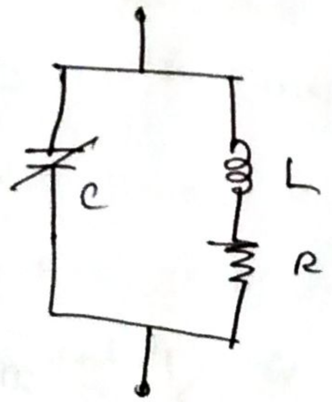
unit - 2

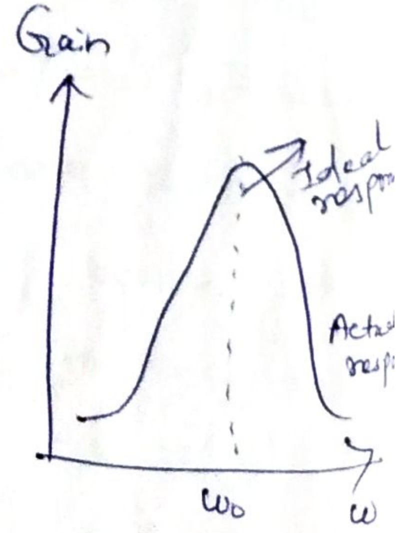
Tuned amplifiers and Blocking Oscillators

~~Introduction~~:-

To amplify the selective range of frequencies, the resistive load R_C is replaced by a tuned circuit. The tuned circuit is capable of amplying a signal over a narrow band of frequencies centered at f_r.

The amplifiers with such a tuned circuit as a load are known as tuned amplifiers.





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

$$Z_r = \frac{L}{CR}.$$

At resonance $X_L = X_C$

$\therefore$ The circuit is like resistive.

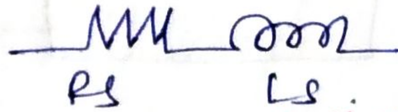
For frequencies above resonance circuit is like capacitive and for frequencies below resonance it is like inductive.

Q factor :-

It is important characteristics of an inductor. It is a measure of how pure or real an inductor is. It also can be defined as the measure of efficiency with which inductor can store the energy.

$$Q = \frac{2\pi \text{ Maximum energy stored per cycle}}{\text{Energy dissipate per cycle}}.$$

$$Q = \frac{\omega L_s}{R_s} = \frac{R_p}{\omega L_p}$$



Coil losses → copper loss, Eddy current, Hysteresis
$f\uparrow$ Loss $\downarrow$ $f\uparrow$ loss $\uparrow$ loss independent of frequency

Dissipation factor :-

⇒ Total loss with in a component.

is defined as $1/Q$.

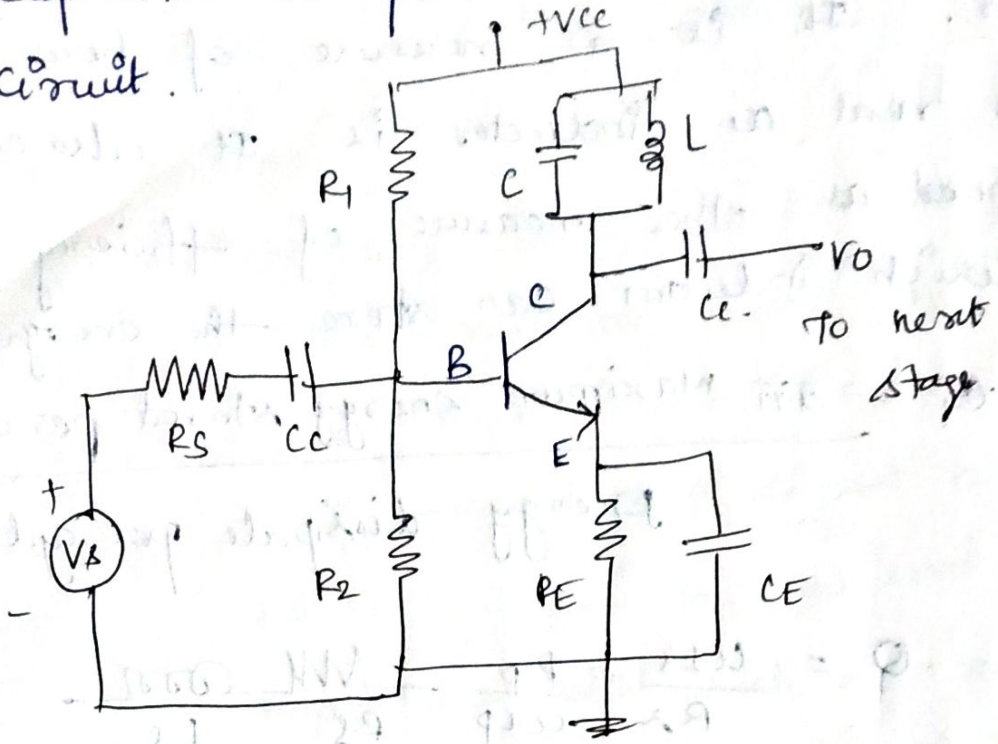
$$Q = \frac{1}{D} = \frac{\omega L_s}{R_s} = \frac{R_p}{\omega L_p}.$$

$$\boxed{D = \frac{R_s}{\omega L_s}}$$

Analysis of capacitive coupled single tuned amplifier..

In a single tuned amplifier the tuned circuit is formed by L and C act as collector load and resonates at frequency of operation.

Resistors R_1, R_2 and R_E along with capacitor CE provides self bias for the circuit.



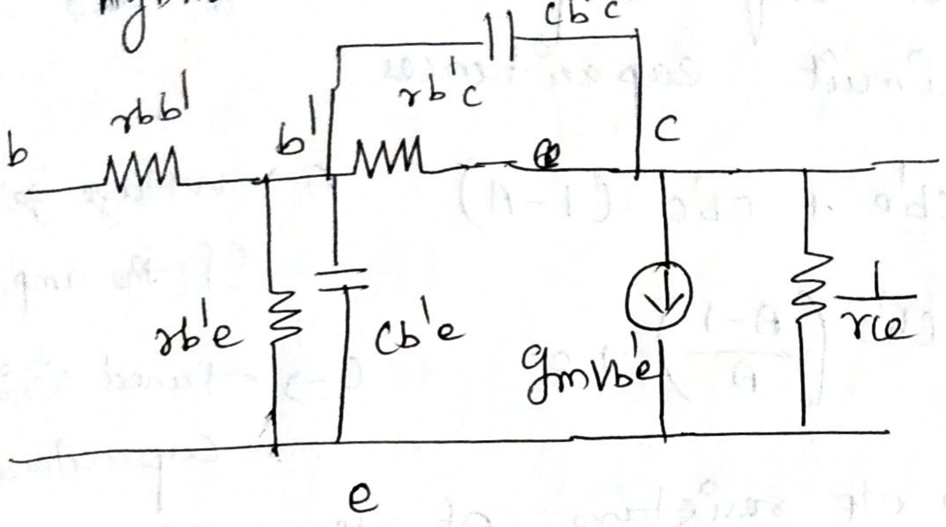
Equivalent circuit for single tuned amplifier using hybrid π parameters is shown.

R_i → input resistance of the next stage

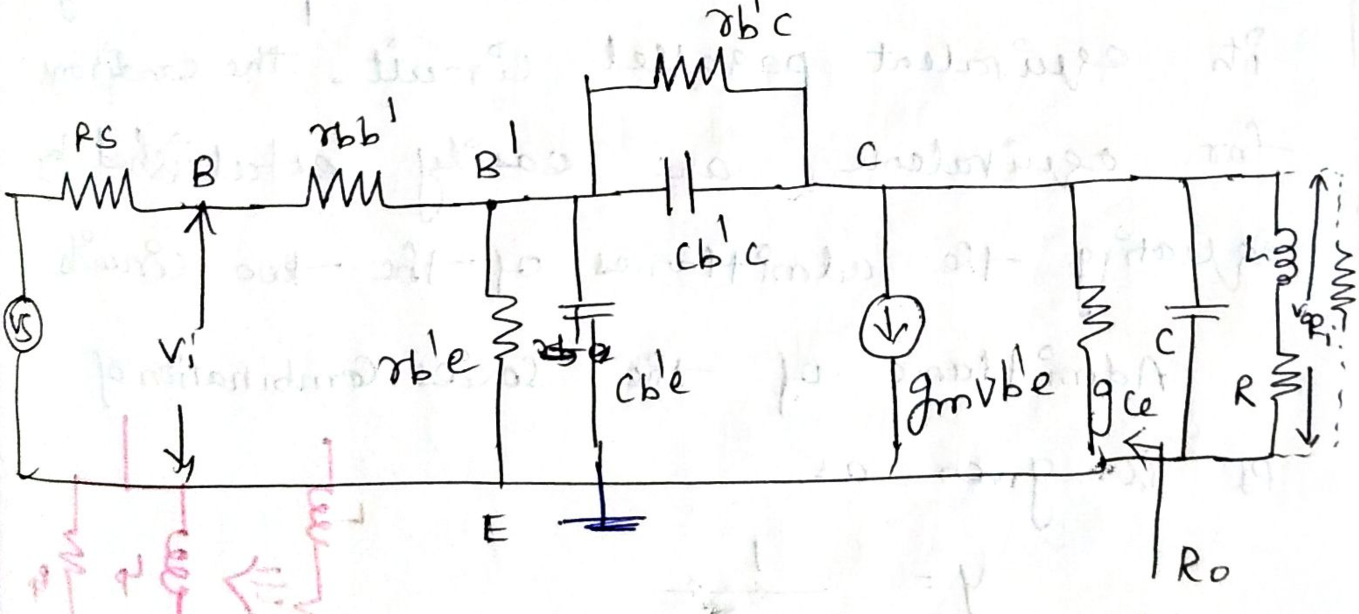
R_o → O/P resistance of the current generator $g_m v_{b'e}$.

The reactances of the bypass capacitor, CE and the coupling capacitors are negligibly small at the operating frequency and hence these elements are neglected in the equivalent circuit.

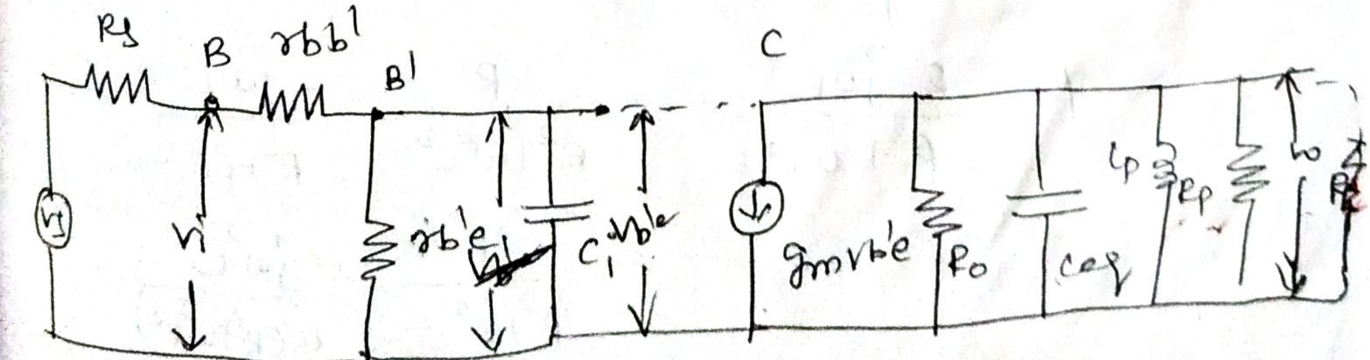
hybrid -π model of a transistor.



Equivalent circuit of single tuned amplifier using hybrid π parameters.



This circuit can be simplified by applying Miller's theorem.



C_i and C_{eq} represent i/p and output circuit capacitances.

$$C_i = C_{b'e} + C_{b'c}(1-A)$$ A → voltage gain of the amplifier

$$C_{eq} = C_{b'c}\left(\frac{A-1}{A}\right) + C$$ C → tuned circuit capacitance

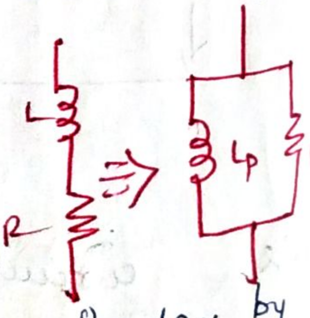
g_{ce} → o/p resistance of the current generator $g_m V_{b'e}$.

$$\frac{1}{r_{ce}} = g_{ce}$$

The series RL circuit is represented by its equivalent parallel circuit. The conditions for equivalence are easily established by equating the admittances of the two circuits.

Admittance of the series combination of RL is given as

$$Y = \frac{1}{R+j\omega L}.$$



Multiplying numerator and denominator by $R-j\omega L$ we get

$$Y = \frac{R-j\omega L}{R^2+\omega^2L^2} = \frac{R}{R^2+\omega^2L^2} - \frac{j\omega L}{R^2+\omega^2L^2}$$

$$= \frac{R}{R^2+\omega^2L^2} - \frac{j\omega^2 L}{\omega(R^2+\omega^2L^2)}$$

$$= \frac{R}{R^2+\omega^2L^2} + \frac{\omega^2 L}{j\omega(R^2+\omega^2L^2)}$$

$$= \frac{1}{R_p} + \frac{1}{j\omega L_p}$$

where $R_p = \frac{R^2 + \omega^2 L^2}{R}$

$L_p = \frac{R^2 + \omega^2 L^2}{\omega^2 L}$.

Centre frequency:

The centre frequency or resonant frequency is given by

$$f_r = \frac{1}{2\pi\sqrt{L_p C_{eq}}}.$$

$$L_p = \frac{R^2 + \omega^2 L^2}{\omega^2 L}$$

$$C_{eq} = C_{b'c}\left(\frac{A-1}{A}\right) + C.$$

$$= C_o + C.$$

∴ C_{eq} is ~~the~~ summation of transistor output capacitance and the tuned circuit capacitance.

Quality factor:

The Quality factor Q of the coil at resonance is given by.

$$Q_r = \frac{\omega_r L}{R}$$

$\omega_r \rightarrow$ centre frequency or resonant frequency.

Quality factor is also called as Unloaded Q. But in practice, transistor output resistance and i/p resistance of the next stage acts as a load for the tuned circuit.

The Quality factor including load is called as loaded Q.

The Q of the coil is usually large so that $\omega L >> R$ in the frequency range of operation.

$$R_p = \frac{R^2 + \omega^2 L^2}{R}$$

$$= R + \frac{\omega^2 L^2}{R}$$

As $\frac{\omega^2 L^2}{R} >> 1$ $\boxed{R_p \approx \frac{\omega^2 L^2}{R}}$

$$L_p = \frac{R^2 + \omega^2 L^2}{\omega^2 L} = \frac{R^2}{\omega^2 L} + L$$

$\boxed{L_p \approx L}$ $\because \omega L >> R$

$$\frac{\omega L}{R} >> 1$$

$$\frac{R}{\omega L} << 1$$

$\therefore$ R_p at resonance is

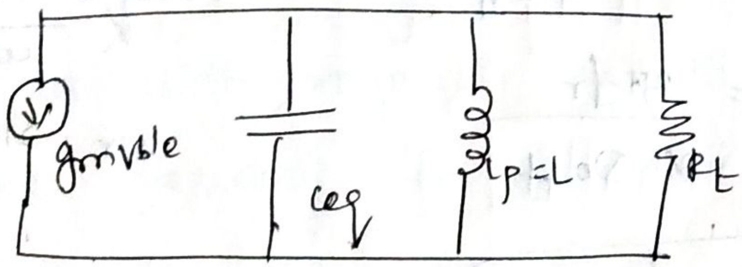
$$R_p = \frac{\omega_r^2 L^2}{R}$$

$$= \omega_r L Q_r \qquad Q_r = \frac{\omega_r L}{R}$$

$$\boxed{R_p = \omega_r L Q_r}$$

$$\therefore \boxed{Q_r = \frac{R_p}{\omega_r L}}$$

The effective quality factor including load can be calculated looking at the simplified equivalent o/p circuit for single tuned amplifier.



