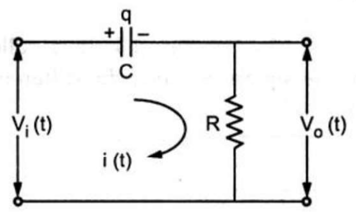
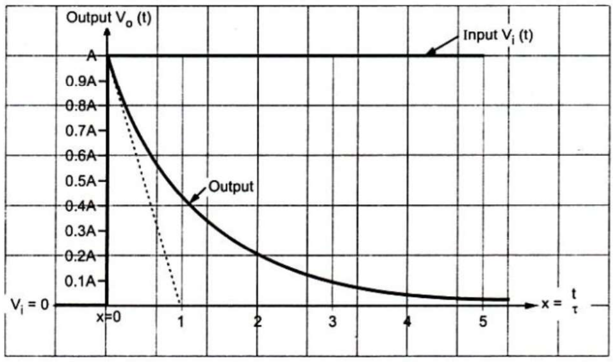
UNIT IV
WAVE SHAPING AND MULTIVIBRATOR CIRCUITS

4.1 High Pass RC Circuit

The output is taken across the resistance R. the input is $V_i(t)$ while the output is $V_0(t)$ and q is the charge of capacitor C. the capacitor totally blocks d.c not allowing it to reach output. Hence the capacitor is called blocking capacitor.

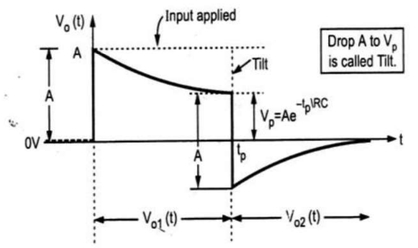


4.1.1 Step input voltage



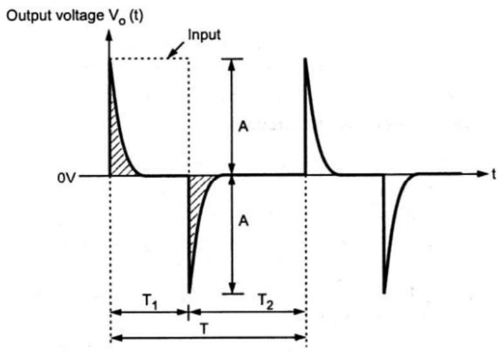
Consider that the step input voltage of magnitude A volts is applied as an input to the high pass RC circuit. The overall response of the circuit to the step input is exponential in nature.

4.1.2 Pulse input voltage



Consider that the pulse type of voltage having pulse width t_p is applied as an input to the high pass RC circuit. The pulse input gets converted to spikes using high pass RC circuit.

4.1.3 Square Wave Input Voltage



For a positive pulse type part of square wave input, there exist a positive spike of amplitude A while for negative part of square wave input, there exist a negative spike of amplitude A.

4.1.4 High Pass RC Circuit as a Differentiator

For a high pass RC circuit, if time constant is very small as compared to the time required by the input signal to make as considerable change, the circuit acts as a differentiator.

The current i is given by

$$i = C\frac{dV_C}{dt} = C\frac{dV_i}{dt}$$

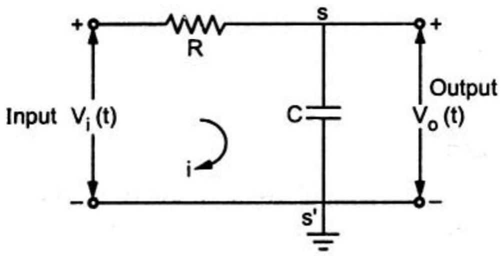
Hence the output which is drop across R is

$$V_0 = iR$$

$$V_0 = RC\frac{dV_i}{dt}$$

The equation shows that the output is differentiation of the input and hence the circuit is called differentiator.

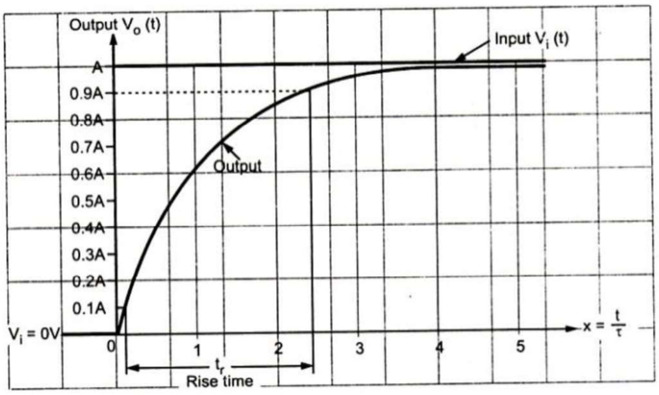
4.2 Low Pass RC Circuit



The output is taken across the capacitanceC. the input is $V_i(t)$ while the output is $V_0(t)$.

The circuit passes the low frequency readily hence called as low pass RC circuit.

4.2.1 Step input voltage

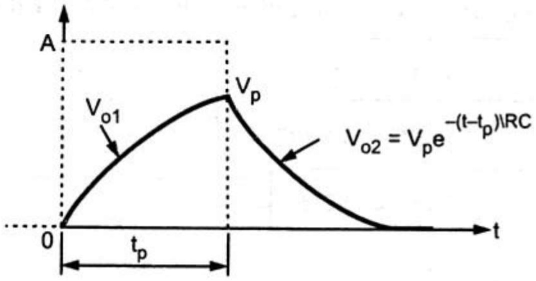


Consider that the step input voltage of magnitude A volts is applied as an input to the low pass RC circuit. The overall response of the circuit to the step input is exponential in nature. It start from zero and rises towards the steady state value A.

Rise Time (t_r)

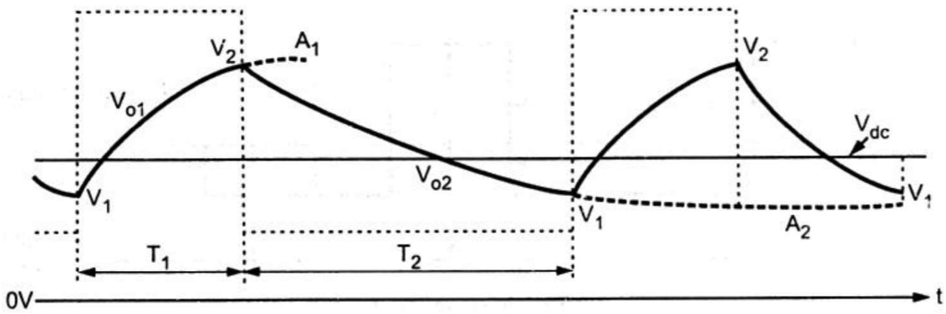
It is the time required by the output response to rise 10% to 90% of its final steady state value.

4.2.2 Pulse input voltage



Consider that the pulse type of voltage having pulse width t_p is applied as an input to the low pass RC circuit.

4.2.3 Square Wave Input Voltage



If the input voltage applied to the low pass RC network is square wave voltage. The out voltage varies exponentially in nature.

4.2.4 Low Pass RC Circuit as anIntegrator

For a low pass RC circuit, if time constant is very large as compared to the time required by the input signal to make as considerable change, the circuit acts as aintegrator.

Hence the output which is voltage across the capacitor is

$$V_0 = V_C = \frac{1}{C}\int idt$$

$$V_0 = \frac{1}{RC}\int V_i(t)dt$$

The equation shows that the output is integration of the input and hence the circuit is called integrator.

4.3 Clipper Circuit or Limiters

The circuits which are used to clip off unwanted portion of the waveform, without distorting the remaining part of the waveform are called clipper circuit or clippers. The clippers also called **Limiters or Slicers**.

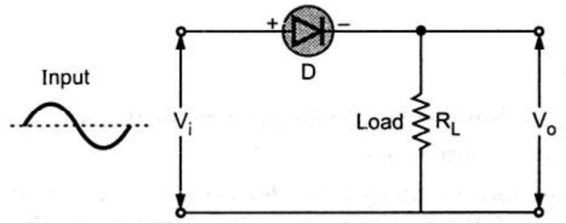
The clipper circuits are mainly classified depending upon the orientation of the diode in the circuit.

When the diode is connected in series with load, such circuit is called **Series Clippers**. When the diode is connected in a branch which is parallel to load, such circuit is called **Parallel Clippers.**

4.3.1Series Negative Clippers

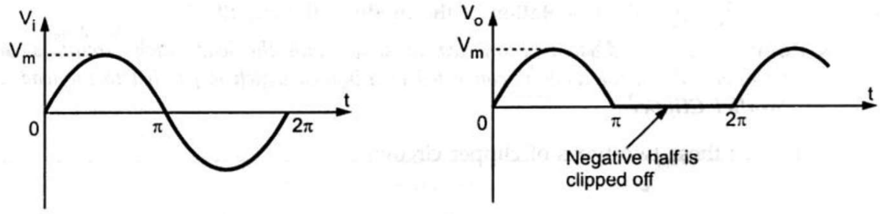
A series negative clipper is basically a half wave rectifier.

