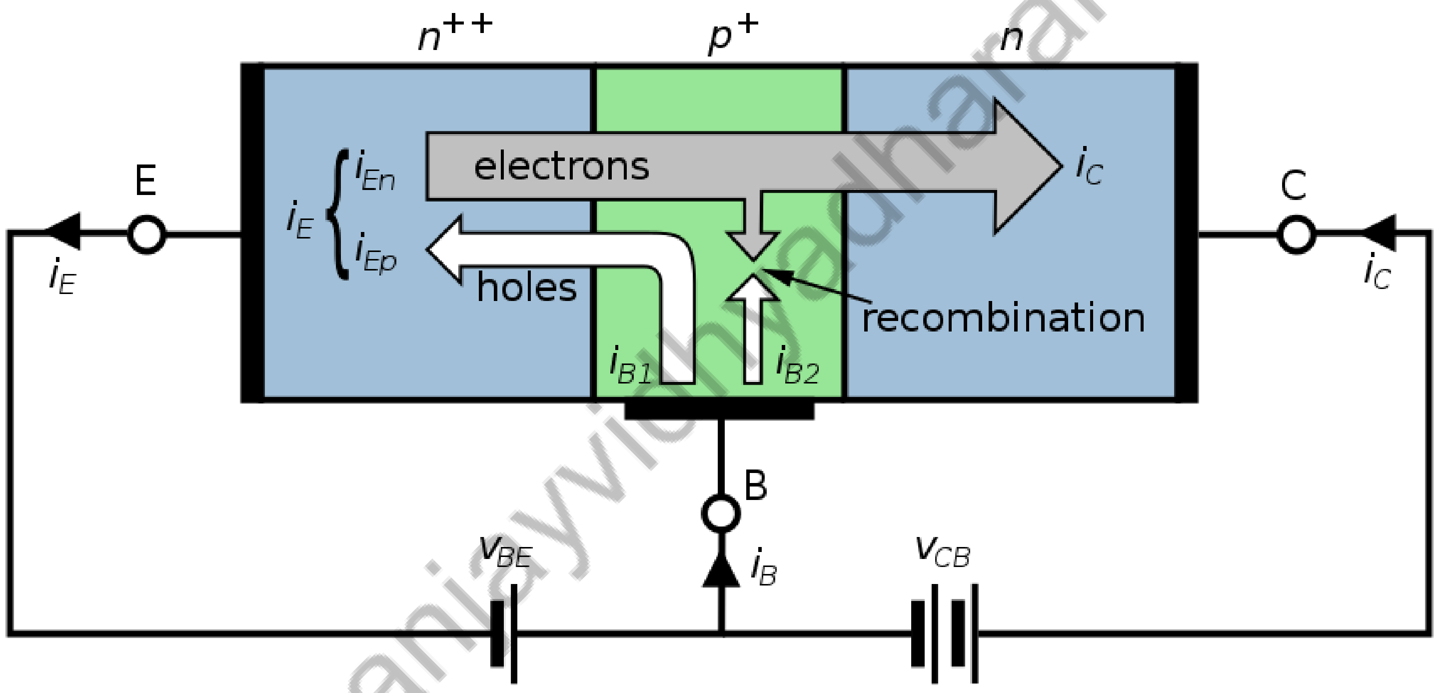
Electrical Science: 2021-22

Lecture 24

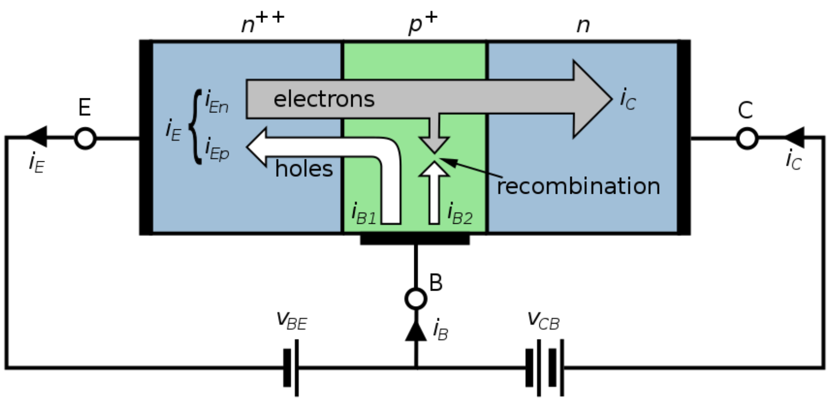
Introduction to BJT

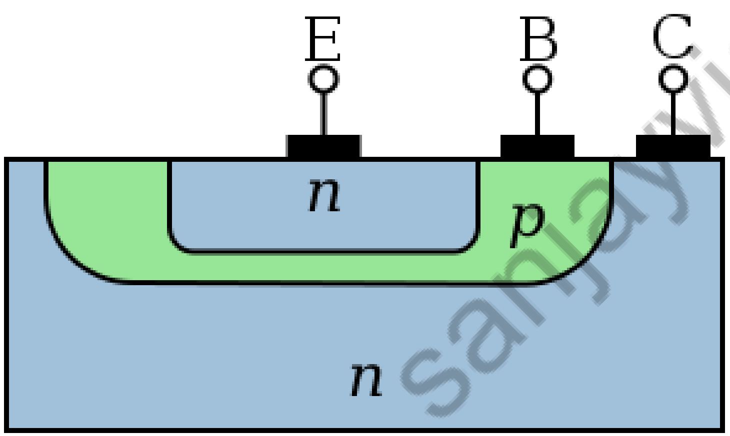
By Dr. Sanjay Vidhyadharan

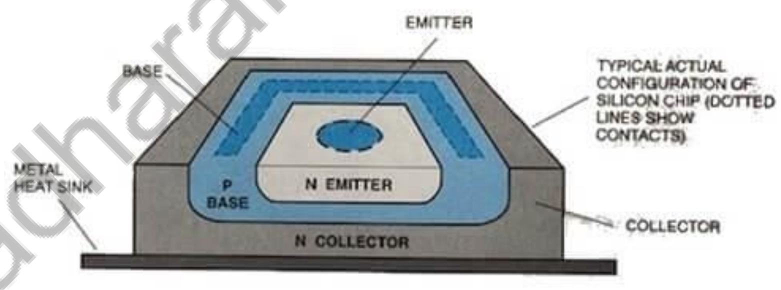
BJT Operation



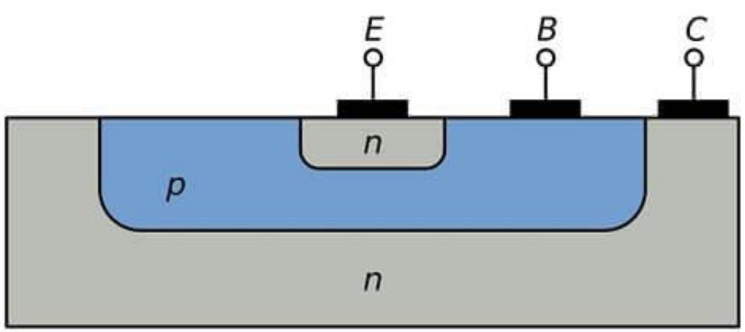
BJT Operation







(a) 3D cross section of NPN BJT



(b) 2D cross section of NPN BJT

Bipolar Junction Transistors

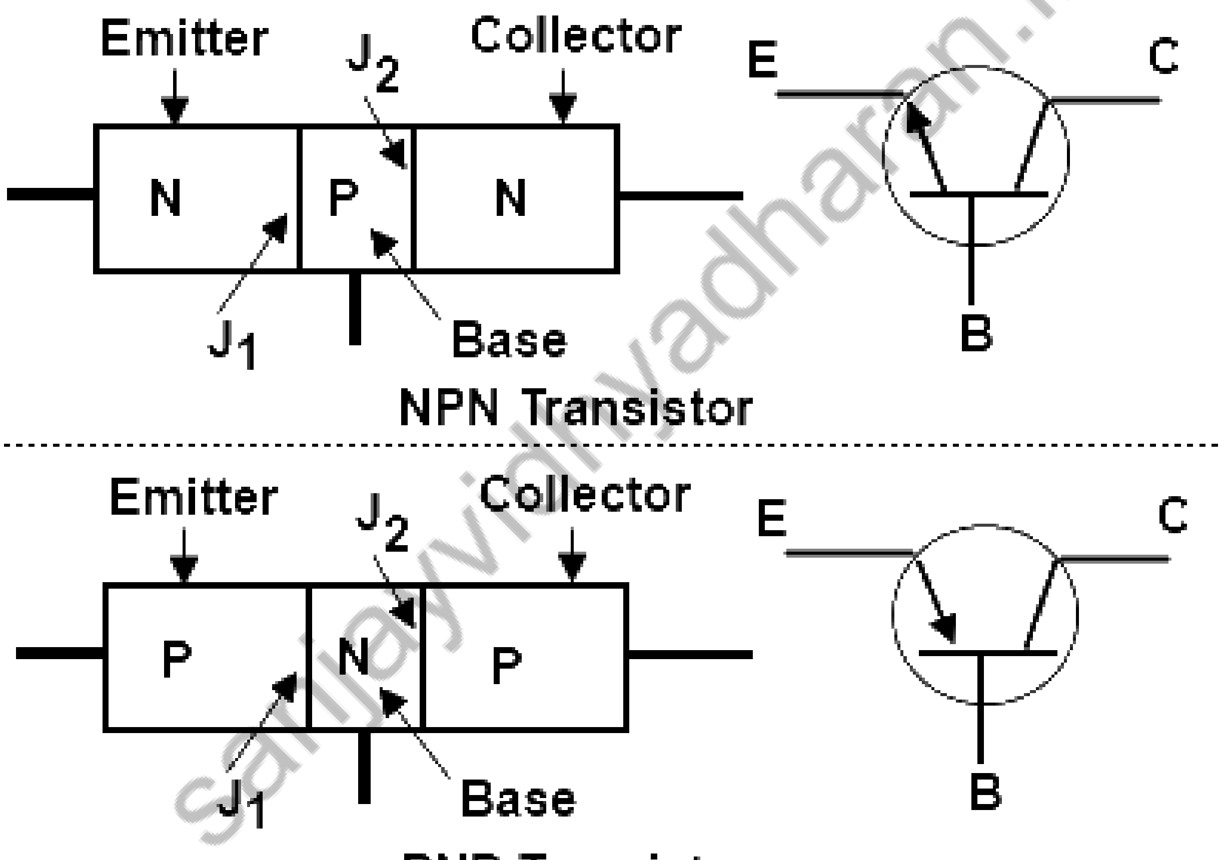
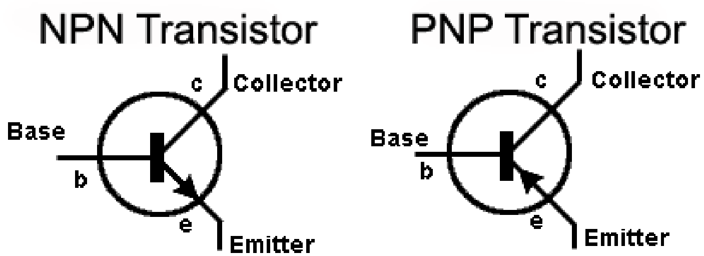


Figure (a)

Bipolar Junction Transistors



N Never
P Points
N iN

P Points
N iN
P Permanently

Bipolar Junction Transistors

- Bipolar: Both electrons and holes (positively charged quasiparticles, absence of electron) contribute to current flow

- Transistor: 3-terminal device (Base, Emitter, Collector) Two types: npn & pnp

- Junction: Consists of an n- (or p-) type silicon sandwiched between two p- (or n-) type silicon regions

