BJT Applications, Feedback amplifiers & its applications

① Bipolar junction transistor as an Amplifier :

Amplification is the process of linearly increasing the amplitude of an electrical signal. The transistor amplifies the current because the collector current is equal to 'β' times the base current.

$$\boxed{I_C = \beta I_B}$$

The base ~~transistor in the~~ current in the transistor is very small compared to the collector current & emitter current because of this the collector current is approximately equal to emitter current

$$I_E = I_C + I_B$$

I_B is too small

$$\boxed{I_E \approx I_C}$$

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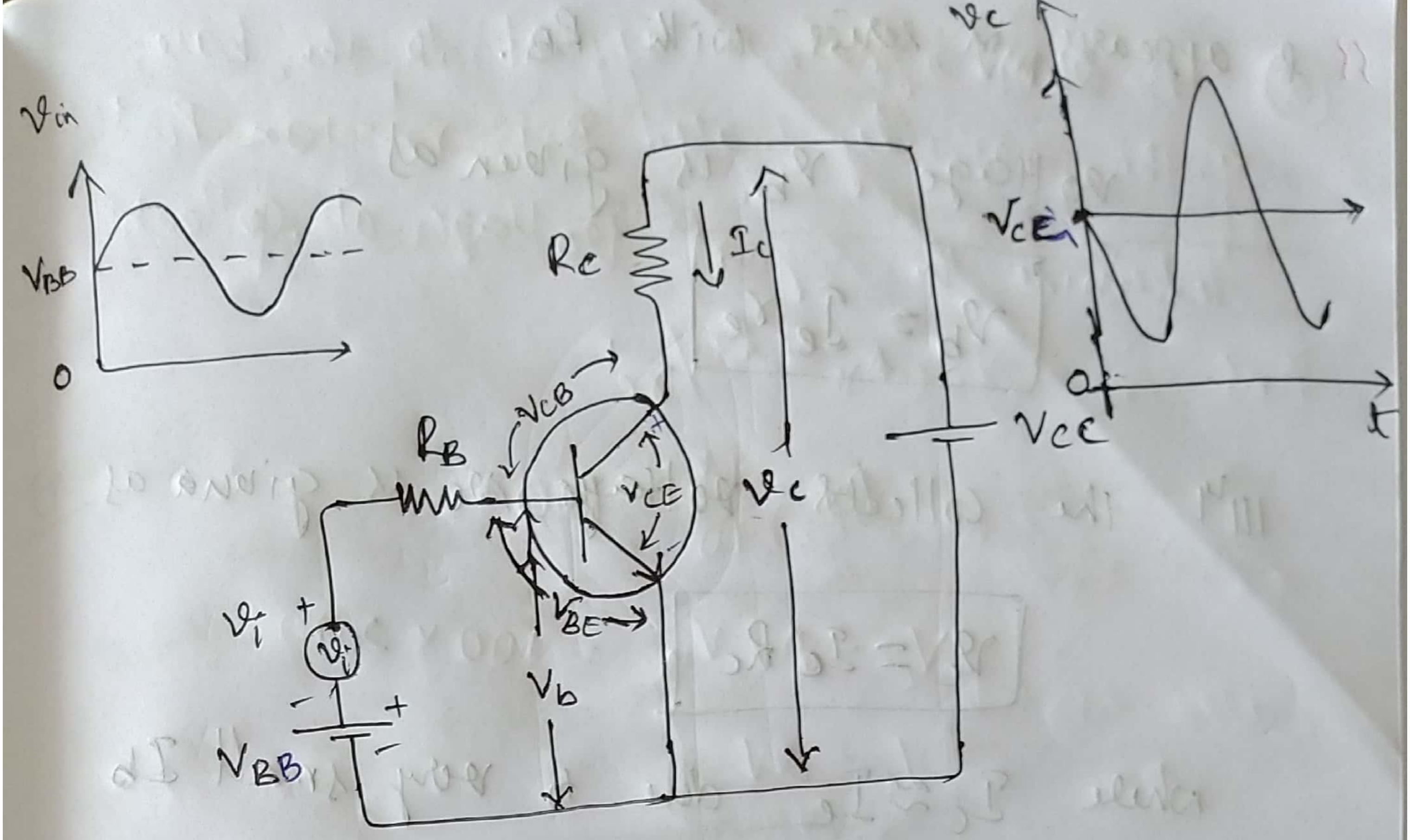


The Fig shows basic transistor amplifier circuit with ac source voltage V_i is superimposed on the dc bias voltage V_{BB} by series connection. V_{CC} is connected to the collector thro' the collector resistance R_C.

