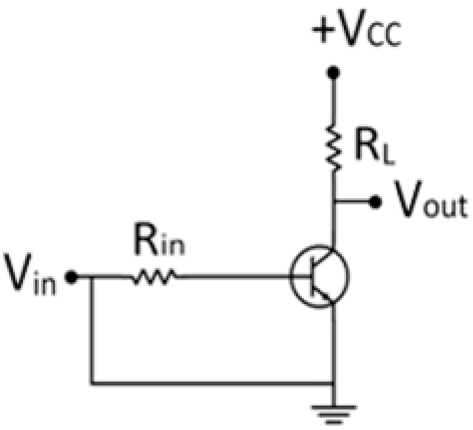
TRANSISTOR AS SWITCH

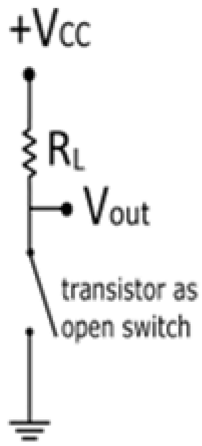
- The transistor operates as a **Single Pole Single Throw (SPST)** solid state switch.
- ***If the transistor is operated in the saturation region, then it acts as closed switch and when it is operated in the cut off region then it behaves as an open switch***.
- When the transistor operating as switch, in the cut off region the current through the transistor is zero and voltage across it is maximum, and in the saturation region the transistor current is maximum and voltage across is zero.
- Therefore, both the on – state and off – state ***power loss is zero*** in the transistor switch.

CUT OFF STATE (OPEN SWITCH)

When transistor operates in the cut off region shows the following characteristics –

- The input is grounded i.e. at zero potential.
- The V_{BE} is less that cut – in voltage 0.7 V.
- Both emitter – base junction and collector – base junction are reverse biased.
- The transistor is fully – off acting as open switch.
- The collector current I_C = 0 A and output voltage $V_{out} = V_{CC}$.



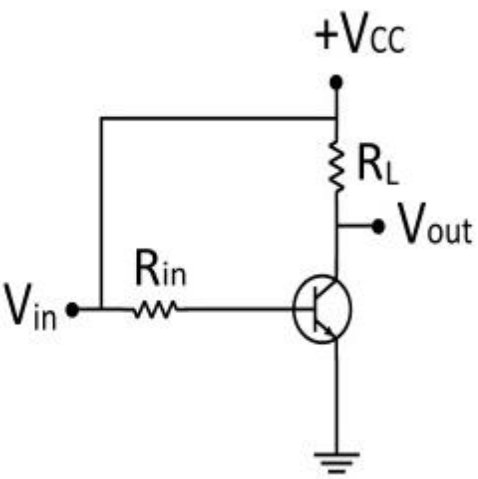


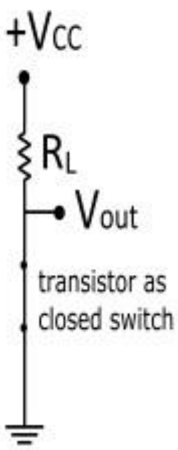
SATURATION STATE (CLOSED SWITCH)

The transistor operating in the saturation region exhibits following characteristics –

- The input is connected to V_{CC}.
- Base – Emitter voltage is greater than cut – in voltage (0.7 V).
- Both the base – emitter junction and base – collector junction are forward biased.
- The transistor is fully – ON and operates as closed switch.
- The collector current is maximum