BJT Applications

Transistor As Switch

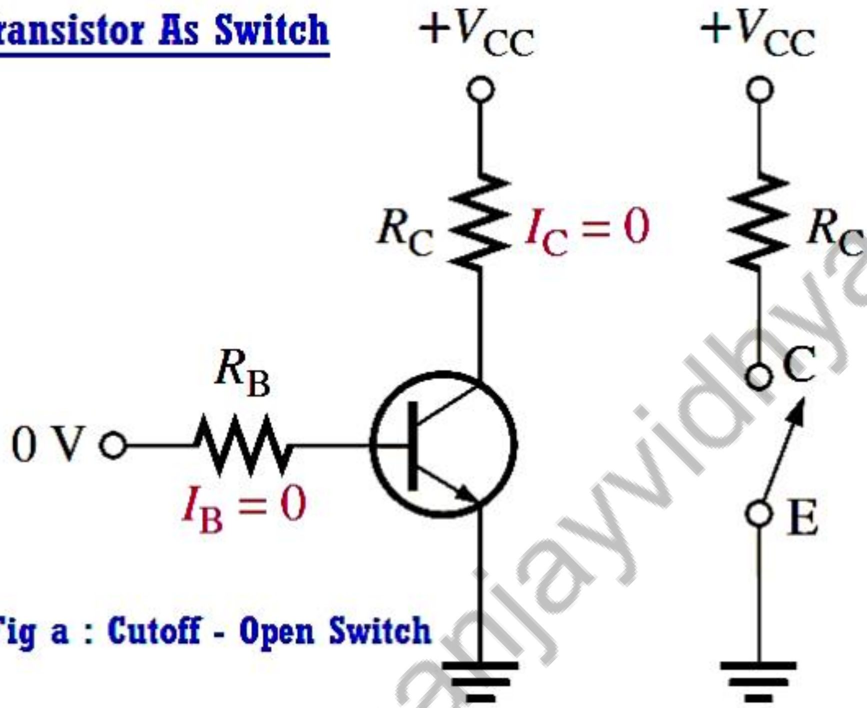
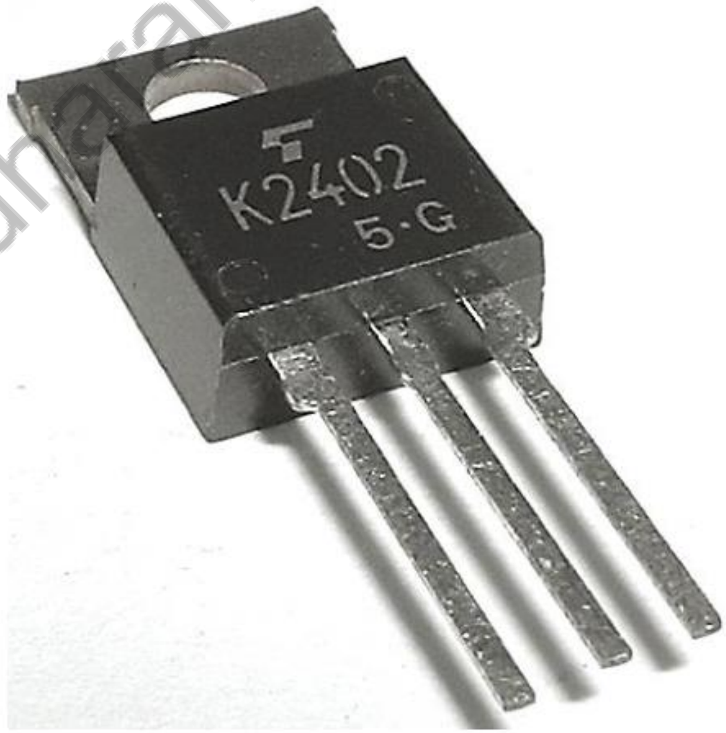
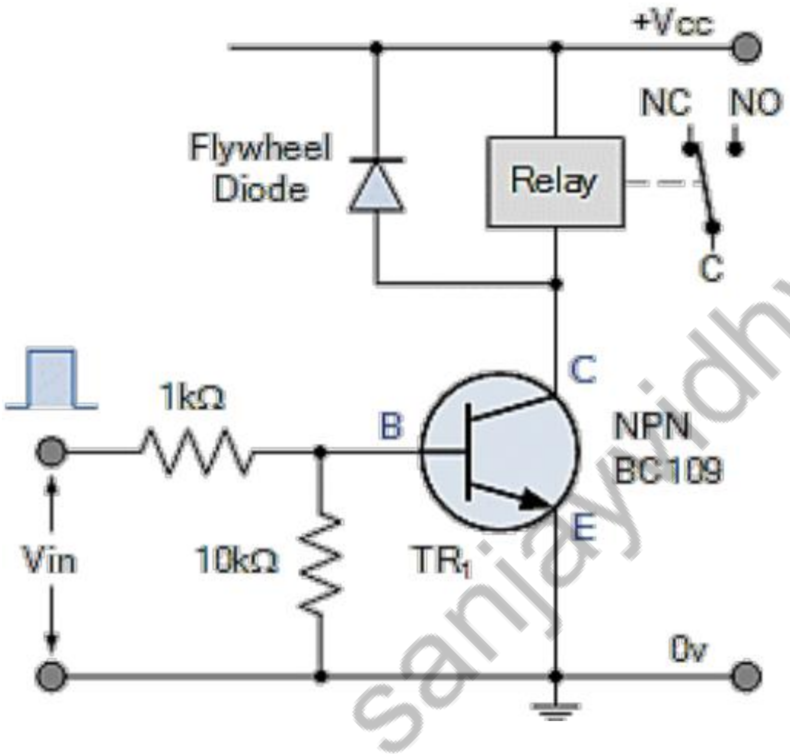