The ac input voltage produces an ac base current which results in much larger collector current, this ac collector current produces an ac voltage across R_C.

The forward biased base emitter junction presents a very low resistance to the ac signal. this internal resistance [emitter resistance] is denoted as $\underline{\underline{r_e'}}$

& appears in series with R_B.

voltage v_b is given as

$$\boxed{v_b = I_e r_e'}$$

IIIly the collector voltage v_c is given as

$$\boxed{v_c = I_c R_c}$$

where $I_c \approx I_e$ due to very small I_b

$$\boxed{v_c = I_e R_c}$$

Voltage gain is defined as the ratio output voltage to input voltage

$$A_v = \frac{v_o}{v_i} = \frac{v_c}{V_b}$$

$$= \frac{I_e R_c}{I_e r_e'}$$

$$\boxed{A_v = \frac{R_c}{r_e'}}$$

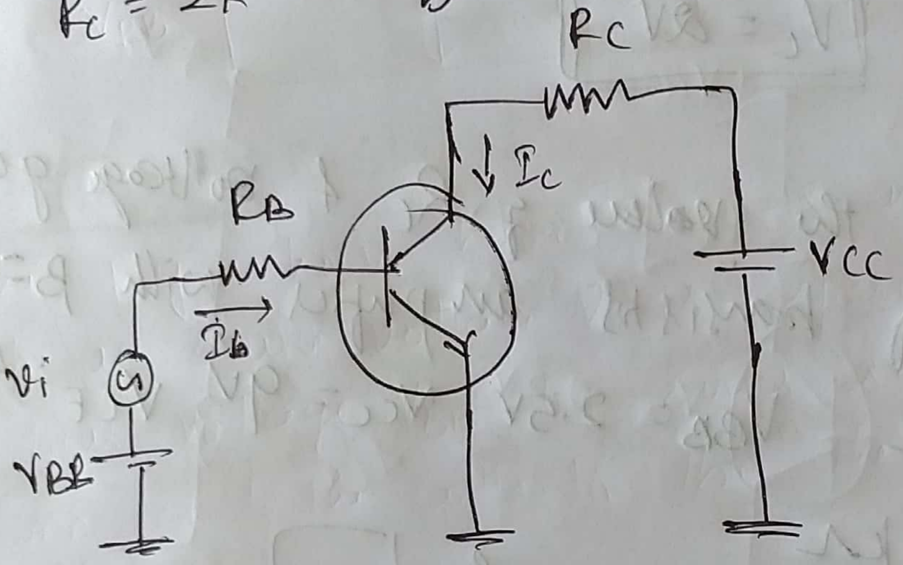
In this equation R_C is always larger than the internal resistance r_e'

$\therefore$ The above circuit provides amplification.

Examples

For the circuit shown bellow determin the voltage gain & ac o/p voltage if $r_e' = 50\Omega$

$R_C = 2k$ & $v_b = 100mV$



voltage gain

$$A_v = \frac{R_C}{r_e'} = \frac{2k}{50} = 40$$

ac o/p voltage is given as

$$V_{out} = A_v V_b = 40 \times 100mA$$
$$= \underline{4V}$$

(2) A 20mV signal is applied to the base of the properlly biased BJT $r_e' = 10\Omega$ $R_C = 1k\Omega$ determine the signal voltage at collector