$$I_C = \frac{V_{CC}}{R_L}$$





MULTIVIBRATORS

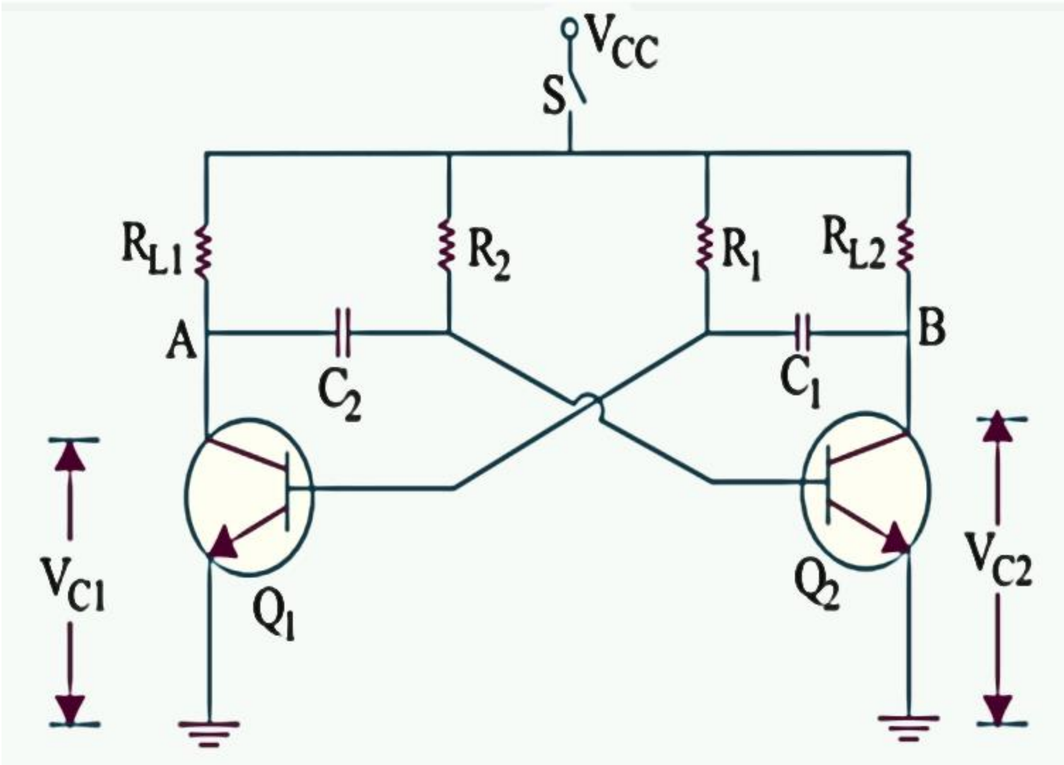
- A **multivibrator** circuit is nothing but a **switching circuit**. It generates non-sinusoidal waves such as square waves, rectangular waves and Saw tooth waves etc.
- Multivibrators are used as frequency generators, frequency dividers and generators of time delays and also as memory elements in computers etc.
- According to the definition, ***A Multivibrator is a two-stage resistance coupled amplifier with positive feedback from the output of one amplifier to the input of the other***.
- Two transistors are connected in feedback so that one controls the state of the other.
- Hence the ON and OFF states of the whole circuit, and the time periods for which the transistors are driven into saturation or cut off are controlled by the conditions of the circuit.

1. ASTABLE MULTIVIBRATOR

- Astable multi vibrator is also known as ***free running relaxation oscillator***
- It generates square wave of known period
- ***An astable multivibrator has no stable states***.
- Once the Multivibrator is ON, it just changes its states on its own after a certain ***time period which is determined by the RC time constants.***
- A dc power supply or V_{cc} is given to the circuit for its operation.

Construction of Astable-Multivibrator

- Two transistors named Q_1 and Q_2 are connected in feedback to one another.
- It consists of two CE amplifier each providing feedback to the other
- Transistors are driven either to saturation or cut off
- Transistor Q_1 forward biased by V_{CC} and R_1.Transistor Q_2 forward biased by V_{CC} and R_2
- The output of Q_1 is coupled to input of Q_2 by C_2.The output of Q_2 is coupled to input of Q_1 by C_1
- The emitters of both the transistors are connected to the ground.
- The collector load resistors R_{L1} and R_{L2} and the biasing resistors R_1 and R_2 are of equal values.
- The capacitors C_1 and C_2 are of equal values.
- The following figure shows the circuit diagram for Astable Multivibrator.



Operation of Astable Multivibrator

- ***When power is switched ON by closing S,*** one transistor will start conducting
- ***Suppose Q1 starts conducting Q_1 will very rapidly driven to saturation and Q2 to cut off.***
- Since Q1 is in saturation, whole of V_{CC} drops across R_{L1}.
- Hence V_{C1}=0 and ***point A is at zero potential***
- Since Q2 in cut off, it conducts no current, there is no drop across R_{L2}. Hence ***point B is at V_{CC}***

Q1 ON	Voltage at A=0
Q2 OFF	Voltage at B=Vcc

- Since A is at 0V, ***C_2 starts to charge through R_2 towards V_{CC}***
- When voltage across C_2 rises sufficiently, (ie more than 0.7V), it biases Q2 in the forward direction so that it starts conducting and is soon driven into saturation
- V_{C2} decreases and becomes almost zero when ***Q2 gets saturated***.
- The potential of point **B decreases from Vcc to almost 0V**
- Now point B is at 0V. ***Q1 is reverse biased and cut off.***
- Voltage at ***A is increased to Vcc***