Operation:



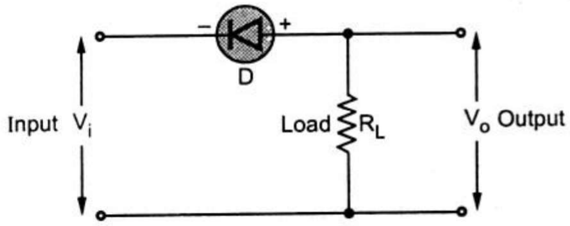
Consider a circuit shown in fig. where diode is connected in series with load. For a positive half cycle, the diode D is forward biased. Hence the voltage waveform across R_L looks like a positive cycle of the input voltage.

While for the negative half cycle, the diode D is reverse biased and hence will not conduct at all. Hence there will not be any voltage available across resistanceR_L. Hence the negative half cycle of input voltage gets clipped off.



(a) Input voltage (b) Output voltage

4.3.2 Series Positive Clippers

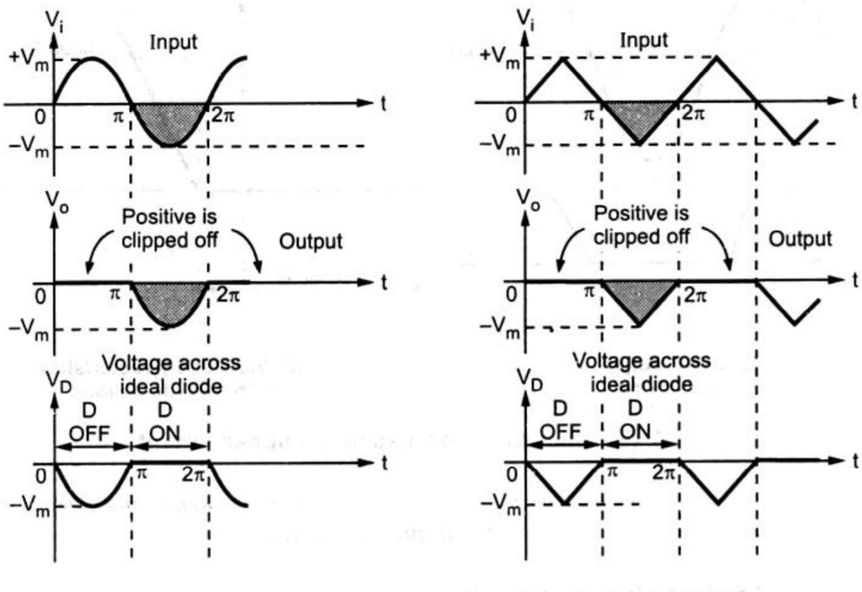


Similar to series negative clipper, a circuit which clipps off positive part of the input can be obtained. It is called series positive clipper.

Operation:

For a positive half cycle, the diode D is reverse biased. Hence it acts as open circuit and $V_0 = 0V$

For the negative half cycle, the diode D conducts. The output voltage V_0 available is same as input voltage. Thus entire negative half cycle of input is available at the output.



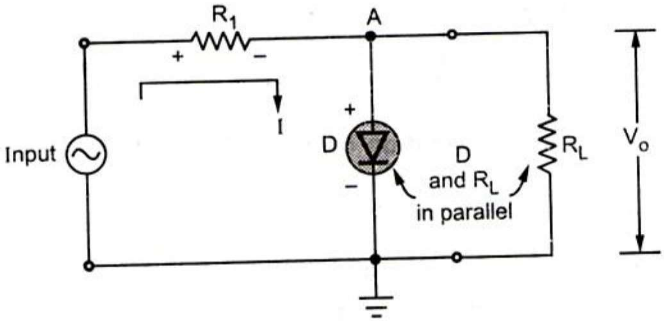
(a) Sinusoidal input (b) Triangular input

4.3.3 Parallel Clippers

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

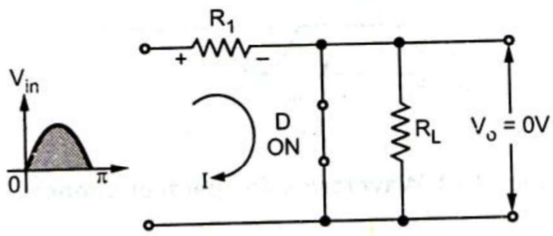
Parallel Clipper with positive Clipping

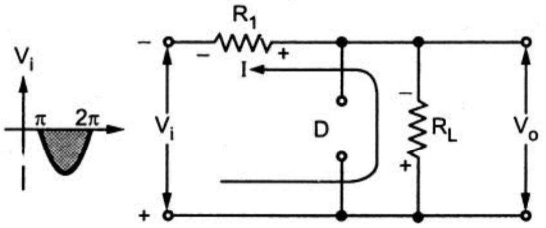
Fig shows the basic parallel clipper circuit in which diode D is connected across the load resistance R_L . The resistance R_L is current controlling resistance.



Operation:

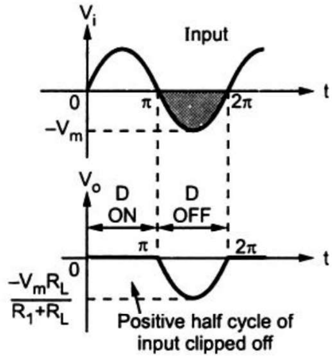
During positive half cycle of the input V_i , the diode D becomes forward biased. AsR_L is in parallel with diode no current flows through it and output voltage $V_0 = 0V$.



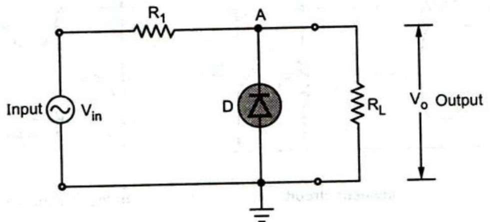


During negative half cycle of the input V_i, the diode D becomes reverse biased and acts as open circuit. The entire current flows through R_L as shown in the fig.

The waveforms are shown in fig.

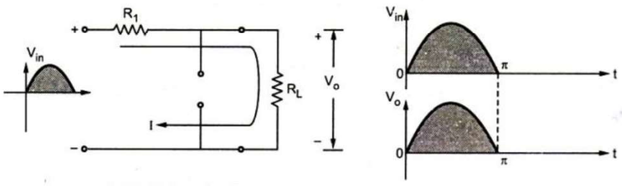


4.3.4 Parallel Clipper with Negative Clipping



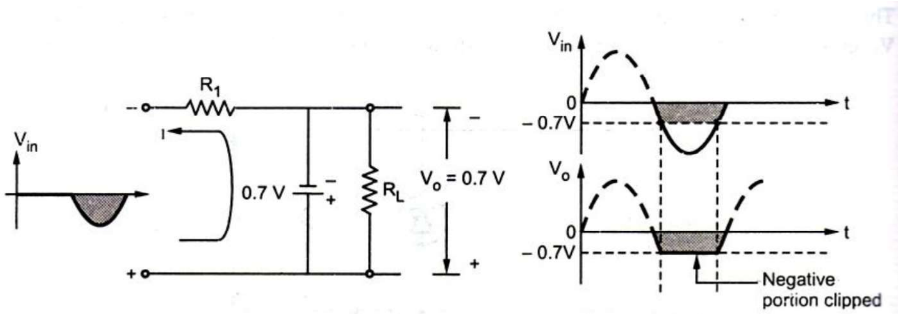
The negative clipping with basic parallel diode can be achieved by reversing the direction of diode.

When V_{in} is positive then the diode is reverse biased and act as an open circuit. Thus the output voltage V_0 is same as V_{in}.



(a) Equivalent circuit (b) Input-output waveforms

Consider the negative half cycle of V_{in}. As V_{in} decrease below zero and becomes -0.7V the diode becomes forward biased and start conducting. Thus the entire negative half cycle gets clipped off.



(a) Equivalent circuit (b) Input-output waveforms

4.4 Clamping Circuits

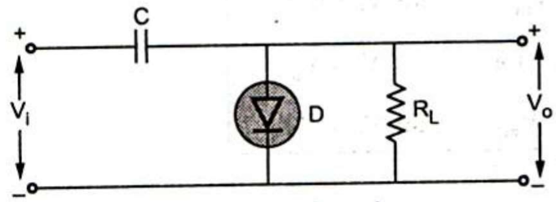
A clamping circuit may be defined as one that holds either extreme of an a.c voltage to a definite level with out distorting the waveform.

The capacitor, diode and resistance are the three basic elements of a clamper circuit. The clamper circuits are also called as **d.c restorer or d.c inserter citrcuit.**

Depending upon whether the positive d.c or negative d.c shift is introduced in the output waveform, the clamper are classified as,

1. Negative clampers
2. Positive clampers.

4.4.1 Negative clamper

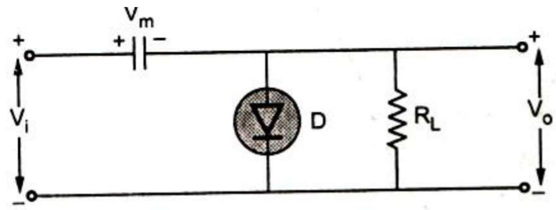


A simple negative clamper which adds a negative level to the a.c output shown in fig.

It consists of a capacitor C, diode D and load resistance R_L.

