Unit-III Multivibrators (MV) →

Multivibrators are non-sinusoidal oscillators. They are also referred as relaxation oscillators. These devices are very useful as pulse generating, storing and counting circuits. They are basically two stage amplifiers with positive feedback from the output of one amplifier to the input of the other. This feedback is supplied in such a manner that one transistor is driven in to saturation and the other to cutoff. It is followed by new set of conditions in which the saturated transistor is driven to cutoff and cutoff transistor is driven to saturation.

There are three basic types of Multivibrators by the type of coupling network.

1. Astable Multivibrator. (AMV)
2. Monostable Multivibrator (MMV)
3. Bistable Multivibrator. (BMV)

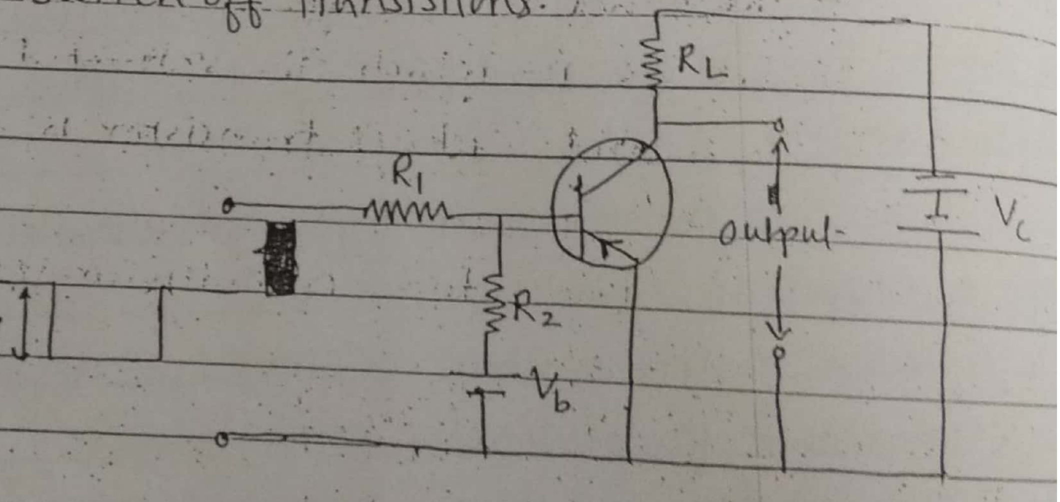
The multivibrators are used –

① as frequency dividers.
② as sawtooth wave generators
③ as square wave and pulse generators.
④ as a standard frequency source when synchronised by external crystal oscillator.
⑤ for many specialised uses in radar and TV circuits.
⑥ as memory elements in computers.

Transistor as a switch:-

An ideal switch is one which offers infinite resistance when open and offers zero resistance when closed. A transistor can be used as a switch in electronic circuits. A transistor when in OFF state offers very large resistance and in ON state offers a low resistance. Hence, it can be used as a switch.

The following circuit explains about switch on and switch off transistions.



When there is no input voltage the base-emitter junction of the transistor is reverse biased due to the battery V_b in the base circuit. The current in R_2 is the reverse saturation current of a junction and the base to emitter voltage is given by,

$$V_{be} = V_b - R_2 \cdot I_{CO}$$

When the input voltage falls suddenly by Vi the transistor does not go in to active state immediately because proper bias voltages have to be established across the junctions of the transistor. The time interval between the instant of switching on and the instant the transistor goes in to active state is called delay time. It is the time required to charge the base emitte and base collector capacitances. When the transistor goes in to active state the output current increases exponentially with time due to the capacitance existing at the input terminals of the transistor. The time required for the output current to rise from 10 to 90 percent of the maximum value is called rise time or turn-on time.

In simple words, A switch is a device that can turn ON or OFF current in an electrical circuit with the help of electronic device here transistor. A transistor can be used as a switch by driving it back and forth between saturation and cutoff

The mode of operating between saturation and cutoff is shown below-

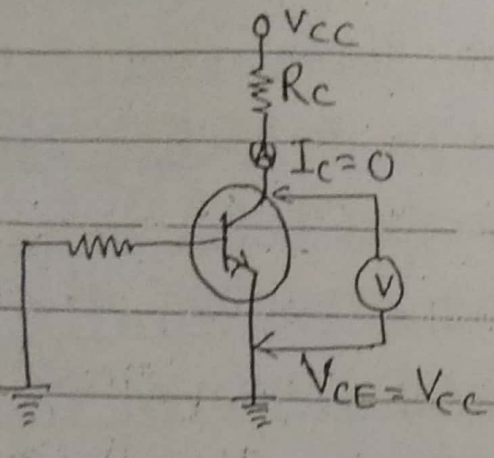


fig ①

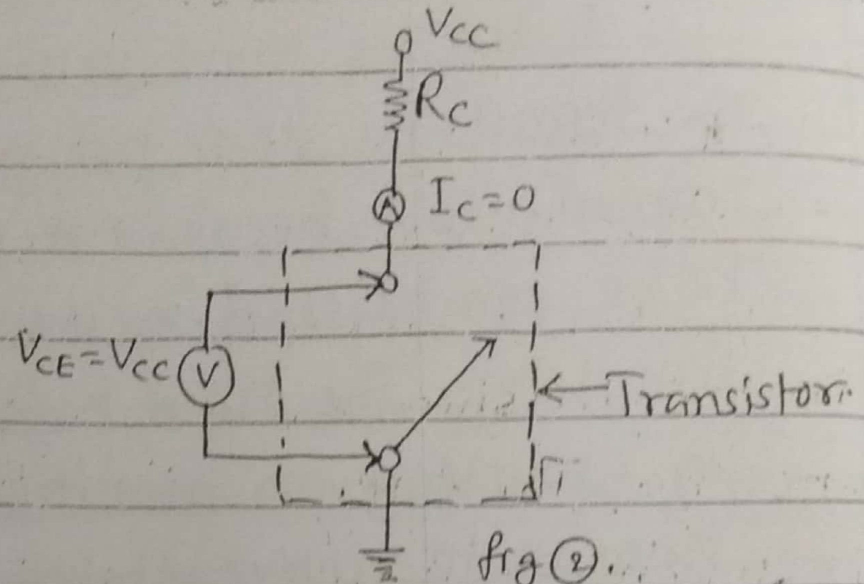


fig ②.