Fig a : Cutoff - Open Switch



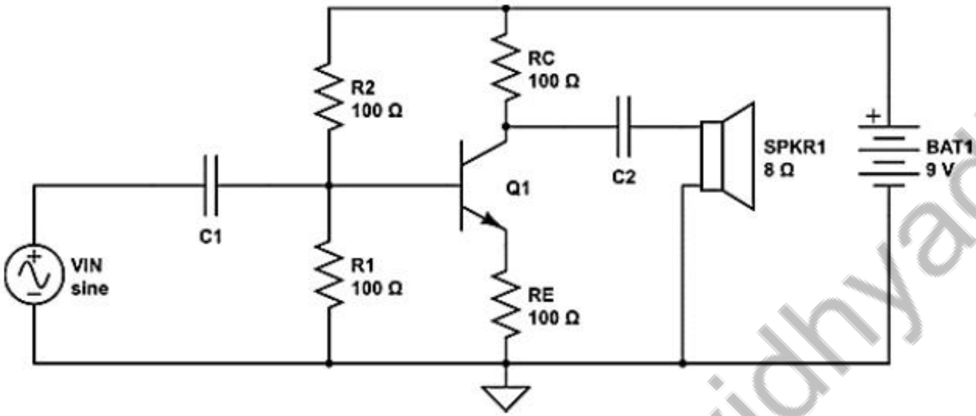
BJT Applications



Single channel 5V relay breakout board

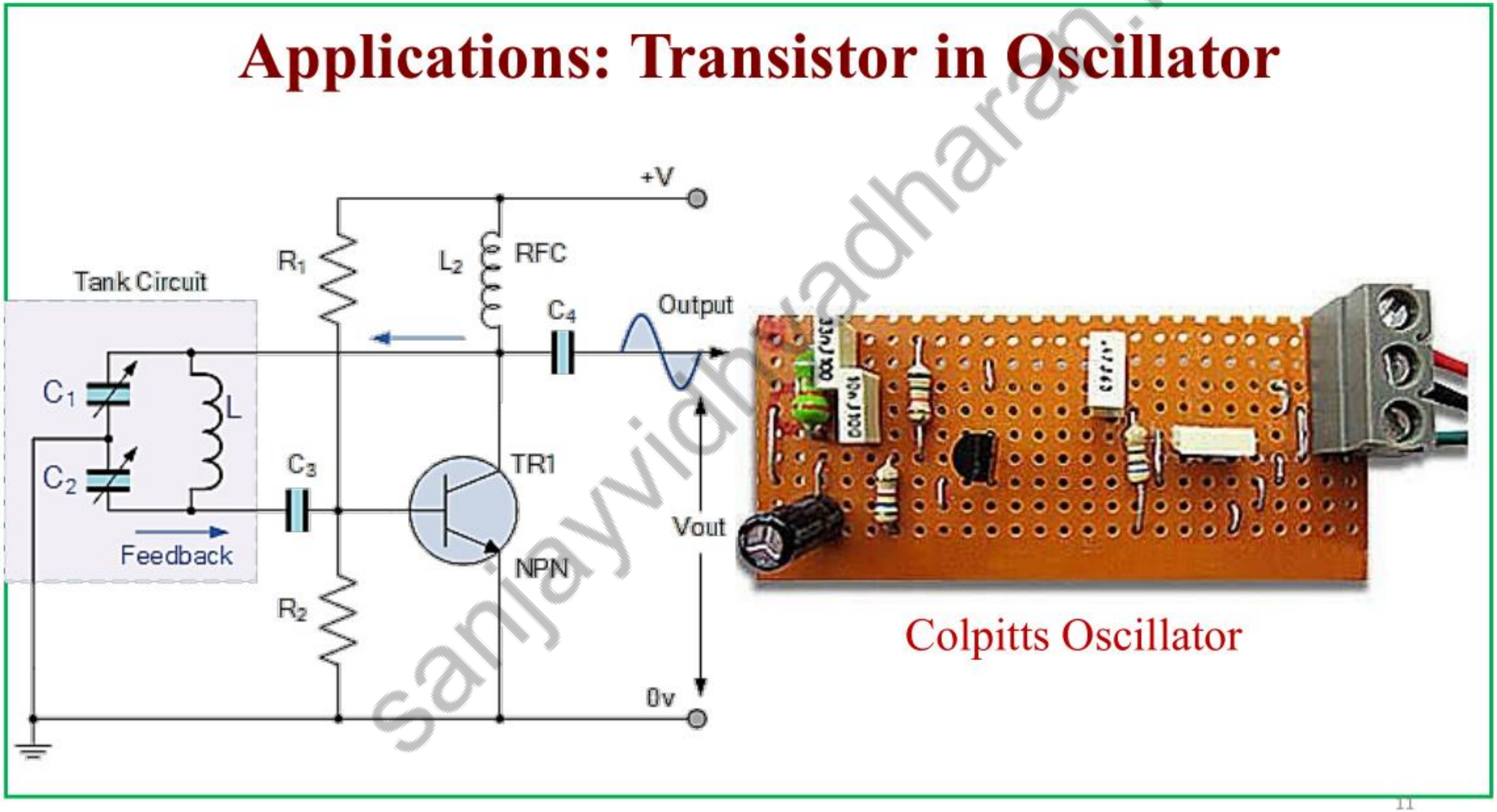
BJT Applications

Applications: Transistor As Amplifier



TDA7297 Power Amplifier & Audio amplifier Module

BJT Applications

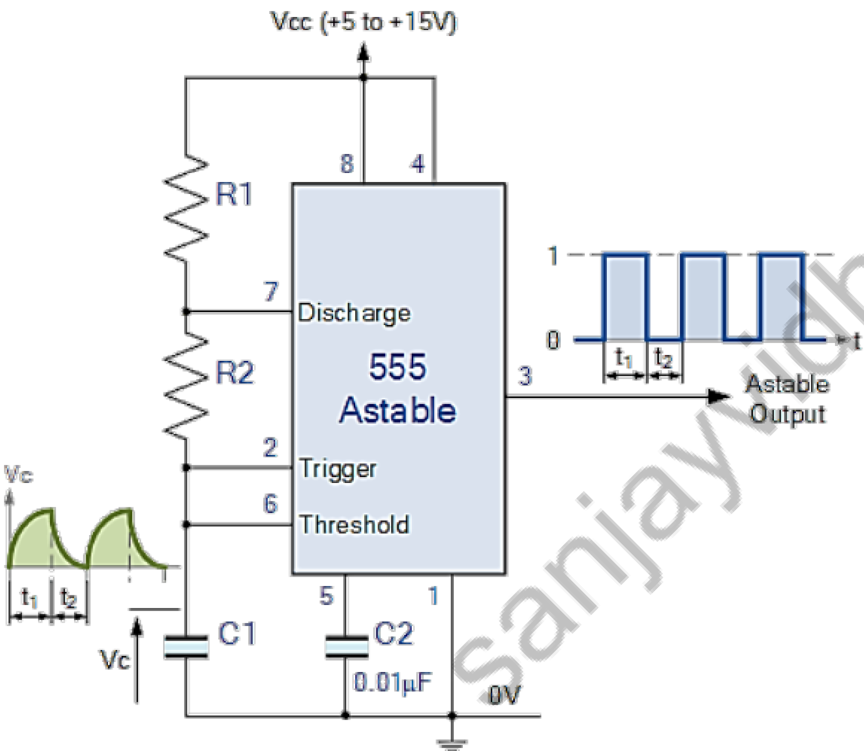


Colpitts Oscillator

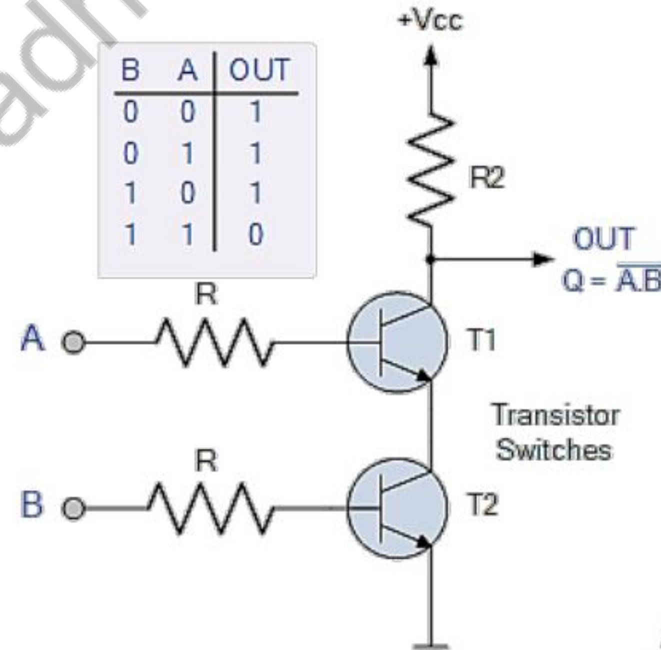
ELECTRICAL ELECTRONICS COMMUNICATION INSTRUMENTATION

BJT Operation

Timer ICs

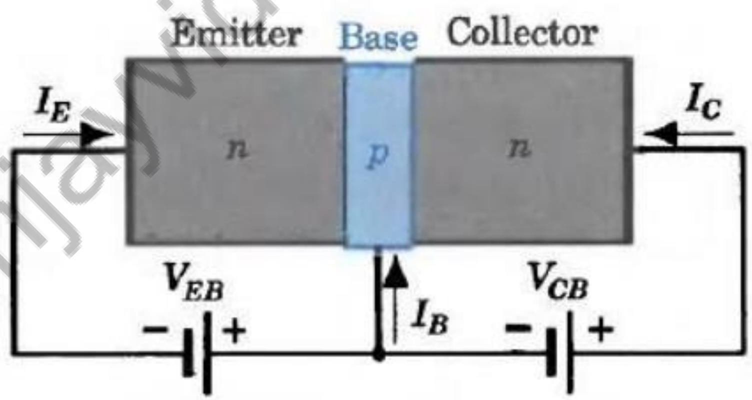


Digital ICs



Bipolar Junction Transistor (BJT) : Modes

Mode	V_{BE}	V_{BC}	
Forward active	**Forward Bias**	**Reverse Bias**	**Amplifier**
Reverse active	Reverse Bias	Forward Bias	
Saturation	Forward Bias	Forward Bias	Switch ON ($V_{CE} \sim 0$)