Ans :-

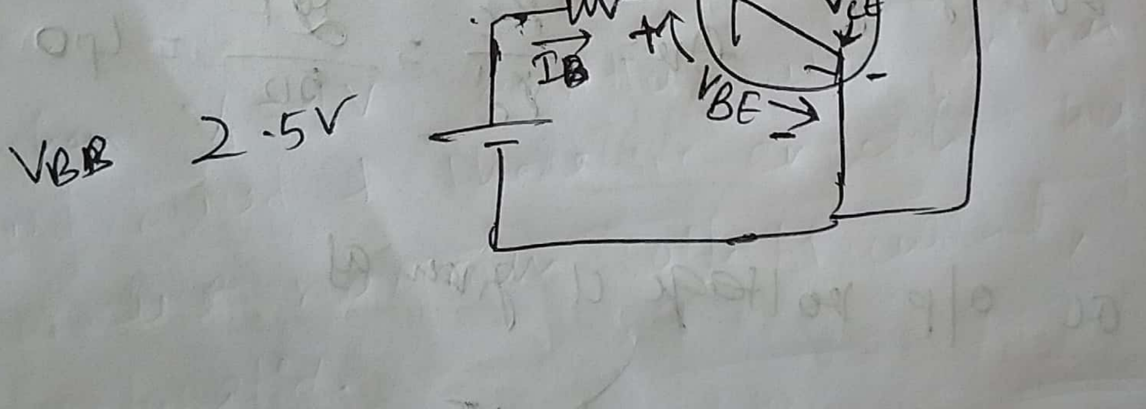
$$A_v = R_C / r_e'$$

$$A_v = \frac{1K}{10} = 100\Omega$$

$$V_C = A_v V_{in} = 100 \times 20m$$

$$\boxed{V_C = 2V}$$

(3) Determine the value of R_C & voltage gain in an npn transistor amplifier with $\beta = 250$ $r_e' = 10\Omega$ $V_{BB} = 2.5V$ $V_{CC} = 9V$ $V_{CE} = 4V$ & $R_B = 100k\Omega$



$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{2.5 - 0.7}{100K} = 18\mu A$$

$$I_C = \beta I_B = 4.5mA$$

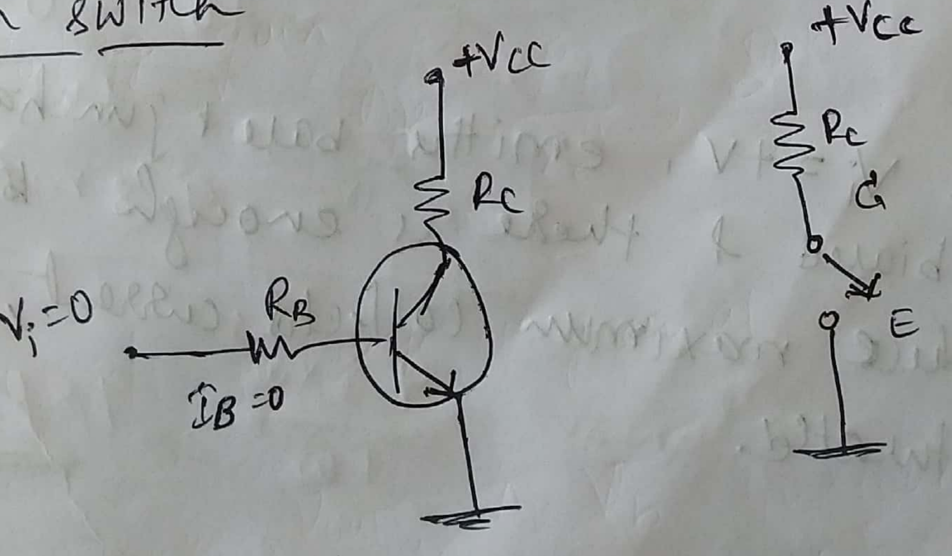
$$R_C = \frac{V_{CC} - V_{CE}}{I_C} = \frac{9-4}{4.5mA} = 1.1k\Omega$$

$$A_v = \frac{R_C}{r_e'} = \frac{1.1k}{10\Omega} = \underline{\underline{110}}.$$

② **BJT as a switch**

To use Transistors as an electronic switch the transistors must be operated in cutoff region (open switch) & in saturation region (Closed switch).

