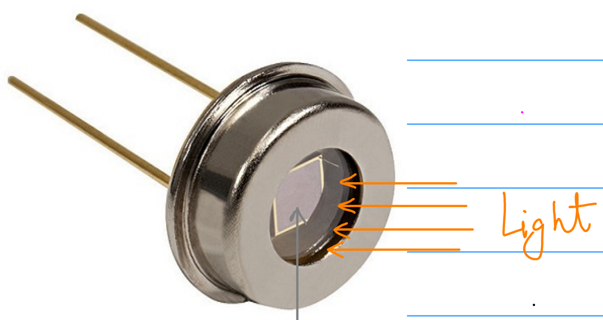
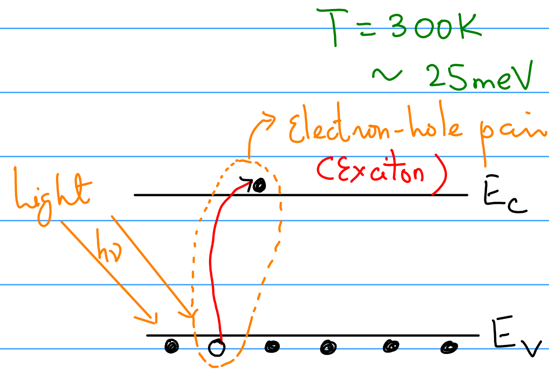
19.10.2023

Special Purpose Diodes

(3) Photo-diode :





Light absorbing material : Generating electron-hole pairs

if the generated electron-hole pairs are dissociated, then "free" charge-carriers are released.
These charges constitute electric-current in external ckt.

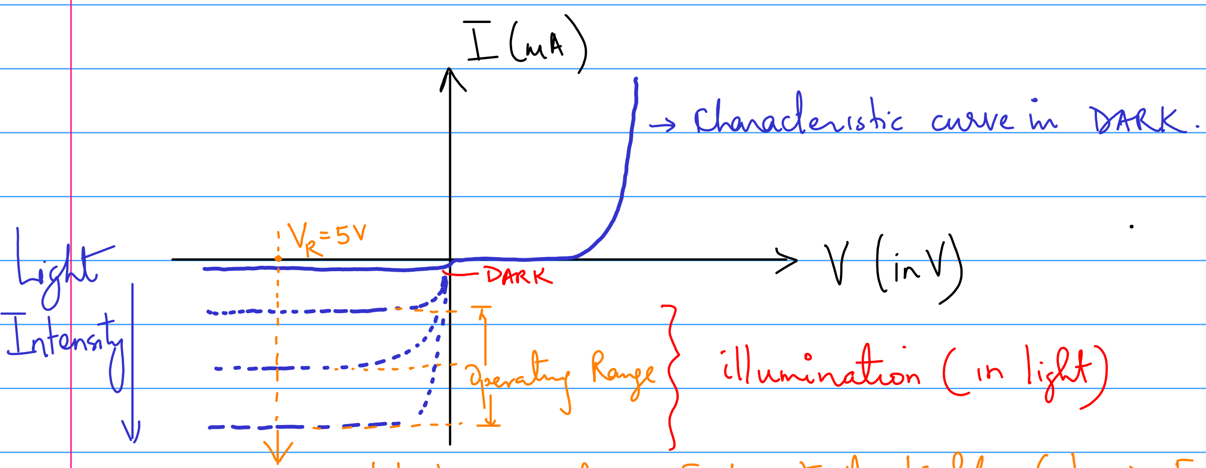
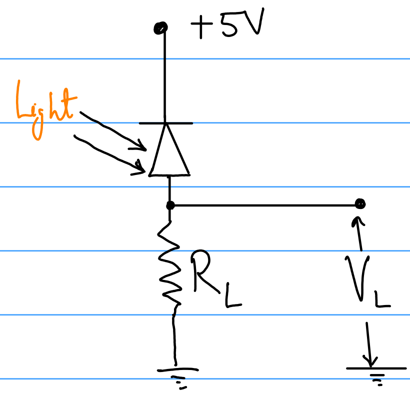
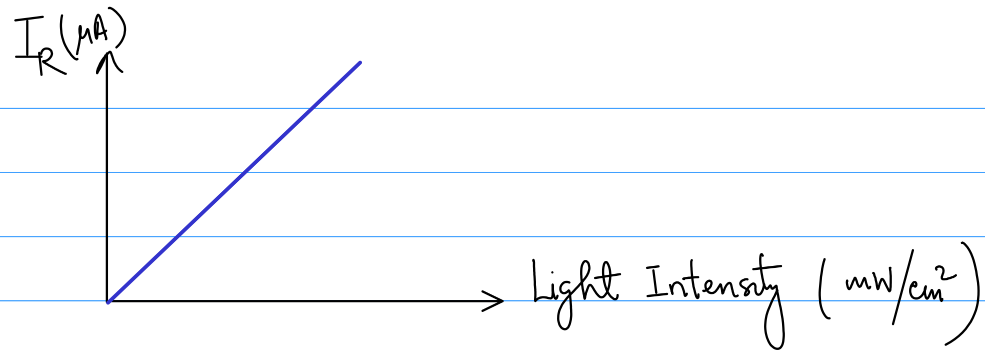