Cut off	Reverse Bias	Reverse Bias	Switch OFF ($I_{C,E} \sim 0$)



Biasing conditions

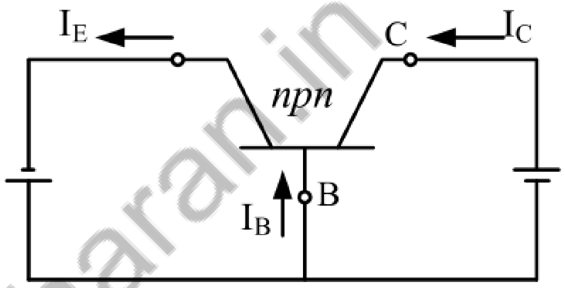
BJT Currents in Forward-Active Mode

$I_E = I_B + I_C$

$I_C \sim \alpha I_E$ $\quad 0.95 < \alpha < 0.995$

α is the **emitter-to-collector gain**

In addition, due to the reverse biased C-B junction, a small reverse saturation current flows, I_{CBO} (collector-to-base leakage current with emitter open)



$\boldsymbol{I_C = \alpha I_E + I_{CBO}} = \alpha(I_C + I_B) + I_{CBO}$

$=> (1-\alpha)I_C = \alpha I_B + I_{CBO}$

$=> I_C = (\alpha/1-\alpha)I_B + (1/1-\alpha)I_{CBO}$

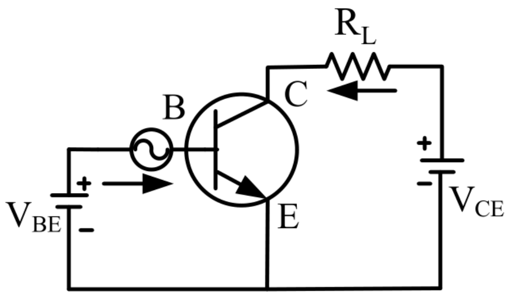
$=> \boldsymbol{I_C = \beta I_B + (\beta+1)I_{CBO}}$

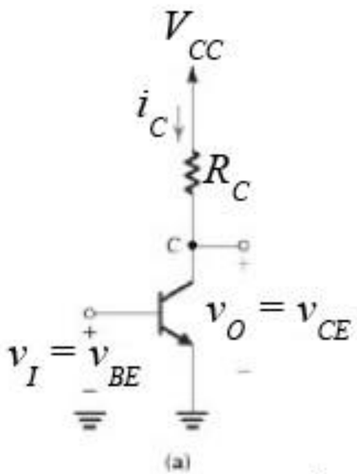
$\beta = \alpha/(1-\alpha)$ is the **base-to-collector gain**