$R_t = R_o \| R_p \| R_i$,

Effective Q factor $(Q_{eff}) = \dfrac{R_t}{\omega_r L}$ (or) $\omega_r C_{eq} R_t$.

Voltage gain:

Voltage gain for single tuned amplifier is given by

$$A_v = -g_m \frac{r_{b'e}}{r_{bb'} + r_{b'e}} \times \frac{R_t}{1 + 2jQ_{eff}\delta}$$

$\to$ fraction variation in the resonant freq

$$A_v \text{ (at resonance)} = \frac{-g_m r_{b'e}}{r_{bb'} + r_{b'e}} \times R_t$$

$$\left| \frac{A_v}{A_v(\text{at resonance})} \right| = \frac{1}{\sqrt{1 + (2\delta Q_{eff})^2}}$$

3 dB bandwidth:-

The 3 dB Bandwidth of a single tuned amplifier is given by

$$\Delta f = \frac{1}{2\pi R_t C_{eq}}$$

$$= \frac{\cancel{Q_{eff}}\ \omega_r}{2\pi Q_{eff}}$$

$Q_{eff} = \omega_r R_t C_{eq}$

$R_t C_{eq} = \frac{Q_{eff}}{\omega_r}$

$$\Delta f = \frac{\cancel{2\pi} f_r}{\cancel{2\pi} Q_{eff}}$$

$\omega_r = 2\pi f_r$

$$\boxed{\Delta f = \frac{f_o}{Q_{eff}}}$$

Effect of cascading single tuned amplifier on Bandwidth:

To obtain high overall gain, several identical stages of tuned amplifiers can be used in cascade.

The overall gain is the product of the voltage gains of the individual stages.

Consider n stages of single tuned direct coupled amplifiers connected in cascade.

The relative gain of the single tuned amplifier with respect to the gain at resonant frequency fr is given by

$$\left| \frac{A_v}{A_v(\text{at resonance})} \right| = \frac{1}{\sqrt{1+(2\delta Q_{eff})^2}}$$

∴ The relative gain of n stage connected cascaded amplifier becomes.

$$\left| \frac{A_v}{A_v(\text{at resonance})} \right|^n = \left[\frac{1}{\sqrt{1+(2\delta Q_{eff})^2}} \right]^n$$

$$= \frac{1}{\left[1+(2\delta Q_{eff})^2\right]^{n/2}}$$

The 3 dB frequencies for the n stage cascaded amplifier can be found by equating

$$\left| \frac{A_v}{A_v(\text{at resonance})} \right|^n = \frac{1}{\sqrt{2}}$$

$$\frac{1}{\left[1+(2\delta Q_{eff})^2\right]^{n/2}} = \frac{1}{\sqrt{2}}$$

$$\left[1+(2\delta Q_{eff})^2\right]^{n/2} = 2^{1/2}$$

$$\left[1+(2\delta Q_{eff})^2\right]^{n} = 2$$

$$1+(2\delta Q_{eff})^2 = 2^{1/n}$$

$$2\delta Q_{eff}^2 = 2^{1/n} - 1$$

$$2\delta Q_{eff} = \pm\sqrt{2^{1/n}-1}$$

$\delta \rightarrow$ fractional frequency variation (i.e)

$$\delta = \frac{\omega-\omega_r}{\omega_r} = \frac{f-f_r}{f_r}.$$

$$2\left(\frac{f-f_r}{f_r}\right) Q_{eff} = \pm\sqrt{2^{1/n}-1}$$

$$2(f-f_r)\, Q_{eff} = \pm f_r\sqrt{2^{1/n}-1}$$

$$f-f_r = \frac{\pm f_r}{2Q_{eff}}\sqrt{2^{1/n}-1}$$

Let us assume f_1 and f_2 are the lower 3dB and upper 3dB frequencies. Then we have

$$f_2 - f_r = \frac{+f_r}{2Q_{eff}}\sqrt{2^{1/n}-1} \quad \text{and}$$

$$f_r - f_1 = -\frac{f_r}{2Q_{eff}}\sqrt{2^{1/n}-1}.$$

The bandwidth of n stage identical amplifier is given as

$$BW_n = f_2 - f_1 = (f_2-f_r)-(f_r-f_1)$$

$$= \frac{f_r}{2Q_{eff}}\sqrt{2^{1/n}-1} - \left(-\frac{f_r}{2Q_{eff}}\sqrt{2^{1/n}-1}\right)$$

$$= \frac{f_r}{2Q_{eff}}\sqrt{2^{1/n}-1} + \frac{f_r}{2Q_{eff}}\sqrt{2^{1/n}-1}$$

$$= \frac{f_r}{Q_{eff}} \sqrt{2^{1/n}-1}$$

$$BW_n = BW_1 \sqrt{2^{1/n}-1}$$

BW_1 is the bandwidth of single stage

and BW_n is the bandwidth of n stages

Staggered Tuned amplifier :-

A double tuned amplifier is a tuned amplifier with transformer coupling btw the amplifier stages in which the inductances of both the primary and secondary windings are tuned seperately with a capacitor across each this results in wider bandwidth and than a single tuned circuit.

cascading multiple stages of double tuned amplifiers results in a reduction of the bandwidth of the over all amplifier.

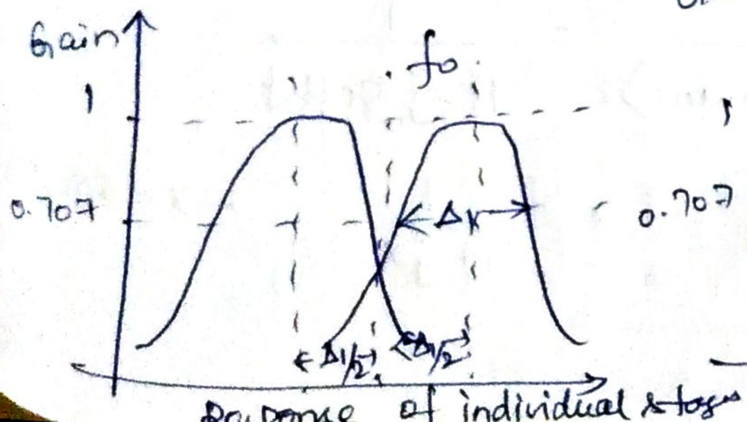
An alternative to double tuning that avoids this loss of bandwidth is staggered tuning.

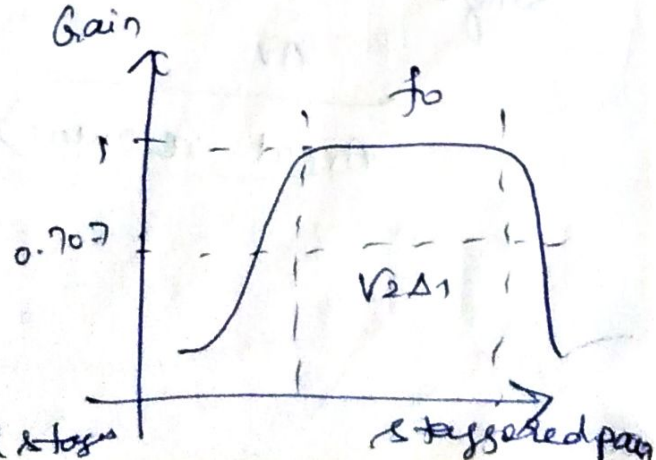
The bandwidth provided by stagger tuned amplifier is greater than any single stage.

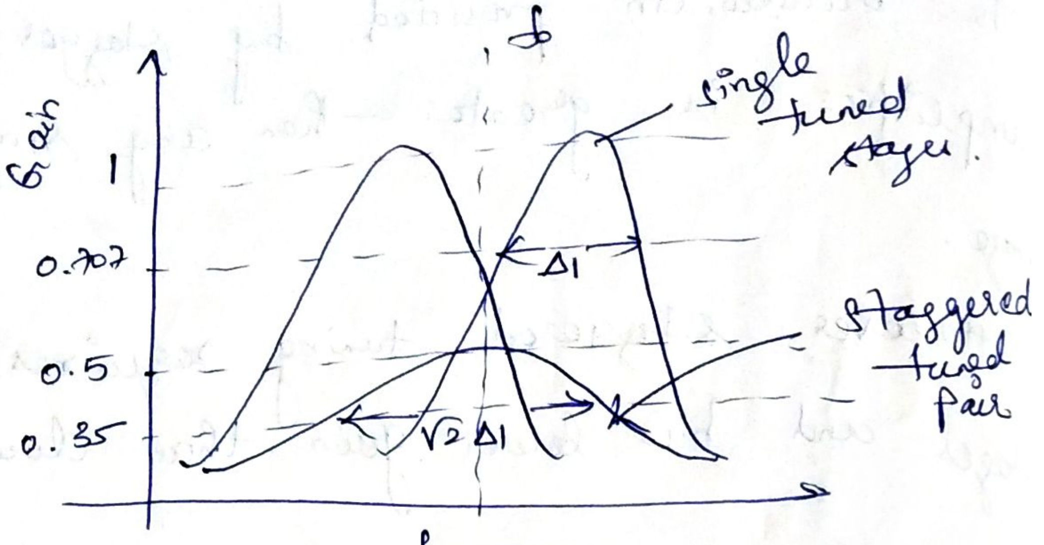
However staggered tuning requires more stages and has lower gain than double tuning.

Two single tuned cascaded amplifiers having certain bandwidth are taken and their resonant frequencies are so adjusted that they are seperated by an amount equal to the bandwidth of each stage.

The advantage of staggered tuned amplifier is to have a better flat, wideband characteristics in contrast with a very sharp, rejective, narrow band characteristic of synchronously tuned circuits.







The stagger tuned idea can easily be extended to more stages. In case of three stages, staggering, the first tuning circuit is tuned to a frequency lower than centre frequency while the third circuit is tuned to higher frequency than centre frequency. The middle tuned circuit is tuned at exact centre frequency.

Analysis:

We know that the gain of the single tuned amplifier is

$$\frac{A_v}{A_v(\text{at resonance})} = \frac{1}{1+2jQ_{eff}\delta}$$

$$= \frac{1}{1+jX} \qquad \because X = 2Q_{eff}\delta$$

In stagger tuned amplifiers the two single tuned cascaded amplifiers with seperate resonant frequencies are used, we can assume that one stage is tuned to frequency $f_r + \delta$ and other stage is tuned to frequency $f_r - \delta$.

$\therefore$ $f_{r1} = f_r + \delta$ and $f_{r2} = f_r - \delta$.

$$\therefore \frac{A_v}{A_v(\text{at resonance})_1} = \frac{1}{1 + j(x+1)}$$

$$\frac{A_v}{A_v(\text{at resonance})_2} = \frac{1}{1+j(x-1)}$$

The overall gain of these two stages is the product of individual gains of the two stages.

$$\frac{A_v}{A_v(\text{at resonance})\text{cascaded}} = \frac{A_v}{A_v(\text{at resonance})_1} \times \frac{A_v}{A_v(\text{at resonance})_2}$$

$$= \frac{1}{1+j(x+1)} \times \frac{1}{1+j(x-1)}$$

$$= \frac{1}{1+j(x-1)+j(x+1)-(x+1)(x-1)}$$

$$= \frac{1}{1+jx-j+jx+j-(x^2-x+x-1)}$$

$$= \frac{1}{1 + j2x - x^2 + 1} = \frac{1}{(2-x^2) + j2x}$$

$$\left| \frac{A_v}{A_v \text{ (at resonance)}} \right|_{\text{cascaded}} = \frac{1}{\sqrt{(2-x^2)^2 + (2x)^2}}$$

$$= \frac{1}{\sqrt{4x^2 + 4 + x^4 - 4x^2}}$$

$$= \frac{1}{\sqrt{4 + x^4}}$$

Substituting the value of x we get

$$\left| \frac{A_v}{A_v \text{(at resonance)}} \right|_{\text{cascaded}} = \frac{1}{\sqrt{4 + (2Q_{eff}\delta)^4}}$$

$$= \frac{1}{\sqrt{4 + 16 Q_{eff}^4 \delta^4}}$$

$$= \frac{1}{\sqrt{4(1 + 4 Q_{eff}^4 \delta^4)}}$$

$$\left| \frac{A_v}{(A_v \text{ (at resonance)})} \right|_{\text{cascaded}} = \frac{1}{2\sqrt{1 + 4 Q_{eff}^4 \delta^4}}$$

Stability of tuned amplifiers:-

In tuned RF amplifiers, transistors are used at the frequencies nearer to their unity gain bandwidth (f_T), to amplify a narrow band of high frequencies centred around a radio frequency.

At this frequency, the inter junction capacitance b/w base and collector C_{bc} of the transistor becomes dominant.

with this circuit condition, if some feedback signal manages to reach the input from output in a positive manner with proper phase shift, then there is possibility of circuit converted to an unstable one, generating its own oscillations and can stop working as an amplifier.

In order to prevent oscillations in tuned RF amplifiers it was necessary to reduce the stage gain to a level that ensured circuit stability.

this is accomplished in several ways such as

→ lowering the Q of tune circuits

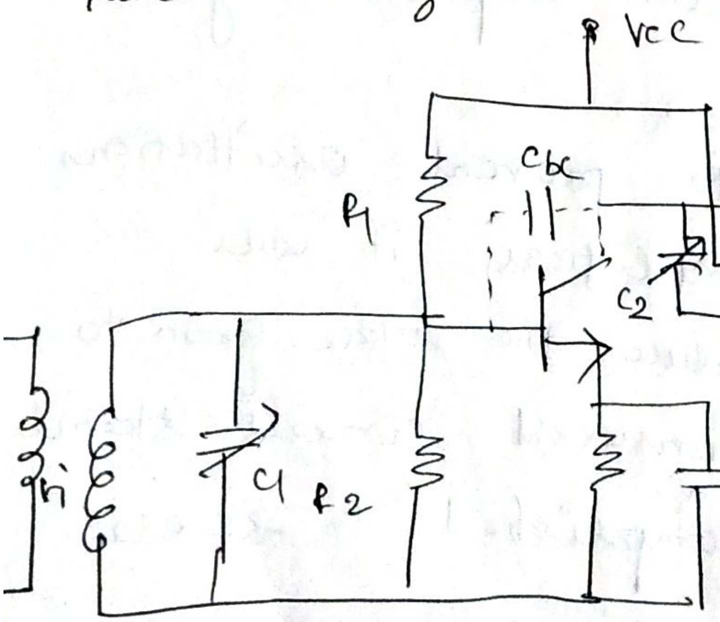
→ stagger tuning

→ loose coupling between the stages

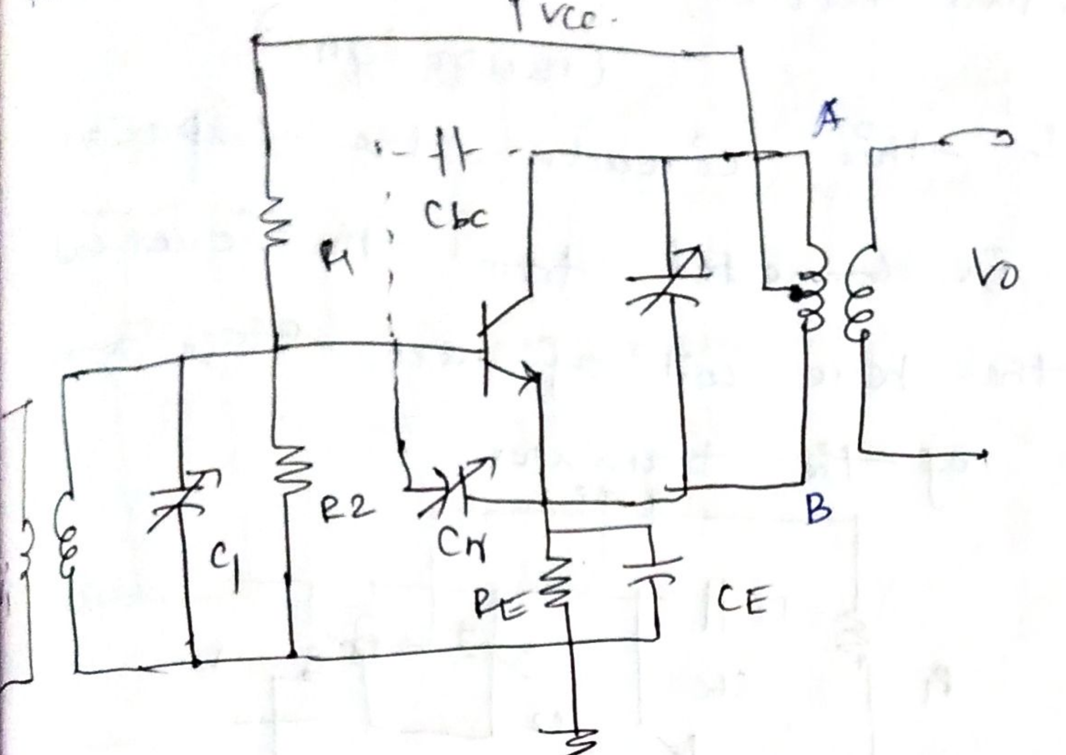
But all these methods reduced gain, detuning and Q reduction had detrimental effects on selectivity.