Open switch

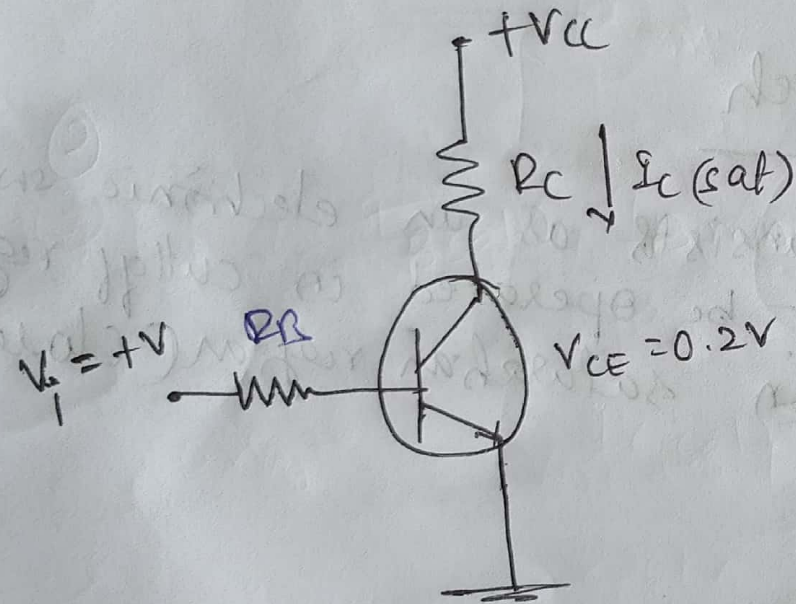


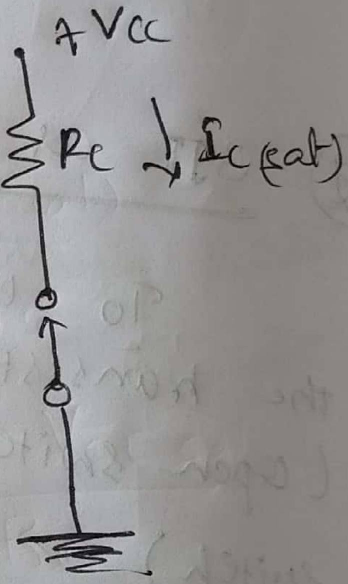
when $\boxed{V_i = 0}$ emitter base junction is reverse biased & transistor is in cut off region. in this condition $\boxed{I_B = 0 \ \& \ I_C = 0, I_E = 0.}$

$$V_{CE} = V_{CC}$$

$$\boxed{V_{CE(cutoff)} = V_{CC}}$$

<u>closed switch</u>





when $V_i = +V$, emitter base junction is forward biased & there is enough base current to produce maximum collector current, transistor is saturated

$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C}$$

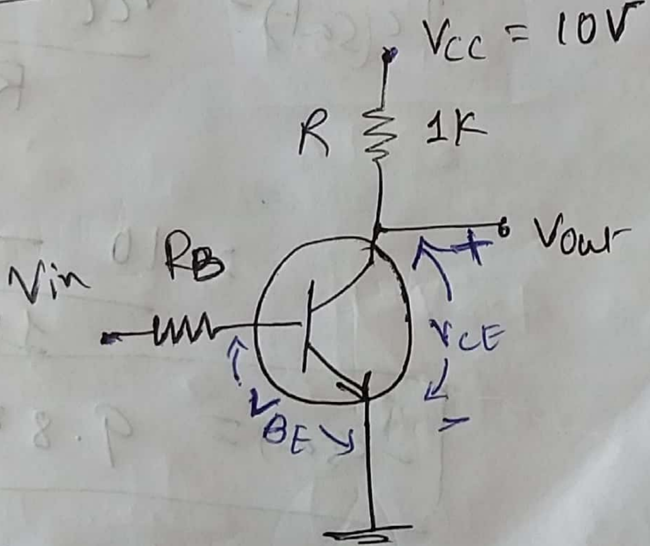
The minimum value of base current required to produce saturation is

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta_{dc}}$$

I_B should be greater than $I_{B(min)}$ for the transistor to operate in saturation.