① When the base input voltage is enough negative the transistor is cut-off and no current flows in collector load R_C. As a result, there is no voltage drop across R_C and the output voltage is ideally V_{CC} i.e. $I_C = 0$ and $V_{CE} = V_{CC}$

[A little leakage current always flows even when the base input voltage is negative or zero.

∴ Output Voltage $= V_{CC} - I_{leakage} \cdot R_C$

If $I_{leakage} = 0$ then output voltage $= V_{CC}$.

This condition is similar to that of an open switch shown in fig ② (i.e. OFF state).

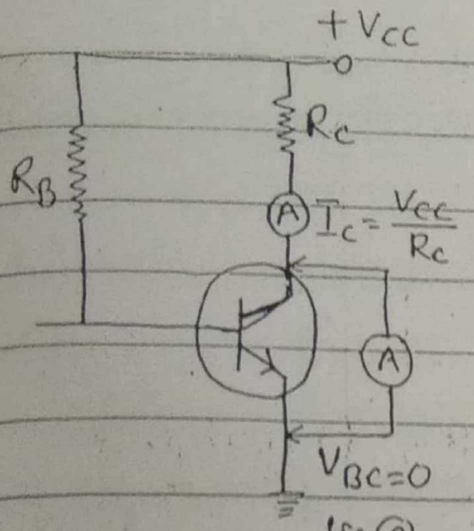


fig ③

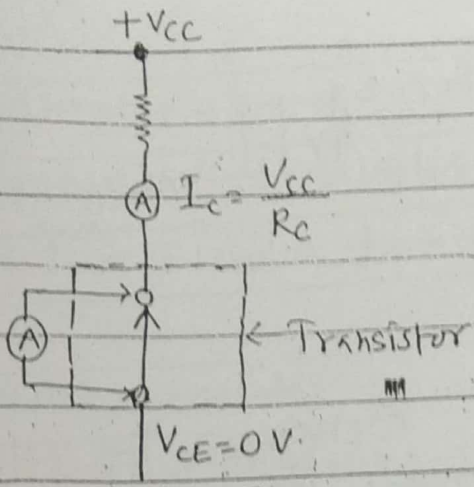


fig ④

② When the input base voltage is positive enough so that transistor saturates, then $I_{C(sat)}$ will flow through R_C. Under this condition, the entire V_{CC} will drop across collector load R_C and output voltage is ideally zero.

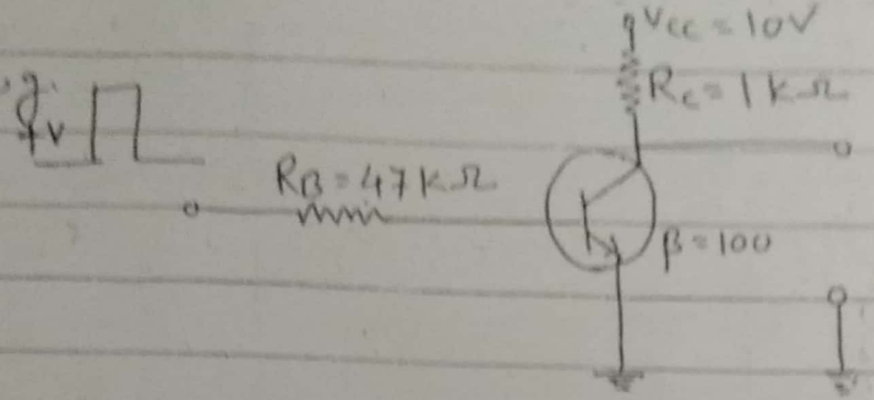
i.e. $I_C = I_{C(sat)} = \frac{V_{CC}}{R_C}$ and $V_{CE} = 0$

This condition is similar to that of a closed switch i.e. (ON-state) as shown in fig ④.

In other words, if the input base voltages are enough negative and positive, the transistor will be driven between cut-off and saturation. Thus a transistor can be used as a switch.

A transistor which is used as a switch is called Switching transistor. It has two states ① ON-state or when collector saturation current flows through the load and ② OFF-state or when collector leakage current flows through the load.

For. e.g.



Determine the value of input voltage (+V) required to saturate the transistor switch.