Instead of loosing the circuit performance to achieve stability, prof L. A. Hazeltine introduced a circuit in which the troublesome effect of the Cbc of the transistor was neutralized by introducing a signal which cancels the signal coupled through the collector to base capacitance.

Tuned RF stage :-



Hazeltine neutralization.

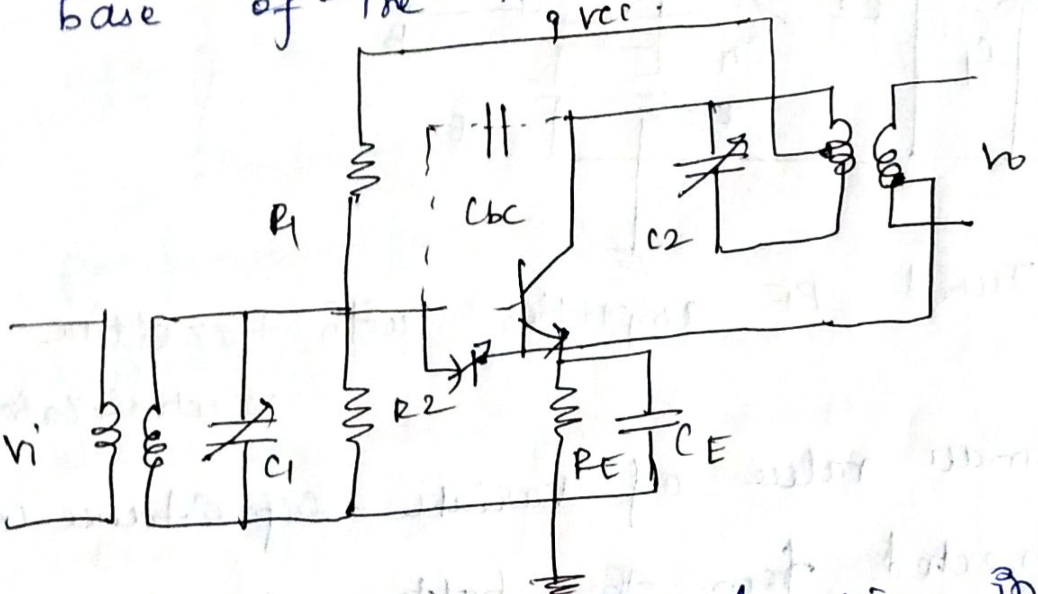


Tuned RF amplifier with Hazeltine neutralization.

A small value of variable capacitance CN is connected from the bottom of coil to the Base. Therefore the internal capacitance Cbc, feeds a signal from the top end of the coil point A, to the transistor base and CN feeds a signal of equal magnitude but opposite polarity from the bottom of coil to the base. The neutralizing capacitor CN can be adjusted correctly to completely nullify the signal fed through Cbc.

Modified Hazeltine neutralization:
(neutrodyne).

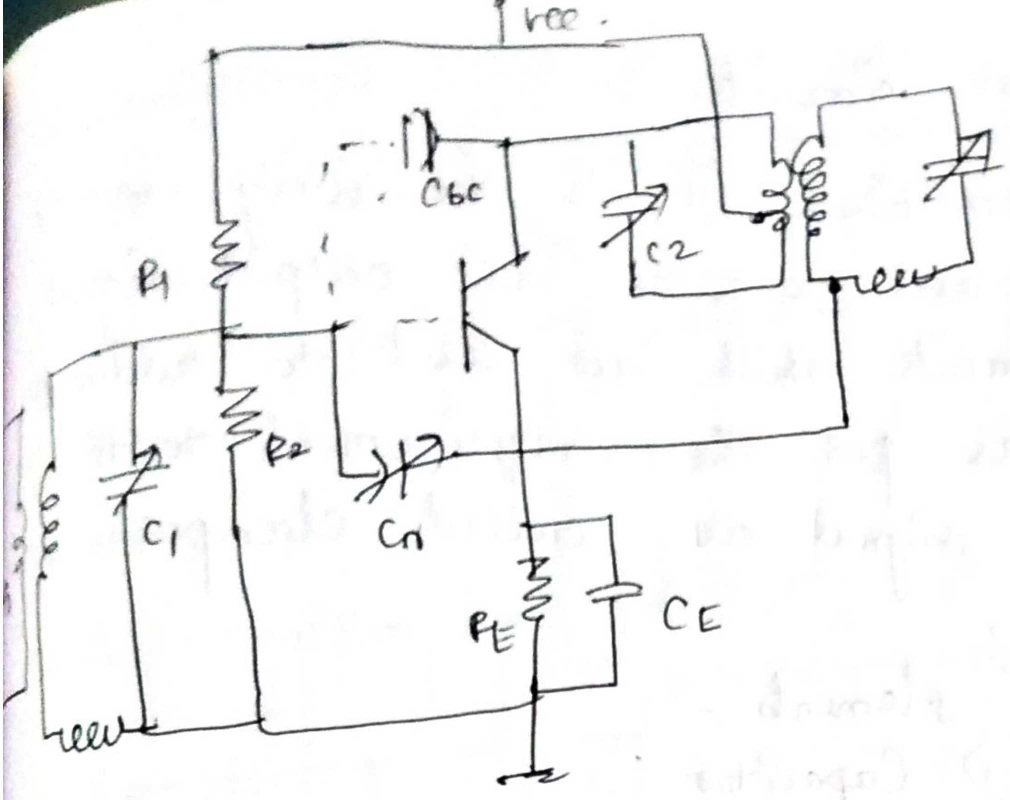
In this circuit, the capacitor C_N is connected from the lower end of the base coil of next stage to the base of the transistor.



Here, the circuit functions in the same manner as the Hazeltine neutralization with the advantage that neutralizing capacitor does not have the supply voltage across it.

neutralization using coil:

In this circuit a part of the tuned circuit at the base of the next stage is oriented for minimum coupling to other windings. ~~If the~~ windings are properly polarized the voltage



across L due to the circulating current in the base circuit will have the proper phase to cancel the signal through the base to collector Cbc capacitance.

Clamper circuits:

Sometimes it is necessary to add a d.c level to the a.c output signal. The circuits which are used to add a d.c level as per the requirements to the a.c o/p signal are called clamper circuits,

Basic Elements :-

1) Capacitor
2) Diode
3) Resistance

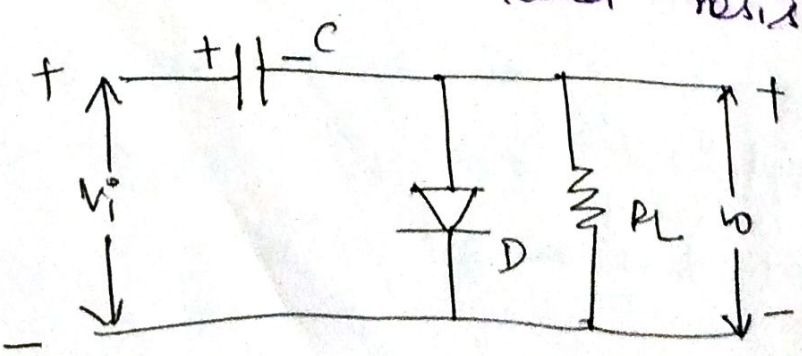
Other names ; d.c restorer, d.c inserter circuits.

Types :-

1) negative clampers
2) positive clampers.

negative clamper :-

A clamper which adds a negative dc level to the a.c output is called negative clamper. It consists of capacitor C, ideal diode D and load resistance RL.



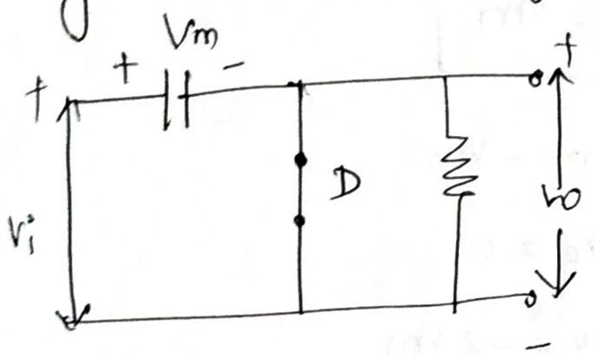
Assumptions :-

1) The diode is ideal in behaviour.

2) the time constant $\tau = RC$ is designed to be very large by selecting large values of R and C.

operation :-

During positive half cycle :-



→ During the first quarter of positive cycle of the i/p voltage v_i, the capacitor gets charged through forward biased diode D upto Vm.

$V_i - V_m = 0$

$V_i = V_m$

→ when D is on, the o/p voltage Vo is zero.

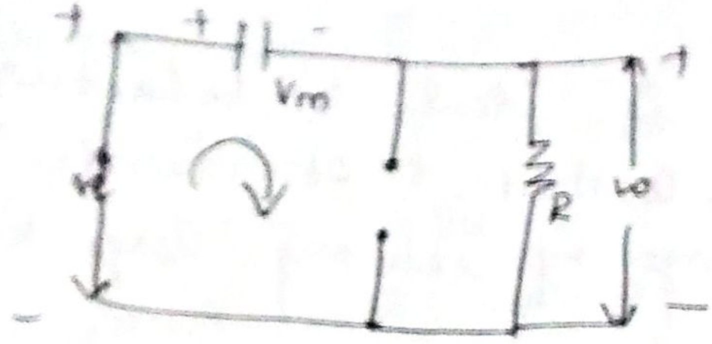
positive quarter cycle $\boxed{V_o = 0}$

→ As i/p voltage decreases after attaining its maximum value Vm, the capacitor remains charged to Vm.

→ Due to large RC time constant the capacitor holds its entire charge and capacitor voltage remains as $V_c = V_m$.

During negative half cycle :-

During negative half cycle, the diode becomes reverse biased and it becomes open circuit.



Apply kvl inside the loop

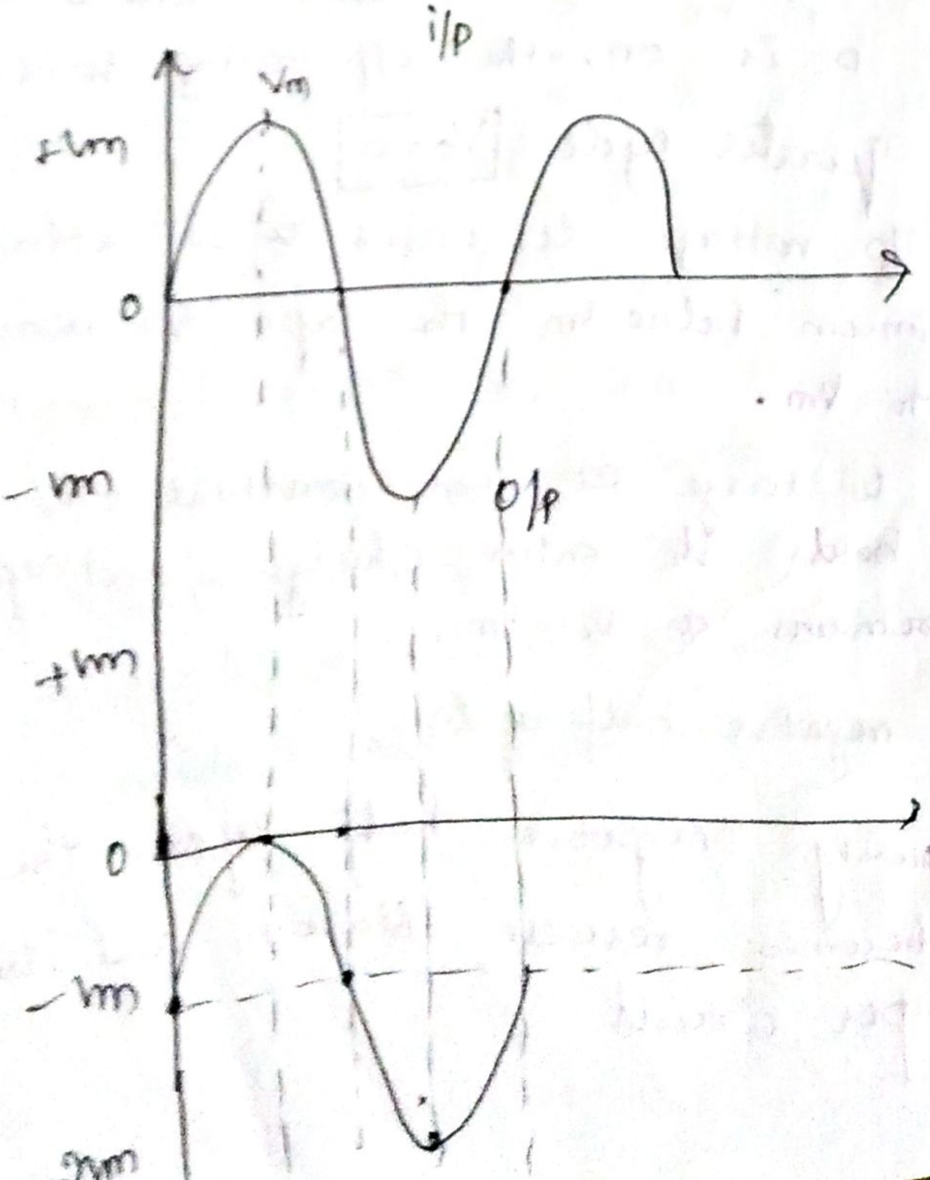
$$V_i - V_m - V_o = 0$$

$$\boxed{V_o = V_i - V_m}$$

$v_i = 0$ $\quad$ $v_o = -V_m$

$v_i = V_m$ $\quad$ $V_o = 0$

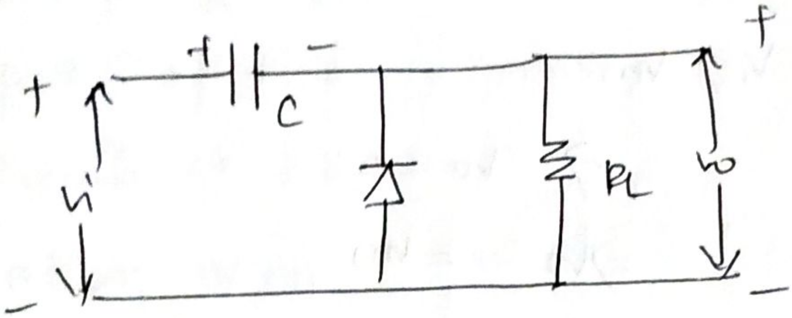
$v_i = -V_m$ $\quad$ $v_o = -2V_m$



the peak to peak amplitude of the i/p is $2V_m$, |||ly the peak to peak amplitude of the o/p is also $2V_m$.