Example

For the circuit shown in the figure



① Determine the value of V_{CE} when $V_{in} = 0$

② calculate minimum value of I_B to saturate transistor if $\beta_{dc} = 100$ assume $V_{CE(sat)} = 0.2V$

③ calculate the maximum value of R_B when $V_{in} = 5V$

① when $V_{in} = 0$ $I_B = 0$ $I_C = 0$

$$\therefore \boxed{V_{CE} = V_{CC}} = 10V$$

②

$$\cancel{I_{B(sat)}}\ I_{B(min)} = \frac{I_{C(sat)}}{\beta_{dc}}$$

$$I_{C(sat)} = \frac{V_{CC} - V_{CE\,sat}}{R_C}$$

$$= \frac{10 - 0.2}{1k}$$

$$\boxed{I_{C(sat)} = 9.8\,mA}$$

$$I_{B(min)} = \frac{9.8 \times 10^{-3}}{100} = 98\,\mu A$$

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(3) $V_{IN} = 5V$

$\therefore V_{BE} = 0.7V$

$$\frac{V_{IN} - V_{BE}}{I_B} = R_B$$

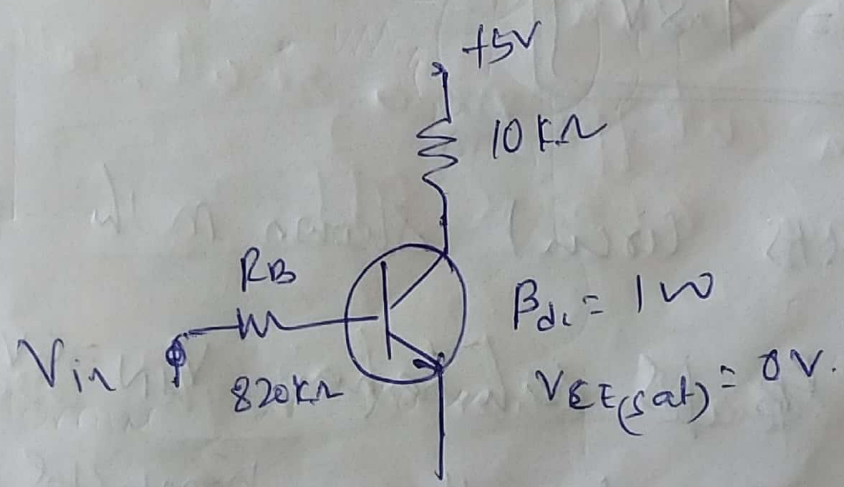
$$R_{B(max)} = \frac{5 - 0.7}{I_{B(min)}} = \frac{4.3}{98 \times 10^{-6}}$$

$$\boxed{R_{B_{Max}} = 43.88k\Omega}$$

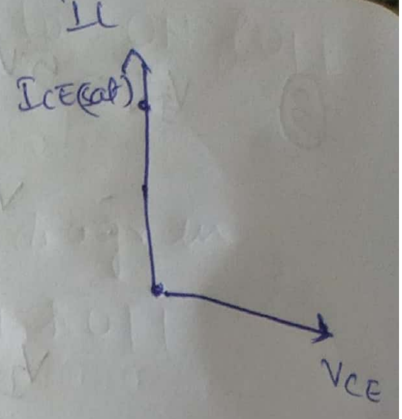
(2) for The transistor circuit shown in the figure determine

(1) I_C (sat) (2) I_B to produce saturation

(3) minimum V_{IN} for saturation.