Assuming the transistor is ideal –

$$I_{c(sat)} = \frac{V_{cc}}{R_c} = \frac{10V}{1k\Omega} = 10\,mA$$

$$\therefore I_B = \frac{I_{c(sat)}}{\beta} = \frac{10\,mA}{100} = 0.1\,mA$$

Now, $+V = I_B \cdot R_B + V_{BE}$

$= (0.1\,mA)(47\,k\Omega) + 0.7$

$= 4.7 + 0.7$

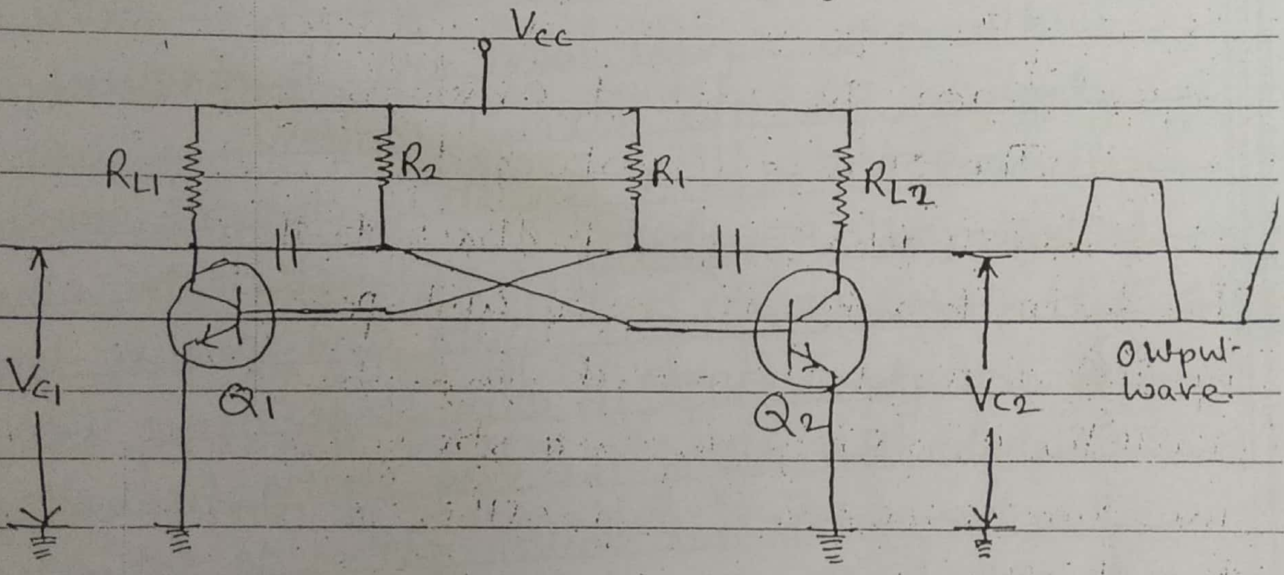
$= 5.4$ Volt.

Hence, In order to saturate a transistor we require a +5.4 Volt.

Transistorized Astable Multivibrator –

The circuit of a symmetrical collector coupled Astable multivibrator using two similar transistors is shown in figure.

A multivibrator which generates square wave of its own (i.e. without any external triggering pulse) is known as an astable or free running multivibrator.



A means not. Hence astable means that it has no stable state. The astable multivibrator has no stable state. It switches back and forth from one state to the other, remaining in each state for a time determined by circuit constants. In other words, at first one transistor conducts (i.e. ON state) and the other stays in the OFF state for some time. After this period of time, the second transistor is automatically turned ON and the first transistor is turned OFF. Thus, the multivibrator will generate a square wave output of its own. The width of the square wave and its frequency will depend upon the circuit constants.

The circuit consists of two CE amplifier stages, each providing a feedback to the other. The feedback ratio is unity and positive because of 180^0 phase shift in each stage. Hence the circuit oscillates. Because of the very strong feedback signa the transistors are driven either to saturation or to cut-off. They do not work on the linear region of their characteristics.

The transistor Q_1 is forward-biased by V_{cc} and R_1, whereas Q_2 is forward biased by V_{cc} and R_2. The collector-emitter voltages of Q_1 and Q_2 are determined by R_{L1} and R_{L2} respectively together with V_{cc}. The output of Q_1 is coupled to the input of Q_2 by C_2

whereas output of Q_2 is coupled to Q_1 by C_1. The output can be taken either from point A or B

Circuit operation –

The circuit operates in two states and phase reversed with respect to each other due to feedback.

(1) When Q_1 is ON, Q_2 is OFF and
(2) When Q_2 is ON, Q_1 is OFF.

When the power is switched on by applying V_{CC}, one of the transistors will start conducting before the other (or slightly faster than the other). because the characteristics of two similar transistor is not exactly alike. If Q_1 starts conducting before Q_2, the feedback system is such that Q_1 will be rapidly driven to saturation and Q_2 to cut off. The process follows the sequence –

① Since Q_1 is in saturation, whole of V_{CC} drops across R_{L1}. Hence $V_{C1} = 0$ and point A is at zero or ground potential.

② Since Q_2 is in cut off i.e. it conducts no current there is no drop across R_{L2}. Hence point B is at V_{CC}.

③ Since A is at 0 Volt, C_2 starts to charge through R_2 towards V_{CC}.

(4) When voltage across C_2 rises sufficiently i.e. mo than 0.7 Volt. It biases Q_2 in the forward direction so that it starts conducting and is soon driv to saturation.

(5) V_{C2} decreases and becomes almost zero when Q_2 gets saturated. The potential of point B decreases from V_{CC} to almost 0 V. This poten decrease (negative swing) is applied to the of Q_1 through C_1. Hence, Q_1 is pulled out of saturation and is soon driven to cut off.

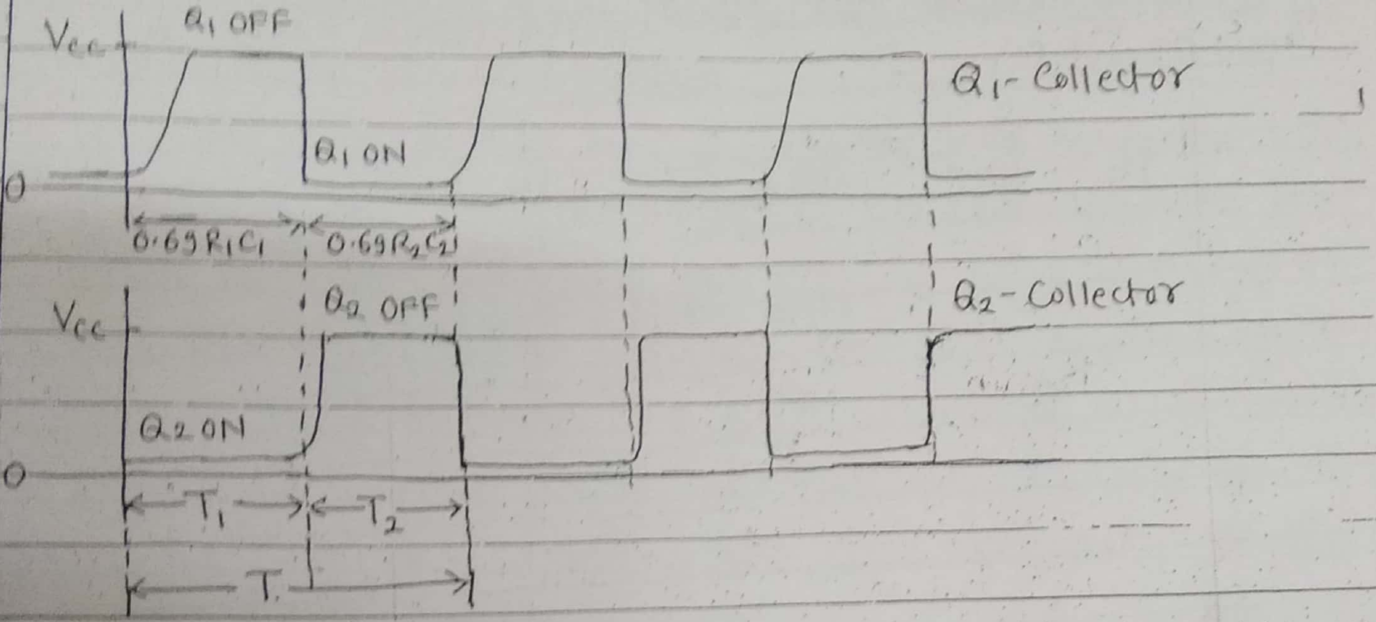
(6) Since, now point B is at 0 V, C_1 starts char through R_1 towards the voltage V_{CC}.