Thus the total swing of the o/p is always same as the total swing of the i/p for a clamper circuit.

positive clamper :-

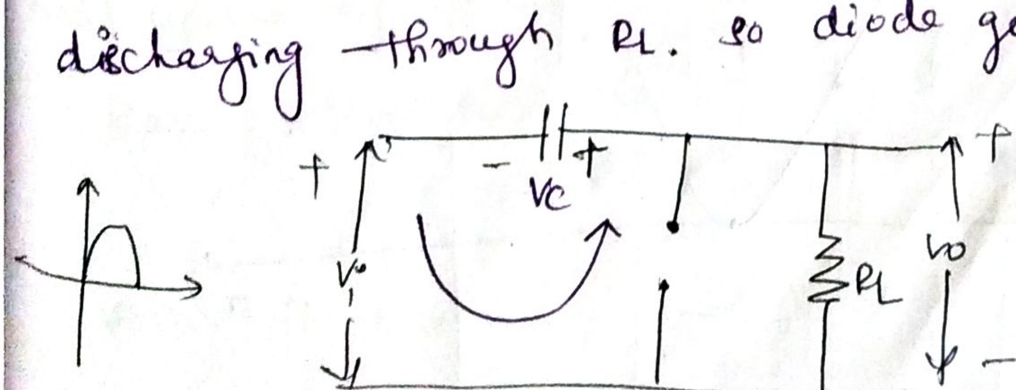


By changing the orientation of the diode in the negative clamper, the positive clamper circuit can be achieved.

operation :-

During positive half cycle :-

During the half cycle the diode is reverse biased. the capacitor starts discharging through R_L. so diode gets open circuit



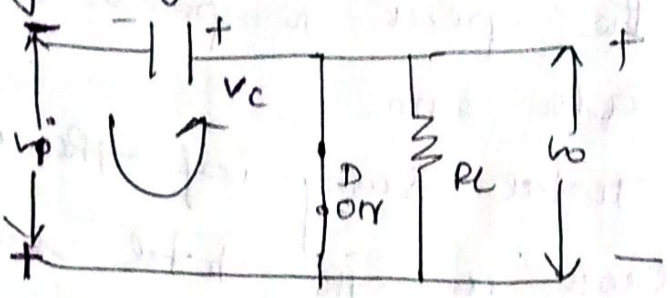
Apply KVL

$V_o - V_C - V_i = 0$

$V_o = V_i + V_C$

$V_o = V_i + V_m$

During negative half cycle :-



During negative half cycle, the diode becomes ~~reverse~~ forward biased and it is short circuited.

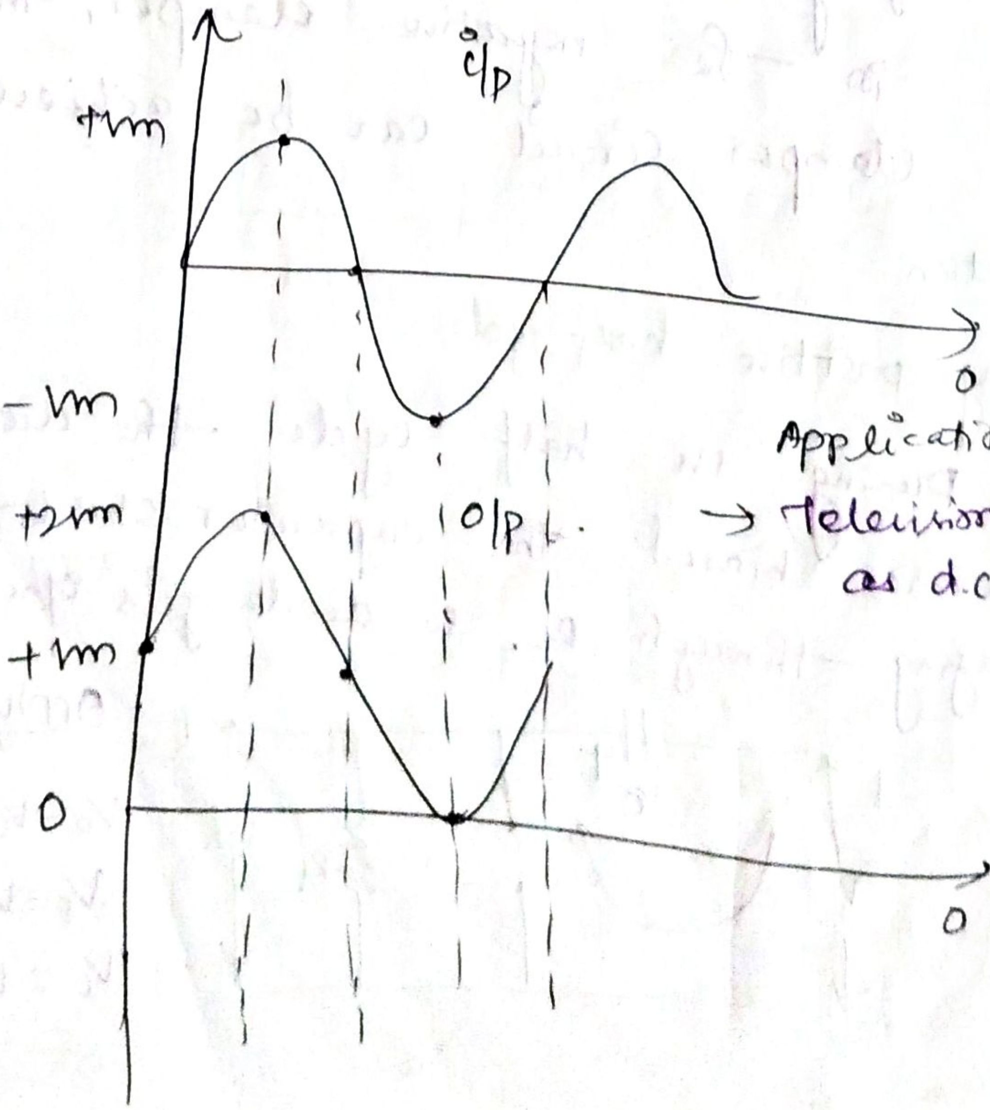
$V_i - V_m = 0$

$V_o = V_i + V_m$

when $V_i = -V_m \Rightarrow V_o = 0$

$V_i = 0 \Rightarrow V_o = V_m$

$V_i = +V_m \quad V_o = 2V_m$.



Application :-

→ Television Receiver as d.c restorer

Clipper circuits :-

The basic action of clipper circuit is to remove the certain portions of the waveform above or below the certain levels, as per the requirements.

Thus the circuits which are used to clip off unwanted portion of the waveform without distorting the remaining part of the waveform are called clipper circuits or clippers.

Other names :- limiters or slicers.

Types :-

series clipper (Diode - series with load) — positive clipper, negative clipper.

Parallel clipper (Diode - paralled with load) — +ve, -ve

Series clippers :-

A series clipper can be used to clip off the entire positive or negative half cycles of i/p waveform.

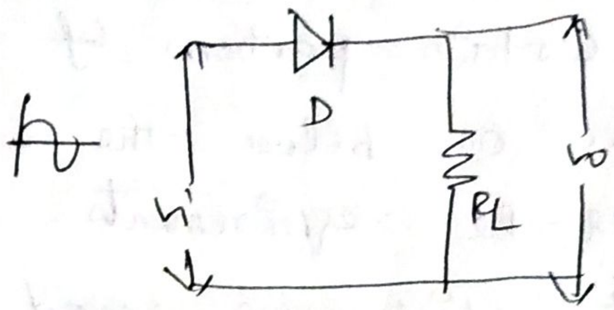
Basic elements : Diode

Resistor.

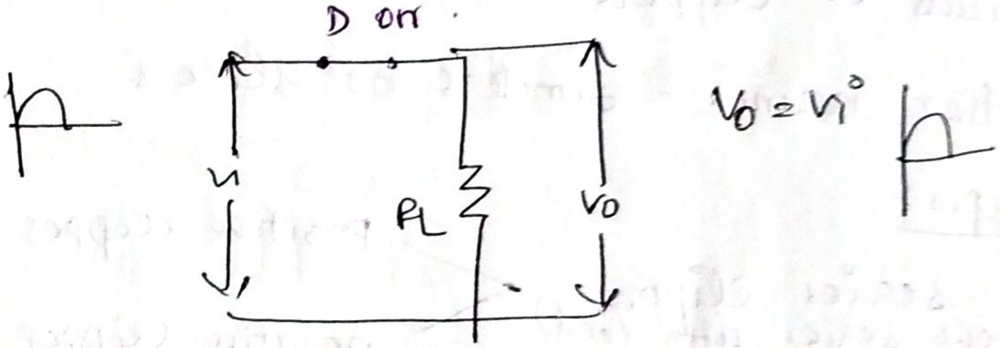
Also it can be used to clip off the portion above or below the certain reference voltages.

Series negative clipper :-

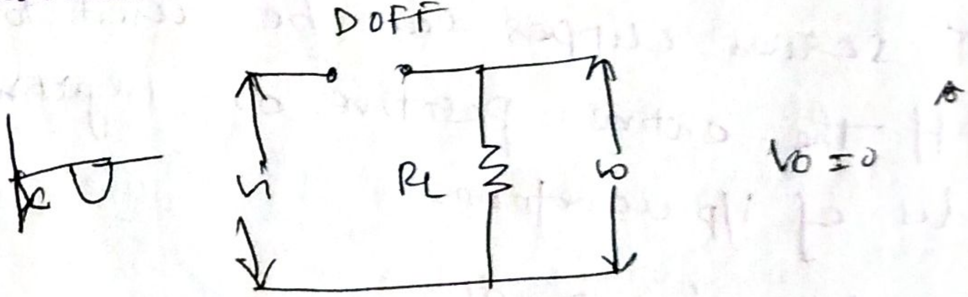
Diode is connected in series with load

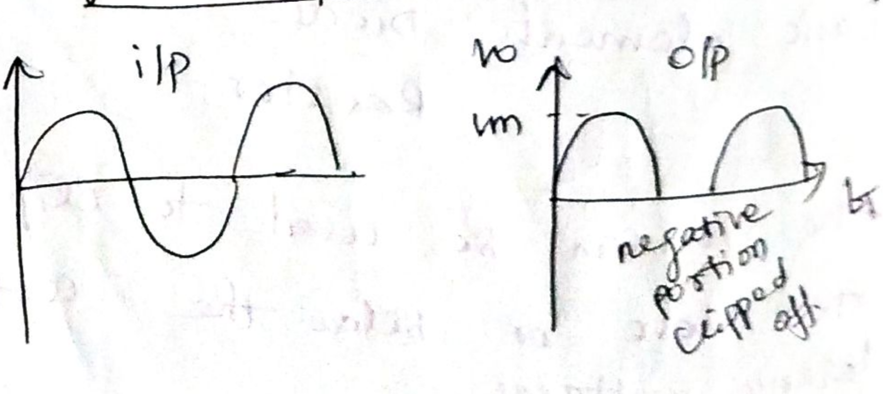


For positive half cycle, diode D is forward biased. Hence the voltage waveform across RL looks like a positive half cycle of the i/p voltage. Diode D is ON.



During negative half cycle, diode D is reverse biased. So Diode is OFF ~~short~~ open circuited.



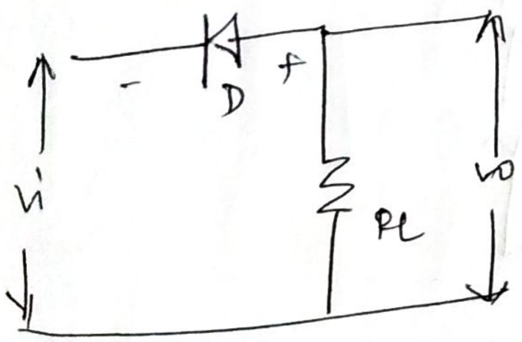


As it clips off negative half cycle of the i/p, it is called series negative clipper.

$$\boxed{\begin{aligned} \therefore V_o &= V_i \quad \text{when } V_i \geq 0 \\ V_o &= 0 \quad\quad V_i < 0 \end{aligned}}$$

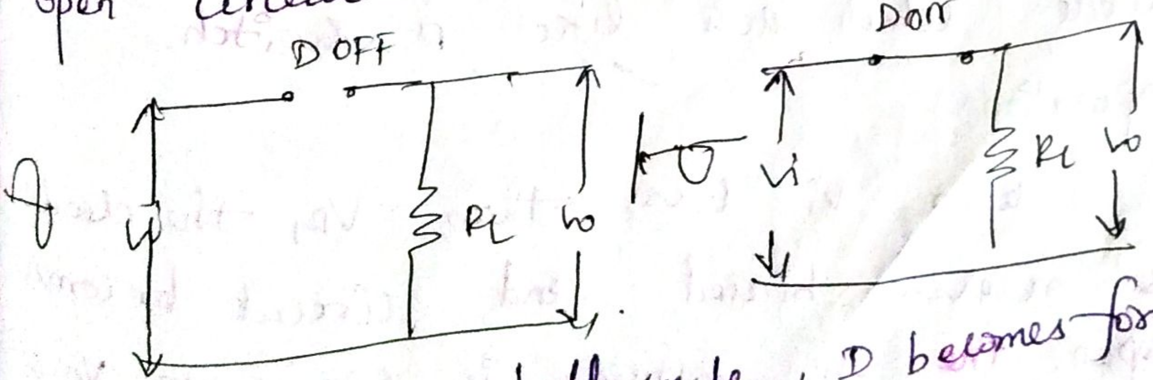
Series positive clipper :-

Similar to series negative clipper, a circuit which clips off positive part of the input can be obtained. It is called Series positive clipper :-



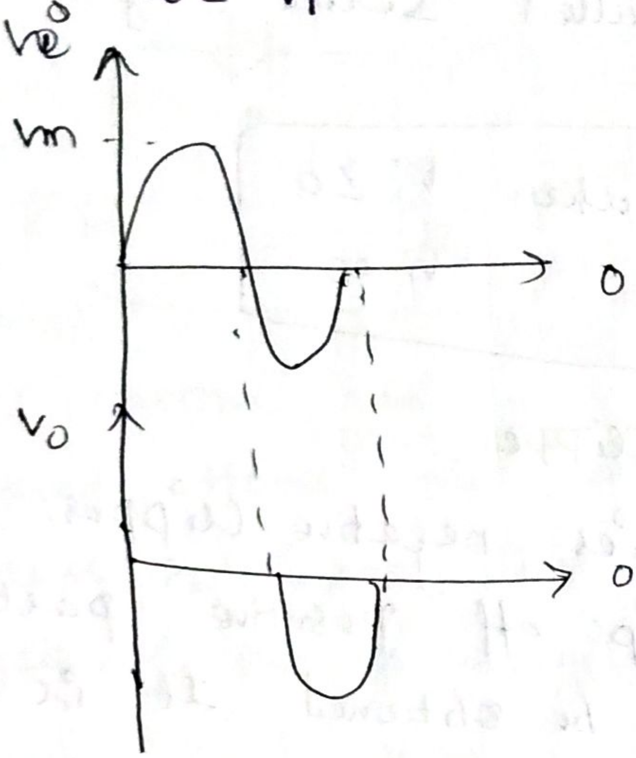
Operation :-

During positive half cycle, the diode D is reverse biased and it becomes open circuited. $\therefore V_o = 0$.