photo-current ∝ Intensity of light. ($h\nu > E_g$)

Ckt. application:

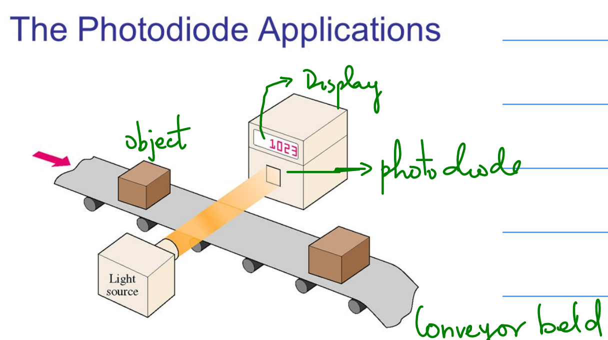


V_L is directly proportional to the light intensity

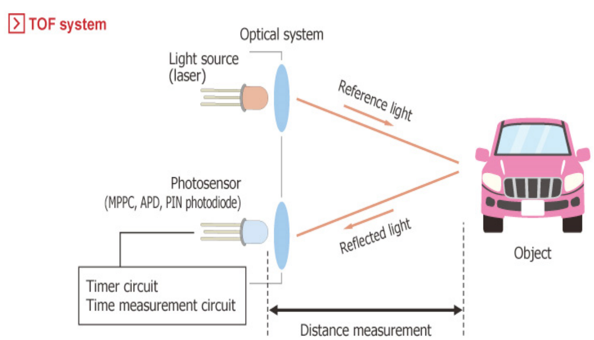


Application of photo-diodes:

(i) Electronic Counter:

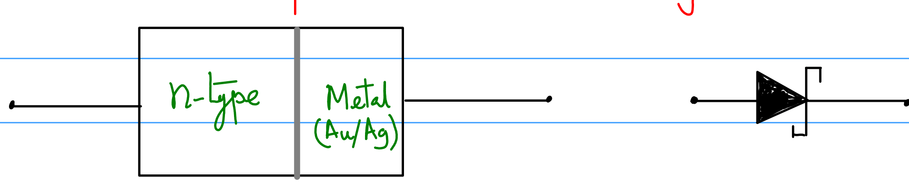


(ii) LiDAR (Light detection and Ranging) : Remote Sensing



④ The Schottky Diode (Hot carrier diode):

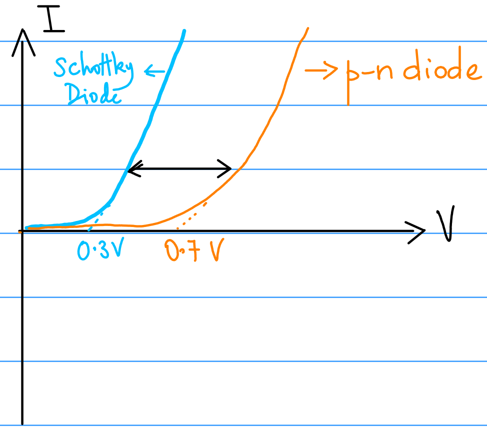
→ Metal-Semiconductor junction (No depletion layer)



- No p-n homojunction. Instead, it has metal-semiconductor junction.
- Operates only with majority charge-carriers (here, it is electron).
  → Unipolar Device.

