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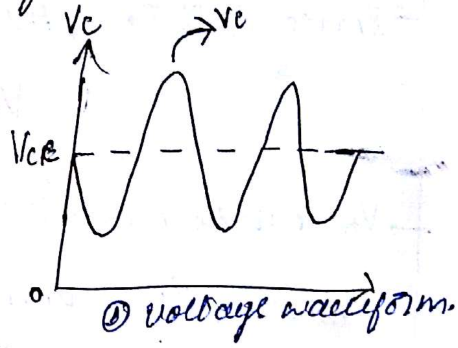
(1)

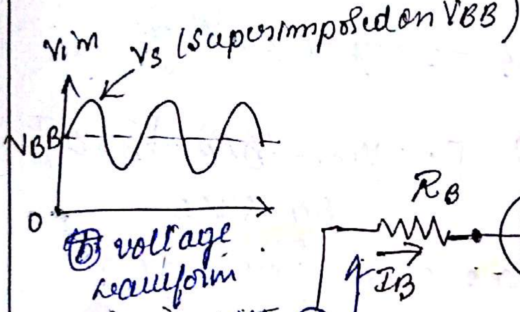
BJT as an Amplifier

+ **Amplification**: is the process of linearly increasing the amplitude of an electrical signal.

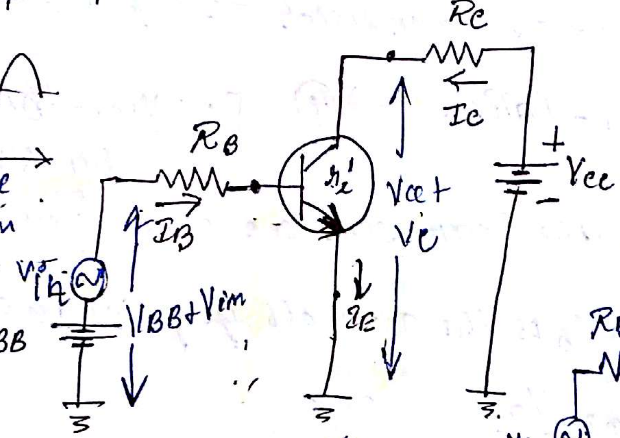
+ A transistor amplifies current because the collector current is equal to the base current multiplied by the current gain β (i.e $I_C = \beta I_B$). The base current is very small compared to the collector and emitter current.



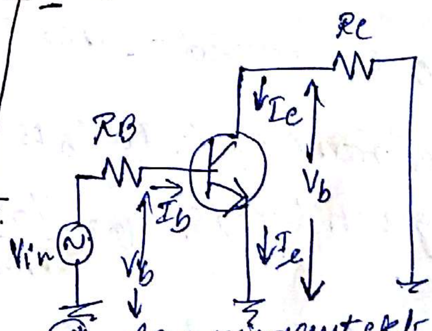
(a) voltage waveform.



(b) voltage waveform



(c) Basic Transistor amplifier



(d) AC equivalent ckt

fig shows basic amplifier ckt with ac source voltage V_s is superimposed on the dc bias voltage V_{BB}. The dc bias voltage V_{BB} is connected to base through the resistor R_B & the dc bias voltage V_{CC} is connected to collector through resistor R_C. (d) AC eq ckt can be represented by making $V_{BB}=0$ & $V_{CC}=0$

- The ac input voltage produces an ac base current, which results in larger ac collector current.
- The ac collector current produces an ac voltage across R_C, thus producing an amplified but inverted reproduction of ac input voltage in active region.
- The forward biased emitter-base junction presents a low resistance to the ac signal.

This internal ac emitter resistance is designated as r_e'

- The ac emitter current is given by

$$I_e \simeq I_c = \frac{V_b}{r_e'} \quad \text{(or)} \quad r_e' = \frac{V_b}{I_e} \simeq \frac{V_b}{I_e} \rightarrow (1)$$

- The ac collector voltage V_c equal to the ac voltage drop across R_c,

$$\therefore V_c = I_c R_c \rightarrow (2)$$

- Since $I_e \simeq I_c$, the ac collector voltage is given by,

$$V_c \simeq I_e R_c \rightarrow (3)$$

- V_b can be considered as transistor ac input voltage

where, $V_b = V_{in} - I_B R_B \rightarrow (4)$ [$\because V_{in} - I_B R_B - V_b = 0$ by KVL]

- V_c considered as the transistor ac output voltage.