① $I_{C\,sat} = \frac{V_{CC} - V_{CE(sat)}}{R_C}$



$= \frac{V_{CC}}{R_C}$

$\boxed{I_{C(sat)} = 500\mu A}$

② $I_{B(min)} = \frac{I_{C}(sat)}{\beta} = 5\mu A$

③ $I_{B\,min} = \frac{V_{IN} - V_{BE}}{R_B}$

$5 \times 10^{-6} = \frac{V_{IN} - 0.7}{820 k\Omega}$

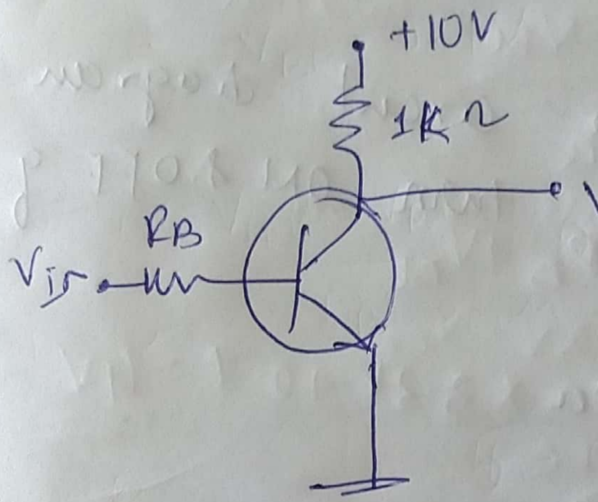
$\boxed{V_{IN} = 4.8V}$

③ The transistor circuit shown in the figure

① value of R_B for saturation $V_{IN} = 5V$

② value of V_{IN} to cut off transistor

Assume $V_{CE(sat)} = 0V$ $\beta_{dc} = 50$.



① $I_{C(sat)} = \dfrac{V_{CC} - V_{CE(sat)}}{R_C}$

$I_{C(sat)} = \dfrac{10V}{1K\Omega} = 10mA$

$\boxed{I_{C(sat)} = 10\,mA}$

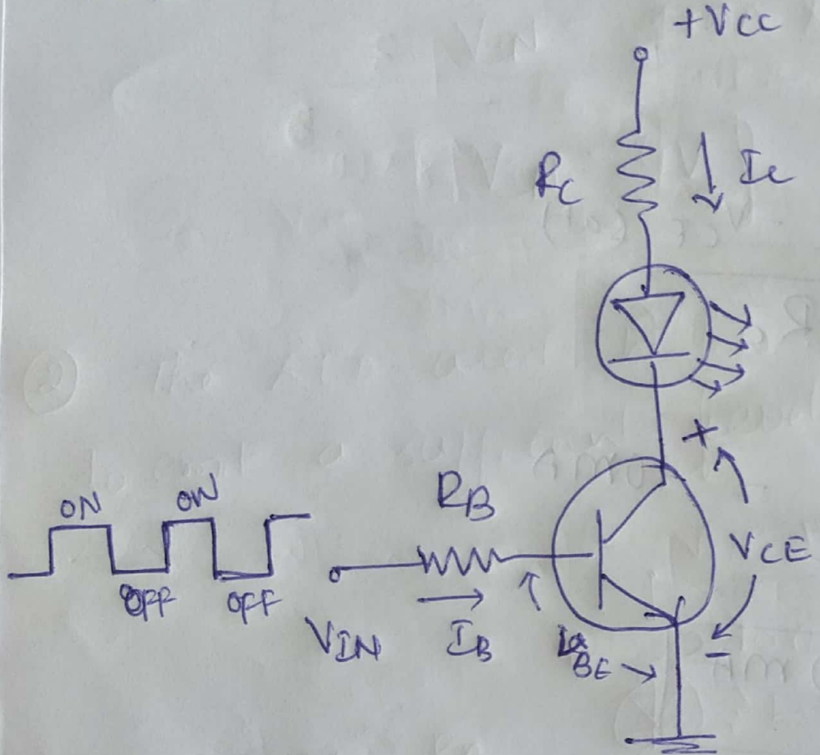
$I_{B(min)} = \dfrac{I_{C(sat)}}{\beta_{dc}} = 200\mu A$

$\boxed{I_{B(min)} = 200\mu A}$

$R_{B(max)} = \dfrac{V_{in} - 0.7}{I_{B\,min}} = \dfrac{5 - 0.7}{200\mu A} = 21.5K\Omega$