(7) When voltage of C_1 increases sufficiently, Q_1 b forward-biased and starts conducting.

In this way, the whole cyle is repeated.

Thus, the circuit alternates between a sta in which Q_1 is ON and Q_2 is OFF and a state which Q_1 is OFF and Q_2 is ON. The time in each state depends on RC values. Since each transistor is driven alternately into saturati and cut off, the voltage waveform at either colle (i.e. points A and B) is essentially a square waveform with a peak amplitude equal to Vc

The output wave form of astable multivibrator is shown below –



The OFF time for transistor Q_1 is $T_1 = 0.69 R_1 C_1$.
and OFF time for transistor Q_2 is $T_2 = 0.69 R_2 C_2$.
Hence, Total time period of the wave is –

$$T = T_1 + T_2$$
$$= 0.69(R_1 C_1 + R_2 C_2).$$

If $R_1 = R_2 = R$ and $C_1 = C_2 = C$ i.e the two stages are symmetrical then, $T = 1.38 \cdot RC$.

The frequency of oscillation is given by reciprocal of time period T –

$$\therefore f = \frac{1}{T} = \frac{1}{1.38 \times RC} = \frac{0.7}{RC}$$

Values of β:–

To produce oscillations, the transistors must saturate for which minimum values of β should be –

$$\beta_1 = \frac{R_1}{R_{L1}} \quad \text{and} \quad \beta_2 = \frac{R_2}{R_{L2}}$$

If $R_1 = R_2 = R$ and $R_{L1} = R_{L2} = R_L$ then.

$$\beta_{min.} = \frac{R}{R_L}$$

Problem – In a ~~a~~ astable multivibrator – $R_1 = R_2 = 10K$; $C_1 = C_2 = 0.01 \mu fd$ and $R_{L1} = R_{L2} = 1K$ Find – ① frequency of circuit oscillation and ② minimum value of transistor β.

Ans –

Since, $T_1 = T_2 = 0.69 \cdot RC$

$$= 0.69 \times 10 \times 10^3 \times 0.01 \times 10^{-6}$$

$$= 69 \mu s.$$

$\therefore T = T_1 + T_2 = 2 \times 69 \mu s. = 138 \mu s.$

$$\therefore f = \frac{1}{T} = \frac{1}{138 \times 10^{-6}} = \underline{7.25 \, kHz}$$

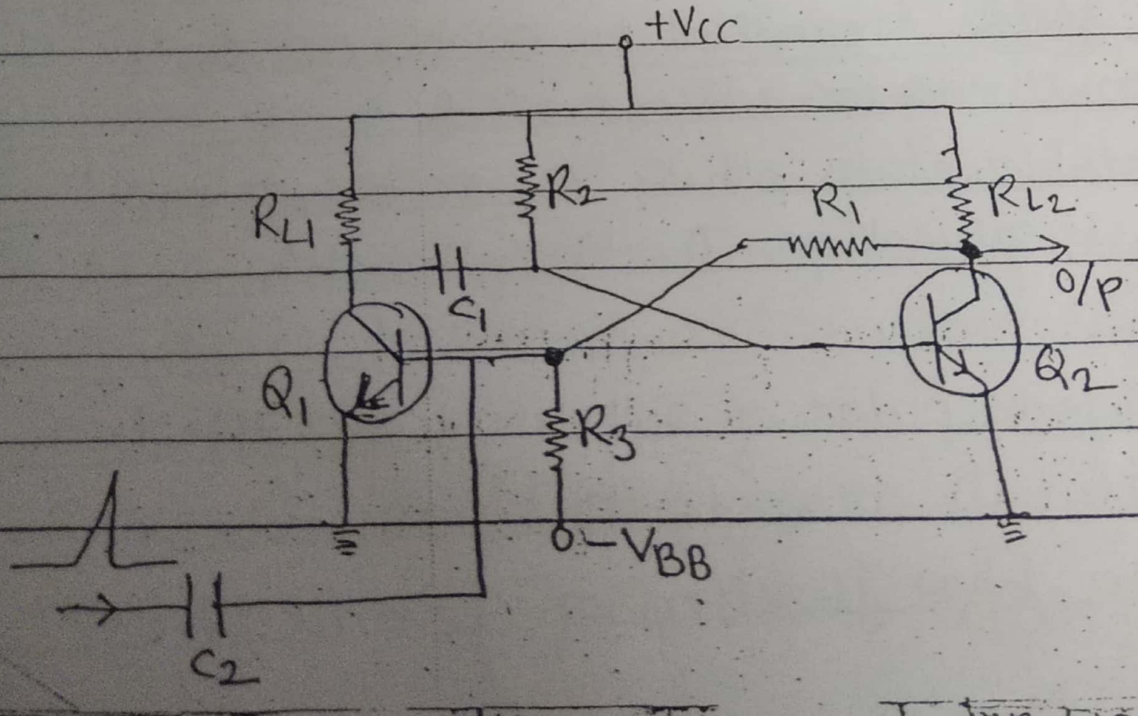
and $\beta = \frac{R}{R_L} = \frac{10 \times 10^3}{1 \times 10^3} = \underline{10}$

Monostable Multivibrator -

A multivibrator in which one transistor is always conducting (i.e. in the ON state) and the other is non-conducting (i.e. in the OFF state) is called a monostable multivibrator.