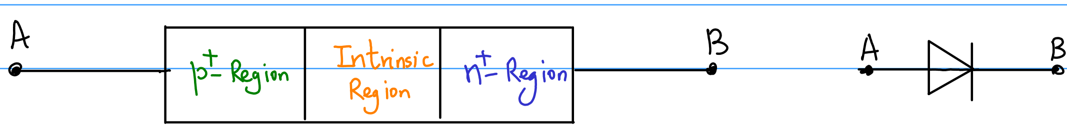
- It offer fast switching action.

Current-Voltage Characteristics :



- Fast turn-ON.
- No minority current in reverse bias.

(5.) **PIN Diode :** Consists of heavily doped p- and n-regions separated by an intrinsic region.

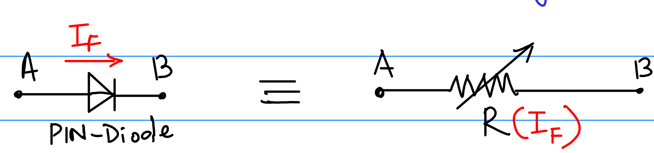


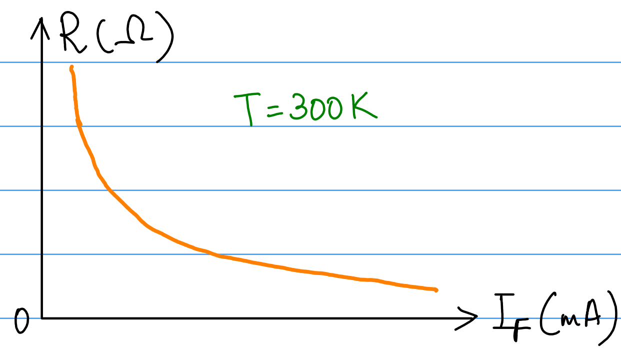
(i) In forward bias, ie, $V_{AB} > 0$

→ The charges from p- and n-regions get injected into the intrinsic region

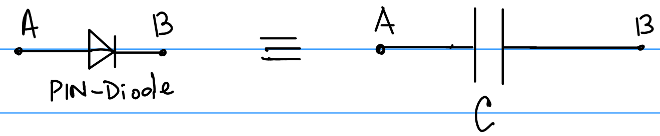
→ The resistance due to intrinsic region reduces.

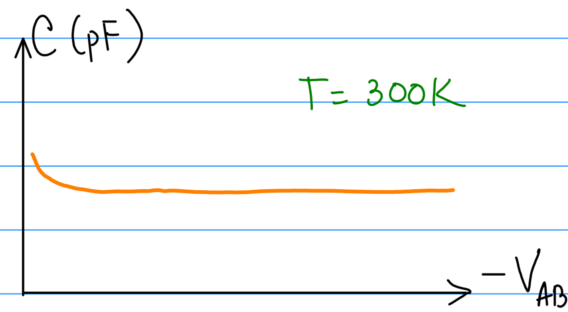
⇒





(ii) Reverse-bias ; $V_{AB} < 0$, the PIN diode is nearly a constant capacitor.





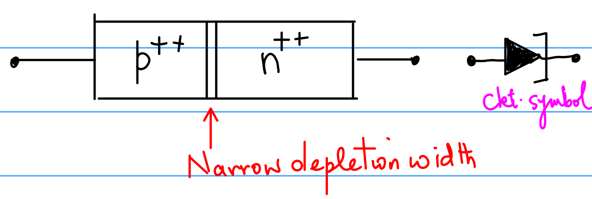
Applications of PIN-Diodes :

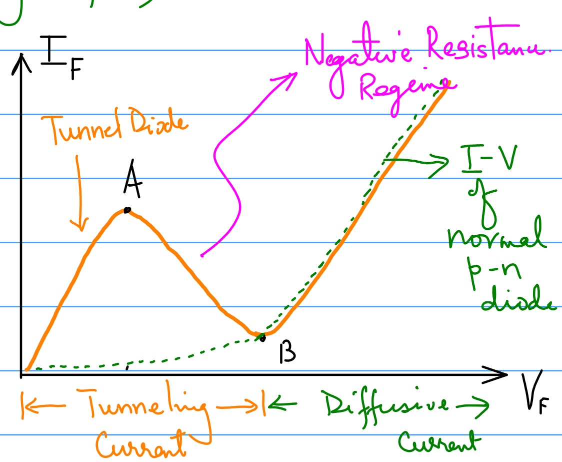
(i) Since resistance is current controlled, $R(I_F)$;
- Modulating device (High frequency signal are modulated with low frequency bias variation)
- As an attenuator device.

