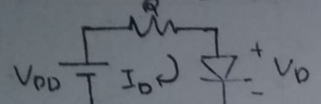
1) Find Operating point for the diode circuit graphically using load line method.

→ Load line is constructed to determine an appropriate 'Q' point for given circuit. In order to construct a load line Volt-Ampere characteristics of the device and Current expression for a given circuit.

Let us consider a circuit as shown.



From figure,

$$V_{DD} - I_D R - V_D = 0$$

$$\therefore I_D = \frac{V_{DD} - V_D}{R} \quad \text{— (i)}$$

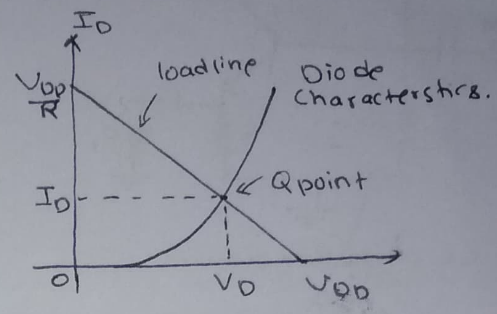
Putting $V_D = 0$ in eqn (i) we get,

I_D = maximum. i.e $I_{Dmax} = \frac{V_{DD}}{R}$ — (ii)

Again, putting $I_D = 0$ in eqn (i)

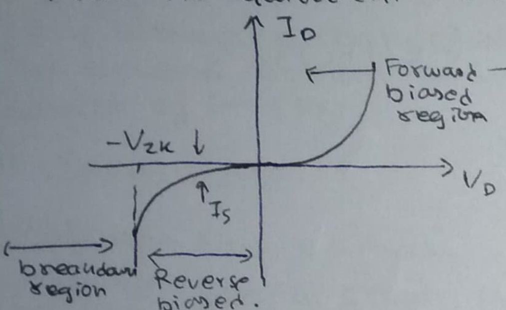
we get, $V_{Dmax} = V_{DD}$ — (iii)

Plotting eqn (ii) & (iii) in figure aside →

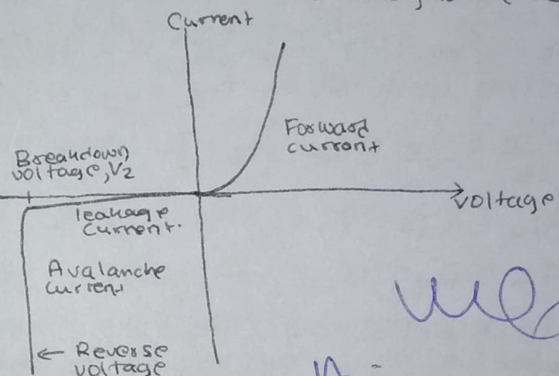


Plotting these points (V_{DD}/R, V_{DD}) an intersection point is obtained. The point is known as O.P or Q point and gives the biasing voltage V_D & I_D.

2) Draw graphs of IV characterstics of ordinary PN junction diode and zener diode. Draw AC equivalent model for PN junction diode and derive its dynamic resistance.



I-V curve of PN junction diode.



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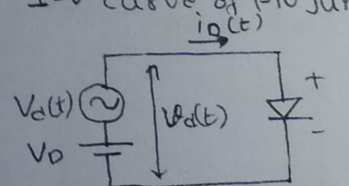


Fig: I

Applying KVL

$$v_D = V_D + v_d(t)$$

Diode current $i_D = I_s e^{\frac{v_D}{nV_T}} = I_s e^{\frac{V_D + v_d(t)}{nV_T}} = I_s e^{\frac{V_D}{nV_T}} . e^{\frac{v_d(t)}{nV_T}}$

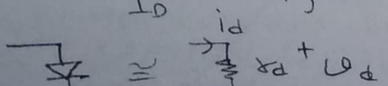
$$= I_D \left[1 + \frac{V_d(t)}{nV_T} + \left(\frac{v_d(t)}{nV_T}\right)^2 \frac{1}{2!} + \cdots \right]$$

Under small signal approximation, $v_d(t)/nV_T \ll 1$

$$i_D = I_D \left(1 + \frac{V_d(t)}{nV_T}\right) = I_D + i_d(t)$$

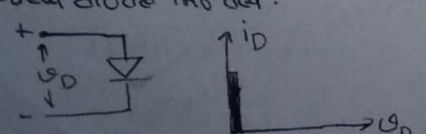
Small signal current $i_d(t) = \frac{I_D}{nV_T} v_d(t) = \frac{v_d(t)}{r_d}$

Where, $r_d = \frac{nV_T}{I_D}$ = dynamic resistance or AC resistance of diode.



3) Explain large signal model of diode.

a) Ideal diode model.



Diode eqn is

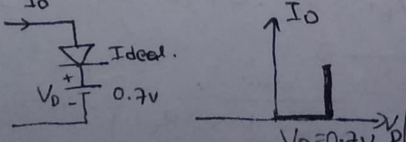
$I_D > 0 \Rightarrow v_D = 0$

$I_D = 0 \Rightarrow v_D < 0$

In Forward biased → Closed S/W

In Reverse biased → Open switch.

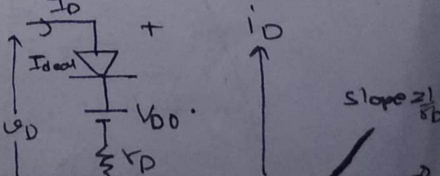
b) Constant voltage drop model



$v_D = 0.7V$ for $I_D > 0$

$V_D < 0.7V$ for $I_D = 0$

c) Piecewise linear model.



$V_D = V_{DO}$ for $I_D = \frac{V_D - V_{DO}}{r_D}$

$V_D < V_{DO}$ for $I_D = 0$

* The Ebers-Moll Model:

This model was proposed by Ebers and Moll. To determine the model of transistor, the EB junction is considered as a pn junction diode. Then normal current through the EB junction and CB junction can be determined as:

$$i_{EF} = I_{EO}\left(e^{\frac{V_{BE}}{\eta V_T}} - 1\right) \quad \text{—} (i)$$

where,

i_{EF} = Forward emitter current

I_{EO} = reverse saturation Emitter current

V_{BE} = Voltage across BE junction.

V_T = Thermal voltage.

Due to emitter forward current, Collector forward current i_{CF} also flows through the CB junction which can be expressed as,

$$i_{CF} = -\alpha_F i_{EF} \quad \text{—} (ii)$$

where, α_F is current gain

-Ve sign the direction, of i_{CF} wrt i_{EF}

Since CB junction for normal operation is reverse biased, i_{CR} flows through the CB junction.

$$i_{CR} = I_{CO}\left(e^{\frac{V_{CB}}{\eta V_T}} - 1\right) \quad \text{—} (iii)$$

where, I_{CO} is the reverse saturation collector current.