A monostable multivibrator has only one stable state. i.e. If one transistor is conducting and the other is non-conducting, the circuit will remain in this position till an external pulse is applied to the circuit to interchange the state. However, after certain time, the circuit will automatically switch back to the original stable state and remains there untill another pulse is applied. Thus, only external pulse will cause it to generate the square wave pulse.

The figure shows the circuit of transistor monostable multivibrator.



It consists of two similar transistors Q_1 and Q_2 with equal collector loads i.e. $R_{L1} = R_{L2}$. The values of V_{BB} and R_3 are such as to reverse bias Q_1 and keep it at cutoff. The collector supply V_{CC} and R_2 forward bias Q_2 and keep it at saturation. The input pulse is given through C_2 to obtain the square wave. The output can be taken from Q_1 or Q_2 i.e. point A or B. In this multivibrator, a single narrow input trigger pulse produces a single rectangular pulse whose amplitude, pulse width and wave shape depends upon the values of circuit components rather than upon the trigger pulse.

The initial stable state is represented by-

① Q_2 conducting at saturation and ② Q_1 is in cutoff.

When trigger pulse is applied to Q_1 through C_2, monostable multivibrator will switch to its opposite unstable state where Q_2 is cutoff and Q_1 conducts at saturation. The circuit action is as follows-

① If positive trigger pulse of sufficient amplitude is applied, it will override the reverse bias of the emitter-base junction of Q_1 and give it a forward bias, Hence Q_1 will start conducting.

② As Q_1 conducts, its collector voltage falls due to voltage drop across R_{L1}. It means that potential of point A falls (negative-going-signal). This negative going voltage is fed to Q_2 via C_1 where it decreases its forward bias.

③ As collector current of Q_2 starts decreasing, potential of point B increases (positive going signal), due to lesser drop over R_{L2}. Hence, soon Q_2 comes out of conduction.

④ The positive going edge signal at point B is fed via R_1 to the base of Q_1 where it increases its forward bias further. As Q_1 conducts more, potential of point A ~~pro~~ approaches 0 V.

⑤ This action is cumulative and ends with Q_1 conducting at saturation and Q_2 cut off.

Circuit Action to Return to initial Stable State –

⑥ Since point A is at almost 0V, C_1 starts to dischang through saturated Q_1 to ground.

⑦ As C_1 dischanges, the negative potential at the base of Q_2 is decreased, and further Q_2 is pulled out of cut off.

⑧ Since Q_2 conducts further, a negative going signal from point B via R_f drives Q_1 into cut off.

Thus, the circuit reverts to its original state with Q_2 conducting at saturation and Q_1-cutoff. It remains in this state till another trigger pulse comes. The entire cycle repeats itself for another pulse.

The output is taken from the collector of Q_2 i.e. point B. It can also be taken from point A of Q_1. The width of this pulse is determined by the time constant of $C_1 R_2$. Since this multivibrator produces one output pulse for every input trigger pulse it receives, it is called mono- or one-shot multivibrator.

The width or duration of the pulse is given by-

$$T = 0.69\, C_1 \cdot R_2$$

It is also known as one shot period.

Uses- It is used in-

① pulse generator circuit to produce a pulse delayed by a time T with respect to the input pulse.

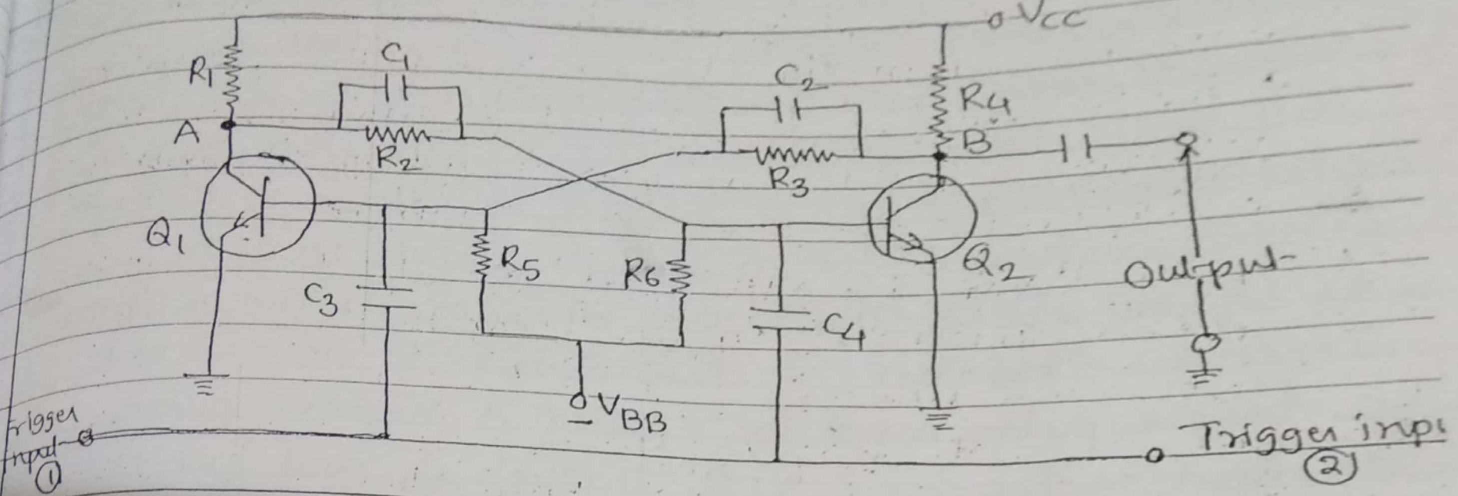
② It is used in computers and telecommunication systems to control the operation or generate pulses wherever required.