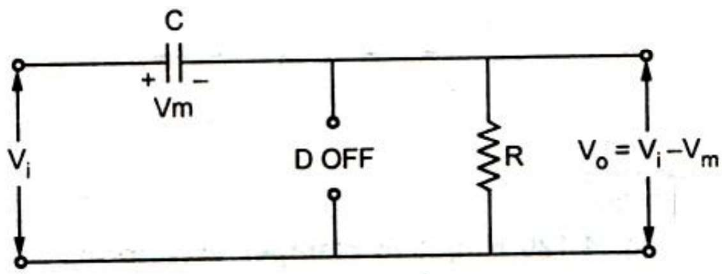
Operation

During the first quarter of positive cycle of the input voltage V_i, the capacitor gets charged through forward biased diode D upto the maximum voltage value V_m of the input signal V_i. The capacitor once charged to V_m, acts as a battery of voltage V_m as shown in fig



Thus when D is ON, the output voltage V_0 is zero. As input voltage decreases after attaining its maximum value V_m , the capacitor remains charged to V_m and the diode D becomes reverse biased.

Due to large RC time constant the capacitor holds its entire charge and capacitor voltage remain as $V_C = V_m$ as shown in fig.



And the output voltage V_0 is now given by,

$$V_0 = V_i - V_C = V_i - V_m$$

In the negative half cycle of V_i, the diode remain reverse biased. The capacitor start discharging through the resistance R_L. As the time constant $R_L C$ is very large, it can ne approximated that the capacitor holds all its charge and remains charged to V_m, during this period also. Hence we can write again that,

$$V_0 = V_i - V_C = V_i - V_m \quad \ldots . for\ negative\ half\ cycle$$

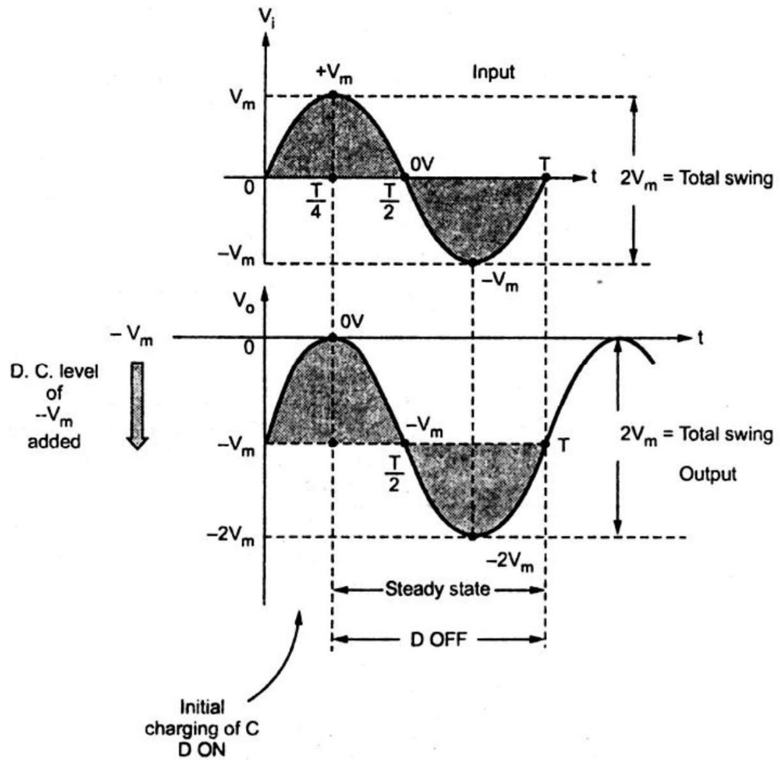
$$V_0 = -V_m \qquad for\ V_i = 0$$

$$V_0 = -0 \qquad for\ V_i = V_m$$

$$V_0 = -2V_m \qquad for\ V_i = -V_m$$

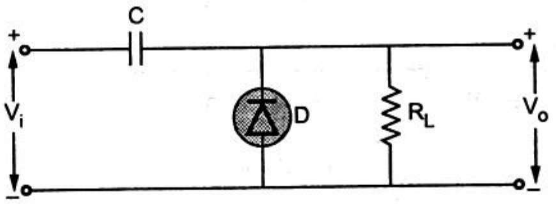
Waveforms

Assuming ideal diode, the input and output waveforms are shown in the fig.

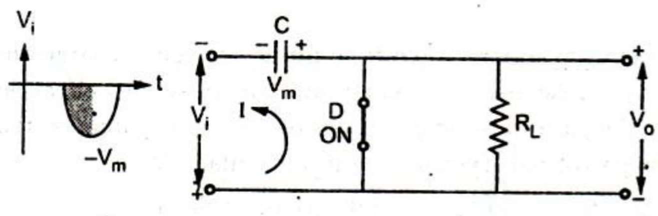


4.4.2 Positive clamper

The circuit is shown in fig.



During the first quarter of negative half cycle of the input voltage V_i, the diode D getsforward biased and almost instantaneous capacitor gets charged equal to the maximum voltage value V_m with the polarities as shown in fig



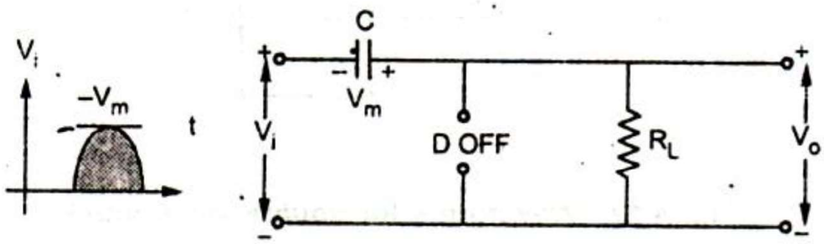
The capacitor once charged to V_m, acts as a battery of voltage V_m with the polarities as shown in fig

Due to large RC time constant the capacitor holds its entire charge all the time.

Thus when $V_i = V_m$, the output voltage $V_0$is $2V_m$. Under steady state conditions we can write,

$$V_0 = V_i + V_C = V_i + V_m$$

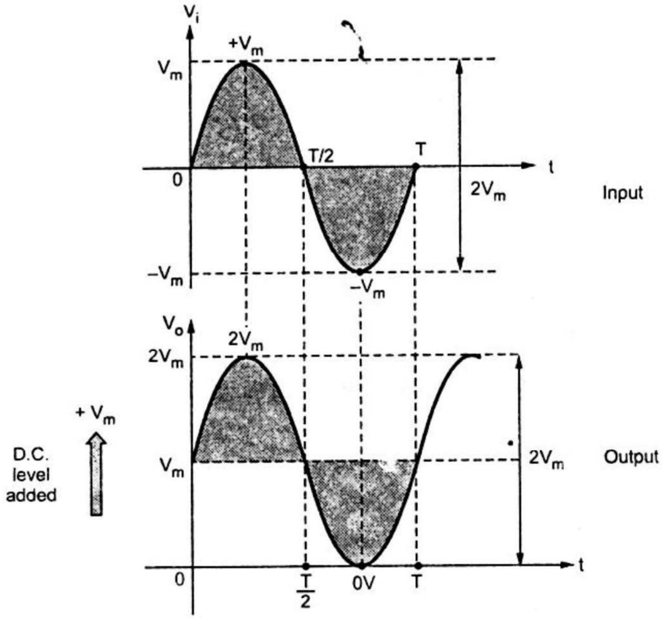
In the positive half cycle of V_i, the diode remain reverse biased. The capacitor start discharging through the resistance R_L. As the time constant R_LC is very large, it hardly gets discharged during positive half cycle of V_i. This is shown in fig.



$$V_0 = V_i + V_m \quad \ldots .for\ positive\ half\ cycle$$
$$V_0 = V_m \quad for\ V_i = 0$$
$$V_0 = 2V_m \quad for\ V_i = V_m$$
$$V_0 = 0 \quad for\ V_i = -V_m$$

Waveforms

Assuming ideal diode, the input and output waveforms are shown in the fig.



4.5 Multivibrator Introduction

An electronic circuit that generates non-sinusoidal signal are called as multivibrators. The multivibrators can be classified in to three categories

i. **AstableMultivibrators.** (OR) Free Running Multivibrators.
ii. **MonostableMultivibrators.** (OR) One Shot Multivibrators (OR) Single swing (OR) Gating Circuit (OR) delay circuit
iii. **BistableMultivibrators.** (OR) Flip-flop (OR) scale of 2 toggle circuit (OR) Eccles-Jordan Circuit (OR) Trigger Circuit.

4.5.1 AstableMultivibrators.

Astablemultivibrator is a multivibrator in which neither state is stable. There are two temporary (quasi stable) states. The circuit changes state continuously from one quasi stable to another at regular time interval without any external triggering.

4.5.2 MonostableMultivibrators.

This has only one stable state. When a pulse is applied to the input circuit, the circuit state is changed suddenly to unstable state for a predetermined time after which the circuit retuned to its original state automatically.

4.5.3 BistableMultivibrators.

It has two stable states. When an external trigger is applied the circuit changes suddenly from one stable state to another.

4.6 Collector Coupled AstableMultivibrator

A free running multivibrator has no stable states, but the circuit has two quasi stable states. When transistor $T_1$is ON and transistor T_2 is OFF and transistor $T_1$is OFF and transistor T_2 is ON and it makes periodic transitions between these states without any external triggering.

