Chapter

16 Semiconductor Devices

Quick Review

p-n Junction Diode

Diode as a rectifier

- Converts AC signal into DC signal
- Has to be used with filter circuit and voltage regulators

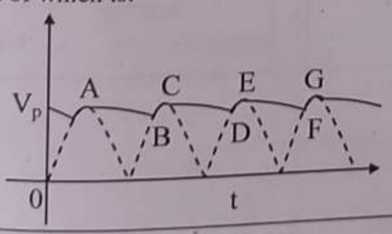
Half-wave Rectifier	Full-wave Rectifier
Consists of one p-n junction diode	Consists of two p-n junction diodes
The diode functions as switch	Both the pulses of AC input are rectified
Alternate pulses of AC input are rectified	Maximum efficiency: 81.2%
Maximum efficiency: 40.6%	Produces less ripple
Output frequency is same as that of input.	Output frequency is twice that of input.

Filter Circuit

$$\text{Ripple factor} = \frac{\text{r.m.s. value of AC component}}{\text{value of DC component}}$$

Filter circuit is used to remove the ripple component in rectifier output.

Most commonly used filter is capacitor filter. Output of which is:

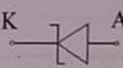


Special purpose Junction Diodes

- There are mainly four commonly used special purpose junction diodes:

Zener Diode

- Heavily doped p-n junction diode
- Works in reverse biased mode
- Used as a voltage regulator



Zener Regulator

- When operated in breakdown region, voltage across Zener remains almost constant regardless of variations in the applied input voltage and variations in the load current.
- The supply voltage V_S must be greater than V_Z.

Photodiode

- Works on principle of photoelectric effect
- Works in reverse biased mode
- Used in electronic counters and switches

Solar Cell

- Works on principle of Photovoltaic effect. Hence, also known as Photovoltaic cell
- Used for charging batteries in electronic equipments

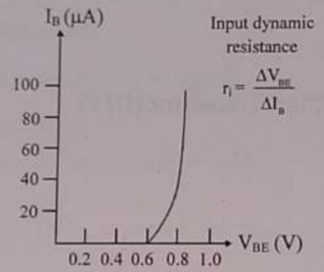
LED

- Light emitting diode works in forward biased mode
- Wavelength of light emitted depends on the semiconductor materials used

Bipolar Junction Transistor

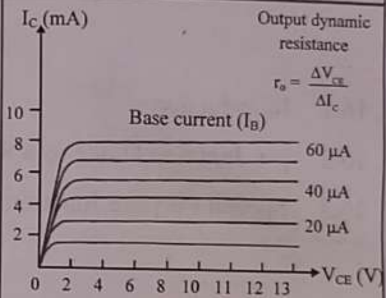
- A junction transistor is a semiconductor device having two junctions and three terminals.
- The current in a transistor is carried by both the electrons and the holes. Hence, the name Bipolar.

Input characteristics



- Till the V_{BE} is less than the barrier potential, the current is very small (nearly zero).
- When V_{BE} is more than the barrier potential, the characteristic is similar to that of a forward biased diode.

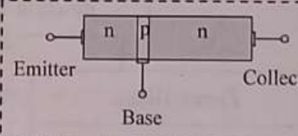
Output characteristics

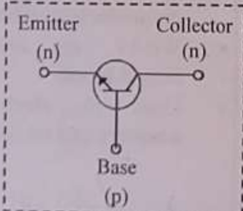


- I_C is independent of V_{CE} as long as the collector-emitter junction is reverse biased.
- I_C is large for large values of I_B when V_{CE} is constant.

n-p-n Transistor

- A p-type semiconductor (base) layer separates two layers of the n-type semiconductor (emitter and collector)

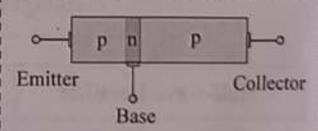


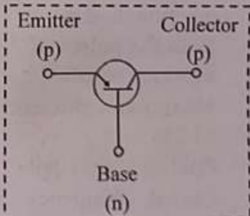


- In circuit symbol of n-p-n transistor, arrow is drawn from base pointing towards emitter.

p-n-p Transistor

- A n-type semiconductor (base) layer separates two layers of the p-type semiconductor (emitter and collector)

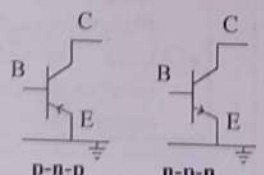




- In circuit symbol of p-n-p transistor, arrow is drawn from emitter pointing towards base.

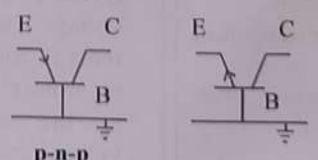
CE configuration

- The emitter of the transistor is common to both the input and the output.