BJT as switch to ON & OFF of an LED

The fig shows the circuit diagram of BJT as a switch to turn ON & OFF of an LED



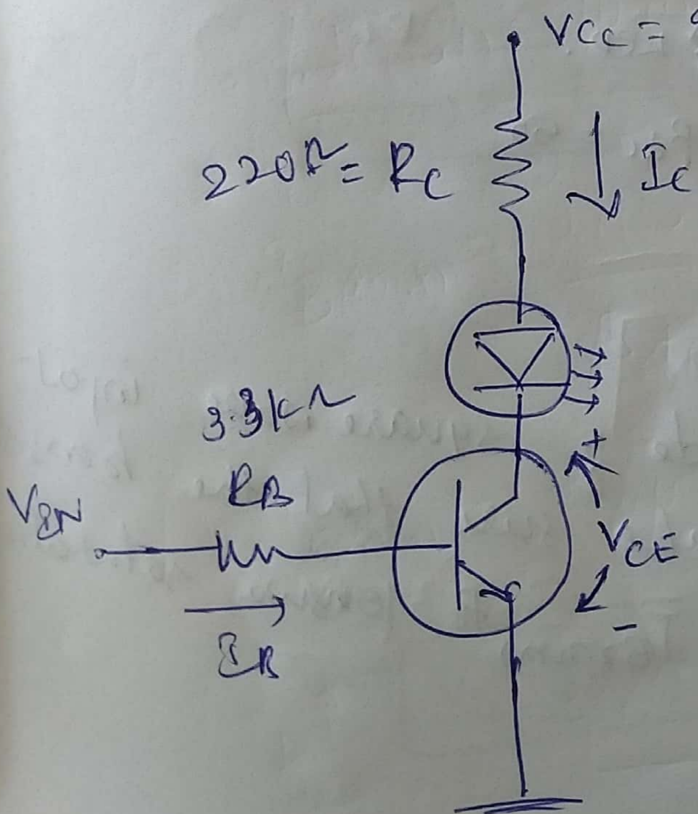
* when a square wave is at ~~'0' level~~ "0" level the base emitter junction is reverse biased & the transistor is in cutt off. As a result, collector I_C is zero & hence LED is **OFF**

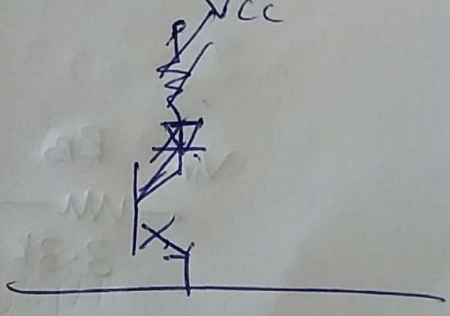
* when a square wave is 'high' level the base emitter junction is forward biased, & the

enough base current will make transistor to operate in saturation region & a saturation current I_C flows thro' the LED & LED is in ON state.

problems

For the transistorized LED driving circuit shown bellow, if $I_{LED} = 30mA$, $V_{LED} = 1.6V$, $V_{CC} = 9V$, $V_{CE(sat)} = 0.2V$, $R_C = 220\Omega$, $R_B = 3.3k\Omega$ & $\beta_{dc} = 50$ determine the amplitude of square wave input voltage necessary to make sure that transistor will operate in saturation region.





$$I_{C(sat)} = \frac{V_{CC} - V_{LED} - V_{CE\,sat}}{R_B}$$

$$\boxed{I_{C(sat)} = 32.7mA}$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta} = 654.5\mu A$$