Bi-stable multi vibrator -

A multivibrator which has both the states stable is called a bistable multivibrator. It requires the application of an external triggering pulse to change the operation from either one state to the other. Thus, one pulse is used to generate half cycle of square wave and another pulse to generate the next half cycle of square wave. It is also known as a flip-flop multivibrator because of the two possible states.

The bistable multivibrator has both the states stable. It will remain in whichever state it happens to be untill a trigger pulse is applied; to switch, to the other state. Suppose at any particular instance, transistor Q_1 is conducting and transistor Q_2 is at cut off. If it left to itself, the bistable multivibrator will stay in this position forever. If an external pulse is applied to the circuit in such a way that Q_1 is cut-off and Q_2 is turned on. The circuit will stay in this new position. An another trigger pulse is then required to switch the circuit back to its original state.

The figure shows the circuit of a typical transistor bistable multivibrator. It consists of two



identical CE amplifier stages with output of one fed to the input of the other. The feedback is coupled through resistors (R_2 and R_3). The resistors R_2 and R_3 are shunted by capacitors C_1 and C_2. The main purpose of capacitors C_1 and C_2 is to improve the switching characteristics of the circuit by passing the high frequency components of the square wave. This allows fast rise and fall times and produces distortionless square wave at the output.

Circuit operation-

When Vcc is applied, one transistor will start conducting slightly ahead of the other due to some differences in the characteristics of the transistor. This will drive one transistor to saturation and the other to cut off as it happens in astable multivibrator. Let Q_1 is turned ON and Q_2 is cutoff i.e. OFF. If left to itself the circuit will stay in this condition. In order to switch the multivibrator to its other state, a trigger pulse must be applied. A negative pulse applied to the base of Q_1 through C_3 will cut it off or a positive pulse is applied to the base of Q_2 through C_4 will cause it to conduct.

Suppose a negative pulse of sufficient magnitude is applied to the base of Q_1 through C_3. This will reduce the forward bias on Q_1 and cause a decrease in its collector current and an increase in collector voltage. The rising collector voltage is coupled to the base of Q_2 where it forward biases the base-emitter junction of Q_2. This will cause an increase in its collector current and decrease in collector voltage. The decreasing collector voltage is applied to the base of Q_1 where it further reverse biases the base-emitter junction of Q_1 to decrease its collector current. With this set of actions, Q_2 is quickly driven to saturation and Q_1 to cutoff. The circuit will now remain stable in this state until a negative trigger pulse at Q_2 (or a positive trigger pulse at Q_1) is applied to change this state.

Since one trigger pulse causes the multivibrator to 'flip' from one state to another and the next pulse causes it to 'flop' back to its original state; the bistable multivibrator is popularly known as flip-flop circuit.

uses –

It is used in –

① in timing circuit as a frequency divider.

② in counting circuits.

③ in computer memory circuits.

Unit-IV - Sweep circuits-

Introduction:-

The circuits which generates the voltages or currents increasing linearly with time are called sweep circuits or time base circuits. If the circuit develops a voltage which increases linearly with time it is called a voltage sweep. The circuit in which the current increases linearly with time is called a current sweep.

Such type of sweep circuits are used in television, radar and Cathode Ray Oscillograph (CRO)

Sweep Voltage Waveforms-

A sweep voltage is one which increases with time and drops to zero abruptly after a certain time. The waveform is of the shape as shown in figure

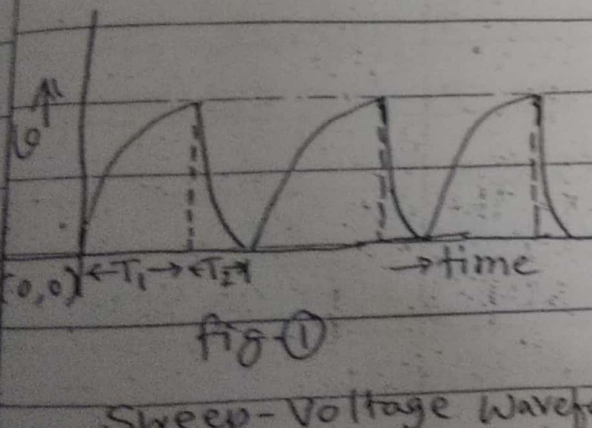
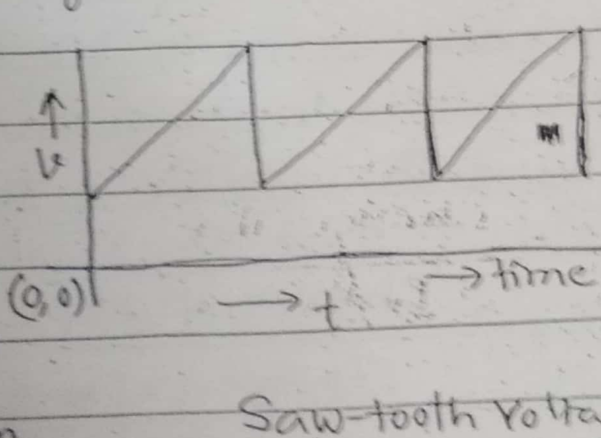


fig ①

Sweep-Voltage Waveform.



Saw-tooth Voltage waveform or ramp voltages.

The time taken by the voltage to increase to its maximum value T_1 is known as the sweep time and the time taken by the voltage to fall to the initial value (T_2) is called the fly-back time or retrace time. The waveform during flyback is not of much consequences but it is essential that the fly-back time should be very short. If the fly-back time is very short we get the waveforms shown in fig. 2. These type of voltages are called saw-tooth voltages because the voltages appears like saw-tooth or ramp voltages.

Ideally, the voltage is expected to increase linearly with time but in practice it is not so. The non-linearity in the voltage is called the sweep speed error and is measured as the ratio of the difference in slope at the begining and the end of the sweep to the initial value of the slope.