Q1 OFF	VOLTAGE AT A=Vcc
Q2 ON	VOLTAGE AT B=0

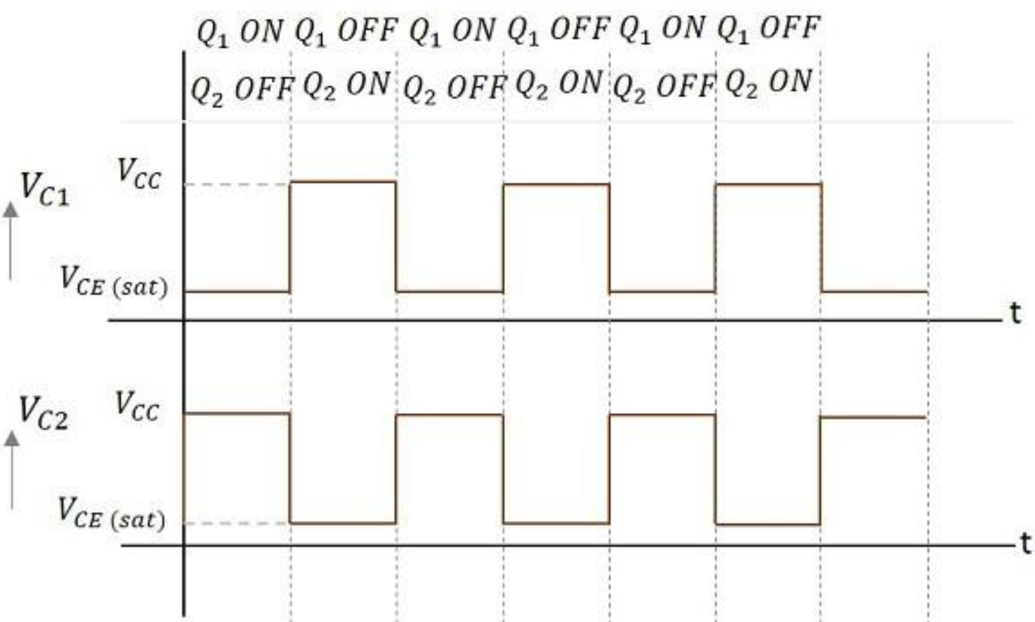
- Now ***C_1 starts charging through R_1***
- When voltage of C_1 increases sufficiently, ***Q_1 becomes forward biased and starts conducting***.
- ***Q_1 is driven into saturation and Q_2 to cut off***

Q1 ON	VOLTAGE AT A=0
Q2 OFF	VOLTAGE AT B=Vcc

- In this way the whole cycle is repeated
- It is seen that the circuit alternates between a state in which Q1 is ON and Q2 is OFF and a state in which Q1 is OFF and Q2 is ON.
- The time in each state depends on RC values.
- Voltage waveform at either collector is a square waveform with peak amplitude equals to Vcc

Waveforms

The output waveforms at the collectors of Q_1 and Q_2 are shown in the following figures.



Frequency of Oscillations

The ON time of transistor Q_1 or the OFF time of transistor Q_2 is given by

$$t_1 = 0.69R_1C_1$$

Similarly, the OFF time of transistor Q_1 or ON time of transistor Q_2 is given by

$$t_2 = 0.69R_2C_2$$

Hence, total time period of square wave

$$t = t_1 + t_2 = 0.69(R_1C_1 + R_2C_2)$$

As $R_1 = R_2 = R$ and $C_1 = C_2 = C$, the frequency of square wave will be

$$\boxed{f = \frac{1}{t} = \frac{1}{1.38RC} = \frac{0.7}{RC}}$$

Advantages

The advantages of using an astable multivibrator are as follows −

- No external triggering required.
- Circuit design is simple
- Inexpensive
- Can function continuously

Disadvantages

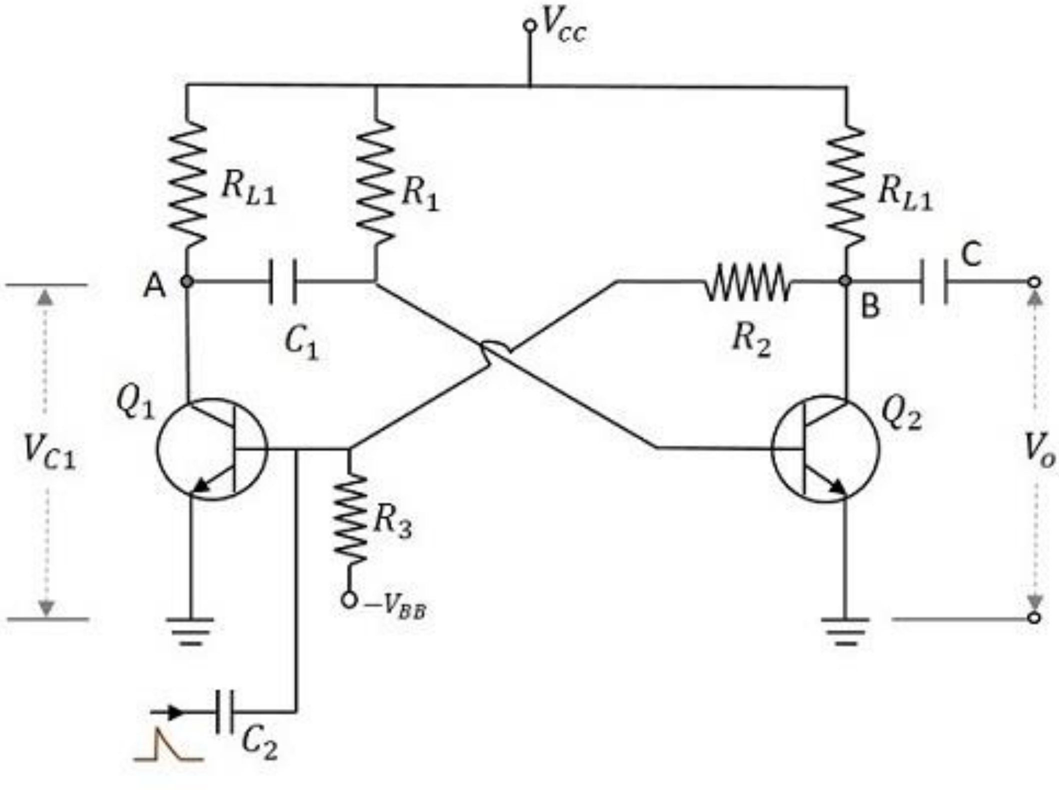
The drawbacks of using an astable multivibrator are as follows −

- Energy absorption is more within the circuit.
- Output signal is of low energy.
- Duty cycle less than or equal to 50% can't be achieved.