During negative half cycle, D becomes forward

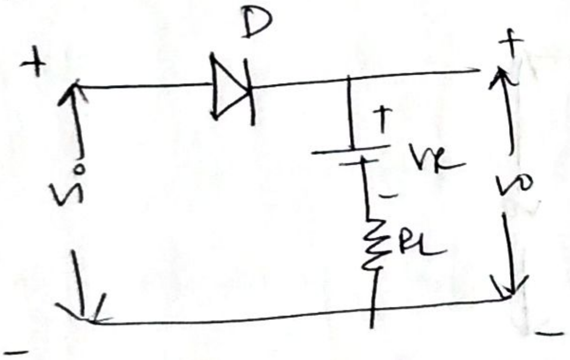
biased and it is in on condition.
So
$V_o = V_i$



$V_o = 0 \quad V_i \geq 0$

$V_o = V_i \quad V_i \leq 0$

Clipping below Reference voltage V_R:-

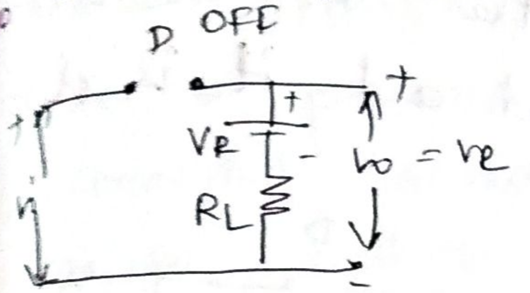


This circuits which clips the portion of waveform, below the reference voltage V_R.

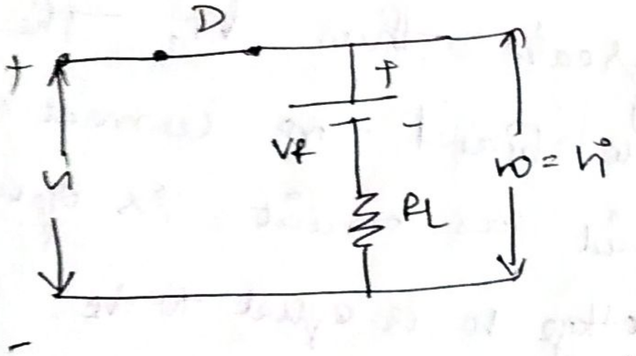
The diode D is an ideal diode which acts like a switch.

operation:

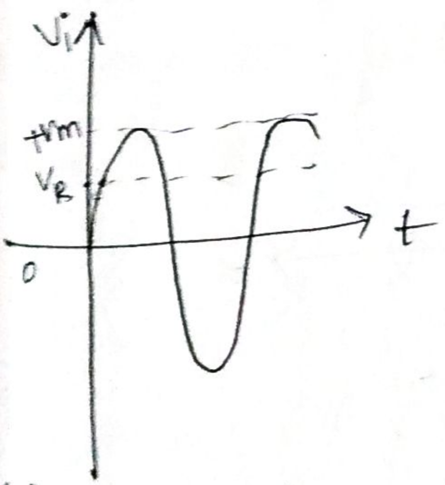
when v_i less than V_R, the diode is reversed biased and circuit becomes open. The O/P voltage is equal to V_R as current flows in the circuit

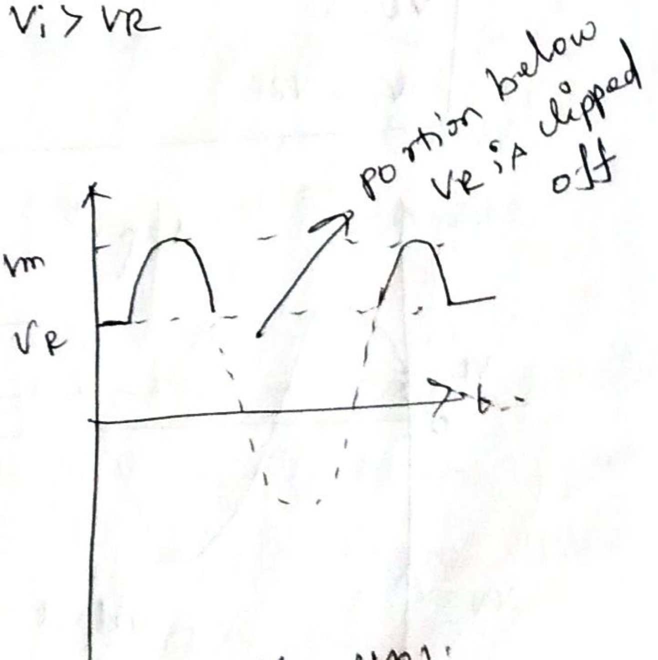


When v_i is greater than V_R, the diode D becomes forward biased and circuit becomes short circuited.

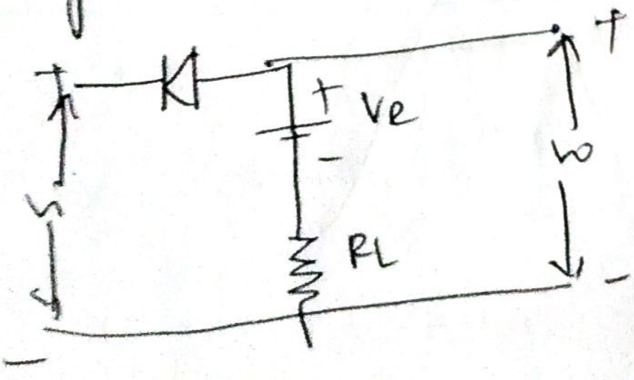


$V_o = V_R$	$V_i < V_R$
$V_o = V_i$	$V_i > V_R$

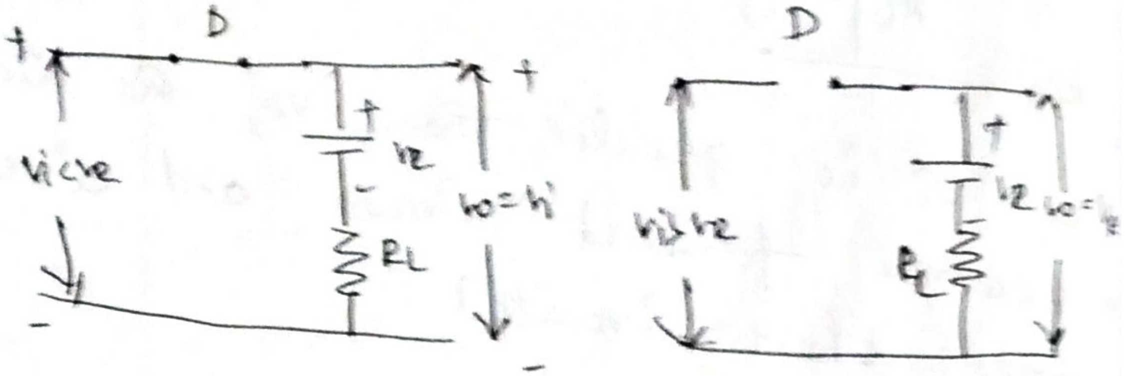




Clipping above Reference voltage (V_R):

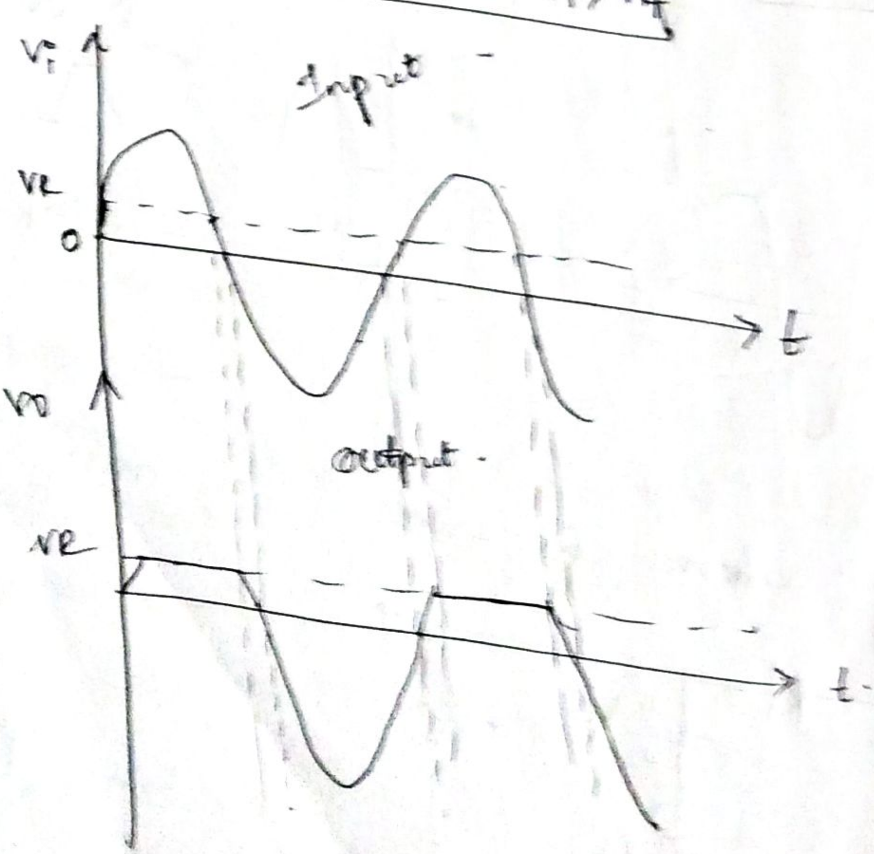


When v_i is less than V_R, the diode becomes forward biased and it is short circuited. $V_o = V_i$



When V_i is greater than V_R, the diode is reverse biased - no current can flow in the circuit as circuit is open and hence o/p voltage V_o is equal to V_R.

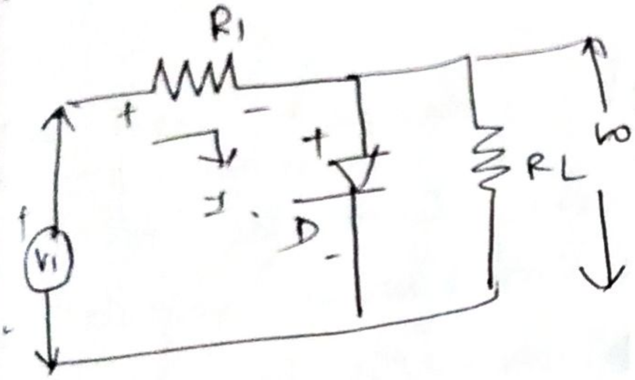
$$\boxed{\begin{array}{ll} V_o = V_i & V_i < V_R \\ V_o = V_R & V_i > V_R \end{array}}$$



parallel clipper:

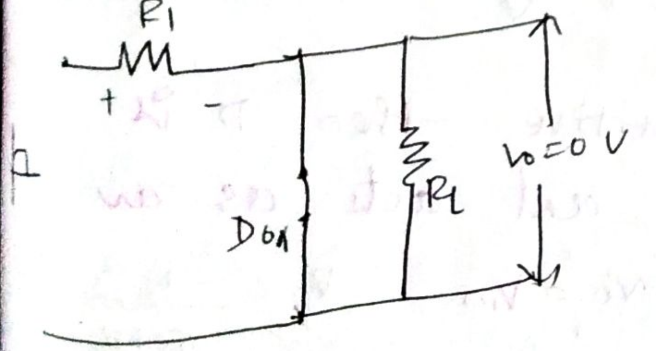
In a parallel circuit, the diode is connected across the load terminals. It can be used to clip or limit the positive or negative part of the i/p signal, as per the requirement.

parallel positive clipper:-



operation:-

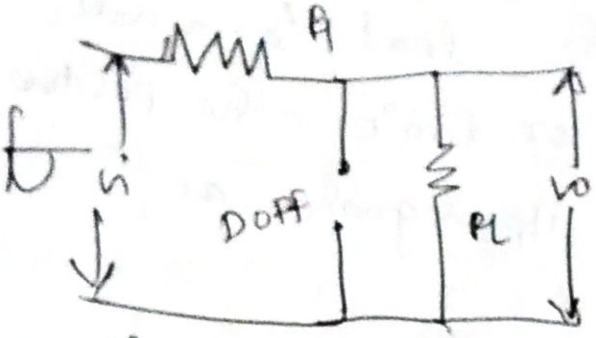
During positive half cycle of the i/p v_i, the diode D becomes forward biased and remains forward biased for the entire half cycle of the i/p.



As RL is in parallel with diode no current flows through it and o/p voltage $V_o = 0V$.

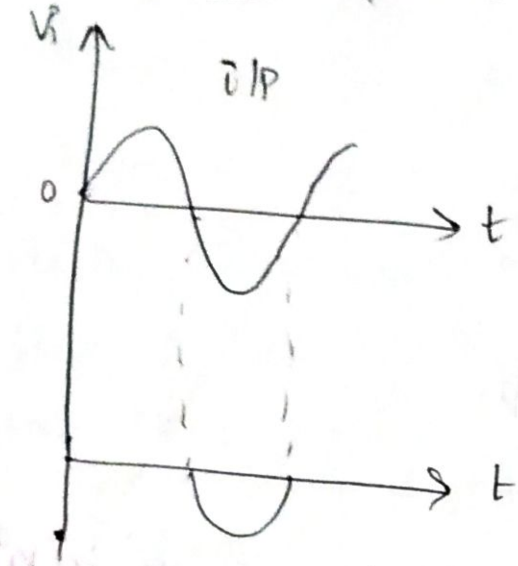
During negative half cycle of the i/p the diode is reverse biased and acts as open circuit. the entire current flows through RL.

$$V_0 = \frac{R_L}{R_1+R_L} V_i \qquad \therefore \quad V_0 \propto V_i$$

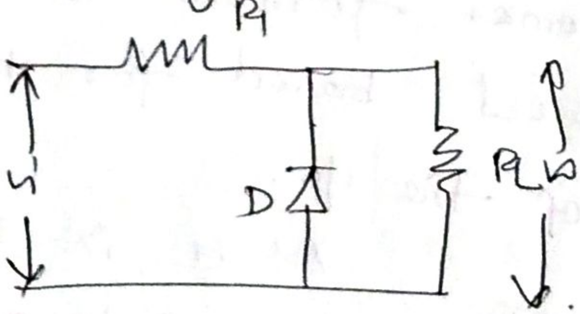


$V_0 = 0 \qquad V_i \geq 0$

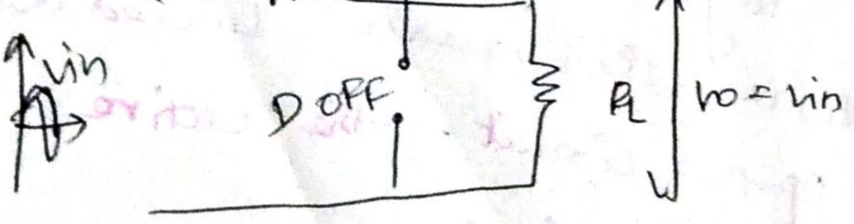
$$V_0 = \frac{V_i R_L}{R_1 + R_L} \qquad V_i < 0$$



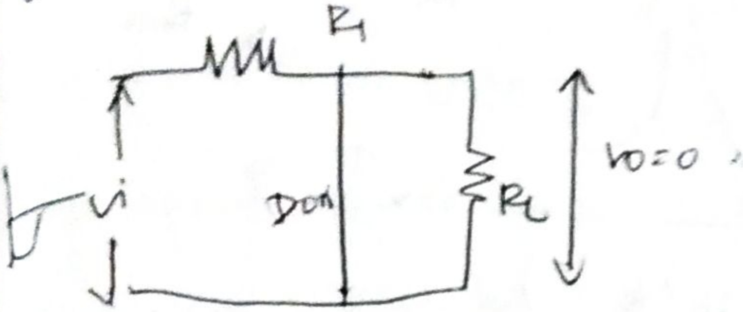
Parallel negative clipper:-



when Vin is positive then D is reversed biased and acts as an open circuit. $\therefore$ $V_o = V_{in}$ $\quad V_0 = \frac{R_L}{R_1+R_L} V_{in}$



when Vin is negative, then D is forward biased and acts as short circuit.



$$V_o = \frac{R_L}{R_1 + R_L} V_{in} \quad V_i > 0$$

$$V_o = 0 \quad V_i < 0$$

Time base generators:

An electronic circuit which generates an output voltage or current waveform, a portion of which varies linearly with time.