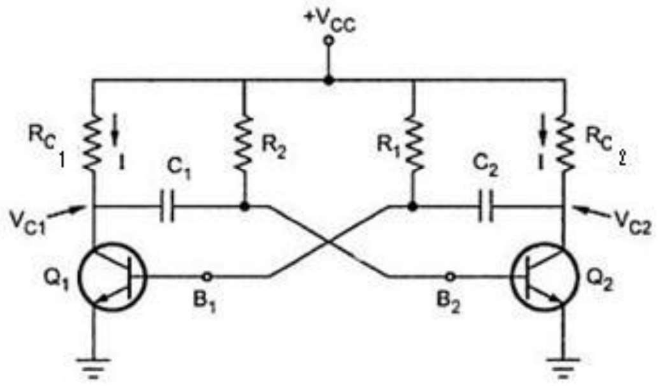


Fig: Collector Coupled AstableMultivibrator

The $R_{C1} and R_{C2}$ arethe collector resistance for transistor T_1&T_2 respectively. C_1 and $C_2$are coupling coupling capacitors, $R_{B1}and$ R_{B2} are biasing resistance.

Under symmetrical condition$R_{C1} = R_{C2}$; $R_{B1} = R_{B2}$; $C_1 = C_2$. The component in one half of the circuit are considered to be equal to their component in the other half, thus the net current in a circuit is zero.

But in practical situation, there is some deviation in these values due to ageing of device or temperature variations etc,. The current flow in one half of the circuit greater than the other, results in which one of the transistor enter into saturated region (ON) and other transistor enter into cutoff (OFF) region.

Working

i. Assume, transistor $T_1$is in saturation (ON) and $T_2$is cutoff mode (OFF), the whole V_{CC} drop across R_{C1}

$\therefore V_{CC} = I_{C1}R_{C1}$. Apply KVL to output circuit of T_1we get,

$$V_{CC} = I_{C1}R_{C1} + V_{C1} \Longrightarrow V_{C1} = V_{CC} - I_{C1}R_{C1}$$

At point X($V_{C1} = 0$) and hence the lower end of R_{C1} is at zero and ground potential.

ii. In the above position, transistor $T_2$is cutoff. It conducts no current.

iii. When lower end of $R_{C1}$is at zero potential, the condenser C_1 start charging through R_{B1} towardsV_{cc}.

iv. When the voltage acrossC_1rises more than 0.7V it is also applied to the base of T_2 thus the transistor T_2 is forward biased and hence start conducting. The transistor $T_2$is soon driven to saturation.

v. When transistor $T_2$is in saturation position, the voltage V_{C2}becomes almost zero.

$\therefore V_{CC} = I_{C2}R_{C2}$ Apply KVL to output circuit of T_1we get,

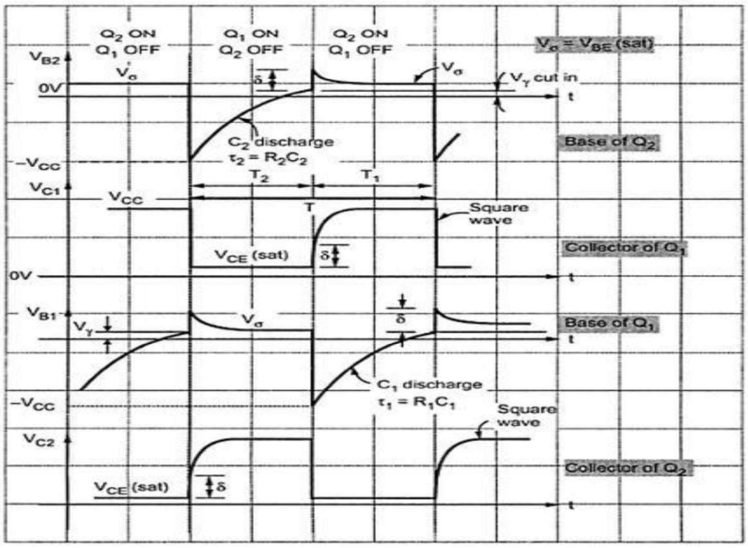
$$V_{CC} = I_{C2}R_{C2} + V_{C2} \Longrightarrow V_{C2} = V_{CC} - I_{C2}R_{C2}$$

The potential at the lower end of R_{c2} decreases from V_{CC} to zero volts. This potential decrease is applied to the base of transistor T_1 through C_2.consequently$T_1$is pulled out of saturation and it soon driven to cutoff.

vi. In the cutoff position of $T_1$the lower end of R_{C2} is at zero potential and hence the condenser C_2starts charging through R_{B1} towards V_{cc}.

vii. When the voltage across C_2 rises more than 0.7V it is also applied to the base of T_1 thus the transistor T_1 is forward biased and hence start conducting.

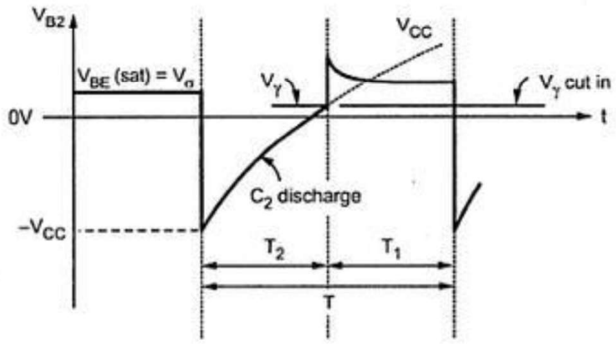
viii. The whole cycle is repeated thus output of square waveform is generated without any input is applied.



Waveforms of collector coupled astable multivibrator

Calculation of switching time and frequency of oscillation

For deriving the expression for time period T which is $T_1 + T_2$, consider the waveform at the base of any transistor shown in figure.



The capacitor C_2 discharges exponentially and the voltage V_{B2} increases exponentially.

$$V_i - \ Initial\ value\ of\ V_{B2} = -V_{CC} \ldots\ldots\ldots..(1)$$

$$V_f - \ Final\ value\ of\ V_{B2} = +V_{CC} \ldots\ldots\ldots\ldots\ldots(2)$$

The voltage across capacitor is given by,

$$V_0 = V_f - (V_f - V\_i)e^{-t/\tau}$$

Where $\tau = R_2C_2$ and $V_0 = V_{B2}$

$$V_{B2} = V_{CC} - \left(V_{CC} - (-V_{CC})\right)e^{-t/R_2C_2} \ldots\ldots\ldots\ldots..(3)$$

$$V_{B2} = V_{CC} - 2V_{CC}e^{-t/R_2C_2}$$

$$V_{B2} = V_{CC}\left(1 - 2e^{-t/R_2C_2}\right) \ldots\ldots\ldots\ldots.(4)$$

We know that at switching time $t = T_2$ and $V_{B2} = V_\gamma$

Substituting in equation (4)

$$V_\gamma = V_{CC}\left(1 - 2e^{-T_2/R_2C_2}\right)$$

The best approximation to obtain $T_2 is$, $V_\gamma = 0V$

$$0 = V_{CC}\left(1 - 2e^{-T_2/R_2C_2}\right)$$

$$1 - 2e^{-T_2/R_2C_2} = 0$$

$$e^{-T_2/R_2C_2} = 0.5$$

$$ln\left(e^{-T_2/R_2C_2}\right) = ln0.5$$

$$\frac{-T_2}{R_2C_2} = -0.69$$

$$T_2 = 0.69R_2C_2$$

Similarly we can write the equation at $t = T_1$we get,

$$T_1 = 0.69R_1C_1$$

$$T = T_1 + T_2$$

$$T = 0.69R_1C_1 + 0.69R_2C_2$$

$$T = 0.69(R_1C_1 + R_2C_2)$$

$$R_1 = R_2 = R \; and \; C_1 = C_2 = C \; then$$

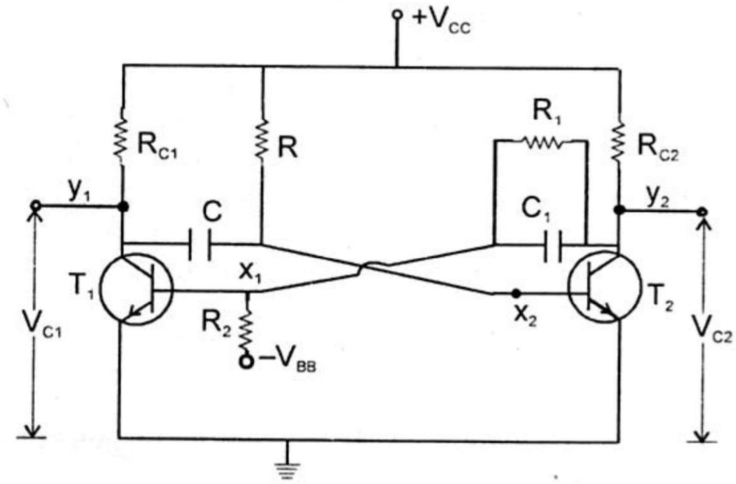
$$T = 0.69(2RC) = 1.38RC$$

Frequency of oscillation of free running multivibrator is given by,

$$F = \frac{1}{T} = \frac{1}{1.38RC} = \frac{0.7}{RC}$$

4.7 MonostableMultivibrator

A monostablemultivibrator has one stable state. ie) permanent state and other as temporary (Quasi stable). When an external trigger is applied to the input, the multivibrator changes the state from stable to quasi stable.



Assume the transistor $T_1 and\ T_2$ and their collector resistance $R_{C1} and\ R_{C2}$ are identical to each other. The output of T_2 is coupled to the input of T_1 through R_1 which is shunted with C_1.