(ii) Certain p-i-n diodes are also used as photodetectors in fiber-optic system (communication).

(iii) Microwave switch (~ GHz frequency range).

(6) The Tunnel Diode : Ge/GaAs (heavily doped)

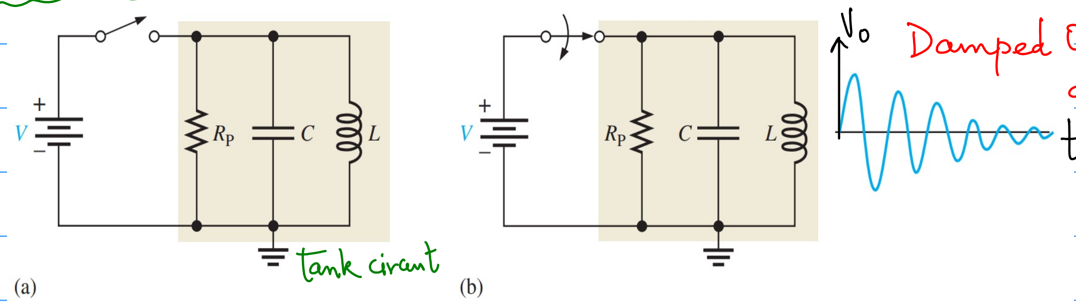




$$R_{AB} = \frac{\Delta V_{AB}}{\Delta I_{AB}} = -ve \text{ (opposite of Ohm's law)}$$

Application of a Tunnel-diode :

Oscillator Circuit :

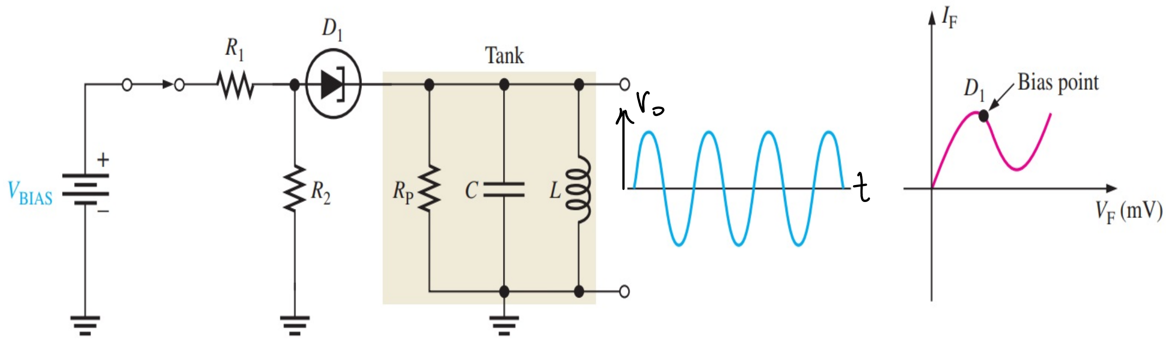


Damped Oscillation due to 'R_p'.

▲ FIGURE 3–55

Parallel resonant circuit.

Tunnel-diode D_1 is connected in series with the tank (oscillator).