Due to this reverse CC, i_{CR} some emitter reverse current i_{ER} also flows across the BE junction.

$$i_{ER} = -\alpha_R i_{CR} \quad \text{—} (iv)$$

From above 4 eq^ns,

$$i_E = i_{EF} + i_{ER} = I_{EO}\left(e^{\frac{V_{BE}}{\eta V_T}} - 1\right) - \alpha_R i_{CR} \quad \text{—} (v)$$

$$i_C = i_{CF} + i_{CR} = -\alpha_F i_{EF} + I_{CO}\left(e^{\frac{V_{CB}}{\eta V_T}} - 1\right) \quad \text{—} (vi)$$

eqn 5 can be explained as parallel combination of forward based diode with i_{EF} and $\alpha_R i_{CR}$

eq^n 6 is parallel combination of current source $\alpha_F i_{EF}$ and i_{CR}

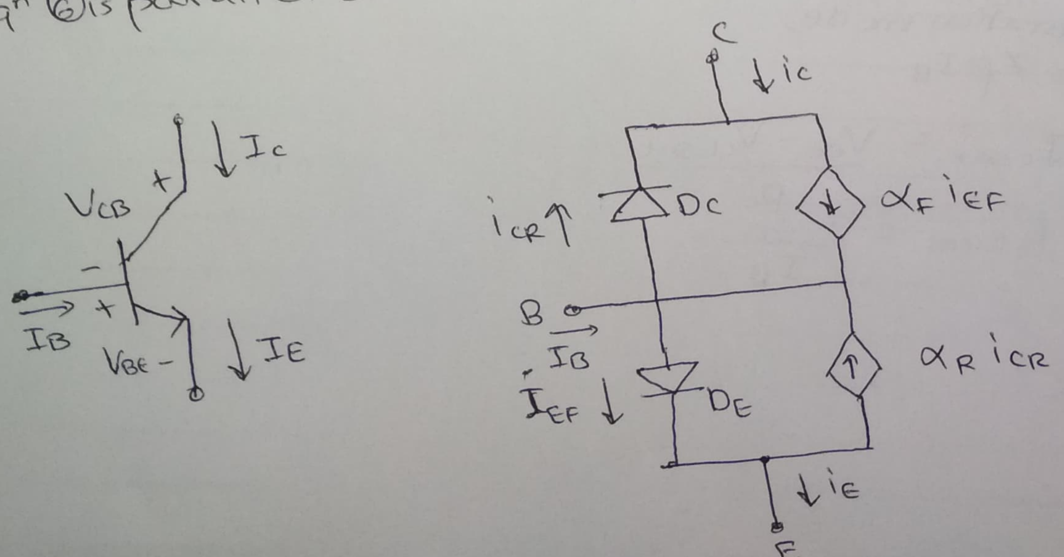
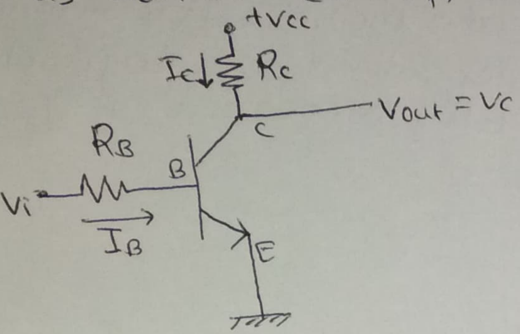


Fig: Eber-molls model of transistor

* Transistor as switch - cutoff and saturation.



* Operaton in cutoff mode:

- When Base-emitter junction is less than 0.5 V, it will be reverse Biased and practically no current flows in the transistor.

$V_{BE} < 0.5V$; $I_B = I_C = I_E = 0$

$\therefore V_{out} = V_C = V_{CC}$

Since, all the currents in transistors are equal to zero, the transistor is in "OFF" condition.

* Operation in saturation mode:

- When $V_{BE} > 0.7V$, the transistor enters into active mode. The V_{BE} can be increased just by increasing the input V_I.

In active mode,

$$I_B = \frac{V_I - V_{BE}}{R_B} = \frac{V_I - 0.7}{R_B}$$

$$I_B = \frac{I_c}{\beta} \text{ [For active mode]}$$

Also,

$$V_c = V_{cc} - I_c R_c$$

I_B can be increased by increasing V_I similarly I_c ~~can be~~ can be increased on increasing I_B. When I_c increases, V_c decreases. If V_c will be less than 0.7 V, then C-B junction become forward biased and enters to saturation region. If V_c is further derecreases, CB junction becomes more forward biased and transistor enters into deep saturation region.

In saturation mode,

$$I_c \neq \beta I_B$$

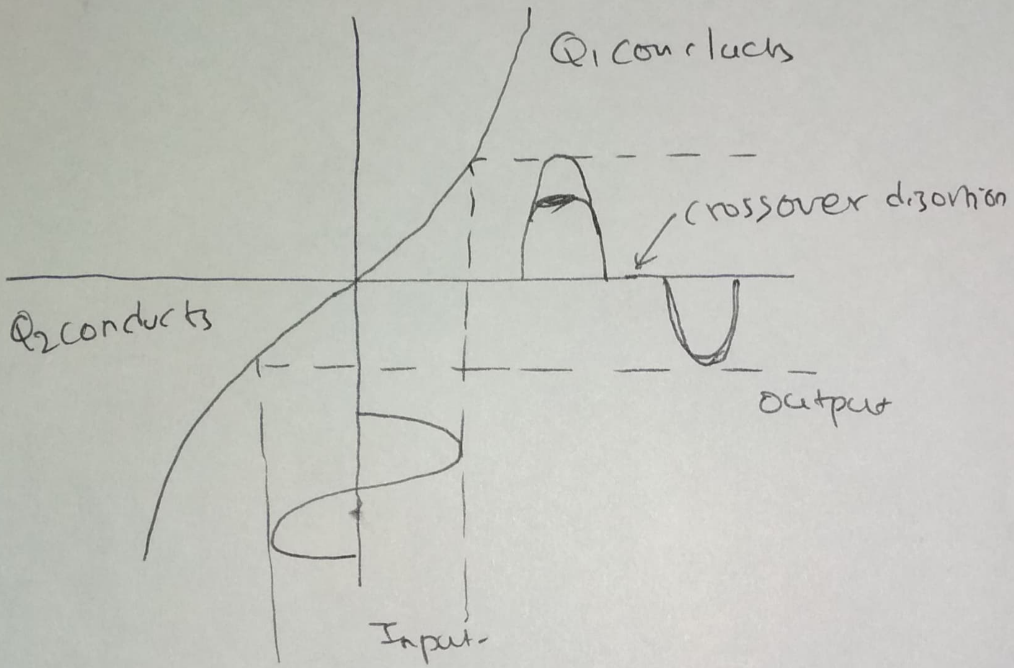
so,

$$I_{csat} = \frac{V_{cc} - V_{CEsat}}{R_c}$$

$$\beta_{forced} = \frac{I_{csat}}{I_B}$$

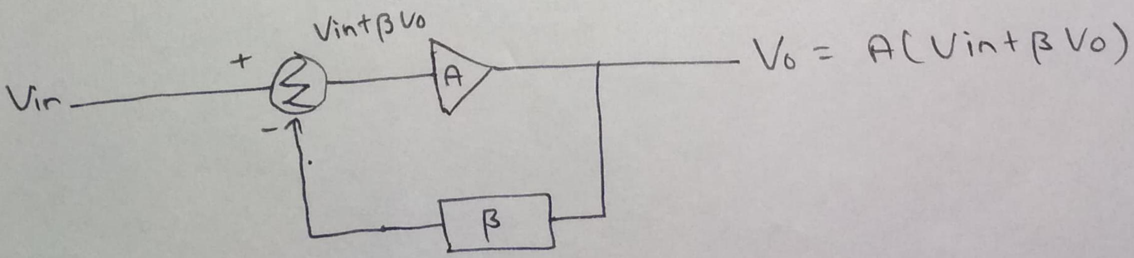
* Crossover distortion and its elimination.

-> This distortion is the result of one of the transistor cutting off before another one starts conducing in Class B amplifier.
~~To elimate the cro~~
It is said to be crossover distortion because it occurs during the time operation crossover from one transistor to another. To eliminate crossover distortion it is necessary to add small amount of forward bias to take the transitior to their averge conduction or beyond.