The capacitor C_1 is a speed up capacitor to make the transition fast and reduce the transition time. Similarly the output of T_1 is coupled to the input of T_2 through C. the value of $R_C\ and - V_{BB}$ makes the transistor T_1 is OFF, when there is triggering signal is applied at X_1 results in T_2 is remains ON and multivibrator is in stable state.

Working

In this circuit an external positive trigger is applied to the input of T_1 ie) at X_1 makes T_1 enter into state, result in the output voltage of T_1 ie) V_{C1} is reduced to zero, which drives T_2 to completely cutoff, thus the voltage at Y_2 rises approximately to V_{CC}.

The device may be driven into saturation or it may operate with in its active region. In either case a current I_1 exists in R_{C1} which causes a voltage drop $I_1 R_{C1}\ at\ Y_1$ and there by increasing voltage across **capacitor C it can't charge instantaneously**. This is **quasi stable** of the multivibrator.

The circuit will remain in this state only for finite time because Y_2 is connected to V_{CC} through R_{C2} and capacitor **C start charging** towards the maximum voltage through path $V_{CC} R\ and\ ON\ transistor\ T_1$**.** Now X_2 will rise in voltage, when voltage across X_2 is equal to the cut in voltage of T_2, a generative action takes place, thus turn off T_1 and **turn ON T_2** and multivibrator to its **stable state**.

Stable State

For $t < 0$ the circuit is stable with transistor T_2 in saturation and transistor T_1 OFF. As transistor T_2 is in saturation the different voltage and current are represented as,

$$V_{C2} = V_{CEsat}\ ;\ V_{B2} = V_{BEsat}\ ;\ V_{C1} = V_{CC}$$

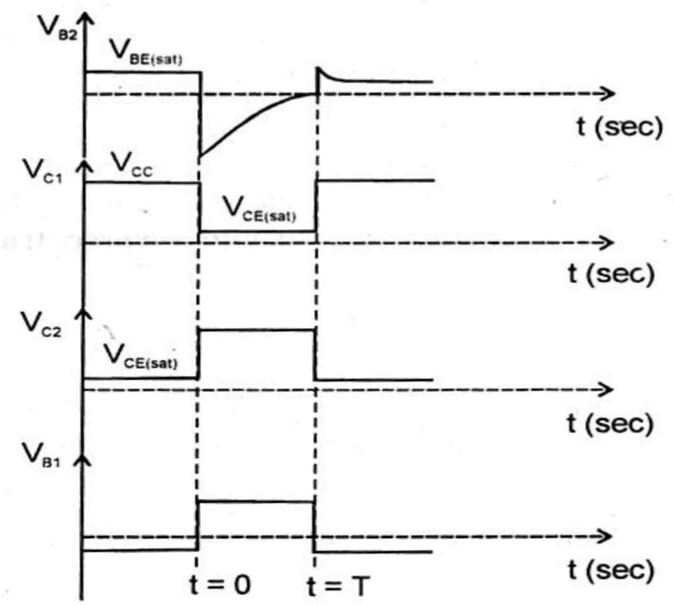
$$I_{C2} = \frac{V_{CC} - V_{CEsat}}{R_{C2}} \approx \frac{V_{CC}}{R_{C2}}\ ;\ I_{B2} = \frac{V_{CC} - V_{BEsat}}{R}$$

Quasi stable state ie) $t = 0$

Let a trigger signal is applied to X_1 at $t = 0$ the change in potential at Y_1 is immediately transmitted to B_2 through capacitor C. Now the transistor T_2 is switched off, thus the potential at Y_2 rises to almost the value V_{CC} from its stable value V_{CEsat}. This increase potential at $B_1$and the transistor T_1come into saturation. The potential at Y_1 falls by $V_{CC} - V_{CEsat}$

$$(V_{B2})_{initial} = V_{BEsat} - (V_{CC} - V_{CEsat})$$

$$(V_{B2})_{initial} = V_{BEsat} + V_{CEsat} - V_{CC}$$



At t=0, T_2 is cutoff and potential at B_2rises exponentially with time due to charging of capacitor C. the potential V_{B2} starts rising towards $+V_{CC}$ with a time constant RC. The base voltage V_{B2} can be represented as,

$$V_{B2} = (V_{B2})_f + \{(V_{B2})_i - (V_{B2})_f\}e^{-t/RC}$$

$$V_{B2} = V_{CC} + \{V_{BEsat} + V_{CEsat} - V_{CC} - V_{CC}\}e^{-t/RC}$$

$$V_{B2} = V_{CC} + \{V_{BEsat} + V_{CEsat} - 2V_{CC}\}e^{-t/RC}$$

The g**ate width or pulse width of the output pulse is defined as the time interval between OFF and ON**. In order to calculate gate width we make use of $V_{B2} = V_\gamma \quad at\ t = T$ then we have,

$$V_\gamma = V_{CC} + \{V_{BEsat} + V_{CEsat} - 2V_{CC}\}e^{-T/RC}$$

$$V_\gamma - V_{CC} = \{V_{BEsat} + V_{CEsat} - 2V_{CC}\}e^{-T/RC}$$

Taking log on both sides,

$$\log_e V_\gamma - V_{CC} = \frac{-T}{RC}\log_e\{V_{BEsat} + V_{CEsat} - 2V_{CC}\}$$

$$-T = RC\frac{\log_e V_\gamma - V_{CC}}{\log_e\{V_{BEsat} + V_{CEsat} - 2V_{CC}\}}$$

$$-T = -RC\left\{\frac{\log_e\{V_{BEsat} + V_{CEsat} - 2V_{CC}\}}{\log_e V_\gamma - V_{CC}}\right\}$$

$$T = RC\left\{\log_e\left\{\frac{2V_{CC} - V_{BEsat} - V_{CEsat}}{V_{CC} - V_\gamma}\right\}\right\}$$

$$T = RC\left\{\log_e 2 + \log_e\left\{\frac{V_{CC} - \left(\frac{V_{BEsat}+V_{CEsat}}{2}\right)}{V_{CC} - V_\gamma}\right\}\right\}$$

$$T = RC\log_e 2 + RC\log_e\left\{\frac{V_{CC} - \left(\frac{V_{BEsat}+V_{CEsat}}{2}\right)}{V_{CC} - V_\gamma}\right\}$$

At room temperature, $V_{BEsat} + V_{CEsat} = 2V_\gamma$ then

$$T = RC\log_e 2 + RC\log_e\left\{\frac{V_{CC} - \left(\frac{2V_\gamma}{2}\right)}{V_{CC} - V_\gamma}\right\}$$

$$= RC\log_e 2 + RC\log_e 1$$

$$= RC\log_e 2$$

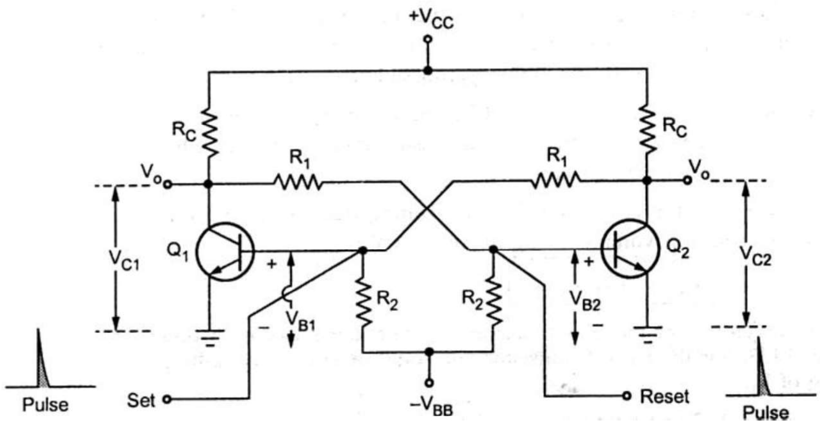
$$T = 0.69RC$$

As soon as transistor T_2begin to conduct, a regenerative action makes T_1 OFF and T_2 ON then the circuit remains in stable until another trigger is applied.

4.8 BistableMultivibrator

A bistablemultivibrator means, it has two stable states. When trigger signal is applied, the circuit changes one state to another. A bistablemultivibrator is used for the performance of many digital operations such as counting and storing the binary information. (Flip-flops or memories).

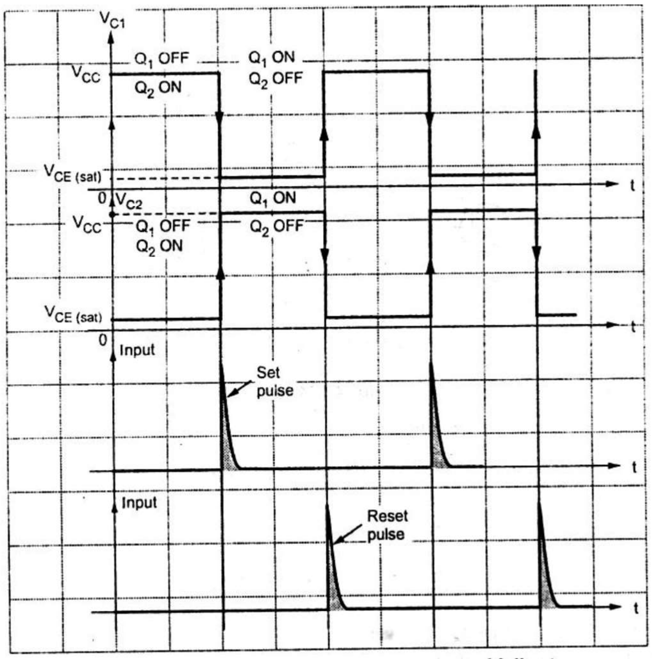
Construction



The bistablemultivibrator uses two active devices which functions as amplifier. The amplifier are coupled in such a way that one transistor is in ON state and other transistor is in OFF state.

