate type	p-type	n-type

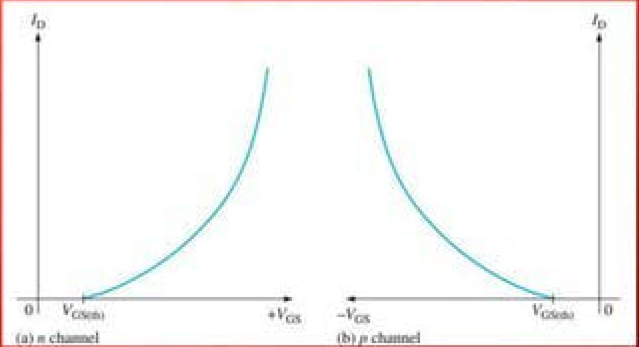
MOSFET CHARACTERISTICS AND PARAMETERS

Much of the discussion concerning JFET characteristics and parameters applies equally to MOSFETs. In this section, MOSFET parameters are discussed.

E-MOSFET TRANSFER CHARACTERISTIC

- An n-channel device requires a positive gate-to-source voltage, and a p-channel device requires a negative gate-to-source voltage.
- There is no drain current when $V_{GS} = 0$.
  T ET
  t s

$$I_D = K(V_{GS} - V_{GS(th)})^2$$



D-MOSFET TRANSFER CHARACTERISTIC

- The D-MOSFET can operate with either positive or negative gate voltages. This is indicated on the general transfer characteristic curves for both n-channel and p-channel MOSFETs.
  The point on the curves where $V_{GS} = 0$ corresponds to I_{DSS}. The point where $I_D = 0$ corresponds to $V_{GS(off)}$.