* Barkhausen Criteria:

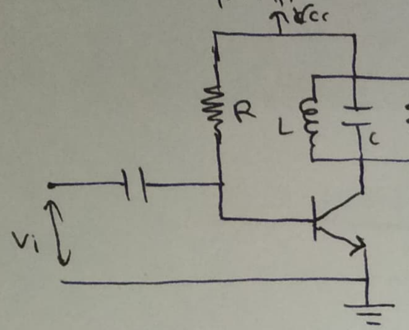
-> Blockdiagram of general oscillator is



Criteria:-

1) Total loop gain βA should be unity ($\beta A = 1$)
2) Total phase difference in a loop should be zero

* Tuned Amplifier



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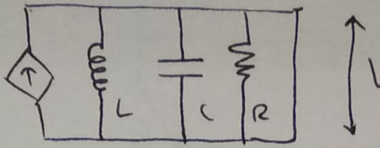


From above figure

$V_o = I_o Z_L$

or $V_o = \frac{I_o}{Y_L}$ — (i)

where Y_L is the admittance of RLC

$Y_L = \frac{1}{R} + j\omega C + \frac{1}{j\omega L}$

or, $Y_L = \frac{1}{R} + j\left(\omega C - \frac{1}{\omega L}\right)$

or $Y_L = G + jB$ — (ii)

At resonance frequency $B = 0$

$\omega_o C - \frac{1}{\omega_o L} = 0$

or $\omega_o^2 = \frac{1}{LC}$

$\therefore \omega_o = \frac{1}{\sqrt{LC}}$ — (iii)

At the cutoff frequency ω_c, (−3dB)

$|B| = |G|$

$|B|^2 = |G|^2$

or $B = \pm G$

or $\omega_c C - \frac{1}{\omega_c L} = \pm \frac{1}{R}$ — (iv)

At lower Resonant frequency

$\omega_c C - \frac{1}{\omega_c L} = -\frac{1}{R}$ — (v)

At higher Resonant frequeny

$\omega_c C - \frac{1}{\omega_c L} = +\frac{1}{R}$ — (vi)

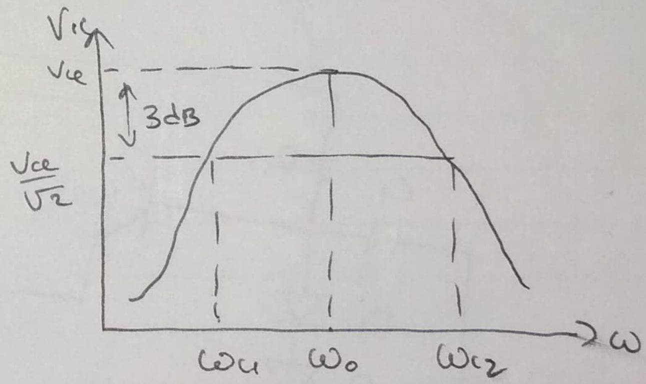
from (v) and (vi)

$\omega_{c1} = -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}}$ — (A)

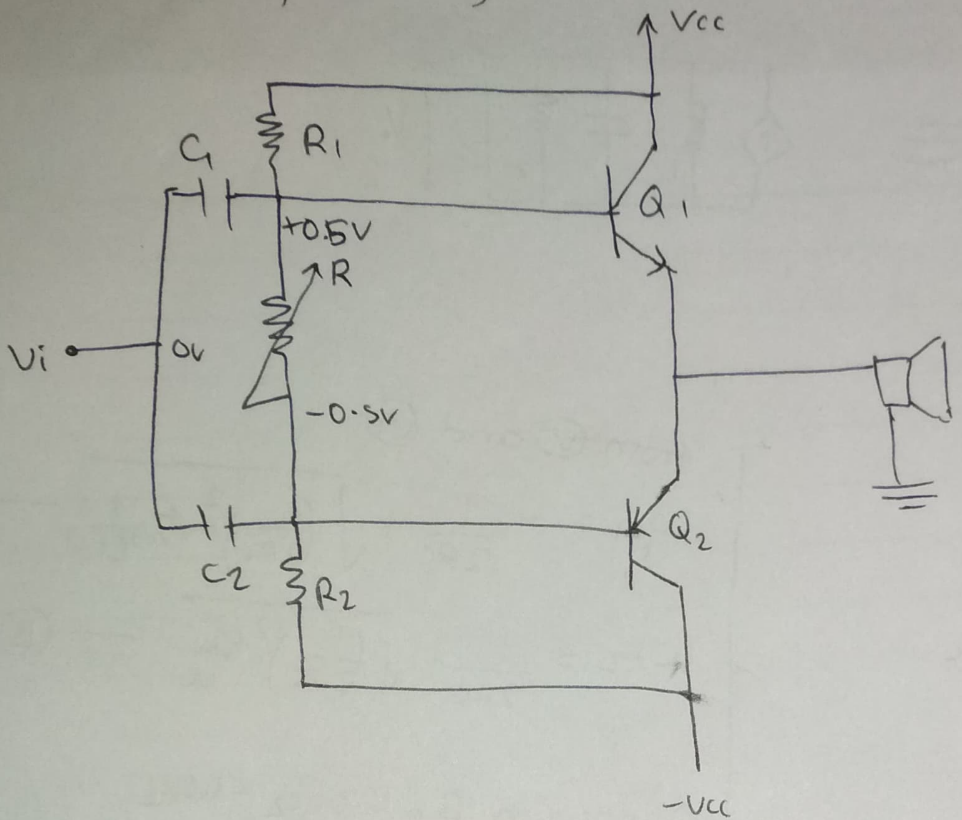
$\omega_{c2} = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}}$ — (B)