The transistor is changing from one state to other state by applying the triggering pulse. The output of one transistor in coupled to other through direct coupling.

Working



Because of the symmetry the current and voltage of $Q_1 and\ Q_2$ is equal. For a trigger signal is applied at the collector terminal of Q_1 then the current $I_1 in\ Q_1$ is decrease hence the potential at collector terminal of Q_1increase.

This will more forward biases the transistorQ_2 hence it enter into saturation region results in which $I_2 in\ Q_2$ increase, hence collector potential of Q_2 reduces to zero it is supplied to the base of Q_1 so the transistor $Q_1$is entered in cutoff (OFF state).

This condition is remains in the same state until the next trigger pulse is applied then Q_1 enter in to ON state Q_2 enters OFF state. the two stable states of the bistablemultivibrator are,

i. Q_1 OFF and Q_2 ON
ii. Q_2 OFF and Q_1 ON

The waveform at the two transistor collectors are complement of each other and shown in fig.

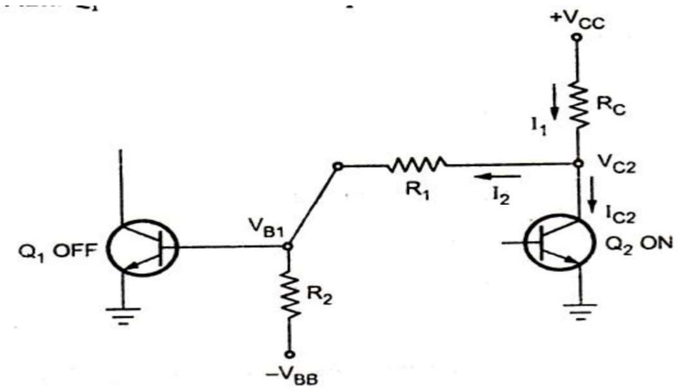
Design of fixed bias bistablemultivibrator

For the design purpose assume that the value of $V_{CC}, V_{BB}, (hfe)_{min}\ and\ I_C$values are known. Now use the following hint to get the design:

1. Assume Q_1, Q_2 to be npn transistor and assume suitable junction voltages depending on whether transistors are silicon or germanium.
2. The base current of the ONB transistor is taken as 1.5 times the minimum value.
$$I_B = 1.5(I_B)_{min}$$
3. The current through R_2 of the ON transistor is taken as one tenth of its collector current.
4. The current through R_1 towards ON transistor can be neglected and hence current drawn from supply by ON transistor can be assumed equal to the collector current of ON transistor, $I_1 = I_{C2}$ can be assumed ignoring I_2.

The unknown resistances can be obtained as below

Assume $Q_2\ ON\ and\ Q_1\ OFF$. Consider the equivalent circuit shown in fig.

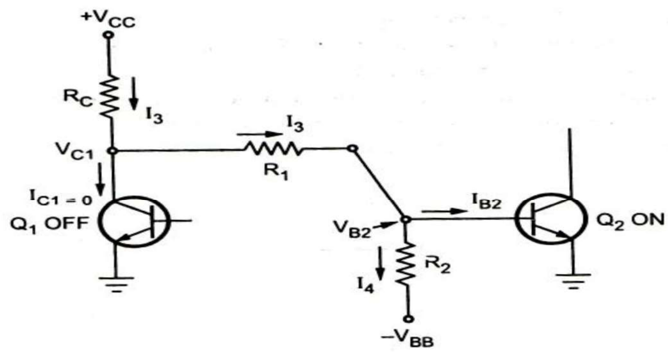


$$V_{C2} = V_{CE(sat)}$$

$$I_1 = \frac{V_{CC} - V_{CE(sat)}}{R_C} \approx I_{C2}$$

$$R_C = \frac{V_{CC} - V_{CE(sat)}}{I_{C2}}$$

So R_C can be determined.



As per hint (3)

$$I_4 = \frac{I_{C2}}{10}$$

$$I_4 = \frac{V_{B2} - (-V_{BB})}{R_2}$$

$$R_2 = \frac{V_{B2} + V_{BB}}{I_4}$$

Thus R_2 is known.

Now current through R_1 is I_3

$$I_3 = I_4 + I_{B2}$$

$$I_{B2} = 1.5(I_{B2})_{min}$$

$I_3$is known.

$$I_3 = \frac{V_{CC} - V_{B2}}{R_1 + R_C}$$

$$R_1 = \frac{V_{CC} - V_{B2}}{I_3} - R_C$$

Thus the final design can be obtained.

4.8.1 Triggering ofBistableMultivibrator

To change the stable state of the bistablemultivibrator, it is necessary to apply an suitable pulse in the circuit. There are two types of triggering used.

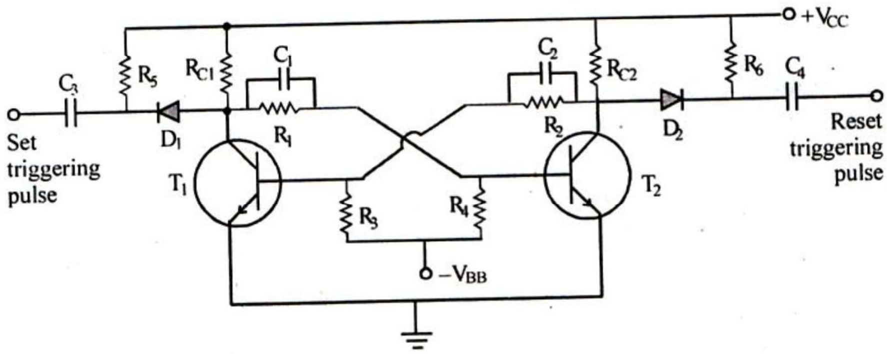
i. Asymmetrical triggering
ii. Symmetrical triggering

Asymmetrical triggering: means two trigger pulse which derived from separated source connected to two transistors T_1&T_2 individually. These are used computer logic circuits.

Symmetrical triggering:means the trigger pulse are applied only at one input and after differentiating they are directed to appropriate transistor sequentially to change the state. These type of triggering used in counter circuits.

Asymmetrical triggering

In this circuit negative triggering is used. Here triggering elements are C_3C_5&C_4C_6.



- When $T_1$is ON $D_1$is reverse biased by the drop across R_{C1} and will not transmit trigger pulse. Thus when $T_1$is ON and set pulse is blocked.
- When $T_1$is ON and $T_2$is OFF the drop across D_2 is zero and hence if the reset trigger pulse is applied and transmitted through D_2 to the base of T_1 is switched OFF and hence regenerative action T_2 start conducting.
- When T_1 is OFF drop across D_1 is zero, if the negative trigger pulse is applied at C_3makes D_1 forward biased and it transmitted to the base of transistor T_2 switch OFF and transistor T_1 is switched ON.

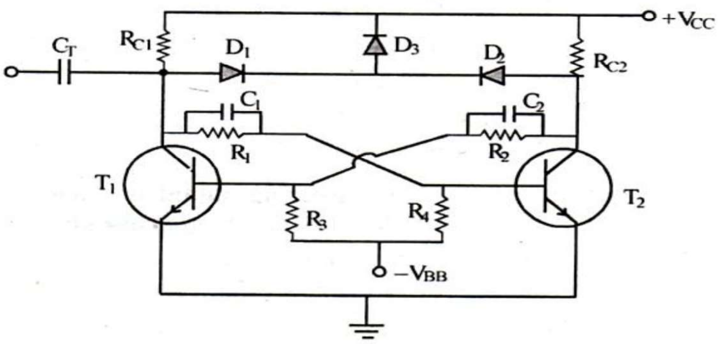
Symmetrical triggering

They are two types of symmetrical triggering namely,

i. Symmetrical collector triggering.
ii. Symmetrical base triggering.

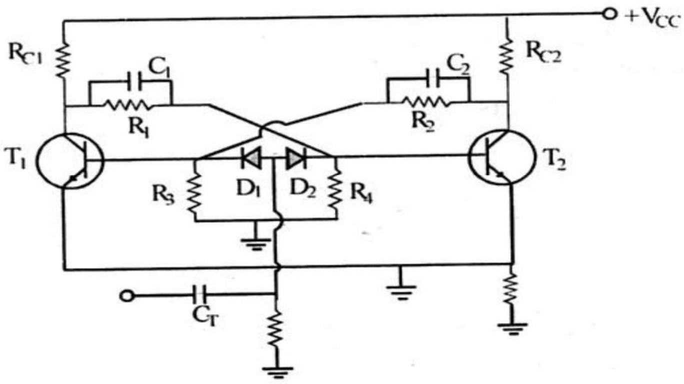
Symmetrical collector triggering

Fig shows Symmetrical collector triggering in which pulse steering diodes D_1 *and* D_2 are used.