- The ratio of V_c to V_b is the ac voltage gain A_v and is given by, $\therefore A_v = \frac{V_o}{V_{in}}$

$$A_v = \frac{V_c}{V_b} \longrightarrow (5)$$

we have, $V_b = I_e r_e'$ [from (1)] $\rightarrow (6)$ where r_e is ac emitter resistance.

substituting eqns. (3) & (6) in (5)

$$A_v = \frac{V_c}{V_b} \simeq \frac{I_e R_c}{I_e r_e'}$$

$\therefore$ Ac voltage gain $\boxed{A_v \simeq \frac{R_c}{r_e'}} \rightarrow (7)$

- eq (7) shows that transistor provides amplification in the form of voltage gain which is ~~in~~dependent of R_c & r_e'

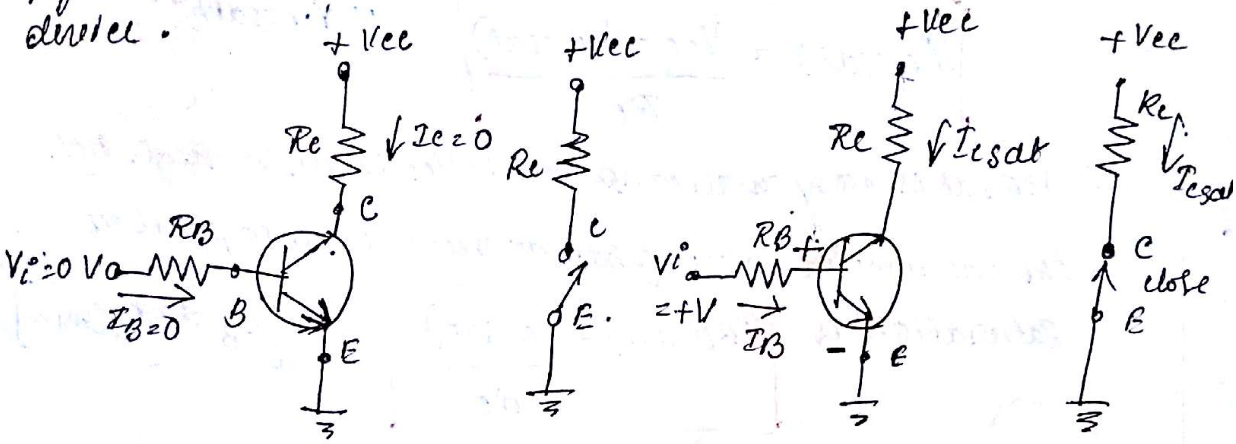
$\because$ R_c is always greater than r_e', the o/p voltage V_c is always greater than i/p voltage V_b.

current gain $\boxed{A_i = I_c/I_B = \beta}$ $\because I_c \gg I_b$ A_i is large

power gain $\boxed{A_p = A_v \cdot A_i}$ - product of voltage gain & current gain.

② BJT as a Switch

- Second major application area of BJT is switching application.
- When used as an electronic switch, a BJT is normally operated alternately in cut-off & saturation.
- fig illustrates the basic operation of transistor as a switching device.



ⓐ cutoff - open switch ⓑ saturation - closed switch

ⓐ The transistor is in cut-off region because the BE junction is reverse biased. Hence, there is ideally an open between collector & emitter.

ⓐ i.e when $V_i = 0$, EB junction is reverse biased & transistor is in cutoff region. In this condition, $I_B = I_C = 0$ and thus open ckt btn collector and emitter.

ⓑ when $V_i = +V$, emitter-Base junction is forward biased. & Base-collector junction are also forward biased. In this condition base current flows & it is greater than I_C / β (to reach its saturation value).

Conditions in cutoff

- As transistor is in cutoff region when base-emitter junction is not forward biased, neglecting leakage current, all of currents are zero & V_{CE} is equal to Vcc.

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

conditions in Saturation

- when base-emitter junction is forward-biased and there is enough base current to produce a maximum collector current. the transistor is saturated.

we have the formula for collector saturation current as.

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

$\because$ V_{CEsat} is very small compared to V_{CC} it can be neglected.

- The minimum value of base current needed to produce saturation is $\boxed{I_{B(min)} = \frac{I_{C(sat)}}{\beta_{dc}}}$ $[I_B >> I_{B(min)}]$

- I_B should be significantly greater than $I_{B\,min}$ to ensure transistor is operated in saturation region.

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③ Transistor switch circuit to switch ON/OFF an LED

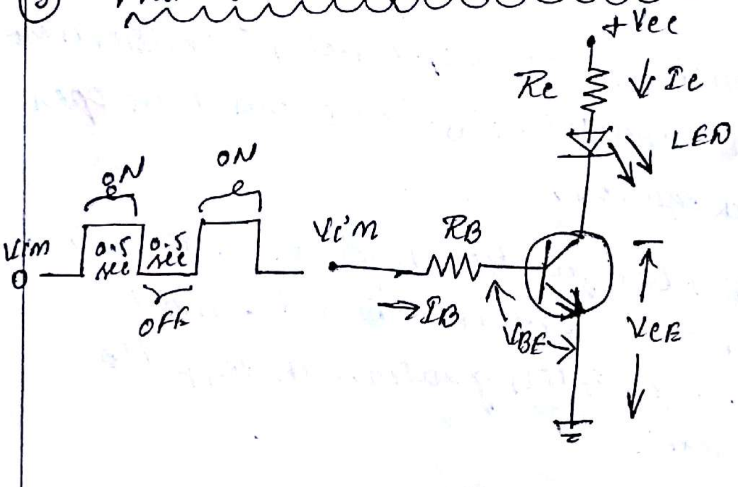

fig ③

fig shows how transistor is used as a switch to turn off & turn on LED.