let $I_{B(min)} = 1mA$

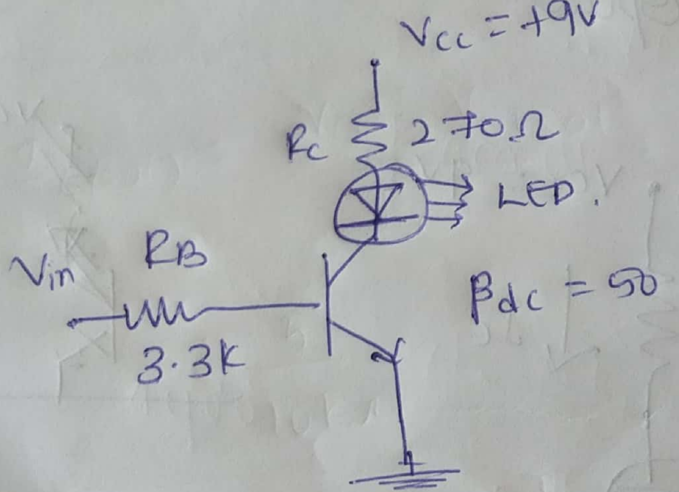
$$I_B = \frac{V_{IN} - V_{BE}}{R_B}$$

$$V_{IN} = I_B R_B + V_{BE}$$

$$V_{IN} = 1mA \times 3.3k + 0.7 = \underline{\underline{4V}}$$

$$\boxed{V_{IN} = 4V}$$

② The LED used bellow ~~uses~~ requires 30mA to emit a sufficient level of light



Determine the amplitude of square wave input voltage neccessarily to make sure that the transistor saturates. we double the $I_{B(min)}$ to ensure saturation

Assume $V_{CE(sat)} = 0.3V$.

Sol: saturation collector current is given as

$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C}$$

$$I_{C(sat)} = \frac{9 - 0.3}{270} = 32.2\ mA$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta} = \frac{32.2 \times 10^{-3}}{50}$$

$$\boxed{I_{B(min)} = 644.4\ \mu A}$$

To double the current to ensure saturation

$$I_{B(min)} = 2 \times 644.4\ \mu A$$

$$\boxed{I_{B(min)} = 1288\ \mu A}$$

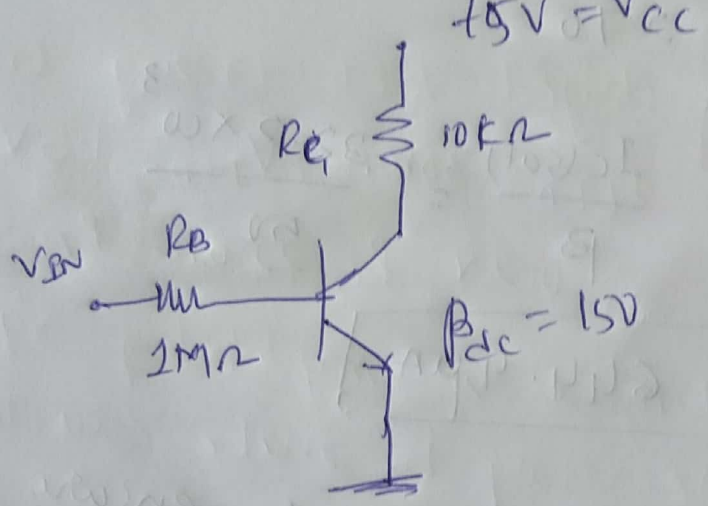
$$I_{B(min)} = \frac{V_{IN} - V_{BE}}{R_B}$$

$$I_{B(min)} \times R_B + V_{BE} = V_{IN}$$

$$\boxed{V_{IN} = 4.95\ V}$$

Amplitude of square wave

③ In the circuit given ① what is the value of I_B neccessary to produce saturation ② what minimum value of V_{IN} is neccessary to saturate? Assume $V_{CE(sat)} = 0V$



$$I_{C(sat)} = \frac{V_{CC} - V_{CEsat}}{R_C} = \frac{V_{CC}}{R_C}$$

$$= \frac{5}{10k\Omega}$$

$$\boxed{I_{C(sat)} = 500\mu A}$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta} = 3.33\mu A$$

$$I_{B(min)} = \frac{V_{IN} - V_{BE}}{R_B}$$

$$V_{IN} = I_{B(min)} R_B + V_{BE}$$

$$= 3.3 \times 10^{-6} \times 1 \times 10^{-6} + 0.7$$

$$\boxed{V_{IN} = 4V}$$