When $T_1$is ON and $T_2$is OFF the voltage at collector of T_1 is zero and it reverse biases diode D_1. So that T_2 will not transmit the negative trigger pulse at the same time. The voltage drop collector of $T_2$is V_{CC}. D_2forward biased. So it transmits the negative pulse to the base of T_1 through R_2C_2 hence state transition takes place due to $T_1$is OFF and $T_2$is ON

Symmetrical base triggering



When the positive trigger pulse is applied to the circuit makes the OFF transistor to ON.

- When $T_1$is OFF and $T_2$is ON the respective base voltage $V_{B1}OFF\ and\ V_{B2}ON$. Thus diode D_2 more reverse biased then diode D_1
- When positive trigger pulse is applied at diode D_1 at that time D_2 gets forward biased and transistor T_1 enters saturation and T_2 becomes cutoff.
- On the arrival of next triggering pulse diode D_2 gets forward biased resulting in transistor $T_1$is OFF and $T_2$is ON

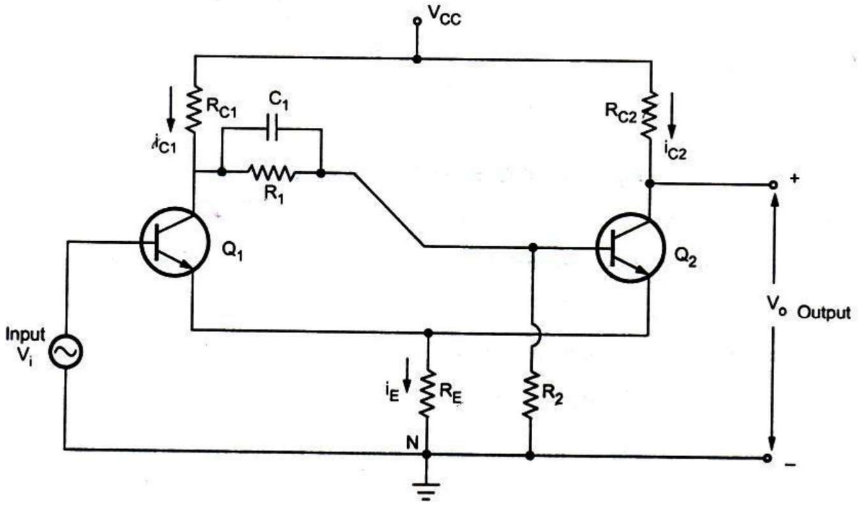
4.9 Schmitt Trigger

The Schmitt trigger is used for wave shaping circuit. It can be used for generating of a square wave form a sine wave input. The circuit has two opposite operating states as in all multivibrator circuit

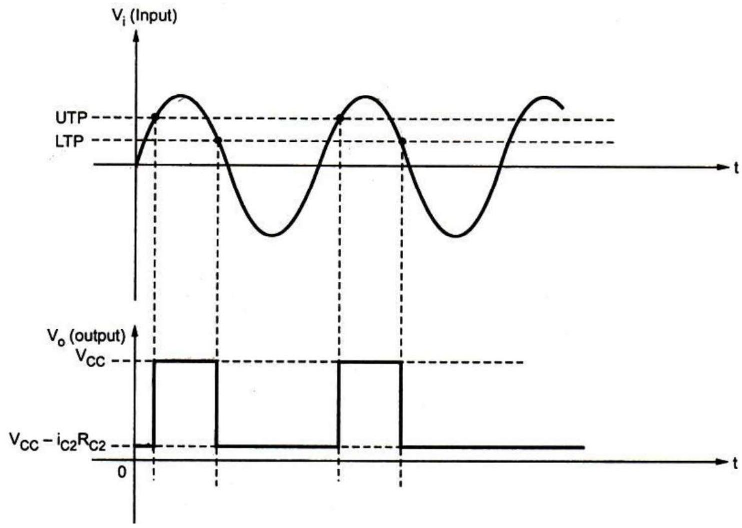
It looks like basic bistable configuration but it differs by the fact that the coupling from collector of the transistor Q_2 to the input of the first stage is missing in this circuit.

The emitter of the transistors are connected to each other and grounded through the resistance R_E.

Let there be initially no signal at input, now when power supply V_{CC} is switched ON, the transistor Q_2 start conducting. The current through R_E produce voltage drop across it. This voltage drop acts as reverse bias across emitter base junction of transistor Q_1 due to which it is cutoff. So voltage at its collector rises to V_{CC}.



The rising voltage is coupled to the base of Q_2 through R_1 which increase the forward bias at the base of Q_2 and so drives it into saturation. At this instant the collector voltage levels are $V_{C1} = V_{CC}$ and $V_{C2} = V_{CEsat}$



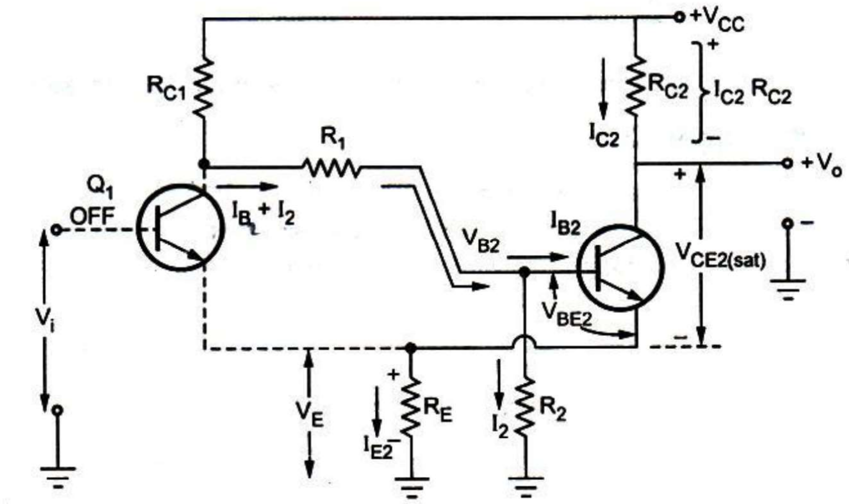
Now suppose an ac signal is applied to the input of Q_1 nothing happens until the cutin voltage. ie) Upper Threshold Point (UTP) is reached. But once the input voltage is more than UTP than transistor Q_1 conducts.

As Q_1 conducts its collector fall below V_{CC}. This fall is coupled through resistor R_1 to the base of Q_2 which reduces its forward bias and Q_2 enter into cutoff state.

Transistor Q_1 will conducts till the input falls below the cut in voltage ie) Lower Threshold Point (LTP), the emitter base junction of transistor Q_1 is reverse biased. Hence collector voltage increase towards V_{CC}. This rising voltage increase forward bias across Q_2 due to which it conduct.

Designing of Schmitt trigger

Calculation of UTP must be equal to V_{B2} when $Q_2$is On



$$V_{B2} = UTP$$
$$V_E = V_i - V_{BE1} = V_{B2} - V_{BE2}$$
$$I_{E2} = I_{C2(on)}$$
$$R_E = \frac{V_E}{I_{E2}}$$

When Q_2 is On $V_{CE2(sat)} = 0.2V$

Apply KVL in output loop,

$$I_{C2}R_{C2} = V_{CC} - V_E - V_{CE2(sat)}$$
$$R_{C2} = \frac{V_{CC} - V_E - V_{CE2(sat)}}{I_{C2(on)}}$$

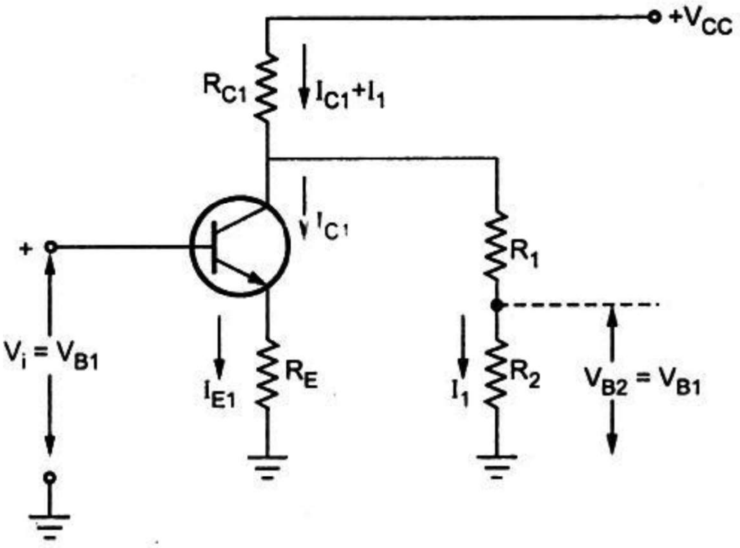
R_2 resistance current is one tenth of its emitter current.

$$I_2 = \frac{I_{E2}}{10}$$
$$R_2 = \frac{V_{B2}}{I_2}$$

Now

$$I_{B2} = \frac{I_{C2}}{h_{femin}}$$
$$I_2 + I_{B2} = \frac{V_{CC} - V_{B2}}{R_{C1} + R_1}$$
$$R_{C1} + R_1 = \frac{V_{CC} - V_{B2}}{I_2 + I_{B2}}$$

Calculation of LTP when Q_1 ON, Q_2 is OFF



$$\boldsymbol{V_i = V_{B2} = V_{B1}}$$
$$V_i = LTP = V_{B2}$$
$$I_1 = \frac{V_{B2}}{R_2}$$
$$I_{C1} = I_{E1} = \frac{V_{B1} - V_{BE1}}{R_E}$$

Apply KVL in output loop,

$$V_{CC} = R_{C1}(I_{C1} + I_1) + I_1(R_1 + R_2)$$
$$V_{CC} = R_{C1}I_{C1} + R_{C1}I_1 + R_1I_1 + R_2I_1$$
$$V_{CC} = R_{C1}I_{C1} + I_1(R_{C1} + R_1) + R_2I_1$$
$$R_{C1}I_{C1} = V_{CC} - I_1\{(R_{C1} + R_1) + R_2\}$$
$$\boldsymbol{R_{C1} = \frac{V_{CC} - I_1\{(R_{C1} + R_1) + R_2\}}{I_{C1}}}$$
$$\boldsymbol{R_1 = (R_{C1} + R_1) - R_{C1}}$$

This completes the design.