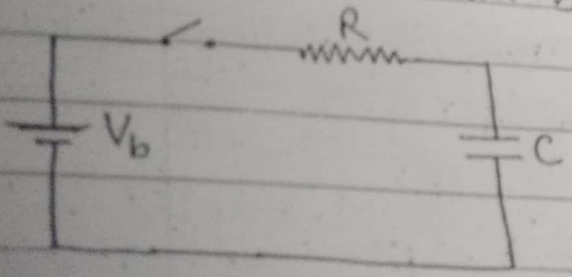
$$e_s = \frac{\text{Change in slope during the sweep}}{\text{Initial value of the slope}}$$

The circuits producing the sweep voltage are called sweep generators. The generators may be free running or astable, when the waveforme repeats itself. The circuits which requires triggeir to generate sweep voltages are called triggered sweep voltages.

Exponential sweep:-

The most common method of generating a sweep voltage is by changing a capacitor through a resistor and discharging it after a certain voltage is reached through a UJT (Uni-junction Transist or a thyratron.

The circuit for achieving exponential sweep takes the form as shown below.



If the key is closed at $t=0$ the voltage across the capacitor at an instant t is given by-

$$v = V_b \{1 - \exp(-t/CR)\} \quad \text{---} \quad (1)$$

$$\therefore \frac{dv}{dt} = -\frac{1}{C \cdot R} \cdot V_b \cdot \exp(-t/CR) \quad \text{——— (2)}$$

If T is the duration of the sweep, the sweep speed error can be found from above equation (2)

$$\therefore e = 1 - \exp(-T/CR) \quad \text{——— (3)}$$

$$= \frac{V}{V_b}$$

where V is the voltage across the capacitor at the end of the sweep. The sweep speed error can be reduced either by increasing the value of V_b or by reducing the value of V. In the former case a high voltage is needed for charging while in the later case the output voltage is very small. The sweep speed can also be found in terms of the sweep time T. Expanding eqn (1) we get,

$$v = V_b \left(\frac{t}{CR} - \frac{t^2}{2RC} + \frac{t^3}{6R^3C^3} - - - \right)$$

$$= \frac{V_b t}{CR} \left(1 - \frac{t}{2RC} + \frac{t^2}{6R^2C^2} - - - \right) \quad \text{——— (4)}$$

If the sweep time is small, the voltage at the end of the sweep.

$$V \cong \frac{V_b T}{CR}$$

$$\frac{V}{V_b} = \frac{T}{RC}$$

The sweep speed error is approximately,

$$e = \frac{T}{RC} \quad \text{—— (5)}$$

Thus, the error can be reduced by increasing the time constant RC.

When a capacitor is charged the voltage across its terminals is given by the equation –

$$v = \frac{q}{C}$$

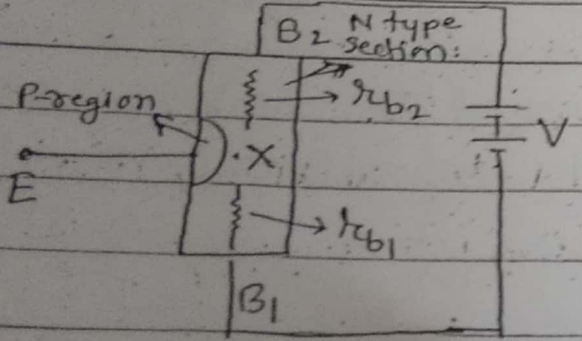
where q is the charge stored by the capacitor. The charge is related to the current flowing into the capacitor by the equation –

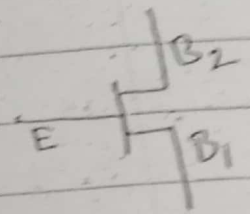
$$q = \int i\,dt$$

This suggests that, the sweep can be made linear, the current flowing into the capacitor is maintained consta

R-C ramp generator —

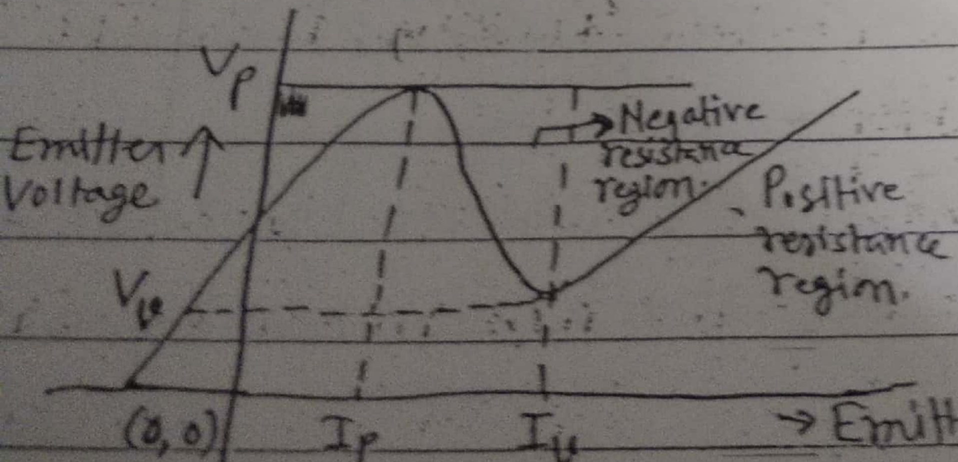
(UJT) - Uni junction transistor is a current controlled negative resistance device. The UJT is manufactured by alloying aluminium on a high resistance N-type silicon bar The alloying produces a P-region. The connections are made to the ends of the bar and the P-region. From the construction it is evident that the structure is a junction diode with two bases B_1 and B_2 and one emitter E. It is also called a double based diode. A P-N junction is formed at point X.