Applications

Astable Multivibrators are used in many applications such as amateur radio equipment, Morse code generators, timer circuits, analog circuits, and TV systems.

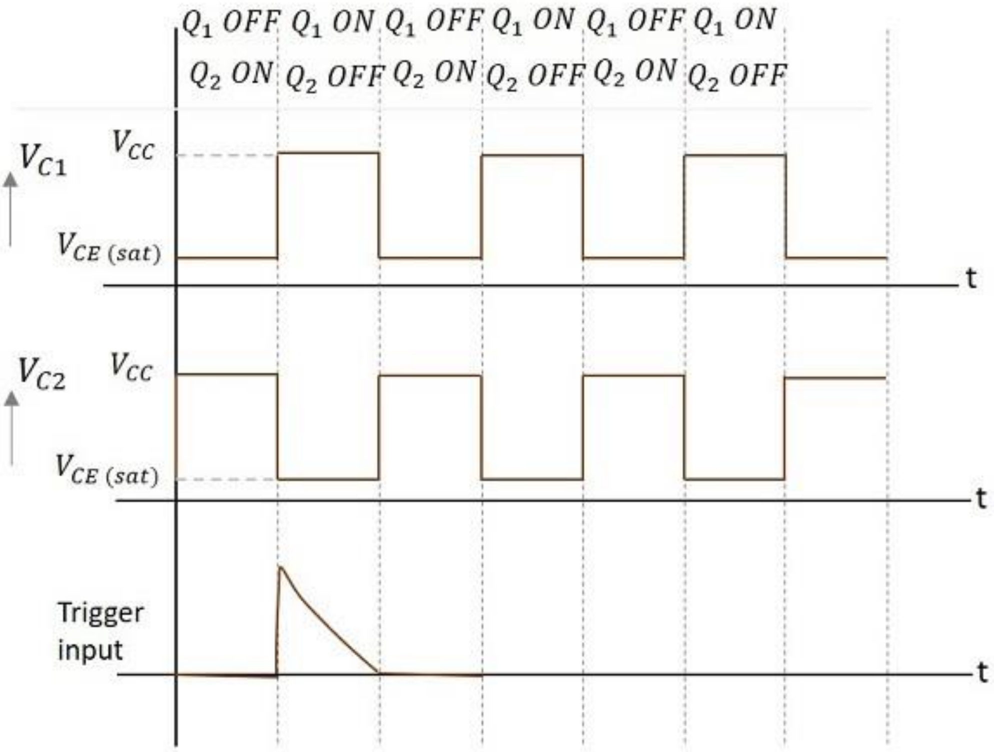
2. MONOSTABLE MULTIVIBRATOR



- ***A monostable multivibrator***, as the name implies, ***has only one stable state***.
- When the transistor conducts, the other remains in non-conducting state.
- A stable state is such a state where the transistor remains without being altered, unless disturbed by some external trigger pulse.
- It is also known as **One-shot Multivibrator**.
- ***The trigger input given will be of very short duration, just to initiate the action***.
- This triggers the circuit to change its state from Stable state to Quasi-stable or Meta-stable or Semi-stable state, in which the circuit remains for a short duration.
- There will be ***one output pulse for one trigger pulse***.

Output Waveforms

The output waveforms at the collectors of Q_1 and Q_2 along with the trigger input given at the base of Q_1 are shown in the following figures.



- The width of this output pulse depends upon the RC time constant.
- Hence it depends on the values of R_1C_1. The duration of pulse is given by

$$T=0.69R_1C_1$$

Advantages

- One trigger pulse is enough.
- Circuit design is simple
- Inexpensive

Disadvantages

The major drawback of using a monostable multivibrator is that the time between the applications of trigger pulse T has to be greater than the RC time constant of the circuit.