Bandwith $B\omega = \omega_{c2} - \omega_{c2}$

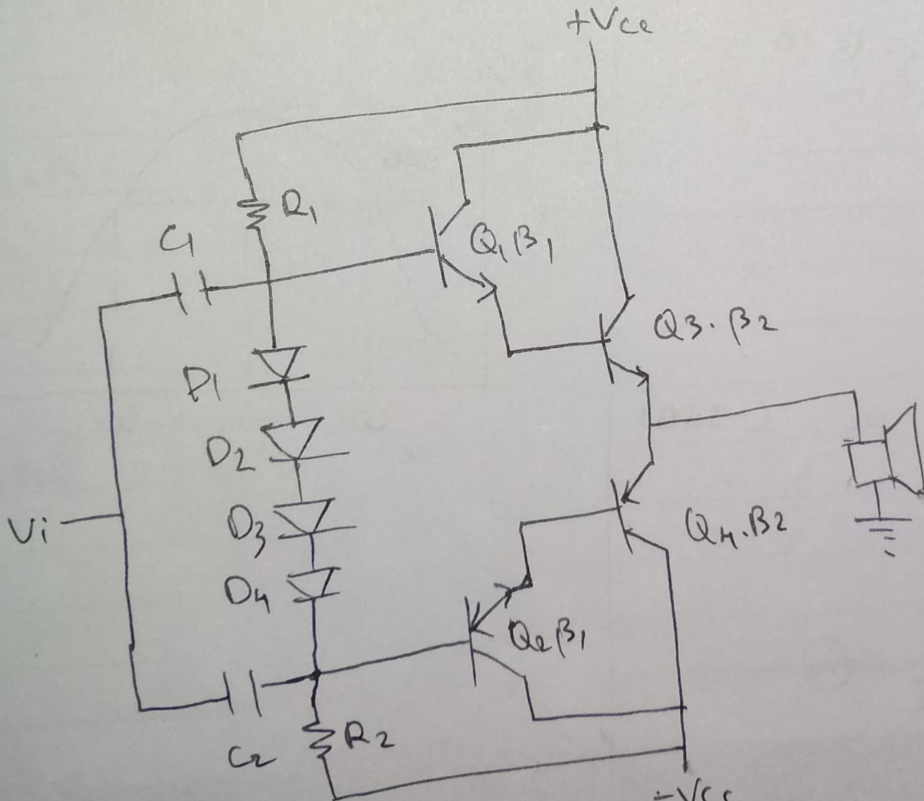
$= \frac{1}{RC}$



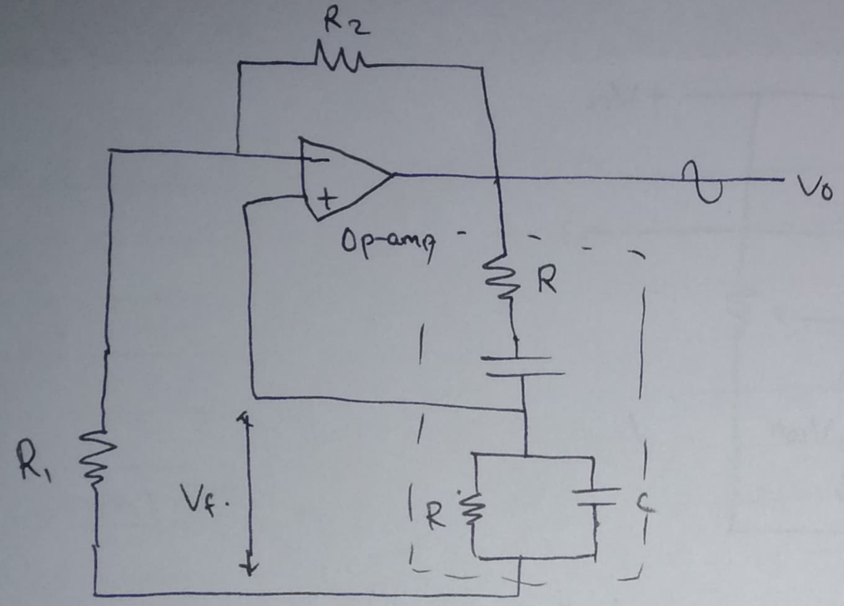
complementary Symmetry of Class AB ~~push~~ amplifier



By Darlington pair transistor



* Wein bridge Oscillator



* The output of Op-Amp is feedback to ~~to the~~ the input terminals of Op-amp through the Resistor voltage divider network and RC wein bridge circuit.

* The upper RC series and ~~RE~~ lower RC parallel circuit produce zero shift at frequency of oscillation.

From figure,

$$Z_1 = R + jx$$

$$Z_2 = \frac{Rjx}{R+jx}$$

we have

$$V_f = V_o \frac{Z_2}{Z_1 + Z_2}$$

or $$\frac{V_f}{V_o} = \frac{\frac{Rjx}{R+jx}}{R+jx + \frac{Rjx}{R+jx}}$$

or $$\frac{V_f}{V_o} = \frac{\frac{Rjx}{R+jx}}{\frac{(R+jx)^2 + Rjx}{(R+jx)}}$$

or $$\frac{V_f}{V_o} = \frac{Rjx}{R^2 + 2Rjx + j^2x^2 + Rjx}$$

or $$\frac{V_f}{V_o} = \frac{Rjx}{(R^2 - x^2) + 3Rjx} \quad \text{—(i)}$$

or $$\frac{V_f}{V_o} = \frac{-Rx}{j(R^2 - x^2) + 3Rx}$$

For zero shift

$$R^2 - x^2 = 0$$

or $$R^2 = x^2$$

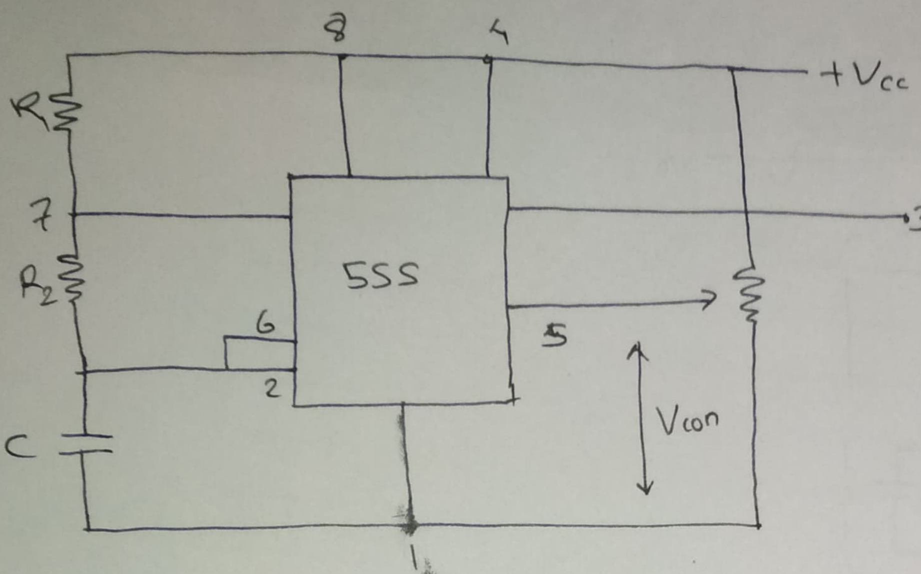
or $$R = \frac{1}{2\pi f C}$$

$$\therefore f = \frac{1}{2\pi RC}$$

$\therefore$ From (i),

$$\frac{V_f}{V_o} = \frac{-Rjx}{-3Rx} = \frac{1}{3}$$

* Voltage Controlled Oscillator using 555 timer



Voltage control oscillator is also called Voltage to frequency converter the frequency can be controlled by controlling Voltage Vcon.
Vcc varies from $\frac{V_{con}}{2}$ to Vcon. If we increase Vccon, it takes capacitor longer to charge and discharge.
Let t_1 be charging time and t_2 be discharging time of capacitor,

$$V_c(t_1) = V_{applied} - [V_{applied} - V_{initial}]\, e^{\frac{-t_1}{(R_1+R_2)C}}$$

$$V_c(t_2) = V_{applied} - [V_{applied} - V_{initial}]\, e^{\frac{-t_2}{R_2C}}$$

For charging,

$$V_{con} = V_{cc} - \left[V_{cc} - \frac{V_{con}}{2}\right] e^{\frac{-t_1}{(R_1+R_2)C}}$$

or, $$\frac{t_1}{(R_1+R_2)C} = \ln\left(\frac{V_{cc} - 0.5V_{con}}{V_{cc} - V_{con}}\right)$$

For discharging,

$$V_{con} = \cancel{V_{cc}}\ 0 - [0 - V_{con}]\, e^{-\frac{t_2}{(R_2)C}}$$

or $$t_2 = R_2 C \ln 2$$

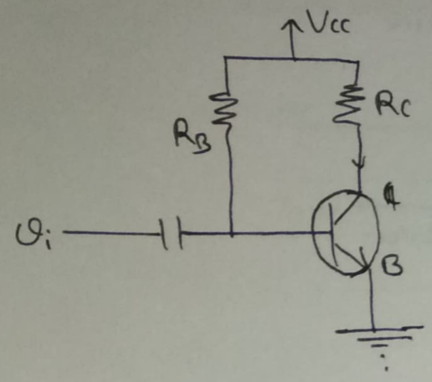
For time period,

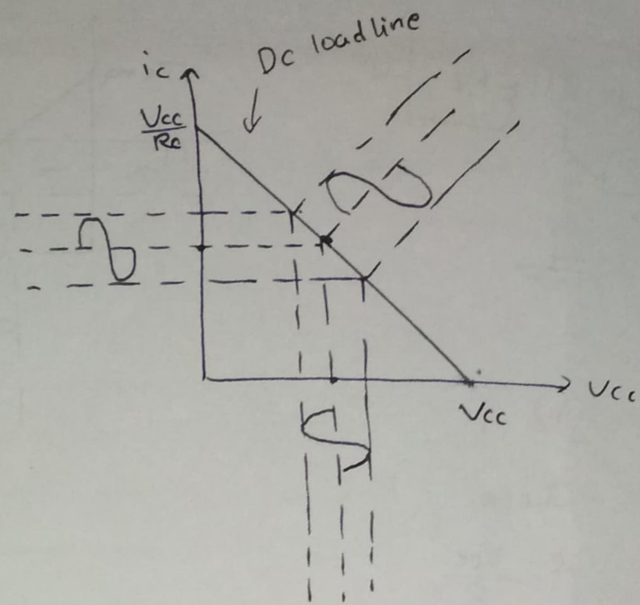
$$T = t_1 + t_2$$
$$= (R_1+R_2)C \ln\left(\frac{V_{cc} - 0.5V_{con}}{V_{cc} - V_{con}}\right) + R_2 C \ln 2$$