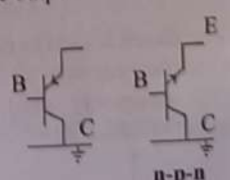
CB configuration

- The base of the transistor is common to both the input and the output.



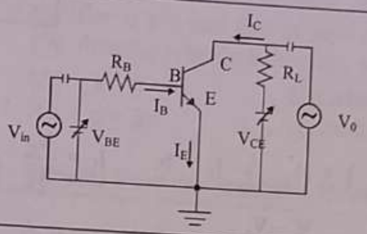
CC configuration

- The collector of the transistor is common to both the input and the output.



CE transistor as an amplifier

- For transistor operating as an amplifier, the E-B junction is forward biased while C-B junction is reverse biased.



Current amplification factor (α)

AC gain

Ratio of a small change in collector current (ΔI_c) to the small change in emitter current (ΔI_E) at constant emitter-base voltage (V_{EB}) is known as ac current gain (α_{ac}).

DC gain

Ratio of collector current (I_C) to emitter current (I_E) is known as dc current gain (α_{dc} or α).
Practical value of α_{dc} lies between 0.95 to 0.99 i.e., less than 1.

Base current amplification factor (β)

AC gain

Ratio of a small change in collector current (ΔI_C) to small change in base current (ΔI_B) at constant collector emitter voltage (V_{CE}) is known as ac current gain (β_{ac}).

DC gain

Ratio of collector current (I_C) to base current (I_B) is known as dc current gain (β_{dc}).
β_{dc} always has value > 1.

Voltage Gain (A_v)

Ratio of change in output voltage (ΔV_o) to change in input voltage (ΔV_i) is known as voltage gain (A_v).

Power Gain

Ratio of change in output power (ΔP_o) to the change in input power (ΔP_i) is known as power gain.

Logic Gates

- **Analog signal:** Signal has continuous values.
- **Digital Signal:** Signal has only two states

NOT gate

X	Y
0	1
1	0

OR gate

A	B	Y
0	0	0
1	0	1
0	1	1
1	1	1

NOR gate

A	B	Y
0	0	1
1	0	0
0	1	0
1	1	0

AND gate

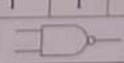
A	B	Y
0	0	0
1	0	0
0	1	0
1	1	1

X-OR gate: $C = A \oplus B$

A	B	C
0	0	0
1	0	1
0	1	1
1	1	0

NAND gate

A	B	Y
0	0	1
1	0	1
0	1	1
1	1	0



Formulae

1. **Zener diode:**

i. Zener current:

a. $\left(I_{Z_{min}}\right) = \left(I_{Z_{max}}\right) - I_L$ b. $I_L = \frac{V_Z}{R_L}$

c. $\left(I_{Z_{max}}\right) = \frac{V_s - V_Z}{R_s}$

ii. Series resistance: $R_s = \frac{(V_s - V_Z)}{I_{Z_{max}}}$

iii. Zener voltage: $V_Z = I_L R_L$

2. **Current in the transistor:** $I_E = I_B + I_C$

3. **Current Gain of transistor:**

i. DC current gain (α_{DC}): $\alpha_{DC} = \frac{I_C}{I_E}$

ii. Current amplification factor (β): $\beta_{DC} = \frac{I_C}{I_B}$

iii. Relation between α and β:

a. $\alpha_{DC} = \frac{\beta_{DC}}{1+\beta_{DC}}$ b. $\beta_{DC} = \frac{\alpha_{DC}}{1-\alpha_{DC}}$

iv. AC current gain: $\beta_{AC} = \frac{\Delta I_C}{\Delta I_B} = \frac{i_C}{i_B}$

4. **Resistance of transistor:**

i. Input dynamic resistance: $r_i = \frac{\Delta V_{BE}}{\Delta I_B}$

ii. Output dynamic resistance: $r_o = \frac{\Delta V_{CE}}{\Delta I_C}$

5. **Voltage gain:**

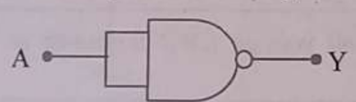
i. $A_V = \frac{V_o}{V_{in}}$ ii. $A_V = -\frac{\Delta V_{CE}}{r_i \Delta I_B}$

iii. $A_V = -\frac{\beta_{AC} R_L}{r_i}$

Shortcuts

1. The output frequency for an AC signal of input frequency "f" is,
f = For half wave rectifier
2f = For full wave rectifier.

2. If both inputs of NAND gates are shorted, then it becomes NOT gate (similar is applicable for NOR gate).



NOT gate