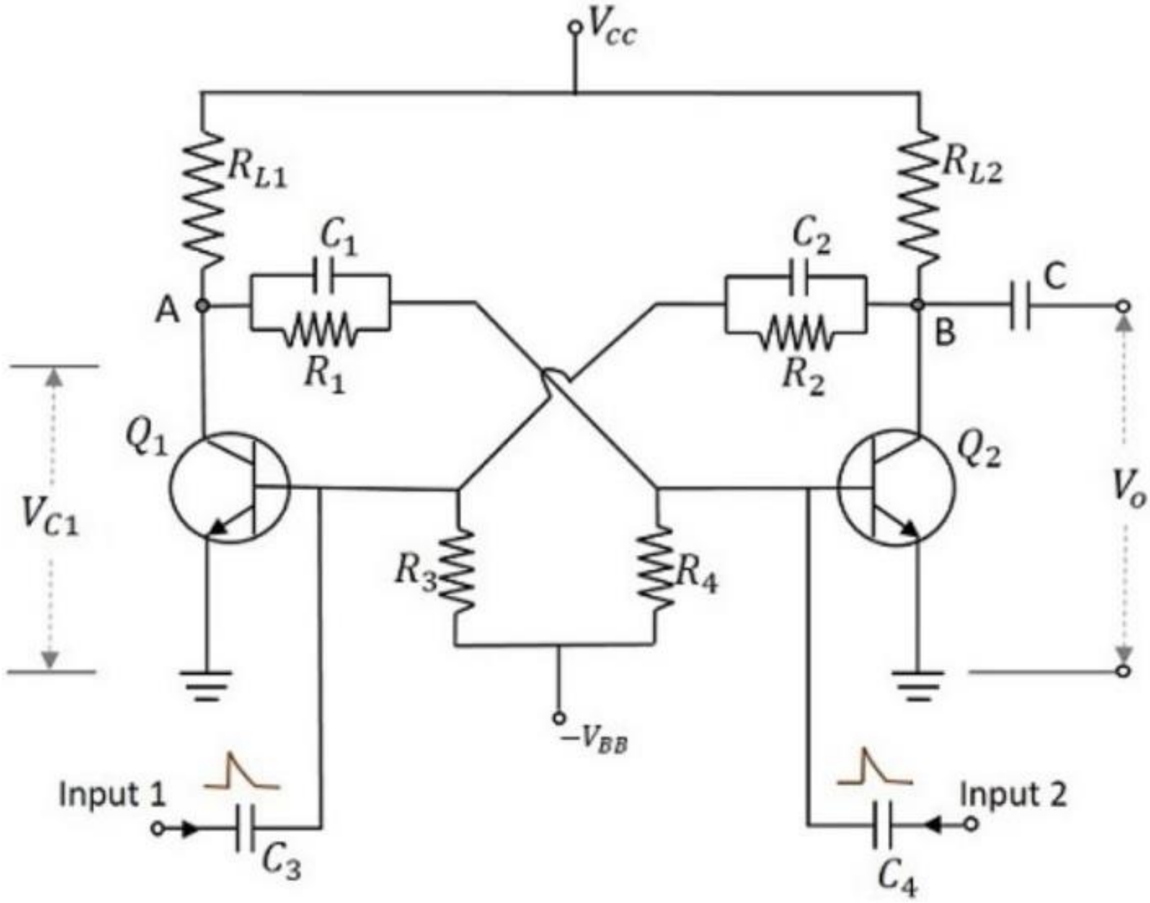
Applications

Monostable Multivibrators are used in applications such as television circuits and control system circuits.

3. BISTABLE MULTIVIBRATOR

- A Bistable Multivibrator has **two stable states**.
- The circuit stays in any one of the two stable states. It continues in that state, unless an external trigger pulse is given.
- This Multivibrator is also known as **Flip-flop**.
- This circuit is simply called as **Binary**.

Circuit diagram



- The Bistable mutivibrator circuit differs from astable multivibrator in the following aspect.
  - **i)** The base resistors are not joined to VCC but to a common source **–V_{BB}.**
  - **ii)** The feedback is coupled through two resistors
- C_1 & C_2 are provided to reduce output distortion.