For frequency,

$$f = \frac{1}{T}$$

* Class A fed Amplifier :-





* Input power (P_i):

$$P_i = V_{CQ} I_{CQ}$$
$$= V_{cc} \cdot \frac{V_{cc}}{2R_C}$$
$$\therefore P_i = \frac{(V_{cc})^2}{2R_C}$$

* Output power (P_o) :-

$$P_o = I_o V_o$$
$$= \frac{V_o}{R_C} \cdot V_o$$
$$\therefore P_o = \frac{V_o^2}{R_C}$$

but, $V_o = \frac{V_{PP}}{2\sqrt{2}}$

$$= \frac{V_{cc}}{2\sqrt{2}}$$

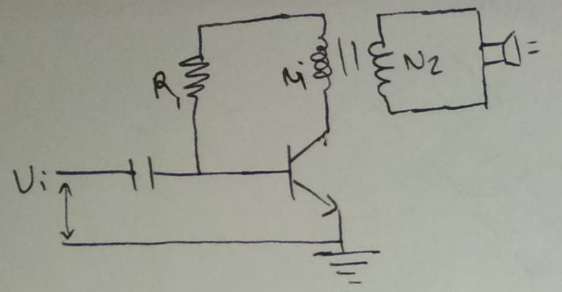
$$\therefore P_o = \frac{V_{cc}^2}{8R_C}$$

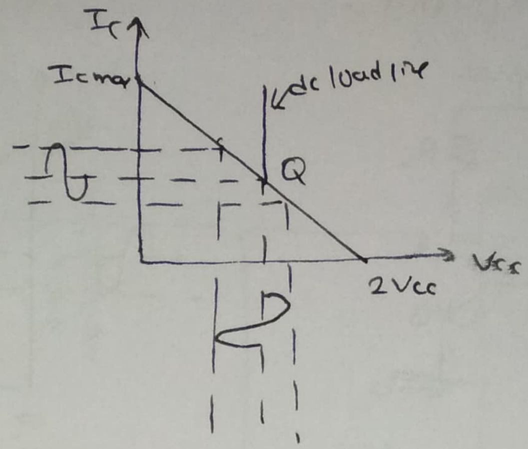
* Efficiency (η):

$$\eta = \frac{P_o}{P_i} \times 100\%$$
$$= \frac{\cancel{V_{cc}^2}}{8\cancel{R_C}} \times \frac{2\cancel{R_C}}{\cancel{V_{cc}^2}} \times 100\%$$

$$\therefore \eta_{max} = 25\%$$

* Transformer Coupled Class A Amplifier.





* Input Power (Pi)

$$P_i = V_{cc} I_{CEQ}$$
$$= V_{cc} \cdot \frac{V_{cc}}{R}$$
$$P_i = \frac{V_{cc}^2}{R} \quad \text{—(I)}$$

where R is the resistance from primary side of transformer.

* Output power (Po)

$$P_o = I_o V_o$$
$$= \frac{V_o^2}{R}$$

where

$$V_o = \frac{V_{PP}}{2\sqrt{2}} = \frac{2V_{cc}}{2\sqrt{2}} = \frac{V_{cc}}{\sqrt{2}}$$

$$\therefore P_o = \frac{V_{cc}^2}{2R} \quad \text{—(II)}$$

* Efficiency:

$$\eta = \frac{P_o}{P_i} \times 100\,\%$$
$$= \frac{V_{cc}^2}{2R} \times \frac{R}{V_{cc}^2} \times 100$$
$$= 50\%$$

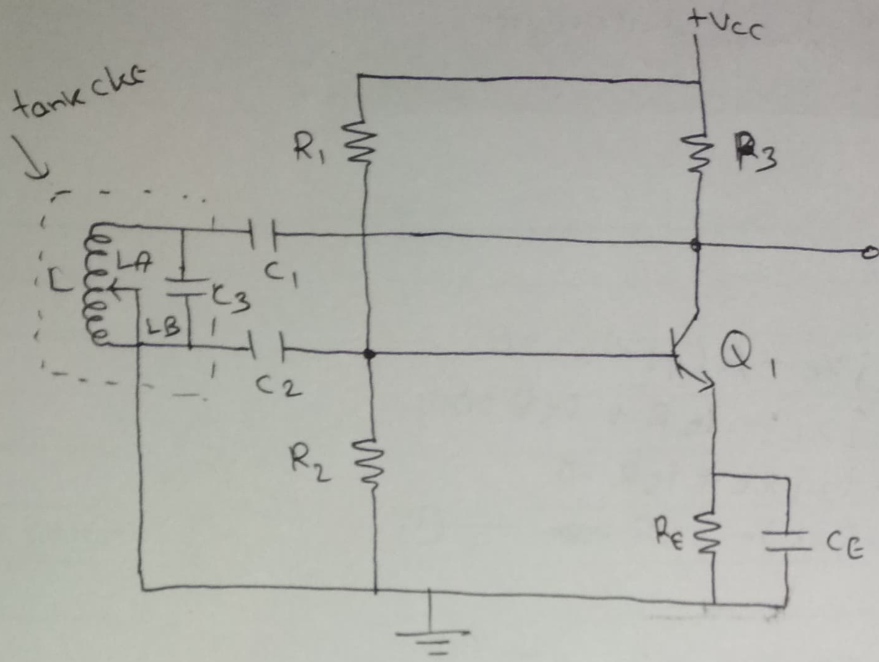
* For general iffiziency.

replace $V_{cc} = \frac{V_{CE\,min} + V_{CE\,max}}{2}$ in eq^n (I)

& " $V_{cc} = \frac{V_{CE\,max} - V_{CE\,min}}{2}$ in eq^n (II)

$$\therefore \eta = 50 \left[\frac{V_{CE(max)} - V_{CE(min)}}{V_{CE(max)} + V_{CE(min)}} \right]^2 \%$$