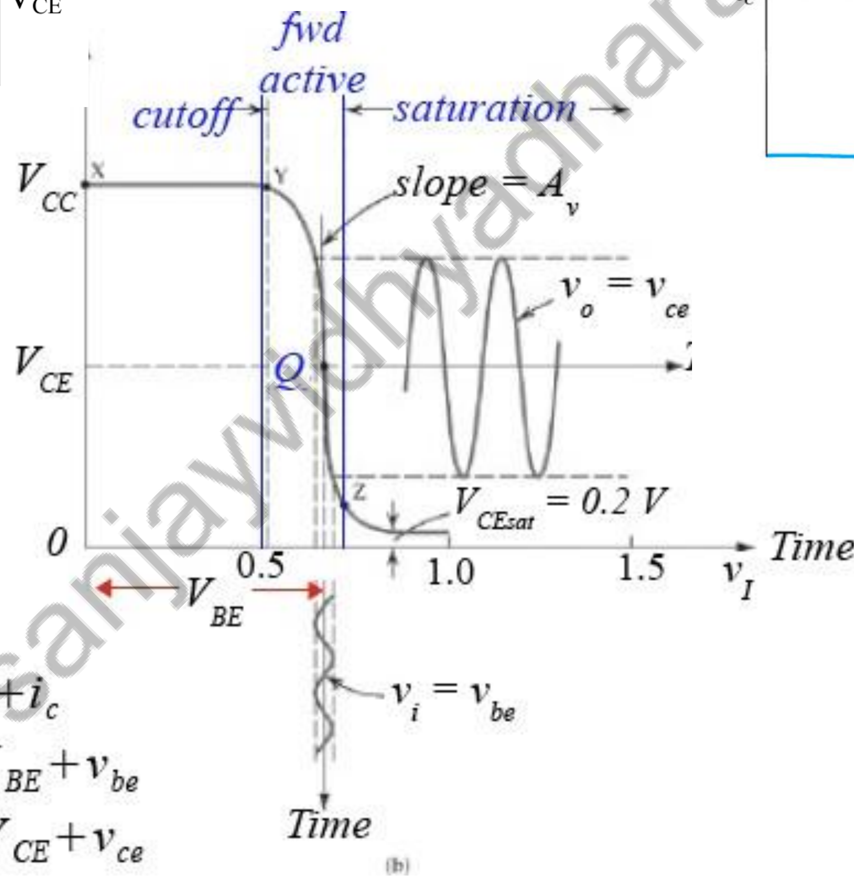
$20 < \beta < 200$

1. $I_E = I_B + I_C$
2. $I_C = \beta I_B$
3. $\beta = \frac{\alpha}{1-\alpha}$ **(20 – 200)**
4. $\alpha = \frac{\beta}{1+\beta}$ **(0.95 – 0.995)**

BJT Amplifier Concept



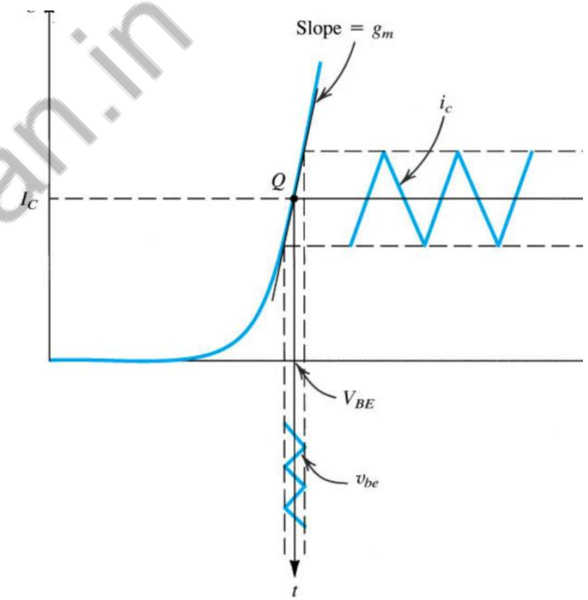




$i_C = I_C + i_c$

$v_{BE} = V_{BE} + v_{be}$

$v_{CE} = V_{CE} + v_{ce}$



$$V_{in} = r_\pi * i_b$$

$$i_c = \beta * i_b$$

$$V_{OUT} = V_{DD} - I_C R_C$$

$$V_{out} = -i_C R_C$$

$$Gain = -\beta R_C / r_\pi$$

BJT DC and Small Signal Equivalent

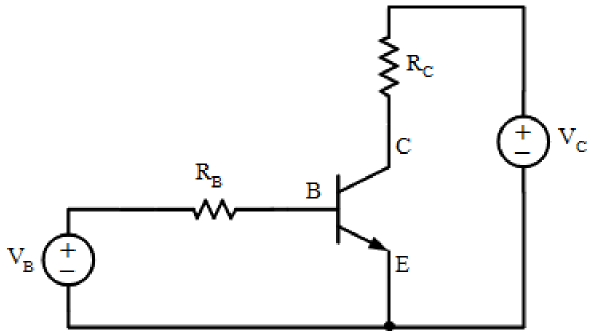
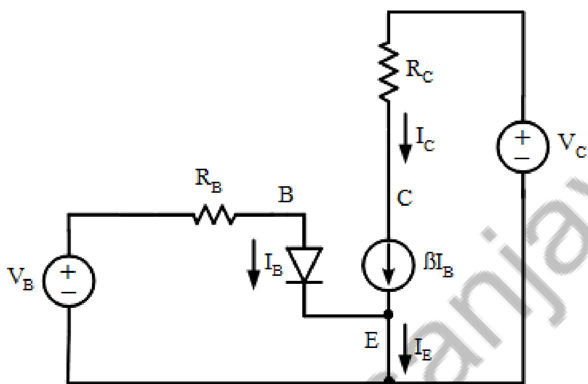
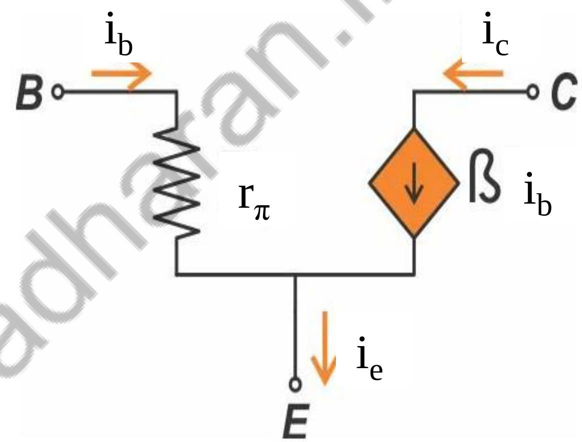
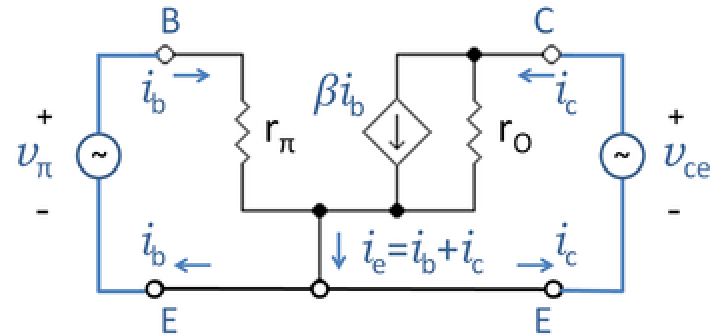


Fig 1: BJT Switch



DC Equivalent Circuit





AC Equivalent Circuit

BJT Biasing

Need for DC biasing

If a signal of very small voltage is given to the input of BJT without biasing, it cannot be amplified. Because, for a BJT, to amplify a signal, two conditions must be met.