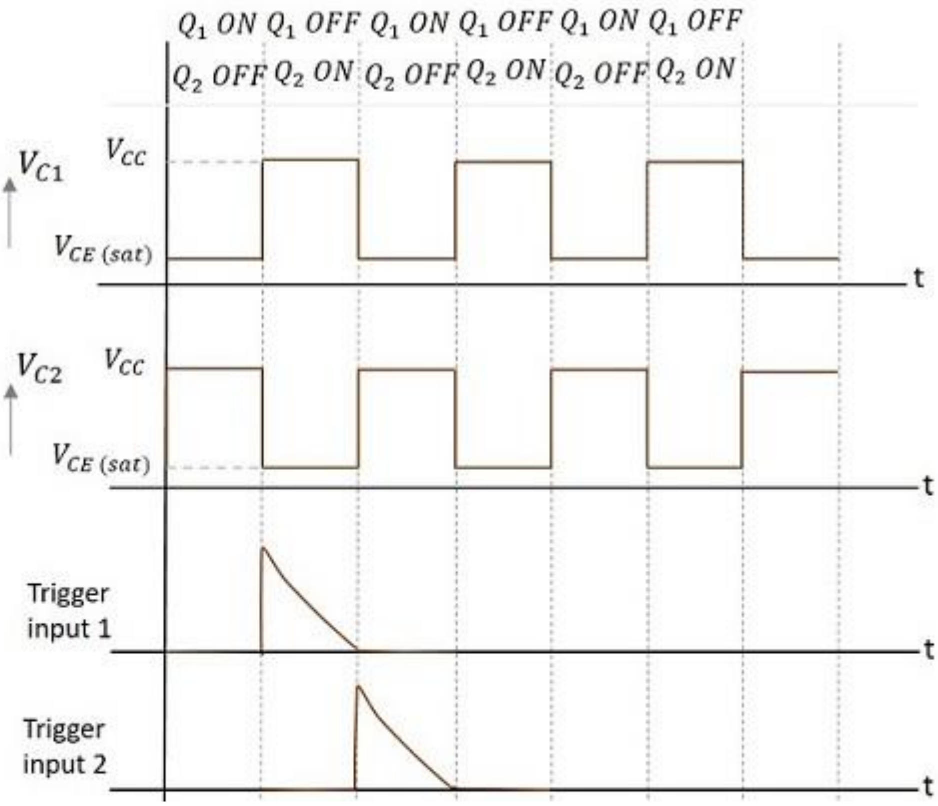
Working

- When a negative trigger pulse is applied to the base of Q1 through C3, the forward bias on Q1 will reduce.
- This decreases the collector current and increases collector voltage.
- The rising collector voltage is coupled to the base of Q2.BE junction of Q2 is forward biased.
- This increases the collector current of Q2 and reduces collector voltage.
- The decreasing voltage is applied to the base of Q1 and it further reverse biases BE junction of Q1.
- Thus, Q1 is driven to cut off and Q2 is driven to saturation.
- The circuit remain stable at this state until a negative trigger pulse is applied to Q2.

Q1 OFF	VA=Vcc
Q2 ON	VB=0

Output Waveforms

The output waveforms at the collectors of Q_1 and Q_2 along with the trigger inputs given at the bases of Q_W and Q_2 are shown in the following figures.



Advantages

The advantages of using a Bistable Multivibrator are as follows –

- Stores the previous output unless disturbed.
- Circuit design is simple

Disadvantages

The drawbacks of a Bistable Multivibrator are as follows –

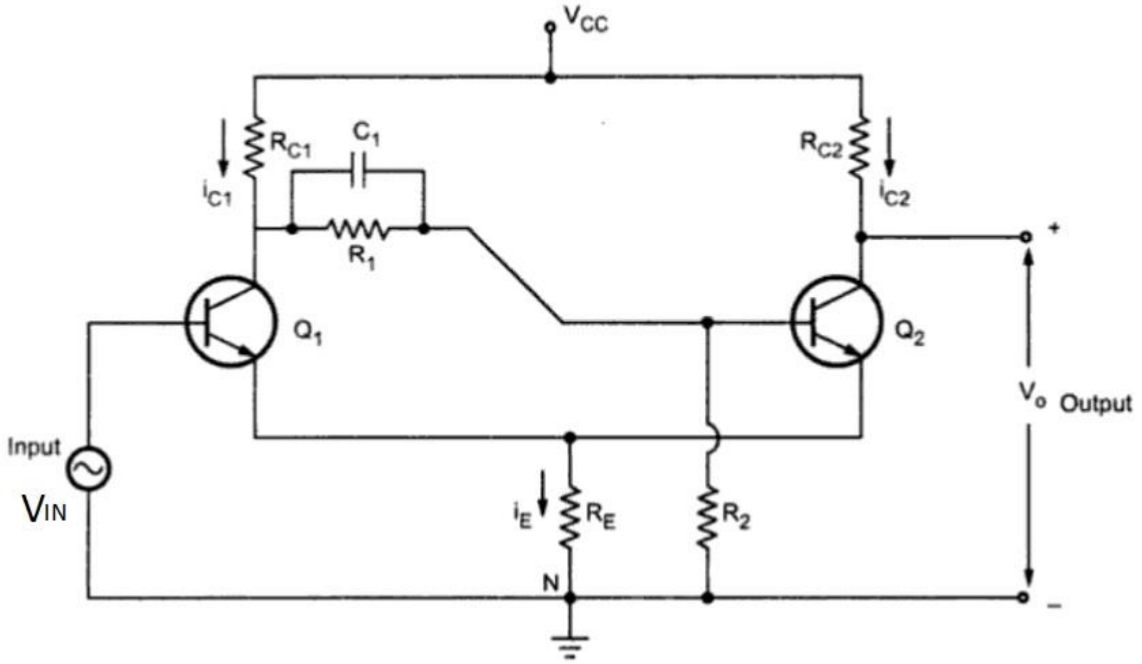
- Two kinds of trigger pulses are required.
- A bit costlier than other Multivibrators.

Applications

Bistable Multivibrators are used in applications such as pulse generation and digital operations like counting and storing of binary information.

SCHMITT TRIGGER

- A Schmitt Trigger is basically a Bistable Circuit whose output states are controlled by the input signal.
- Hence, it can be used as a ***level detecting circuit***.
- Even though the circuit looks like a typical Bistable Multivibrator circuit, this circuit is missing the coupling from collector of Q_2 to input of Q_1.
- Emitters of Q_1 and Q_2 are connected to each other and grounded through R_E. Also, R_E acts as a feedback path.