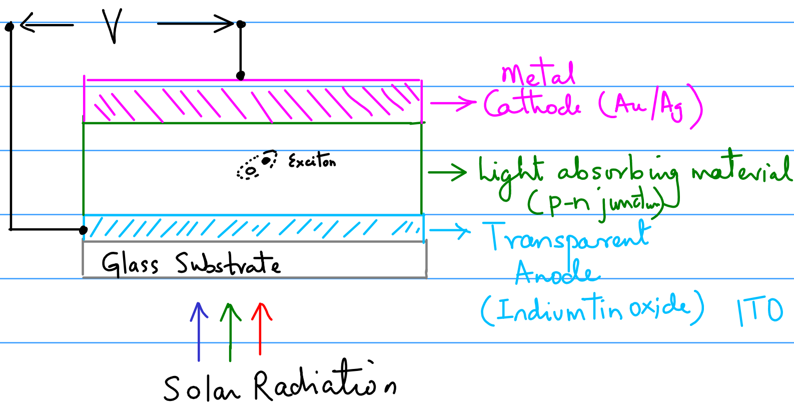


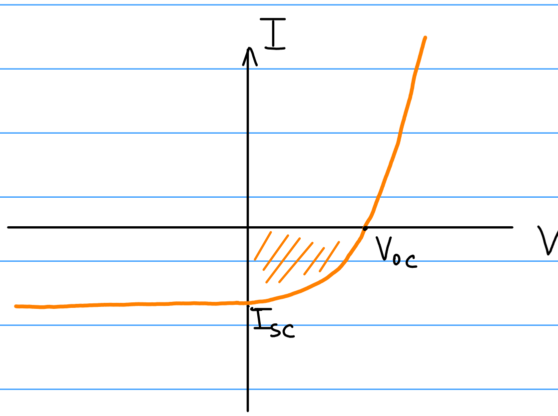
▲ FIGURE 3–56

Basic tunnel diode oscillator.

Negative resistance of the Tunnel-diode counters the positive resistance of the oscillator circuit.

(7) Solar Cells :





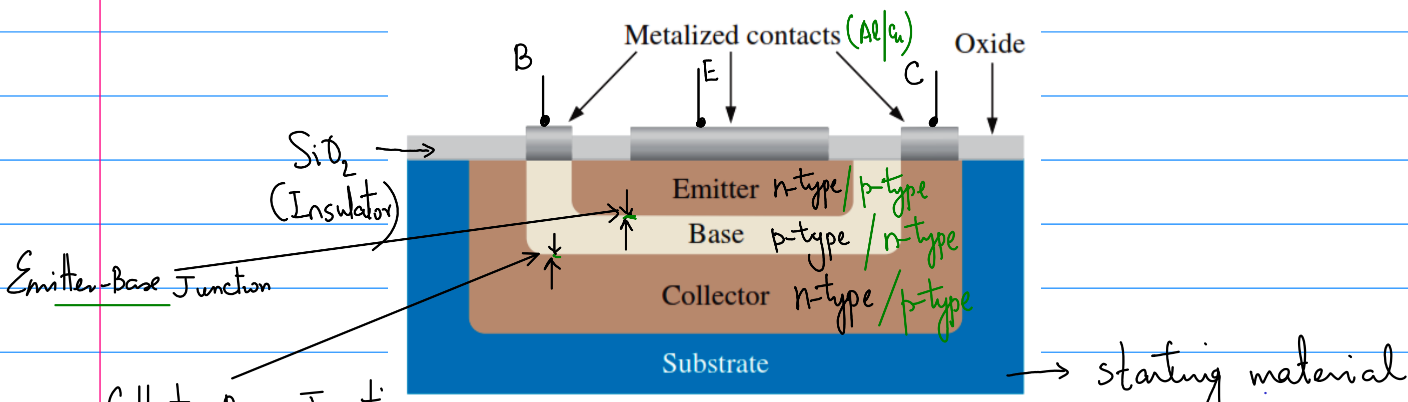
Bipolar Junction Transistors (BJTs)

– 1951, William Schockley

Bipolar : Both electrons & holes are participating in device operation.

Junction : p-n / n-p (Barrier potential associated with junction).

Transistor : Transfer of resistor (ie, transfer of current levels)



(a) Basic epitaxial planar structure
growth

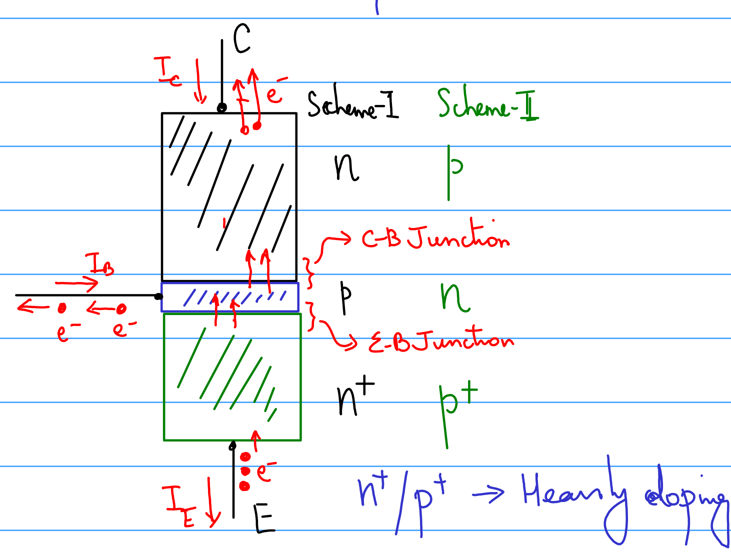
Fabrication of a BJTs.