It generates high frequency saw tooth wave can be termed as a time base generator.

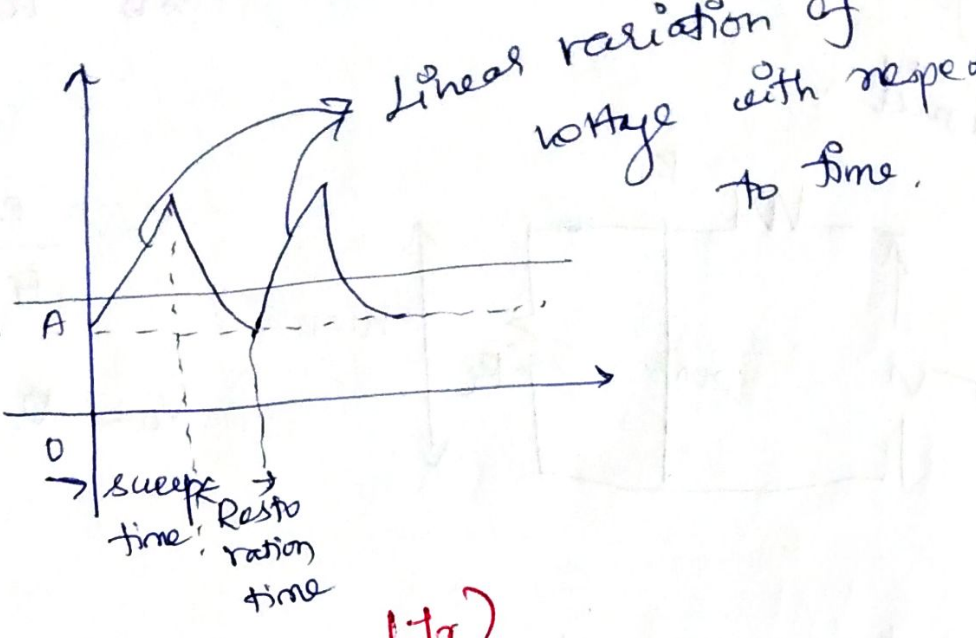
Voltage time base circuits:

Circuits used to generate a linear variation of voltage with time are called voltage time base generator. It is also called as linear time base generators.

Application:

1) CRO (to sweep the electron beam horizontally across the screen)
2) Radar
3) Television indicators.

4) precise time measurements.



Restoration time :- (T_r)

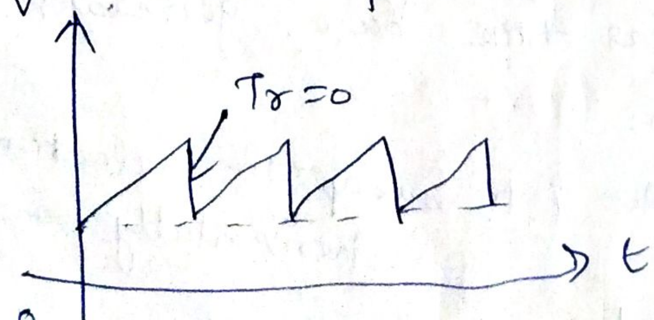
The time required for the voltage to ~~attain~~ maximum value ~~and~~ return to the initial value is called restoration time. (Return time or flyback time). T_r

Sweep time :- (T_s)

The period during which voltage increases linearly is called sweep time and it is denoted as T_s.

Usually $T_r << T_s$.

When T_r tends to zero the o/p becomes sawtooth waveform (or ramp waveform.



Errors of Generation of sweep waveform:-

→ sweep speed error
→ Displacement error
→ Transmission error

$\Rightarrow$ sweep parameters.

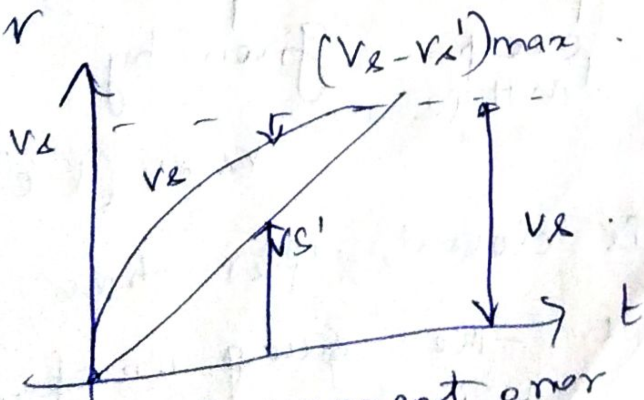
Sweep speed error (e_s):

sweep generator should keep sweep speed constant.

Sweep speed ⇒ The rate of change of sweep voltage with time. Any change in sweep speed deviates sweep voltage from maintaining linear slope.

The error due to sweep speed is called sweep-speed error or slope error,

e_s = Difference in slope at beginning and end of sweep / Initial value of slope.



Displacement error

Displacement error: (ed)

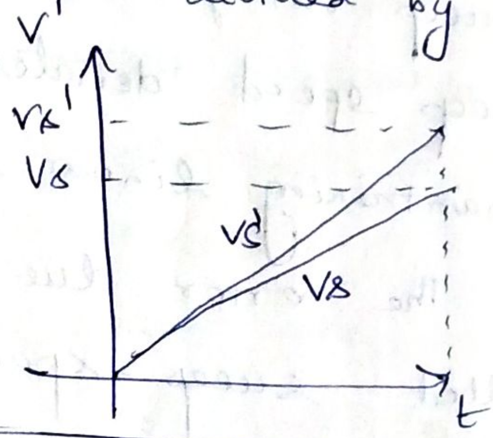
⇒ Maximum difference between the actual sweep voltage and linear sweep which passes through the beginning and end point of the actual sweep.

$$ed = \frac{(V_s - V_s')_{max}}{V_s}.$$

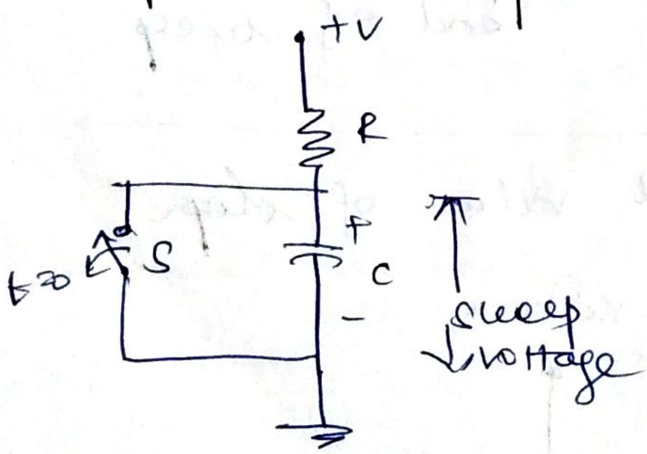
Transmission error: (er)

It is defined as the difference btw the input & output divided by the input.

$$et = \frac{V_s' - V_s}{V_s'}$$



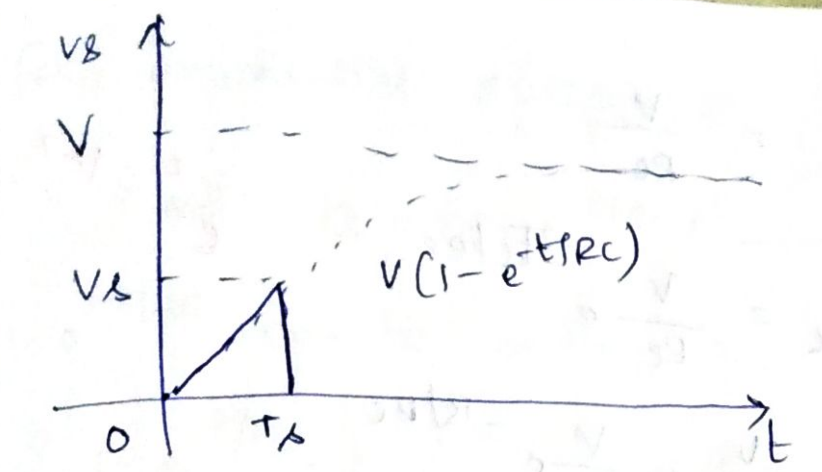
Exponential sweep circuit:



At t=0, switch S is opened and the sweep voltage V_s is given by

$$V_s = V\left(1 - e^{-t/RC}\right).$$

If switch is closed, after time interval T_s, we get the sweep waveform.



Let us derive the expressions for sweep speed error (e_s), sweep displacement error(e_d), sweep transmission error (e_t)

Expression for e_s :-

The sweep speed error is given by

e_s = Difference in slope at beginning and end of sweep
/ Initial value of slope.

$$= \frac{\left|\frac{dV_s}{dt}\right|_{t=0} - \left|\frac{dV_s}{dt}\right|_{t=T_s}}{\left|\frac{dV_s}{dt}\right|_{t=0}}$$

We know the $V_s = V(1-e^{-t/RC})$ — ①

RC = Time constant

Differentiating eqn ① with respect to time

$$\frac{dV_s}{dt} = V\left(0 - e^{-t/RC}\right) \times \frac{-1}{RC}$$

$$= \frac{V}{RC} e^{-t/RC}$$

$$\left.\frac{dv_s}{dt}\right|_{t=0} = \frac{V}{RC}$$

$e^{-x} = 1-x$

$$\left.\frac{dv_s}{dt}\right|_{t=T_s} = \frac{V}{RC} e^{-T_s/RC}$$

$$\therefore \quad e_s = \frac{\frac{V}{RC} - \frac{V}{RC} e^{-T_s/RC}}{\frac{V}{RC}}$$

$$e_s = 1 - e^{-T_s/RC}$$

If $T_s << RC$ then we can write.

$$e^{-T_s/RC} \approx 1 - \frac{T_s}{RC}$$

$$e_s = 1 - \left(1 - \frac{T_s}{RC}\right)$$

$$e_s = \frac{T_s}{RC}.$$

By definition sweep speed error is also given as

$$e_s = \frac{V_s}{V} \begin{array}{l} \rightarrow \text{sweep voltage} \\ \rightarrow \text{supply voltage} \end{array}$$

$$\boxed{e_s = \frac{V_s}{V} = \frac{T_s}{RC} = \frac{T_s}{\tau}.}$$

Expression for Displacement error (e_d)

The displacement error is given as

$$e_d = \frac{(V_s - V_s')_{max}}{V_s}$$

For exponential sweep

$$1-e^{-x} = 1-\left(1-x+\frac{x^2}{2}-\frac{x^3}{3}+\dots\right)$$

$$V_s = V(1-e^{-t/RC}) \quad \text{—— (1)}$$

$1-e^{-t/RC}$ can be written as

$$1-e^{-t/RC} = 1-\left(1-\frac{t}{RC}+\frac{(t/RC)^2}{2}-\frac{(t/RC)^3}{2}+\dots\right)$$

neglecting higher order terms.

$$1-e^{-t/RC} = 1-\left(1-\frac{t}{RC}+\frac{(t/RC)^2}{2}\right)$$

$$= 1-1+\frac{t}{RC}-\frac{(t/RC)^2}{2}$$

$$= \frac{t}{RC}-\frac{(t/RC)^2}{2} \Rightarrow \frac{t}{RC}-\frac{t^2/R^2C^2}{2}$$

$$1-e^{-t/RC} = \frac{t}{RC}\left(1-\frac{t}{2RC}\right)$$

substitute this value in eqn (1) we get.

$$V_s = V\left(\frac{t}{RC}\left(1-\frac{t}{2RC}\right)\right)$$

$$\boxed{V_s = \frac{Vt}{RC}\left(1-\frac{t}{2RC}\right)}$$

$$\frac{VT_s}{RC} - \frac{VT_s^2}{2R^2C^2}$$

The slope of linear sweep can be given as V/RC

$$\therefore \boxed{V_s' = \frac{Vt}{RC}}$$

$$V_s - V_s' = \frac{Vt}{RC}\left(1-\frac{t}{2RC}\right) - \frac{Vt}{RC}$$

$$= \frac{V\cancel{t}}{\cancel{R}C}\left[1 - \frac{Vt^2}{2R^2C^2}\right] - \frac{V\cancel{t}}{\cancel{R}C}$$

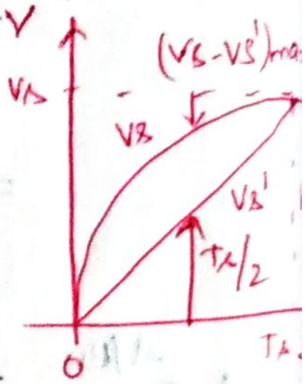
$$= \frac{Vt}{RC} \times \frac{t}{2RC}$$

The deviation is maximum when $t = T_s/2$

$$\therefore \left|V_s - V_s'\right|_{max} = \frac{V(T_s/2)(T_s/2)}{RC \cdot 2RC}$$

we know that $V_s' = \frac{Vt}{RC}$

Looking at the figure in displacement error at $t = T_s$ $V_s' = V_s$



$$V_s = \frac{VT_s}{RC}$$

$$\therefore \quad e_d = \frac{\dfrac{V(T_s/2)(T_s/2)}{RC \cdot 2RC}}{\dfrac{VT_s}{RC}}$$

$$e_d = \frac{\dfrac{\dfrac{VT_s^2}{4}}{2RC^2}}{\dfrac{VT_s}{RC}} \Rightarrow \frac{\dfrac{VT_s^2}{4}}{2RC\cancel{f}} \times \frac{\cancel{R}C}{\cancel{VT_s}}$$

$$\boxed{e_d = \frac{T_s}{8RC}}$$

Expression for transmission error (e_t)

The transmission error is given as

$$e_t = \frac{V_s' - V_s}{V_s'}$$

we know that

$$V_s = \frac{Vt}{RC}\left(1 - \frac{t}{2RC}\right)$$

the slope of linear sweep can be given as

$$V_s' = \frac{Vt}{RC}$$

at $t = T_s$, $V_s = V_s$ and $V_s' = V_s'$.

$$\therefore V_s' = \frac{VT_s}{RC} \text{ and}$$

$$V_s = \frac{VT_s}{RC}\left(1 - \frac{T_s}{2RC}\right).$$

$$\therefore e_t = \frac{\frac{VT_s}{RC} - \frac{VT_s}{RC}\left(1 - \frac{T_s}{2RC}\right)}{\frac{VT_s}{RC}}$$

$$= \frac{\cancel{\frac{VT_s}{RC}}\left(1 - \left(1 - \frac{T_s}{2RC}\right)\right)}{\cancel{\frac{VT_s}{RC}}}$$

$$= 1 - 1 + \frac{T_s}{2RC}$$

$$\therefore \quad e_s = \frac{T_s}{RC}$$

$$e_d = \frac{T_s}{8RC}$$

$$e_t = \frac{T_s}{2RC}.$$

Relation btw e_s, e_d and e_t:

$$e_s = \frac{T_s}{RC}, \quad e_d = \frac{T_s}{8RC}, \quad e_t = \frac{T_s}{2RC}$$

$$e_d = \frac{e_s}{8} \quad \text{(or)} \quad e_d = \frac{e_t}{4}$$

$$\therefore \quad e_d = \frac{e_s}{8} = \frac{e_t}{4}.$$

By using this relation if one of the errors is known we can easily calculate other errors.