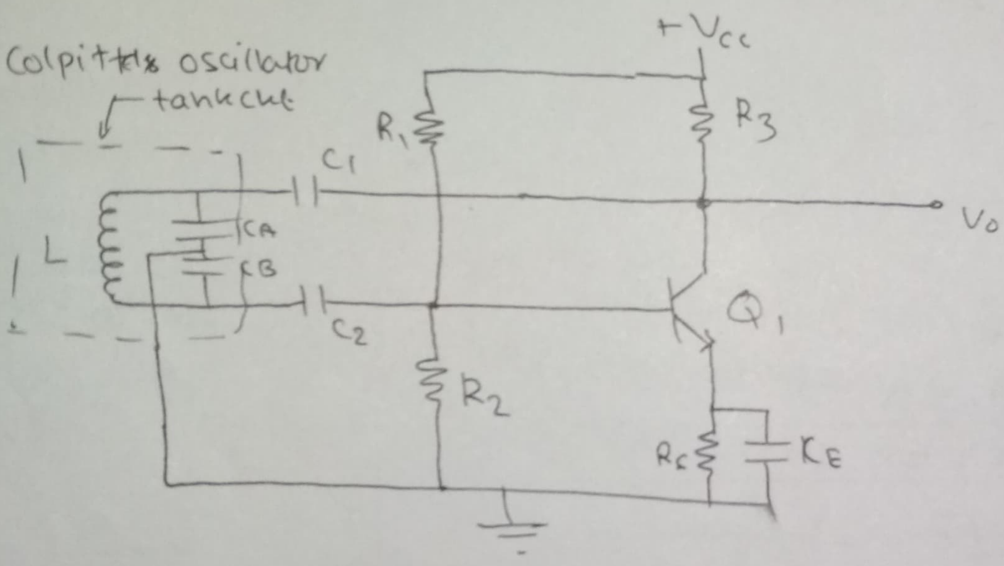
* Hartley Oscillator



$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\pi\sqrt{(LA+LB).c}}$$

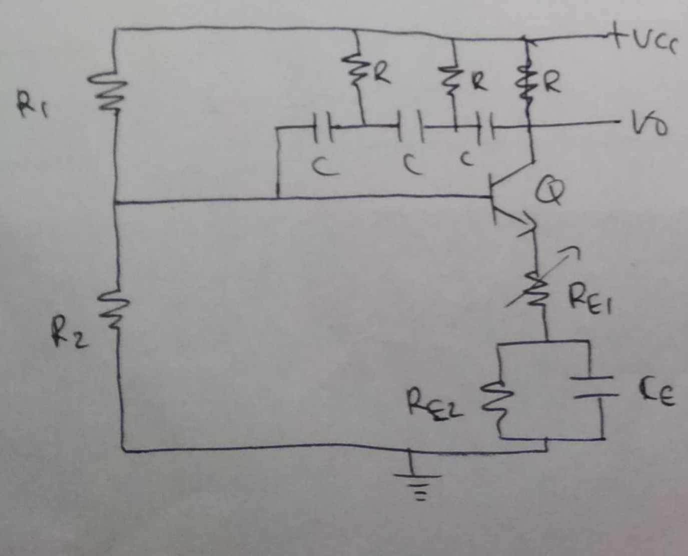
* Colpitts oscillator



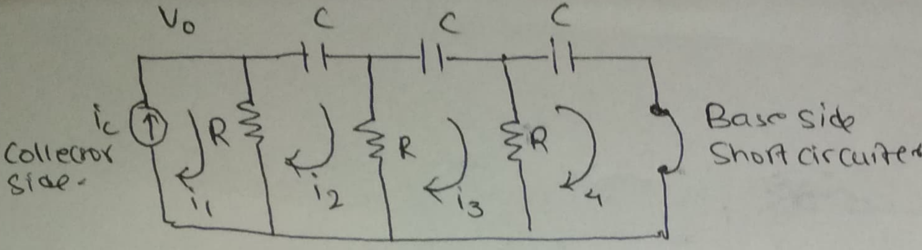
$$f = \frac{1}{2\pi\sqrt{LC}}$$

Where, $C = \frac{C_A C_B}{C_A + C_B}$

* RC shift oscillator.



$$f = \frac{1}{2\pi RC\sqrt{6}}$$



From above figure,

~~in loop ①~~, $i_1 = i_c$.

~~in loop ④~~, $i_4 = i_b$.

in loop ②

$\cancel{i_1R_1} - R(i_2 - i_1) + i_2 jX_c - R(i_2 - i_3) = 0$

or $-\cancel{R}\, i_2R + i_1R + i_2 jX_c - i_2R + i_3R = 0$

or $i_1R - 2i_2R + i_2 jX_c + i_3R = 0$

or $i_1R = i_2(2R - jX_c) - i_3R \cancel{=0}$ —— (i)

in loop ③

$i_2R = i_3(2R - jX_c) - i_4R$ —— (ii)

in loop ④

$i_3R = i_4(R - jX_c)$ —— (iii)

Eliminating i_2 and i_3 from (iii), (ii) & (i) we get,

$$\frac{i_4}{i_1} = \frac{R^3}{R^3 - 5RX^2 + j(-6R^2X + X^3)} \quad \text{—— (iv)}$$

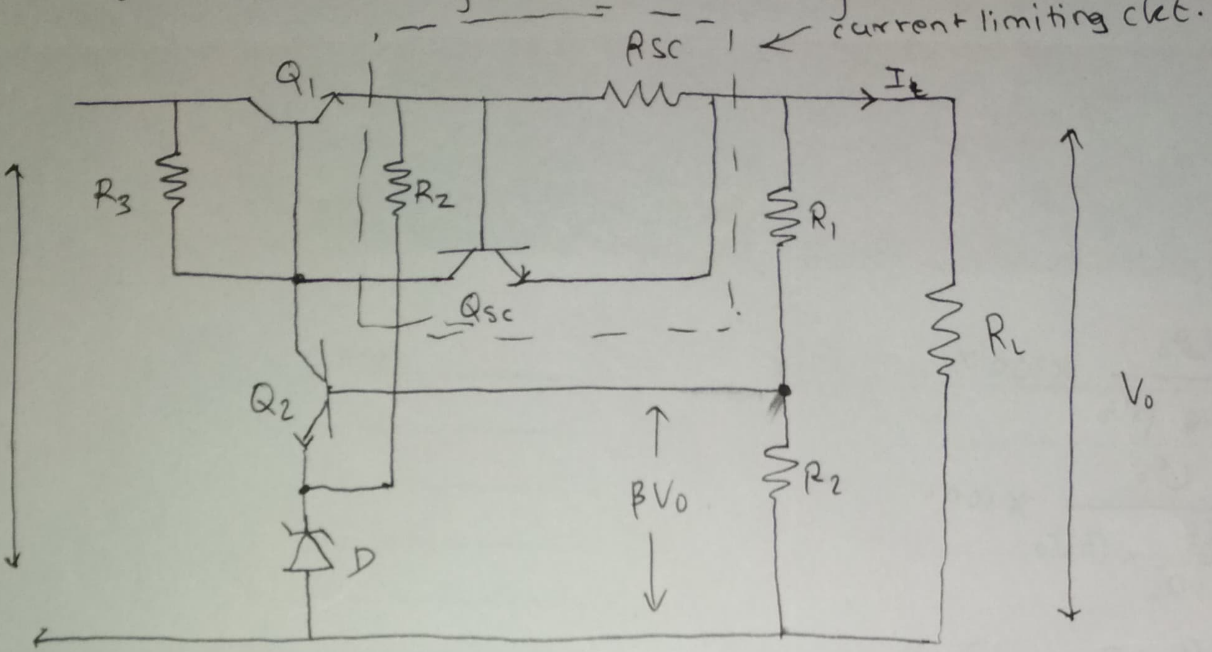
For 180° phaseshift, expression containg j vanishes, ie $-6R^2 + X^3 = 0$

$X(-6R^2 + X^2) = 0$ since, $X \neq 0$

$\therefore X = + R\sqrt{6} = \frac{1}{2\pi f_o C}$

or $\boxed{f_o = \frac{1}{2\pi RC\sqrt{6}}}$

* Voltage regular using current limitting circuit.



Operation:-

→ When I_L is normal, Voltage across Rsc is ~~normal so~~ very small so that there is no voltage on base of transistor Qsc. In this moment circuit behaves as normal voltage regulator.

→ When I_L is excessibly increases due to short circuit or overload, Voltage across Rsc also increases enough to turn on the transistor Qsc due to which ~~so~~ more current flows through R_3.

→ When more current flow through R_3 there lacks the ~~bo~~ current in base of transistor Q_1 due to which the conduction of Q_1 decreases preventing further increase in load current.

→ In this way, the voltage and current throughout the circuit remains regulated.