4.10 Example with Solutions

Example 1: Design a Schmitt trigger circuit to have $V_{CC} = 12V$, UTP=5V, LTP=3V, and $I_C = 1mA$ using two silicon NPN transistor with $h_{fe(min)} = 5V$ and $I_2 = 0.1I_{C2}$.

Solution:

$$UTP = 5V, \quad LTP = 3V, \quad V_{CC} = 12V$$
$$V_i = V_{B2} = UTP = 5V when Q_2 is ON$$
$$V_E = V_i - V_{BE1} = V_{B2} - V_{BE2} = 5 - 0.7 = 4.3V$$
$$I_{E2} = I_{C2(on)} = 1mA$$

$$R_E = \frac{V_E}{I_{E2}} = \frac{4.3}{1 \times 10^{-3}} = 4.3K\Omega$$

When $Q_2$is On$V_{CE2(sat)} = 0.2V$

$$R_{C2} = \frac{12 - 4.3 - 0.2}{1 \times 10^{-3}} = 7.5K\Omega$$

$$I_2 = 0.1I_{C2} = \frac{I_{E2}}{10} = \frac{1}{10} \times 1 \times 10^{-3} = 1 \times 10^{-4}A$$

$$R_2 = \frac{V_{B2}}{I_2} = \frac{5}{1 \times 10^{-4}} = 50K\Omega$$

Now

$$I_{B2} = \frac{I_{C2}}{h_{femin}} = \frac{1 \times 10^{-3}}{100} = 10\mu A$$

$$R_{C1} + R_1 = \frac{V_{CC} - V_{B2}}{I_2 + I_{B2}} = \frac{12 - 5}{1 \times 10^{-4} + 10 \times 10^{-6}} = 63.6363 \times 10^3$$

$$V_{B2} = V_{B1} = LTP = 3V and Q_1 is ON$$

$$V_i = LTP = V_{B2}$$

$$I_1 = \frac{V_{B2}}{R_2} = \frac{3}{50 \times 10^3} = 60\mu A$$

$$I_{C1} = I_{E1} = \frac{V_{B1} - V_{BE1}}{R_E} = \frac{3 - 0.7}{4.3 \times 10^3} = 5.348 \times 10^{-4}A$$

$$V_{CC} = R_{C1}I_{C1} + I_1(R_{C1} + R_1) + R_2I_1$$

$$12 = R_{C1} \times 5.348 \times 10^{-4} + 60 \times 10^{-6} \times 63.6363 \times 10^3 + 60 \times 10^{-6} \times 50 \times 10^3$$

$$R_{C1} = 9.6892\ K\Omega$$

$$R_1 = (R_{C1} + R_1) - R_{C1} = 63.6363 \times 10^3 - 9.6892 \times 10^3 = 53.947K\Omega$$

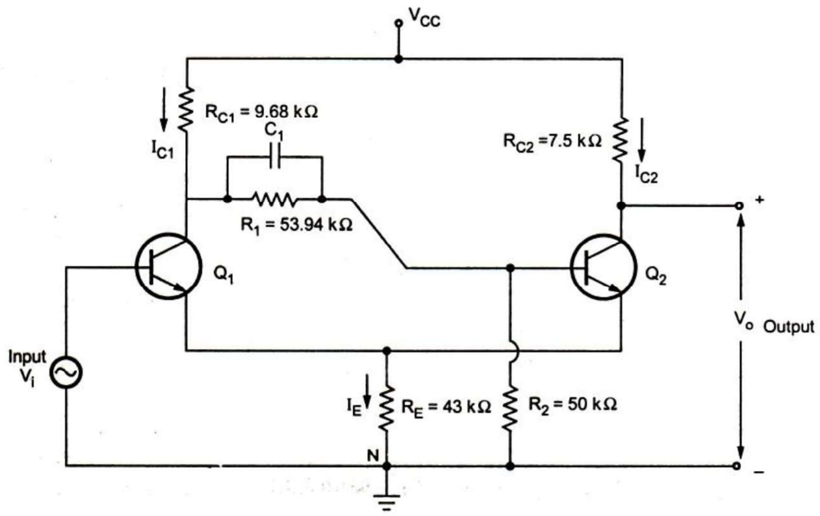
When $Q_2$is ON

$$V_0 = V_{CC} - I_{C2(ON)}R_{C2} = 12 - 1 \times 10^{-3} \times 7.5 \times 10^3 = 4.5V$$

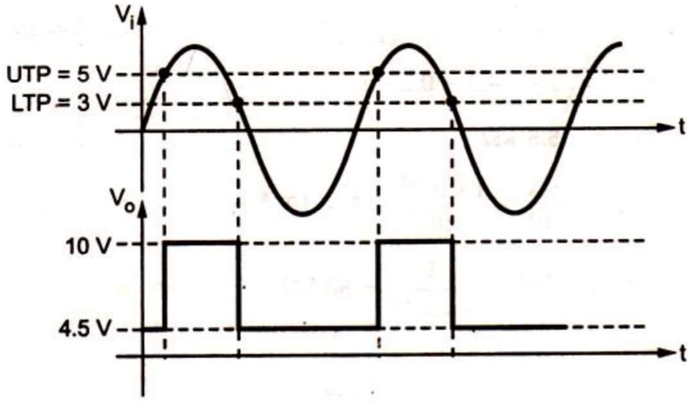
When $Q_2$is OFF

$$V_0 = V_{CC} = 12V$$

The designed circuit is,



The input and output waveforms are,



Example 2: Determine the period and frequency of oscillation for an astablemultivibrator with component values $R_1 = 1K\Omega, \mathrm{R}_2 = 5K\Omega, \mathrm{C}_1 = 0.1\mu A and C_2 = 0.03\mu A$.

Solution:

The period is $T = 0.69(R_1C_1 + R_2C_2)$

$$= 0.69(1 \times 10^3 \times 0.1 \times 10^{-6} + 5 \times 10^3 \times .03 \times 10^{-6})$$

$$= 0.1725 msec$$

$$f = \frac{1}{T} = \frac{1}{0.1725 \times 10^{-3}}$$

$$= 5.78 KHz$$

Example 3: Determine the value of capacitor to be used in an astablemultivibrator to provide a train of pulse 2µsec width at a repetition rate of 75KHz with $R_1 = R_2 = 10K\Omega$.

Solution:

Each pulse width is 2µsec

$$T_1 = 2\mu sec$$

$f = 75KHz$

$T = \frac{1}{f} = \frac{1}{75 \times 10^3} = 13.33\mu sec$

Now $T = T_1 + T_2$

$T_2 = T - T_1 = 13.33 - 2$

$= 11.33\mu sec$

$T_1 = 0.69R_1C_1$

$2 \times 10^{-6} = 0.69 \times 10 \times 10^3 C_1$

$C_1 = 289.85pF$

$T_2 = 0.69R_2C_2$

$11.33 \times 10^{-6} = 0.69 \times 10 \times 10^3 C_2$

$C_2 = 1.642nF$

Example 4: If $R_1 = 10K\Omega$ and $R_2 = 5K\Omega$and $C_1 = C_2 = 0.1\mu F$, find the frequency and duty cycle of the astable output.

Solution:

$T_1 = 0.69R_1C_1 = 0.69 \times 10 \times 10^3 \times .1 \times 10^{-6}$

$= 0.69msec$

$T_2 = 0.69R_2C_2 = 0.69 \times 5 \times 10^3 \times .1 \times 10^{-6}$

$= 0.345msec$

$T = T_1 + T_2 = 1.035msec$

$f = \frac{1}{T} = \frac{1}{1.035 \times 10^{-3}}$

$= 966.18Hz$

$Dutycycle = \frac{T_2}{T_1 + T_2} = \frac{0.345}{0.69 + 0.345}$

$= 0.33 = 33.3\%$

4.11 Two Marks Question and Answers

1. What is High pass RC circuit? Why it is called high-pass filter?
   i. A simple circuit consisting of a series capacitor and a shunt resistor is called high pass RC circuit.
   ii. At very high frequencies the capacitor acts as a short circuit and all the higher frequency components appear at the output with less attenuation than the lower frequency components. Hence this circuit is called high-pass circuit.
2. Why high-pass RC circuit is called Differentiator?
   High-pass RC circuit gives an output waveform similar to the first derivative of the input waveform. Hence it is called Differentiator.
3. What is Low pass RC circuit? Why it is called low-pass filter?
   i. A simple circuit consisting of a series resistor and a shunt capacitor is called Low pass RC circuit.
   ii. At very high frequencies the capacitor acts as a virtual short circuit and output falls to zero. Hence this circuit is called low-pass filter
4. Why low-pass RC circuit is called Integrator?