Sweep speed for Exponential charging:

The sweep speed is defined as the rate of change of sweep voltage with respect to time. we know that

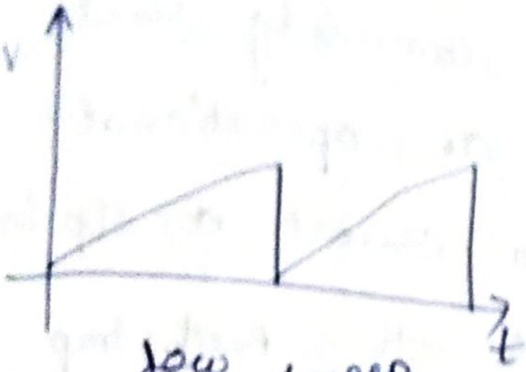
$$V_s = V\left(1 - e^{-t/RC}\right)$$

Differentiate this equation with respect to time we get

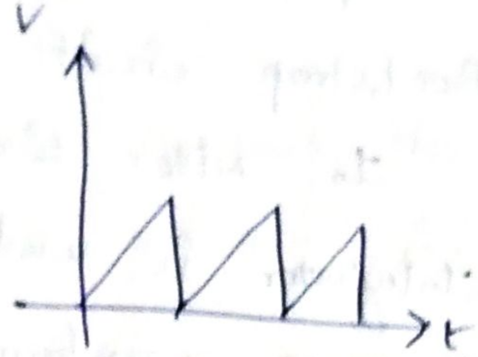
Sweep speed -

$$\frac{dv_s}{dt} = \left(-e^{-t/RC}\right)\left(\frac{-1}{RC}\right)$$

$$\frac{dv_s}{dt} = \frac{V}{RC} e^{-t/RC}$$



Low sweep speed



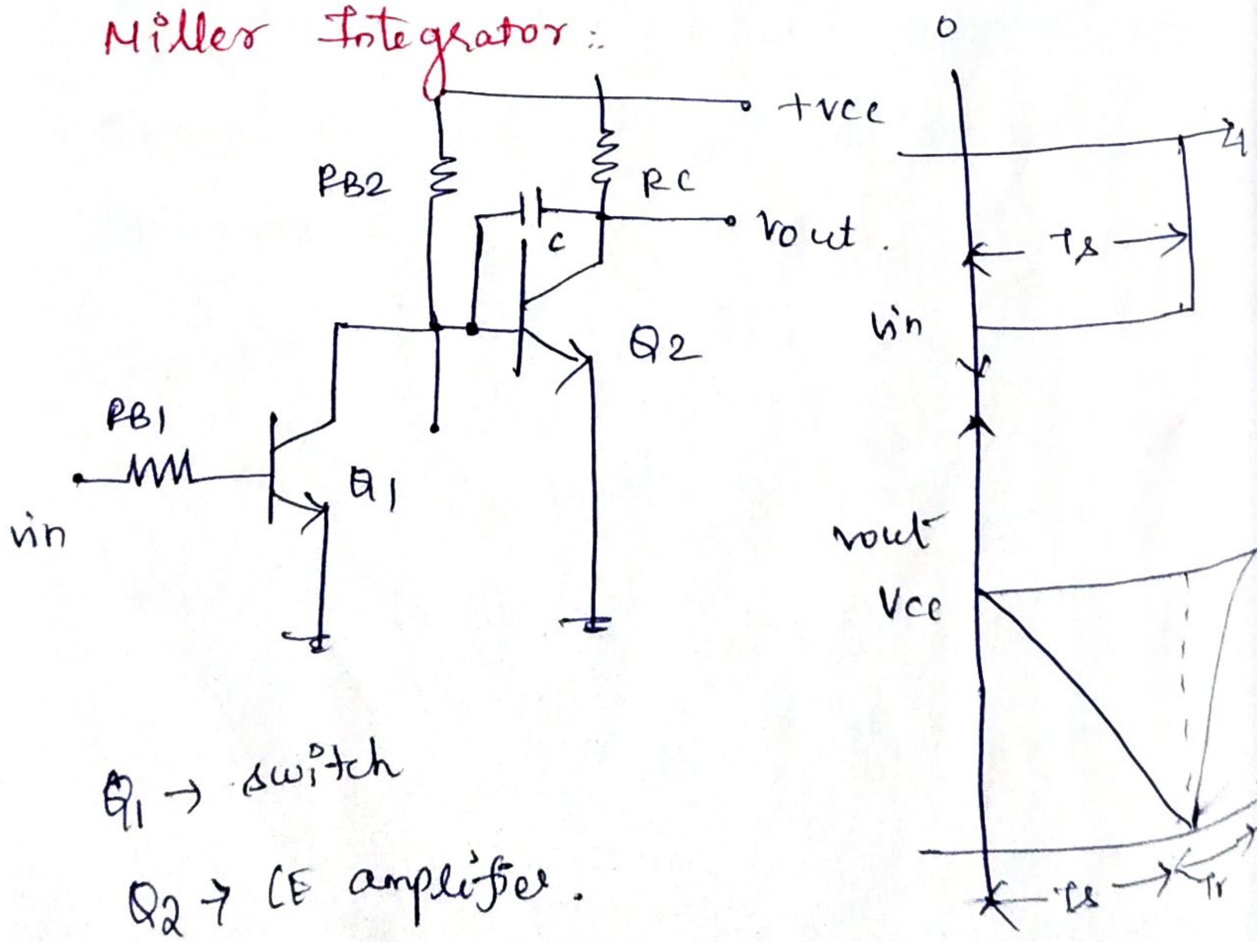
High sweep speed

Voltage Time Base Circuit :-

Among several methods to achieve sweep linearity, the Miller circuit and Bootstrap circuit are commonly used.

In Miller circuit, an operational Integrator is used to convert a step into a ramp waveform. In the Bootstrap circuit a constant current is approximated by maintaining nearly constant voltage across a fixed resistor in series with a capacitor.

Miller Integrator :-



$Q_1 \rightarrow$ switch

$Q_2 \rightarrow$ CE amplifier.

Case 1 :- Q_1 is ON and Q_2 is OFF

$V_o = V_{cc}$

Case 2 :- When a negative pulse is applied to the base of Q_1.

$Q_1 \rightarrow$ OFF, which increases the bias to Q_2 and as a result Q_2 is turned ON.

As Q_2 conducts, Vout begins to decrease :

The rate of decrease of o/p is controlled by rate of discharge of capacitor.

Time constant of the discharge $\boxed{\tau_d = R_B C}$

Case 3 :- When the i/p pulse is removed

Q_1 turns ON and Q_2 turns OFF.

The capacitor starts charges quickly to $+V_{cc}$ through R_C with time constant

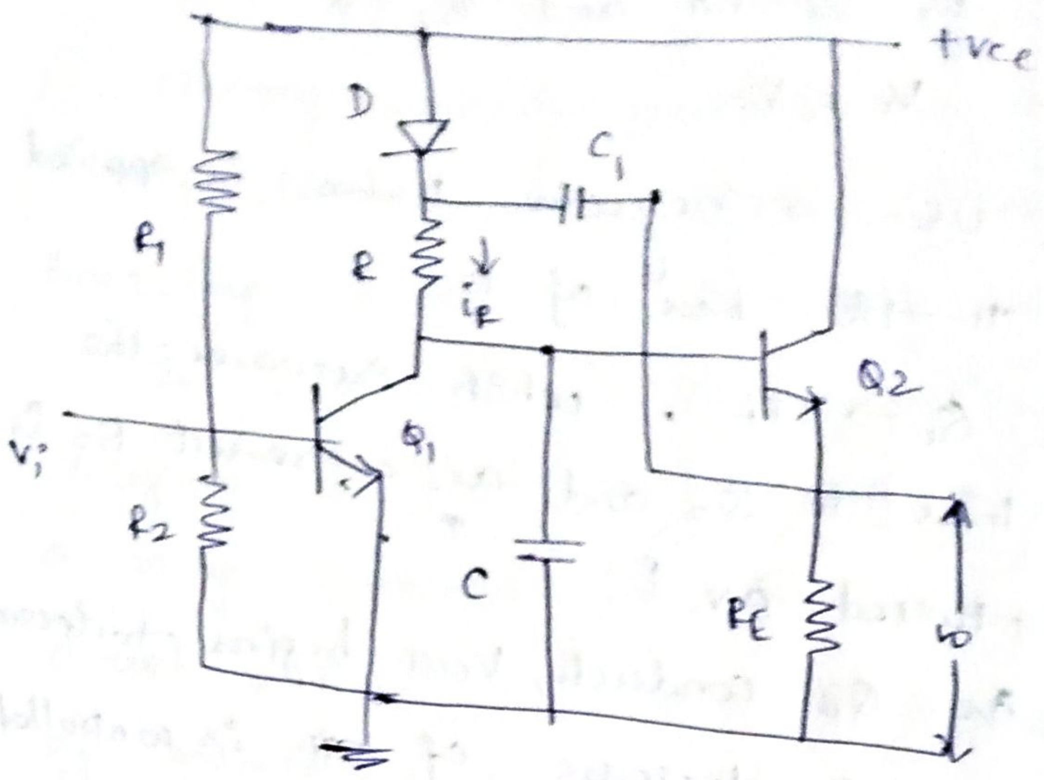
$\boxed{\tau_c = R_C C}$

Bootstrap sweep circuit :-

It is a commonly used method for acheiving a constant charging current.

$Q_1 \rightarrow$ Acts as a switch

$Q_2 \rightarrow$ Emitter follower.



V_0 = voltage across the capacitor C

1) Q_1 is on and Q_2 is OFF.

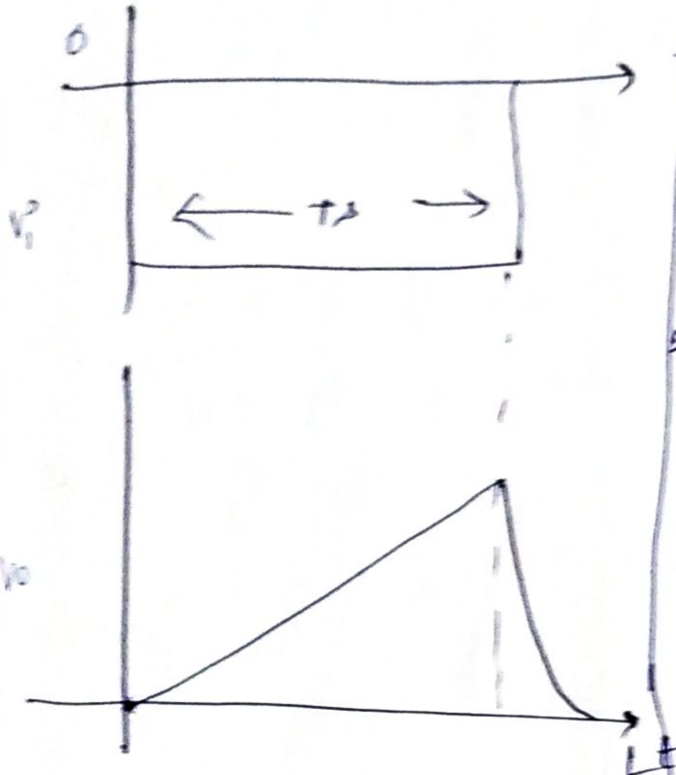
C_1 is charged to the voltage V_{cc} and the o/p voltage $V_0 = 0$.

2) When a negative pulse is applied to the base of Q_1, Q_1 is turned OFF. C_1 starts discharges and C starts charging through resistor R. As a result the base voltage of Q_2 and V_0 start increasing from zero volts.

$C_1 >> C$.

$$\boxed{V_0 = \frac{V_{cc}\, t}{RC}}$$

3) when a negative pulse is removed, c discharges and $V_0 = 0$. then the capacitor C_1 again charges to the supply voltage V_{cc}.



1) Q_1 ON Q_2 OFF

$C_1 \to$ charging

$C \to$ discharging.

$V_0 = 0$

(apply -ve pulse)

2) Q_1 OFF Q_2 ON

$C_1 \to$ discharging

$C \to$ charging

$$V_0 = \frac{V_{cc}\,t}{RC}$$

3) Removing -ve pulse

Q_1 ON Q_2 OFF

$C_1 \to$ charging

$C \to$ discharging

$V_0 = 0$.

Blocking Oscillators :

A special type of wave generator which is used to produce a single narrow pulse or train of pulse is called a blocking oscillator.

Important elements

1) Active device like transistor
2) pulse transformer.

The properly controlled winding polarities produce a regenerative feedback.

The circuit with such a regenerative fb produces a single pulse or pulse train called a blocking oscillator.

→ If it is used to produce a single pulse then it is called monostable operation.

→ If it produces pulse train then it is called astable operation

Astable blocking Oscillator :

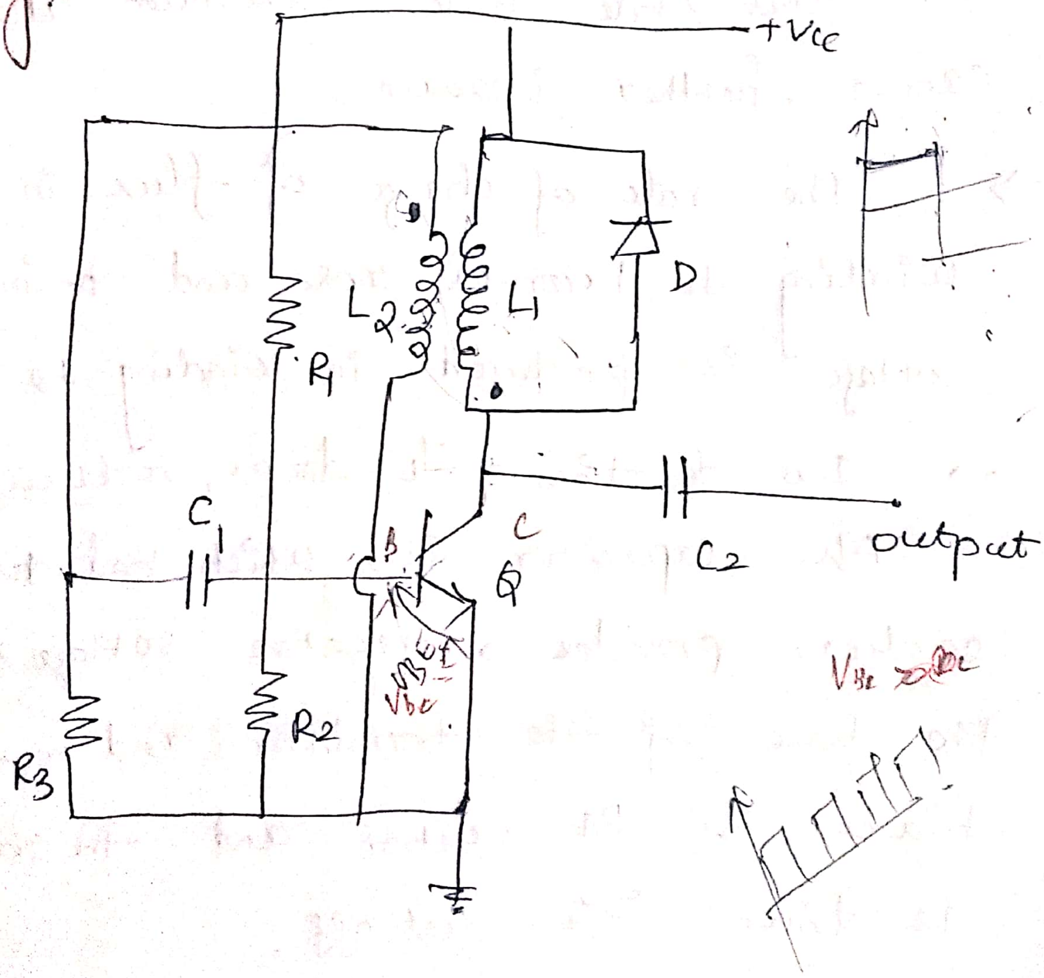
It is also called as free running blocking oscillator.