Operation of the Circuit

- When V_{IN} is zero, Q_1 is cut-off and Q_2 is in saturation. As a result, the output voltage V_O is LOW. If $V_{CE(SAT)}$ is assumed to be 0, then the voltage across R_E is given by:

$$\frac{V_{cc}R_E}{R_{C2}+R_E}$$

- This voltage is also the emitter voltage of Q_1. So, for Q_1 to conduct, the input voltage V_{IN} must greater than sum of the emitter voltage and 0.7 V i.e.,

$$\frac{V_{cc}R_E}{R_{C2}+R_E}+0.7$$

- When the V_{IN} is greater than this voltage, Q_1 starts conducting and Q_2 is cutoff due to regenerative action.
- As a result, the output V_O goes HIGH. Now the voltage across the R_E changes to a new value and is given by:

$$\frac{V_{cc}R_E}{R_{C1}+R_E}$$

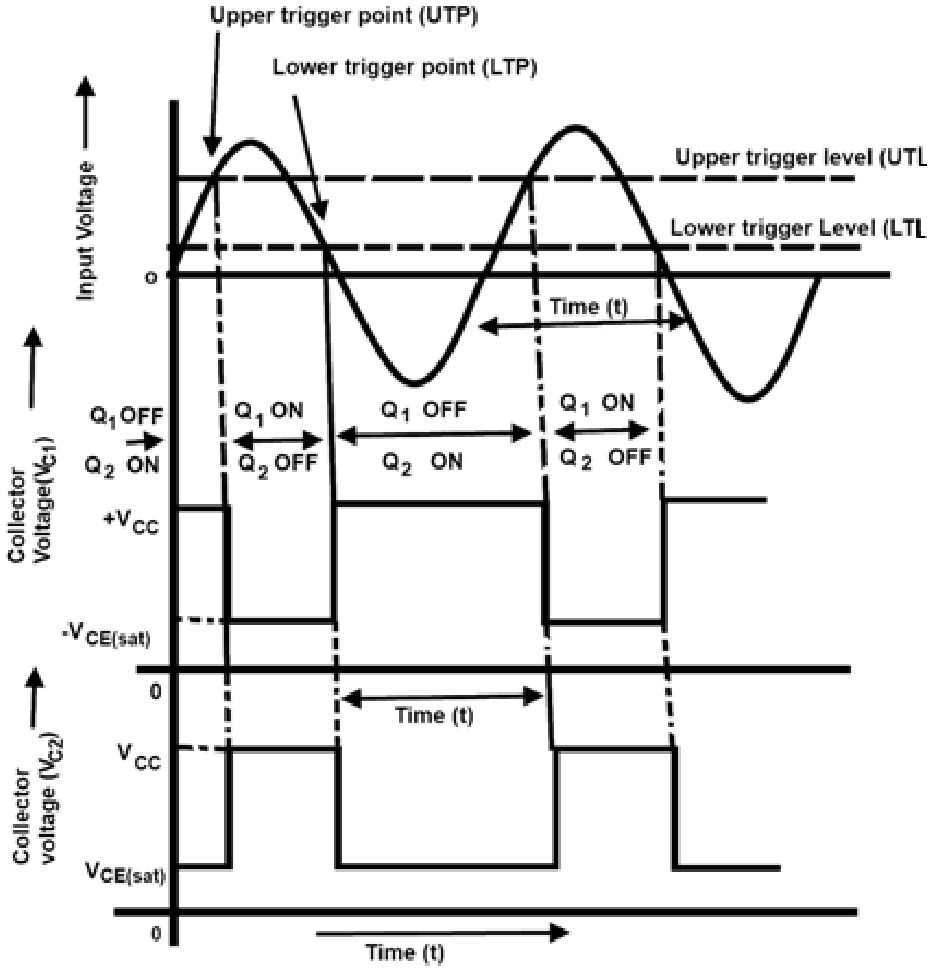
- Transistor Q_1 will conduct as long as the input voltage V_{IN} is greater than or equal to the following:

$$\frac{V_{cc}R_E}{R_{C1}+R_E}+0.7$$

- If V_{IN} falls below this value, then Q_1 comes out of saturation and the rest of the circuit operates due to regenerative action of Q_1 going to cutoff and Q_2 to saturation.
- The output states HIGH and LOW are dependent on the input voltage levels given by the equations:

$$\frac{V_{cc}R_E}{R_{C1}+R_E}+0.7$$

$$\frac{V_{cc}R_E}{R_{C2}+R_E}+0.7$$

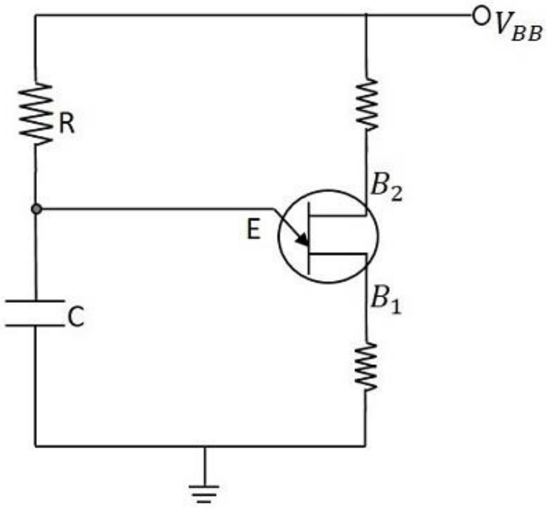


UJT RELAXATION OSCILLATOR

- A relaxation oscillator is a device that produces a **non-sinusoidal waveform** on its own.
- This waveform depends generally upon the charging and discharging time constants of a capacitor in the circuit.