- A square wave input voltage with a period of 1 sec (0.5 sec on time & 0.5 sec off-time) is applied to the input

- when square wave is at 0V, the base emitter junction is reverse biased and the transistor is in cut-off. As a result, collector current I_C is zero and hence LED does not emitt light.

- when square wave goes high, the BE junction is forward biased & there is enough base current to operate the transistor in saturation
- As a result, collector current I_C flows & it forward bias is the LED. The resulting I_C through LED causes to emit light.

- Thus the LED is on for 0.5 sec & off for 0.5 sec.

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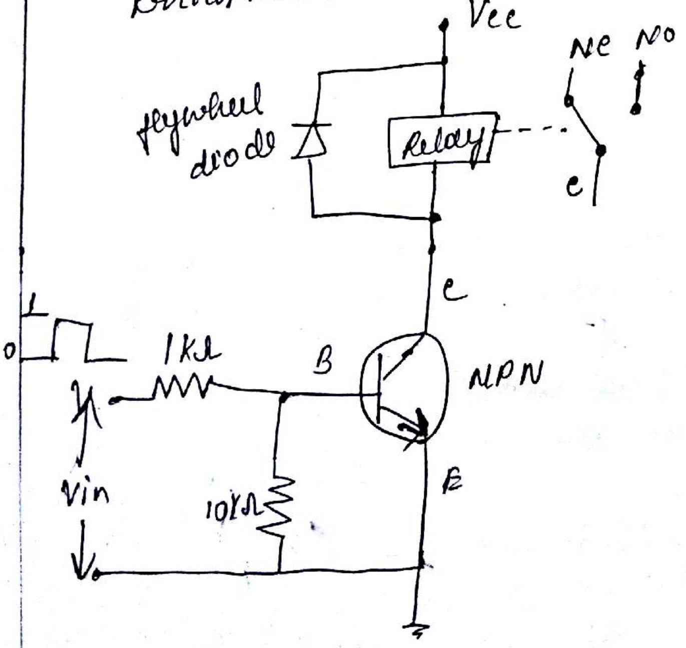
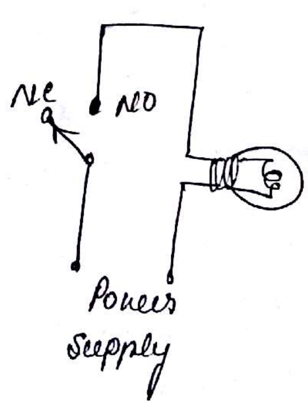
④ Relay Switch circuit using BJT.

Draw & Explain working of relay switch circuit using BJT to ~~open~~ Turn OFF/ON lamp.

- Relays are electromechanical devices that use an electromagnet to operate a pair of movable contacts from an open position to a closed position.
- The advantage of relays is that it takes a relatively small amount of power to operate relay coil. but the relay itself can be used to control motors, heaters, lamps or ac circuits which themselves can draw a lot more electrical power.



Relay Switch circuit



lamp ckt

fig @ shows a typical relay switch ckt. The circuit has the coil driven by NPN transistor switch, depending on input voltage level. When base voltage of transistor is zero, the transistor is cut-off & acts as open switch. As a result no collector current flows & the relay coil is de-energized. In this condition, NC (normally closed) contact remains close & normally open contact remains open

- when base voltage of transistor is sufficient enough to drive transistor in saturation, it acts as closed switch.
- Ic flows & relay coil is energized.
- NC contact gets open & NO normally open contact gets close.

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Relationship between α & β

β_{dc}: The dc current gain of the Transistor is the ratio of the dc collector current (I_C) to the dc base current (I_B) i.e

$$\boxed{\beta = \beta_{dc} = I_C/I_B}$$

α_{dc}: The ratio of dc collector current (I_C) to the dc emitter current (I_E) i.e

$$\boxed{\alpha = \alpha_{dc} = \frac{I_C}{I_E}}$$

$\because I_C < I_E$. α_{dc} is unity

$$\alpha = \frac{I_C}{I_E} = \frac{I_E - I_B}{I_E} = 1 - \frac{I_B}{I_E}.$$

we know that $I_E = I_C + I_B$

$\Rightarrow I_B = I_E - I_C$

$$\beta = \frac{I_C}{I_B} \Rightarrow \frac{I_C}{I_E - I_C}$$

dividing numerator & denominator of RHS of above eqn by I_E we get,

$$\beta = \frac{I_C/I_E}{I_E/I_E - I_C/I_E} \Rightarrow \boxed{\beta = \frac{\alpha}{1-\alpha}}$$

$\because \alpha = \frac{I_C}{I_E}$

W.K.T $\alpha = \frac{I_C}{I_E}$ and $I_E = I_B + I_C$

$$\alpha = \frac{I_C}{I_B + I_C}$$

Dividing num & denominator of RHS of above eq by I_B, we get

$$\alpha = \frac{I_C/I_B}{I_B/I_B + I_C/I_B} \Rightarrow \boxed{\alpha = \frac{\beta}{1+\beta}}$$

$\because \beta = I_C/I_B$.