Thickness :

C : Thickest layer

B : Thinnest layer

E : Moderate thickness

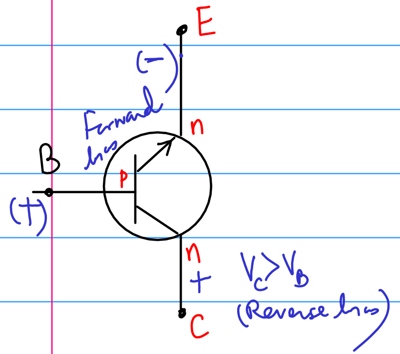


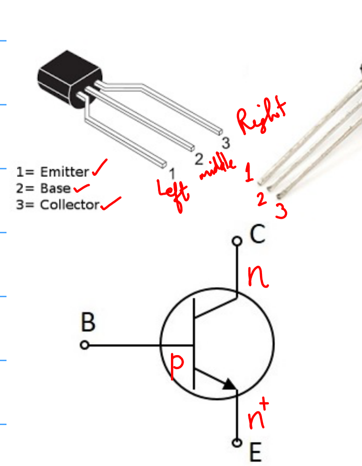
Doping levels :

C : Moderately doped ($\sim 10^{14-15}\ cm^{-3}$) dopant

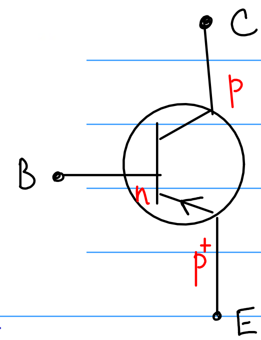
B : Lightly doped ($10^{12-13}\ cm^{-3}$)

E : Heavily doped ($10^{16-18}\ cm^{-3}$)





n-p-n Transistor



p-n-p Transistor

Basic BJT operation:

(i) Emitter-Base Junction : Forward-Bias

(ii) Collector-Base Junction : Reverse-Bias

$I_B \uparrow$ 2 times

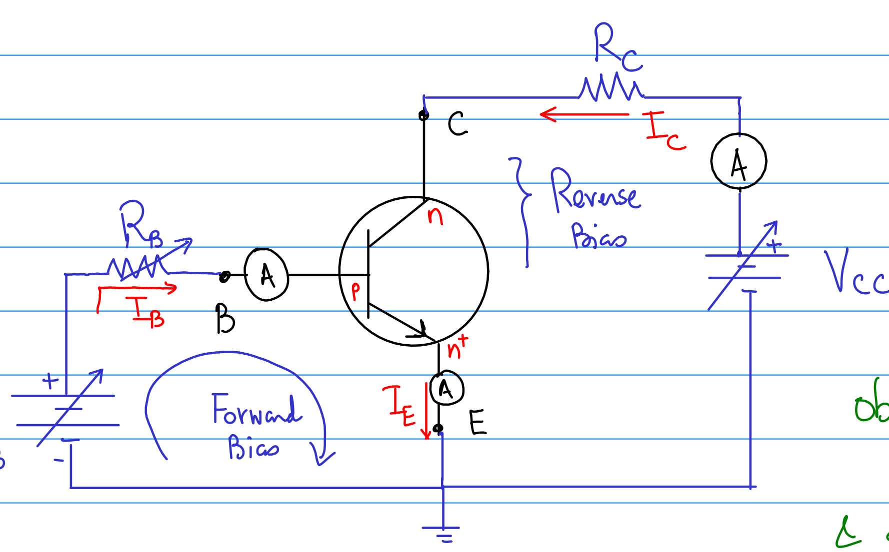
$I_{B_1} = 10\mu A$

$I_{B_2} = 20\mu A$

$I_C = \beta I_B \Big|_{DC}$

$I_{C_1} = 100 \times 10\mu A = 1mA$

$I_{C_2} = 100 \times 20\mu A = 2mA$



$\underbrace{V_C > V_B}$

We are trying to observe the current levels in the collector, Base & Emitter terminal.