We know,

- Input regulated voltage,

$$V_i = V_{R3} + V_{BE1} + V_o$$

Let $V_i = \Delta V_i$ & $V_o = \Delta V_o$ is very small change in dc voltages. considering AC quantities only,

$$v_i = v_{R3} + v_{BE1} + v_o$$

$$\approx v_{R3} \quad (v_{BE1} \text{ \& } v_o \text{ is very small}).$$

- Output of transistor Q_2,

$$v_{R3} = A_v \times \beta V_o$$

$$= \frac{R_3}{R_e + R_2} \cdot \beta V_o \qquad \left(\because A_v = \frac{R_3}{R_e + R_2}\right)$$

$$\approx v_i$$

Stability factor :

$$S_v = \frac{\Delta V_o}{\Delta V_i} \times 100\%$$

$$= \frac{v_o}{v_i} \times 100\%$$

$$= \frac{v_o}{A_v \cdot \beta V_o} \times 100\%$$

$$= \frac{v_o}{\frac{R_3}{R_e+R_2} \times \beta V_o} \times 100\%$$

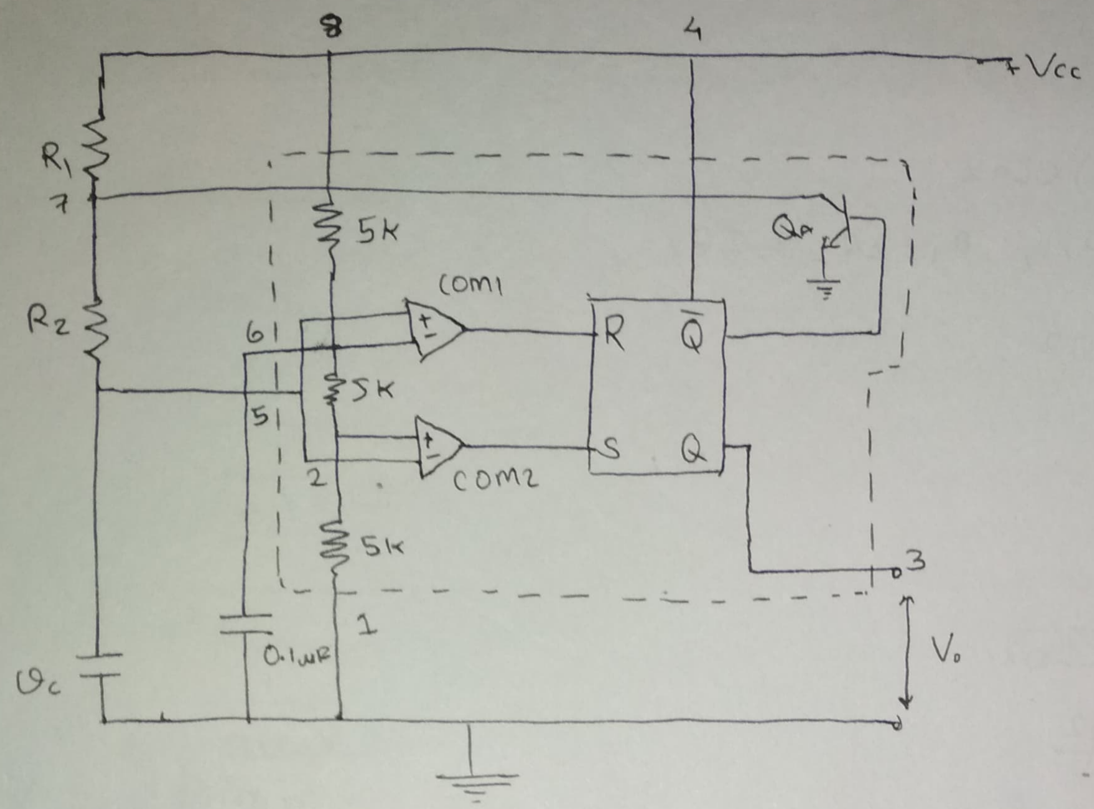
$$= \frac{R_e+R_2}{R_3} \times \frac{R_1+R_2}{R_2} \times 100\%$$

$S_v \approx 1.5\%$

Best case, $S_v = 0$

worst case, $S_v = 1$

* AMV using 555 timer



Operation:

- When $V_c = 0$, $R=0$ & $S=1$, $Q=1$ and $\bar{Q}=0$, Q_A transistor turns off, pin 7 is open circuited, Capacitor starts to charge through (R_1+R_2) towards Vcc.
- when $V_c > \frac{V_{cc}}{3}$, $R=0$ & $S=0$, no change, Q_A still turns off so capacitor charging continues.
- When $V_c \geq \frac{2V_{cc}}{3}$, $R=1$ & $S=0$, $Q=0$, $\bar{Q}=1$, Q_A ~~transistor~~ transistor turns on, pin 7 is short circuited to ground. so capacitor starts to discharge through R_2 towards ground. from $\frac{2V_{cc}}{3}$
- When $V_c < \frac{2V_{cc}}{3}$, $R=0$ & $S=0$, no change, capacitor continues discharging
- When $V_c \leq \frac{V_{cc}}{3}$, $R=0$ & $S=1$, $Q=1$ & $\bar{Q}=0$, Q_A transistor turns off and capacitor starts to charge again.
- whole process repeated endlessly

For Time period & frequency,

→ ~~For Charg~~ Let t_1 be the charging time & t_2 be the discharging time of capacitor.

$$V_c(t_1) = V_{applied} - (V_{applied} - V_{initial})\, e^{\frac{-t_1}{(R_1+R_2)C}}$$

$$V_c(t_2) = V_{applied} - (V_{applied} - V_{initial})\, e^{\frac{-t_2}{R_2 C}}$$

For charging,

$$t_1 = (R_1+R_2)\,C\ln 2$$

For discharging,

$$t_2 = R_2 C \ln 2$$

$$T = t_1 + t_2$$

$$\therefore T = (R_1 + 2R_2)\,C\ln 2$$

when, $2R_2 >> R_1$, $R_1 + 2R_2 \approx 2R_2$

$$\therefore T = 2R_2 C \ln 2$$

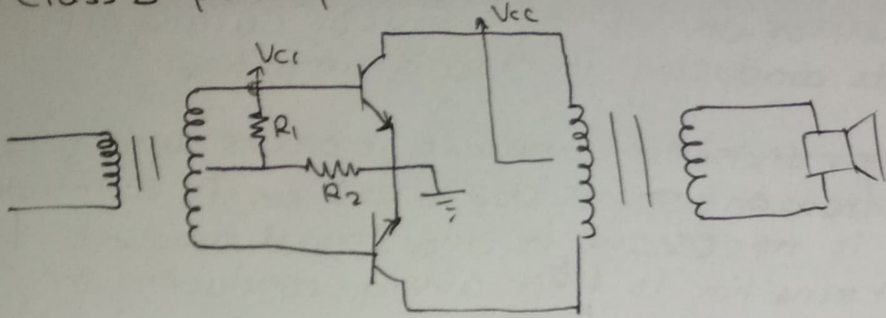
For frequency,

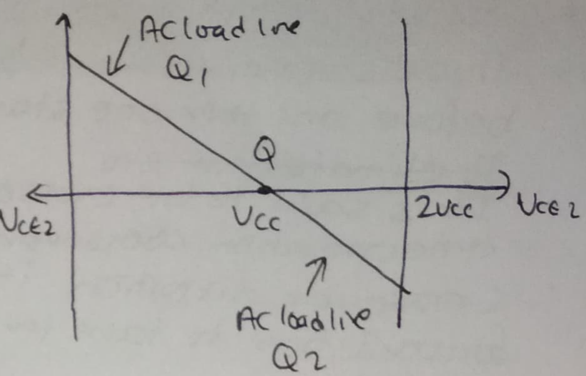
$$f = \frac{1}{T}$$

$$= \frac{1}{2R_2 C\ln 2}$$

$$\therefore f = \frac{0.72}{RC}$$

* Class B push-pull amplifier





* Input power:

$$P_i = V_{cc} I_{DC}$$
$$= V_{cc} \cdot \frac{2}{\pi} \frac{V_{cc}}{R}$$
$$= \frac{2}{\pi} \frac{V_{cc}^2}{R}$$

* Output power:

$$P_o = I_o V_o$$
$$= \frac{V_o}{R} \cdot V_o$$
$$= \frac{V_o^2}{R}$$

But, $V_o = \frac{V_{PP}}{2\sqrt{2}} = \frac{2V_{cc}}{2\sqrt{2}} = \frac{V_{cc}}{\sqrt{2}}$