It produces train of pulses, when triggered. There are two types of astable blocking Oscillator

1) Diode Controlled astable blocking oscillator
(Base timing)

2) RC Controlled astable blocking Oscillator
(Emitter timing)

Astable Blocking Oscillator with Base timing:



→ when supply is switched on, the base voltage increases rapidly. when this voltage becomes greater than VBE, the Collector current Ic increases.

→ The increase in Ic through the windings, induces a voltage in winding L_2 of the pulse transformer.

→ Hence the base emitter junction of the transistor is more forward biased and I_c further increases.

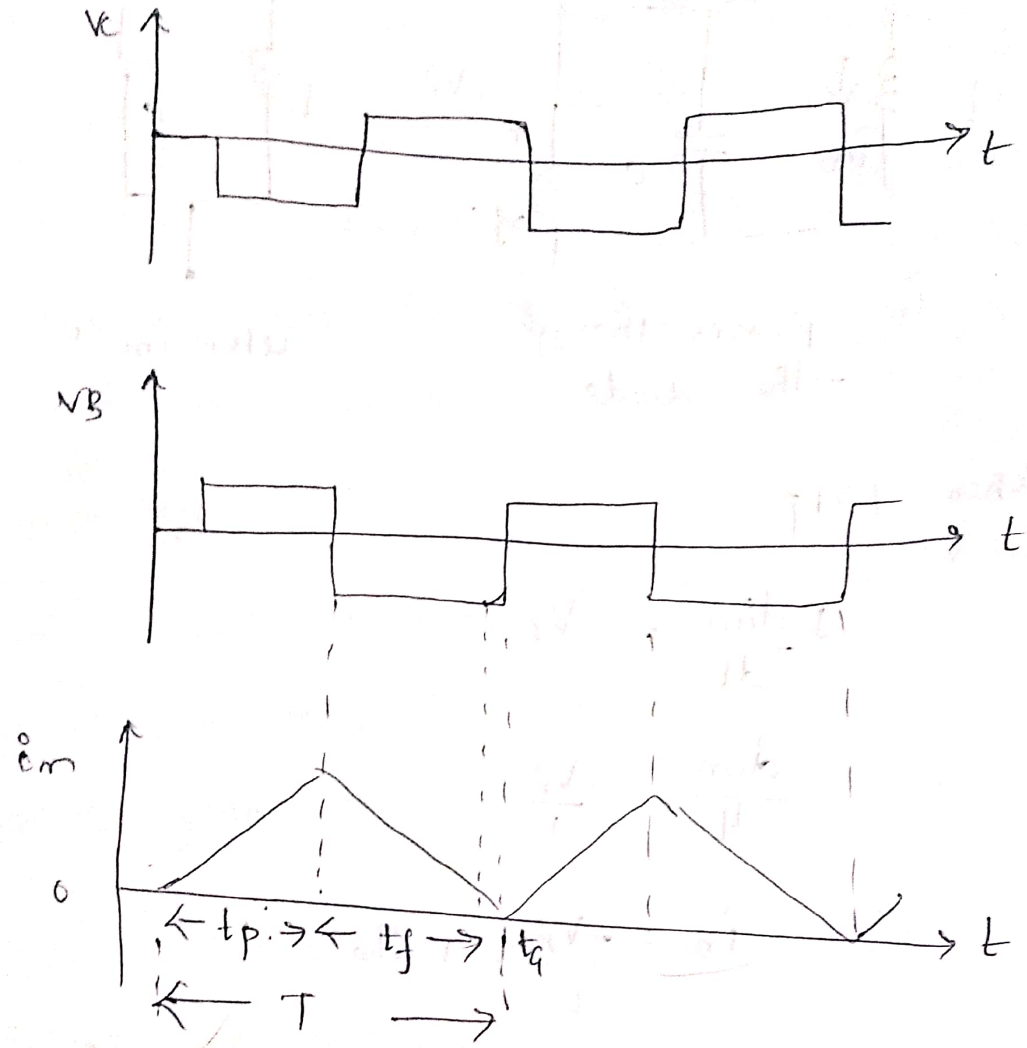
→ Because of the regenerative action, the transistor is driven into saturation. At this state I_c is maximum and it cannot further increase.

→ ∴ The rate of change of flux in winding L_1 becomes zero and no induced voltage is produced in winding L_2.

→ Due to this I_b drops, reducing I_c. Also capacitor C_1, which had charged earlier, provides a negative voltage to the base of the transistor and reverse biases its BE junction and the transistor is driven into cut off.

→ When the capacitor discharges a sufficient amount of charge, the reverse bias of the transistor decreases and forward bias increases due to which the transistor starts conducting again.

waveforms:



$t_p \to$ pulse width. $L \to$ magnetizing inductance

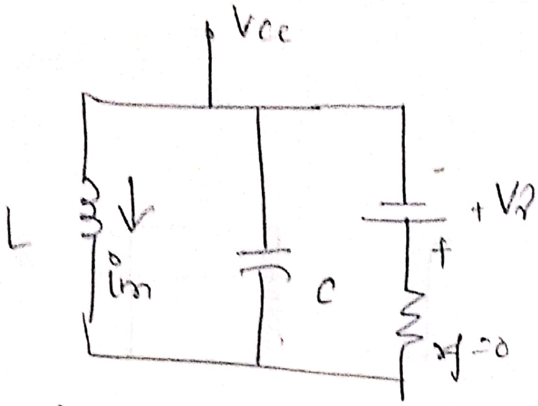
Magnetizing current $i_m = \frac{V_{cc}\, t_p}{(n+1) L} = I_o$.

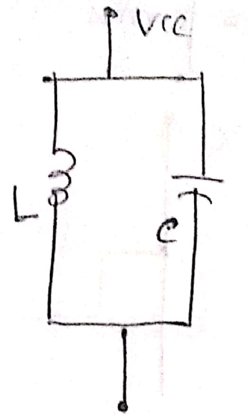
$$t_p = \frac{nL}{R}$$

$$I_o = \frac{V_{cc}\, n \cancel{L}}{(n+1) \cancel{L} R}$$

$$\boxed{I_o = \frac{n}{(n+1)} \frac{V_{cc}}{R}}$$

Peak magnetizing current is not dependent on the magnetizing inductance L.





i_m passes through the diode.

when $i_m = 0$

when $t > t_p$

$$L\frac{di_m}{dt} = -V_\gamma$$

$$\frac{di_m}{dt} = \frac{-V_\gamma}{L}$$

$$i_m = \frac{-V_\gamma}{L}t + I_o$$

After the pulse ends, the current decreases linearly with time.

$$t_f \le \frac{L I_o}{V_\gamma} = \frac{n}{n+1}\frac{V_{cc}}{R}\frac{L}{V_\gamma}$$

$$= \frac{n}{(n+1)}\frac{L}{R}\frac{V_{cc}}{V_\gamma}.$$

$$t_a = 15.7\sqrt{LC}.$$

when $V_{BE} >> V_\gamma$, the ~~cd~~ transistor Q is turned on again without an external trigger.

$V_{BE} >> V_\gamma$	Q ON.
$V_{BE} << V_\gamma$	Q OFF

$$\boxed{T = t_p + t_f + t_r}$$

Advantages :-

→ The voltage waveforms at collector and base are nearly rectangular

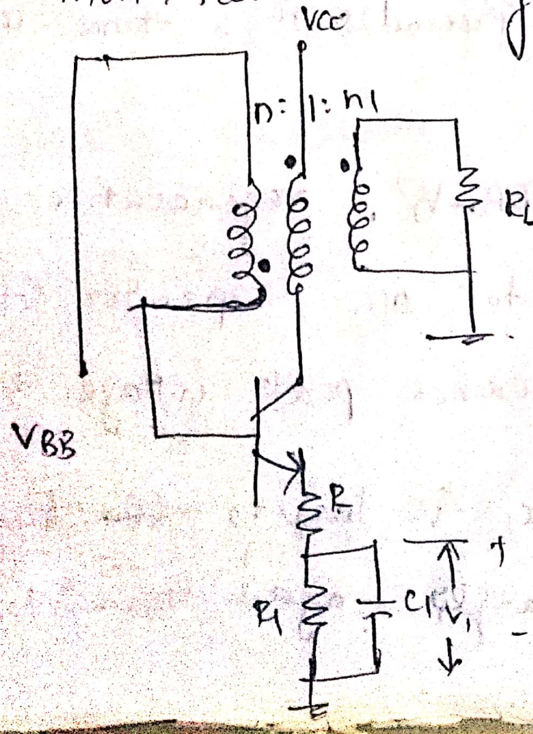
→ Design equations are simpler, the synthesis of the circuit is easier to meet the desired specifications.

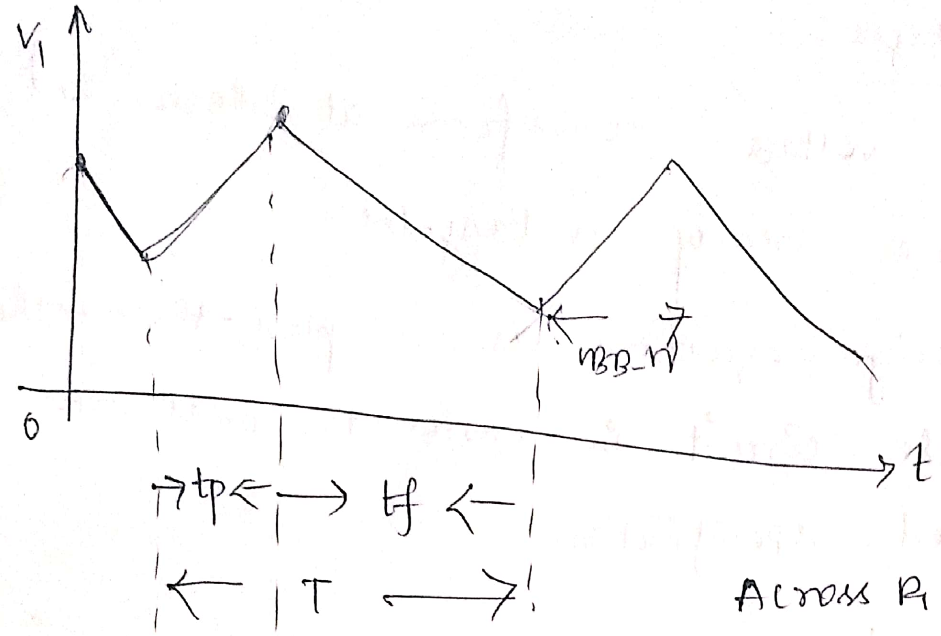
Disadvantages :-

→ For a given pulse duration, tp tf can be changed only by changing the diode cut in voltage V_γ or the supply voltage V_{CC}.

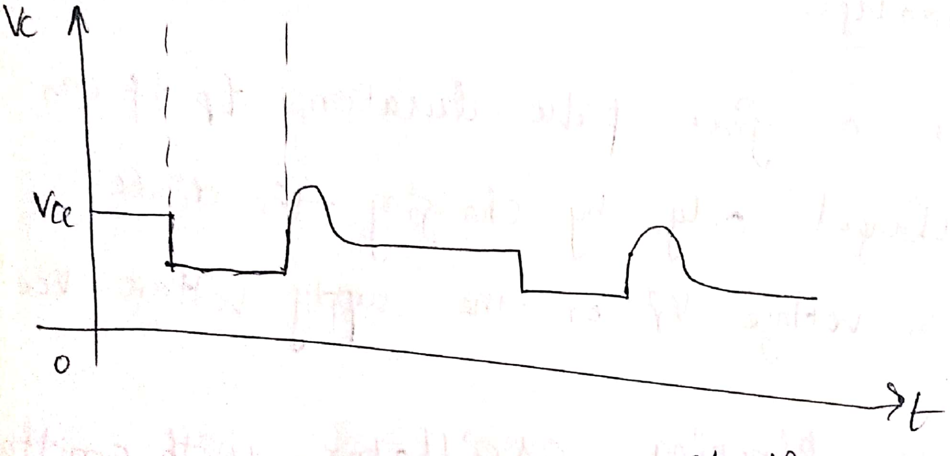
Astable Blocking oscillator with emitter Timing (RC Controlled).

It is obtained with the inclusion of R_1C_1 network in the emitter circuit of a monostable blocking oscillator.





Across R_1C_1



at the collector.

1) Voltage V_1 on C_1 is larger than $(V_{BB} - V_\gamma)$

$V_\gamma \to$ cut in base to emitter voltage.

$\therefore$ Transistor OFF and C_1 discharges exponentially to ground with a time constant R_1C_1.

2) when $V_1 = V_{BB} - V_\gamma$, regenerative action starts. Transistor ON. capacitor starts charging and reaches peak voltage V_1.

3) when V_1 on C_1 is larger, ~~the~~ transistor OFF, C_1 discharges $\therefore$ again transistor turned ON.

The discharge equation of a capacitor is given by

$$V_C = V_i e^{-t/RC}$$

$V_C \rightarrow$ Capacitor voltage while discharging

$V_i \rightarrow$ Initial voltage from which discharge starts

$$V_C = V_{BB} - V_\gamma \qquad V_i = V_1, \; t = t_f$$

$$V_{BB} - V_\gamma = V_1 e^{-t_f/R_1C_1}$$

$$e^{-t_f/R_1C_1} = \frac{V_{BB} - V_\gamma}{V_1}$$

$$-t_f/R_1C_1 = \ln\left[\frac{V_{BB} - V_\gamma}{V_1}\right]$$

$$t_f = -R_1C_1 \ln\left(\frac{V_{BB} - V_\gamma}{V_1}\right)$$

$$t_f = R_1C_1 \ln\left(\frac{V_1}{V_{BB} - V_\gamma}\right)$$

The total period of the RC controlled astable blocking oscillator is given by

$$\boxed{T = t_p + t_f}$$

Advantages:-

1) The frequency of oscillation can be varied by changing the values of R_1 and C_1

2) It is stable with temperature changes.

Disadvantages

1) A small changes in voltage V_1 will produce a large change in ff which results in instability from cycle to cycle.