Construction and Working

- The emitter of UJT is connected with a resistor and capacitor as shown.
- The RC time constant determines the timings of the output waveform of the relaxation oscillator.
- Both the bases are connected with a resistor each.
- The dc voltage supply V_{BB} is given.
- The following figure shows how to use a UJT as a relaxation oscillator.

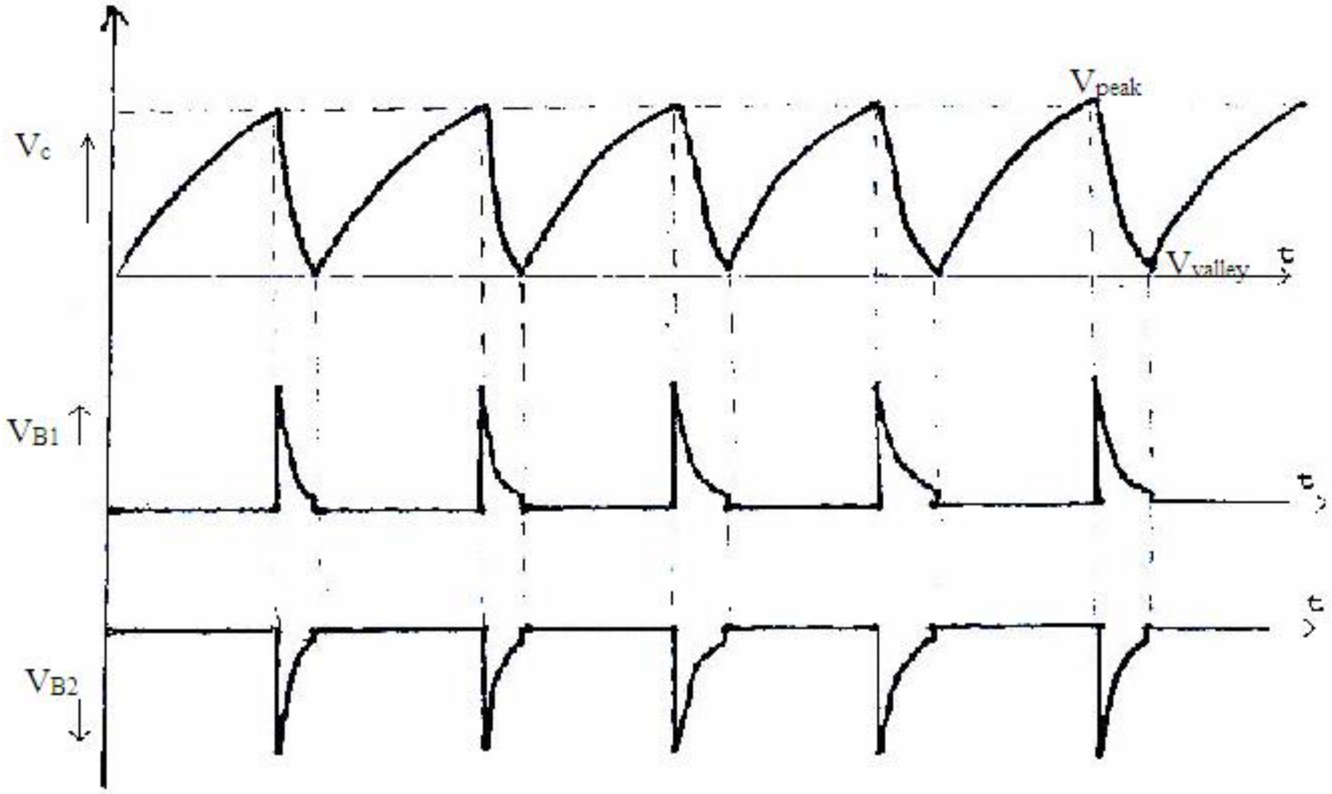


Working

- ***Initially, the voltage across the capacitor is zero***.

$$V_c=0$$

- The UJT is in OFF condition. The resistor **R** provides a path for the ***capacitor C to charge through the voltage applied.***
- The capacitor usually starts charging and continues to charge until the maximum voltage V_{BB}.
- But in this circuit, when the ***voltage across capacitor reaches a value, which enables the UJT to turn ON (the peak voltage) then the capacitor stops to charge and starts discharging through UJT***.
- Now, this ***discharging continues until the minimum voltage which turns the UJT OFF (the valley voltage)***.
- This process continues and the voltage across the capacitor, when indicated on a graph, the following waveform is observed.



- So, the charge and discharge of capacitor produces the sweep waveform as shown above.
- The charging time produces increasing sweep and the discharging time produces decreasing sweep. The repetition of this cycle, forms a continuous sweep output waveform.
- As the output is a non-sinusoidal waveform, this circuit is said to be working as a relaxation oscillator.

Applications of Relaxation Oscillator

- Relaxation oscillators are widely used in function generators, electronic beepers, SMPS, inverters, blinkers, and voltage-controlled oscillators.