- Any change in the Base-Emitter terminals, the change is directly appearing in the collector terminal.

$I_E = I_B + I_C$

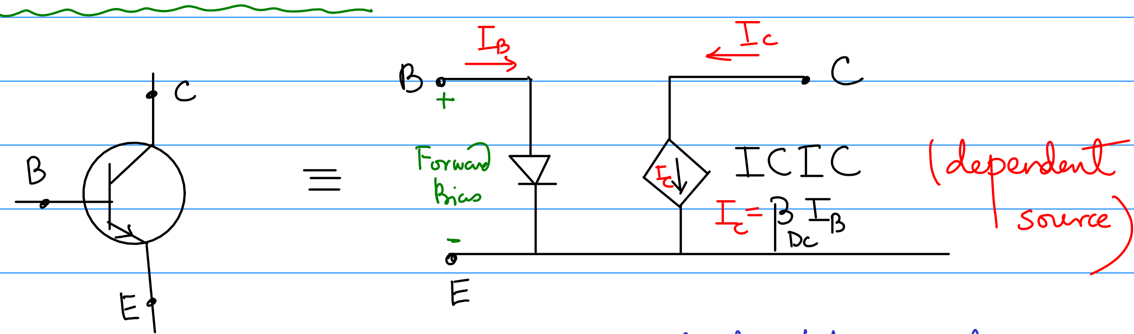
$\boxed{I_E \,;\, I_C \sim mA}$; $\boxed{I_B \sim \mu A}$

We define a parameter, $\beta_{DC} = \dfrac{I_C}{I_B} = \dfrac{\sim mA}{\sim \mu A} \simeq 100$ (typical)

β_{DC} = typically varies b/w 50–300

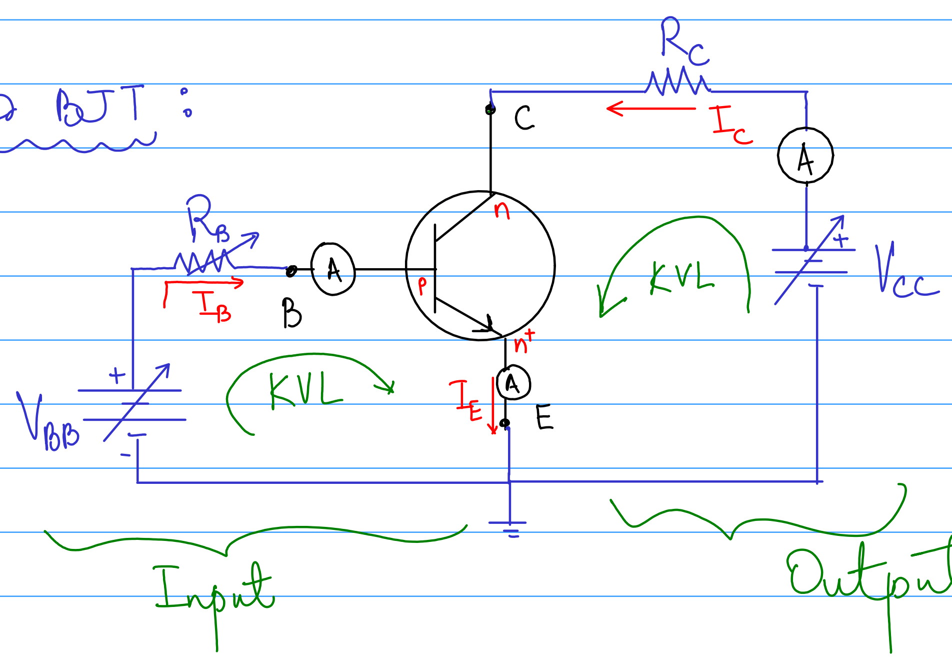
- Common-Emitter Current Gain (β_{DC})
- Common-Base Current Gain (α_{DC})

Transistor DC Model:



Equivalent ckt model.

Biased BJT:



$V_{CC} = I_C R_C + V_{CE}$

$\underset{\sim\sim}{I_C} = \dfrac{V_{CC} - V_{CE}}{R_C}$

$V_{BB} = I_B \cdot R_B + V_{BE} \Rightarrow \underset{\sim\sim}{I_B} = \dfrac{V_{BB} - V_{BE}}{R_B}$