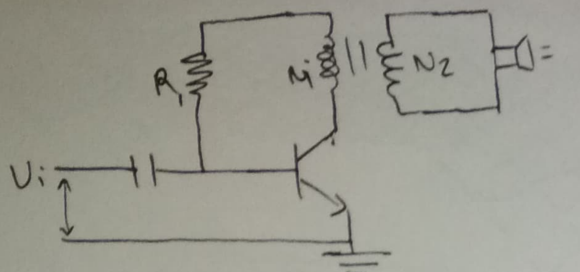
$$\therefore P_o = \frac{V_{cc}^2}{2R}$$

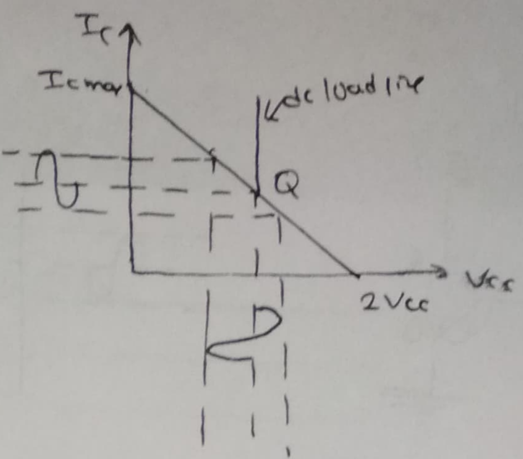
* Efficiency:

$$\eta = \frac{P_o}{P_i} \times 100\%$$
$$= \frac{\cancel{V_{cc}^2}}{2\cancel{R}} \cdot \frac{\pi}{2} \frac{\cancel{R}}{\cancel{V_{cc}^2}} \times 100$$
$$= 25\pi$$

$\therefore \eta = 78.5\%$ (max efficiency)

* Transformer Coupled Class A Amplifier.





* Input Power (P_i)

$$P_i = V_{CC} I_{CEQ}$$

$$= V_{CC} \cdot \frac{V_{CC}}{R}$$

$$P_i = \frac{V_{CC}^2}{R} \quad \text{——} (1)$$

where R is the resistance from primary side of transformer.

* Output power (P_o)

$$P_o = I_o V_o$$

$$= \frac{V_o^2}{R}$$

where

$$V_o = \frac{V_{PP}}{2\sqrt{2}} = \frac{2V_{CC}}{2\sqrt{2}} = \frac{V_{CC}}{\sqrt{2}}$$

$$\therefore P_o = \frac{V_{CC}^2}{2R} \quad \text{——} (11)$$

* Efficiency:

$$\eta = \frac{P_o}{P_i} \times 100\,\%$$

$$= \frac{V_{CC}^2}{2R} \times \frac{R}{V_{CC}^2} \times 100$$

$$= 50\%$$

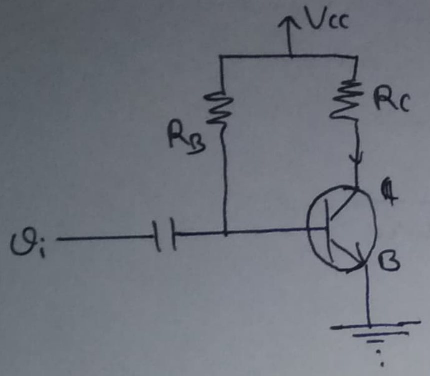
* For general efficiency.

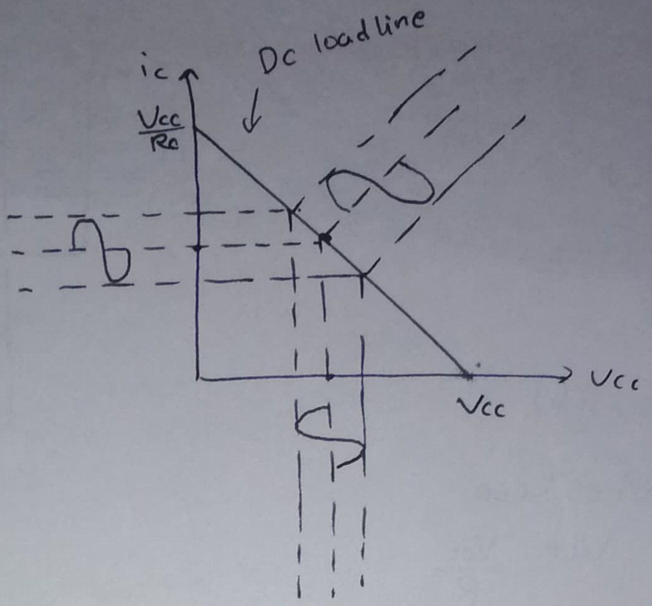
replace $V_{CC} = \dfrac{V_{CE\,min} + V_{CE\,max}}{2}$ in eq^n (1)

& " $V_{CC} = \dfrac{V_{CE\,max} - V_{CE\,min}}{2}$ in eq^n (11)

$$\therefore \eta = 50 \left[\frac{V_{CE(max)} - V_{CE(min)}}{V_{CE(max)} + V_{CE(min)}} \right]^2 \%$$

* Class A fed Amplifier :-





* Input power (P_i) :

$$P_i = V_{CQ} I_{CQ}$$
$$= V_{cc} \cdot \frac{V_{cc}}{2R_C}$$
$$\therefore P_i = \frac{(V_{cc})^2}{2R_C}$$

* Output power (P_o) :-

$$P_o = I_o V_o$$
$$= \frac{V_o}{R_C} \cdot V_o$$
$$\therefore P_o = \frac{V_o^2}{R_C}$$

but, $V_o = \frac{V_{PP}}{2\sqrt{2}}$

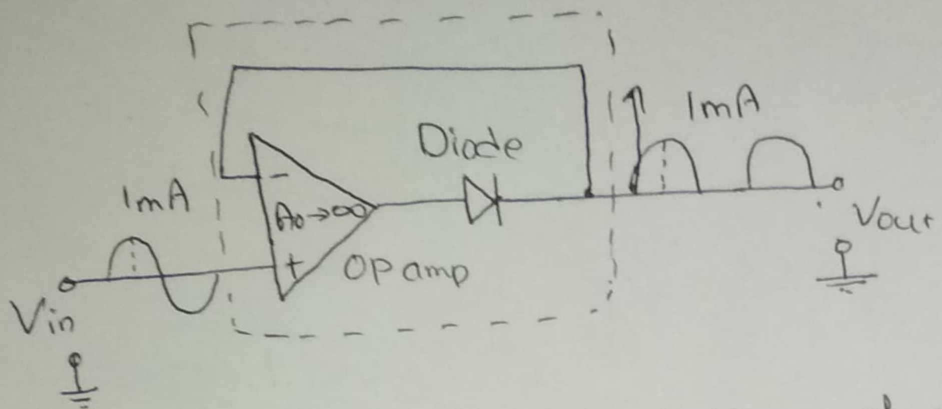
$$= \frac{V_{cc}}{2\sqrt{2}}$$
$$\therefore P_o = \frac{V_{cc}^2}{8R_C}$$

* Efficiency (η):

$$\eta = \frac{P_o}{P_i} \times 100\%$$
$$= \frac{\cancel{V_{cc}^2}}{8\cancel{R_C}} \times \frac{2\cancel{R_C}}{\cancel{V_{cc}^2}} \times 100\%$$
$$\therefore \eta_{max} = 25\%$$

* Precision Rectifier Circuit.

→ It is a special class of wave shaping circuit used in design of instrumentation systems with very precise transfer characteristics



- For positive input cycle output voltage of opamp will go ~~higher~~ positive and diode will conduct establishing closed feed back path betn op-amp's output and negative input terminal. This will cause a virtual short circuit to appear betn two input terminals of op-amp.

$$V_{out} = V_{in} \text{ for } V_{in} \geq 0$$

- For opamp to start operation, Vin has to exceed only a negligible small voltage equal to diode drop divided by opamp's open-loop gain.