Symbol

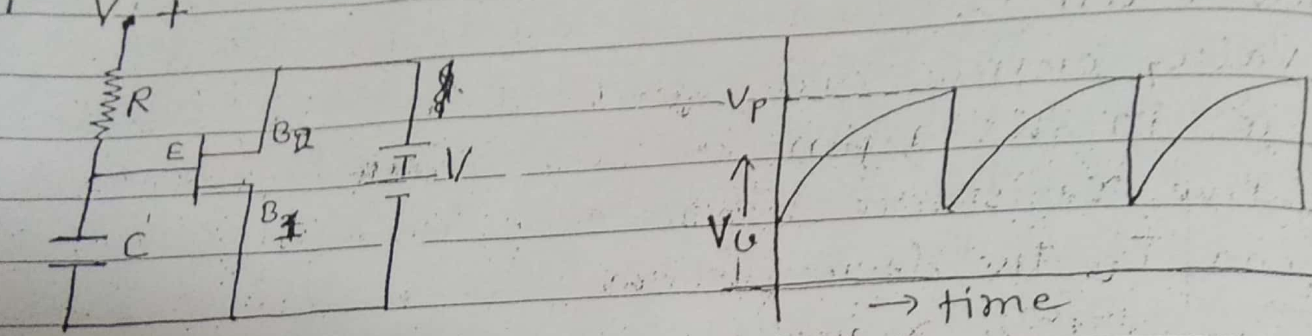
The characteristics of the UJT is shown below —



In the figure V_P is the voltage at which the diode starts conducting and is called the firing voltage. The firing voltage is equal to $\eta V + V_\gamma$, where ηV is the potential on the N side of the junction and V_γ is the cut-in voltage. I_P is called the peak current. As the current increases from I_P, the emitter voltage decreases till the current becomes I_V. I_V is called the valley current and V_V is called the valley voltage, in this region the device exhibits negative resistance. When the current increases beyond I_V the device behaves as a normal diode having positive resistance. From the figure, it is obvious that the characteristic is triple valued for current but single valued for voltage, the device is called a current controlled negative resistance device. The peak current decreases with increasing temperature.

From the characteristic it is clear that the device offers very large impedance in the off state, the leakage current's being in the order of few nano amperes. After firing the current increases regeneratively. This characteristic suggests its use in trigger and oscillator circuits.

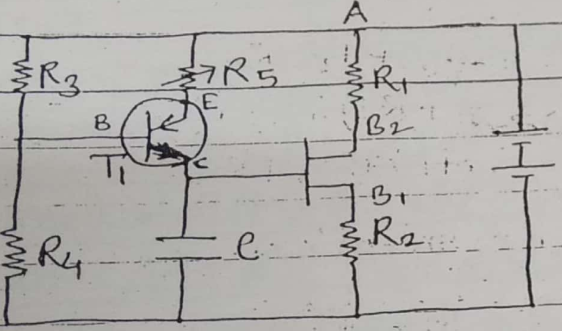
A ~~Ramp~~ RC- ramp generator circuit is designed by using a UJT ~~sweep~~ oscillator generator circuit with a slight modification by involving a transistor in it. A UJT sweep generator is shown below. in fig ①.



A UJT- oscillator generates oscillations when the emitter voltage increases exponentially to voltage V_p; the peak voltage and after the UJT fires the voltage falls regeneratively to V_v; the valley voltage. The waveform produced by this circuit is a saw-tooth wave but for exponential rise as shown in fig ②.

In free running mode the condenser charges from V_v to V_p; when the voltage rises to V_p, the condenser discharges through the UJT. The discharge can be considered instantaneous as the current through UJT increases regeneratively. The waveform at the emitter is of the shape shown in fig. (2). This circuit is also called relaxation oscillator.

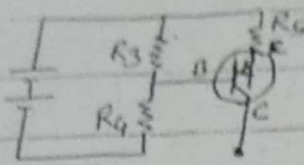
A UJT can be made to generate a linear sweep if the condenser is charged by constant current. To generate a constant current we make use of the fact that the collector current of a transistor is determined by the emitter base voltage and is practically independent of the collector potential. The modified circuit then will take the form as shown below -



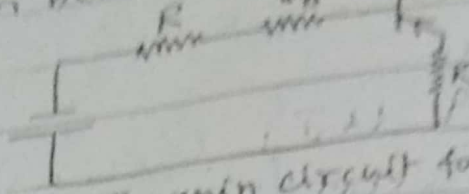
Under free running conditions the emitter potential of the UJT varies between the valley voltage V_v and the peak voltage V_p. The potential is always less than the potential at point A. The transistor T_1 connected as shown in the circuit is in active state because its emitter potential is positive with respect to its collector potential.

The collector current of the transistor is determined by

The resistances R_3, R_4 and R_5.
The transistor circuit can be redrawn as



Transistor circuit.



The Thevenin circuit for the base of the transistor.

The Thevenin voltage is $V' = \dfrac{V \cdot R_3}{(R_3 + R_4)}$

and the Thevenin resistance is - $R = \dfrac{R_3 \cdot R_4}{R_3 + R_4}$

Neglecting the small forward voltage of the base emitter junction we have -

$$V' = (R + r_b) i_b + I_E \cdot R_5$$
$$= i_b (R + r_b + R_5) + \beta \cdot i_b \cdot R_5$$
$$= i_b [R_5 (1+\beta) + r_b + R]$$

The base current in the transistor is therefore -

$$I_b = \frac{V'}{R_5(1+\beta) + r_b + R}$$

and the collector current -

$$I_C = \frac{\beta \cdot V'}{R_5(1+\beta) + r_b + R}.$$

The collector current can be varied to convenient value by adjusting the resistor R_5.

Since the changing current of the capacitor is maintained constant the voltage across its terminals increases linearly with time. During oscillations the voltage across the capacitor increases from V_U to V_P. The time required to change the capacitor which is also the sweep time is therefore-

$$T = \frac{C(V_P - V_U)}{I_C}$$

The current I_c can be varied by adjusting R_S and the circuit generates linear sweeps with vary sweep times. The linear sweeps are the saw-tooth waveforms or ramp waveforms as shown in figure

The drawback of the circuit is that the time required for the capacitor to discharge is determined by the regenerative increase of current through the UJT. This results in large flyback times and only slow speed sweeps can be produce by the circuit.