- The input voltage should exceed **cut-in voltage** for the transistor to be **ON**.
- The BJT should be in the **active region**, to be operated as an **amplifier**.

Factors affecting the operating point

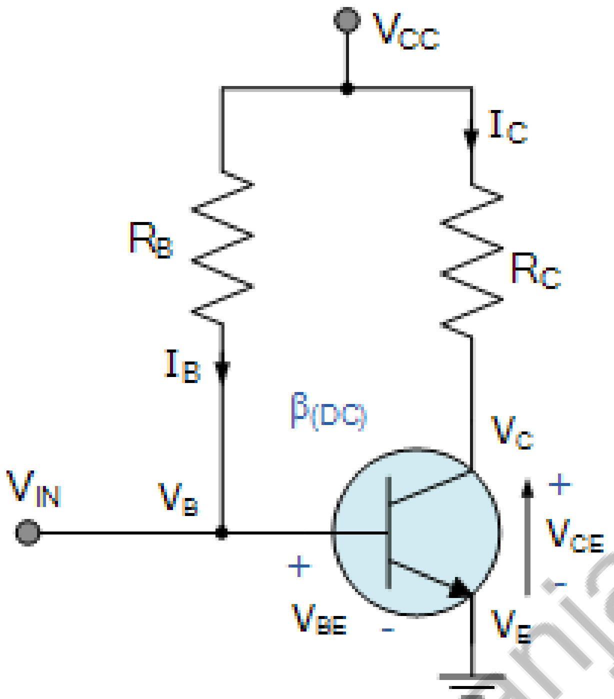
The main factor that affect the operating point is the temperature. The operating point shifts due to change in temperature. As temperature increases, the values of I_{CE}, β, V_{BE} gets affected.

- I_{CBO} gets doubled (for every 10^o rise)
- V_{BE} decreases by 2.5mv (for every 1^o rise)

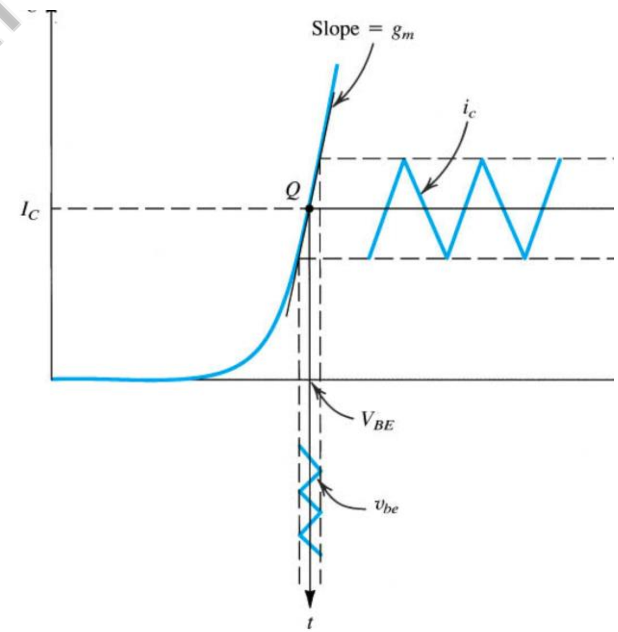
So the main problem which affects the operating point is temperature. Hence operating point should be made independent of the temperature so as to achieve stability. To achieve this, biasing circuits are introduced.

BJT Biasing

Fixed Base Biasing



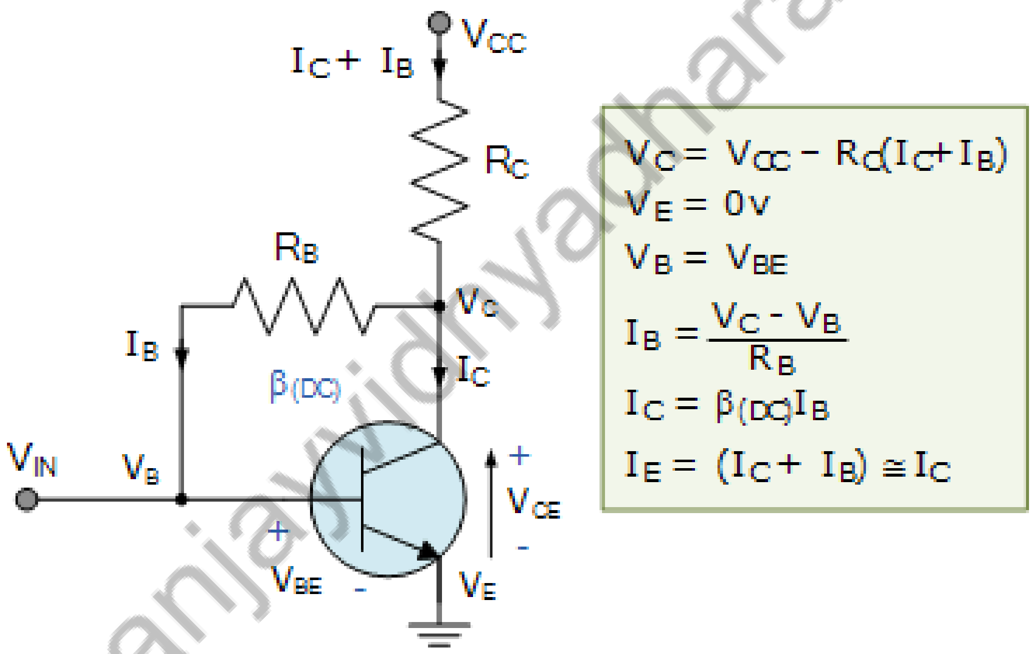
$$V_C = V_{CC} - (I_C R_C)$$
$$V_{CE} = V_C - V_E$$
$$V_E = 0v$$
$$V_B = V_{BE}$$
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$
$$I_C = \beta_{(DC)} I_B$$
$$I_E = (I_C + I_B) \cong I_C$$



$$\Delta I_B = \frac{\Delta V_{CC} - \Delta V_{BE}}{R_B}$$

BJT Biasing

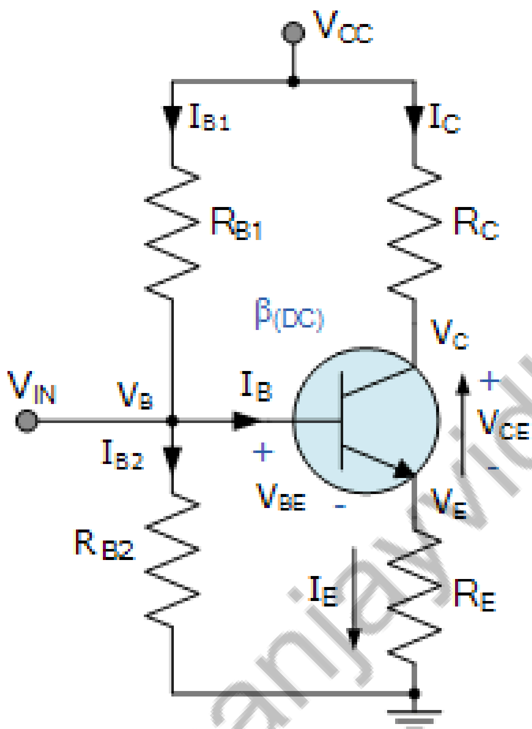
Collector Feedback Biasing



$$\Delta I_B = \frac{\Delta V_C - \Delta V_{BE}}{R_B}$$

BJT Biasing

Emitter Feedback Biasing



$V_C = V_{CC} - R_C I_C = (V_E + V_{CE})$

$V_E = I_E R_E = V_B - V_{BE}$

$V_{CE} = V_C - V_E = V_{CC} - (I_C R_C + I_E R_E)$

$V_B = V_{BE} + V_E = V_{RB2} = \left(\frac{R_{B2}}{R_{B1} + R_{B2}}\right) V_{CC}$

$I_{B2} = \frac{V_B}{R_{B2}}$

$I_{B1} = I_B + I_{B2} = \frac{V_{CC} - V_B}{R_{B1}}$

$R_B = \frac{R_{B1} \times R_{B2}}{R_{B1} + R_{B2}}$ $\quad I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta)R_E}$

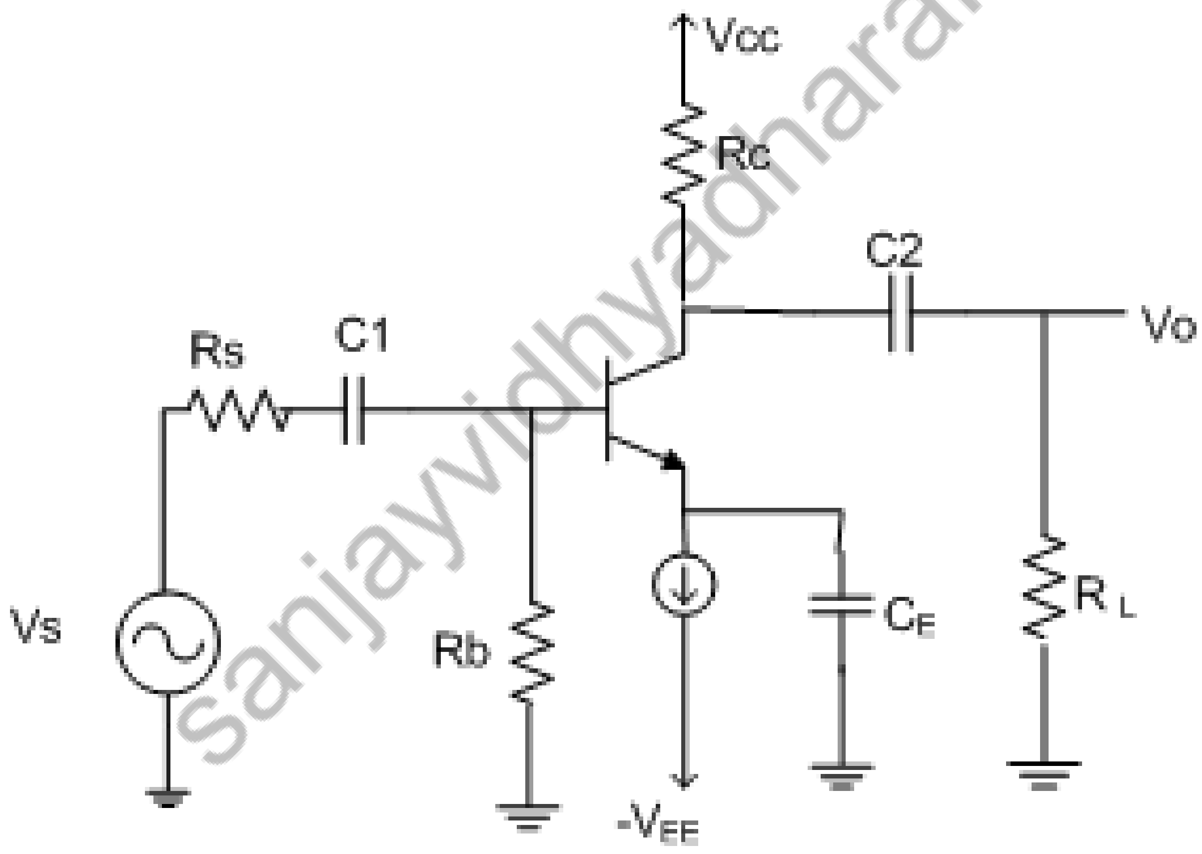
$I_C = \beta_{(DC)} I_B$

$I_E = I_C + I_B = \frac{V_E}{R_E}$

$$\Delta I_B = \frac{\Delta V_B - \Delta V_{BE}}{R_B + (1 + \beta) R_E}$$

BJT Biasing

Constant Current Biasing



Thank you