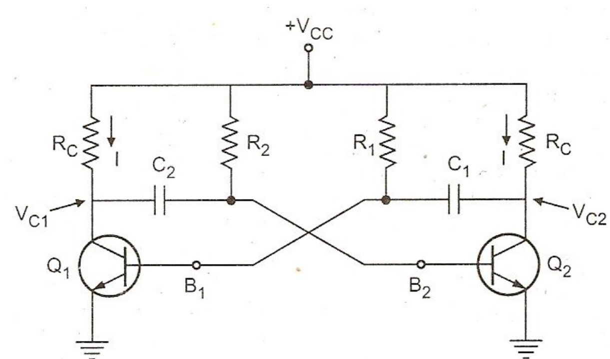
L – 20: ASTABLE MONOSTABLE MULTIVIBRATOR AND SCHMITT TRIGGER CIRCUIT

Collector Coupled Astable Multivibrator

Astable multivibrator has two states, both are quasi-stable, which means, the multivibrator cannot remain in any of the two states indefinitely but it keeps on alternating the states.

Construction:

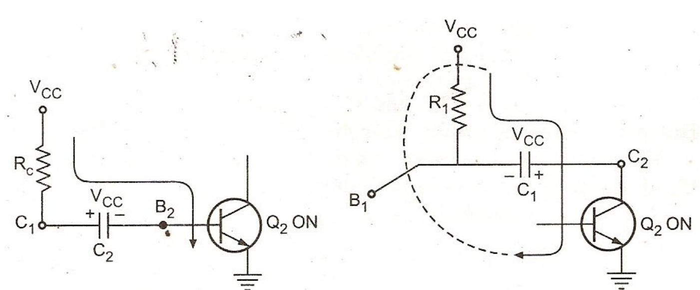
Q_2 and Q_1 are identical transistors; The collector of Q_2 is coupled to base of Q_1 through capacitor C_1 while collector of Q_1 is coupled to base of Q_2 through capacitor C_1 . The capacitive coupling is used between stages, due to which neither can remain permanently cut-off. The circuit has two quasi-stable states and it makes periodic switching between these states without any external trigger signal.



Principle of work:

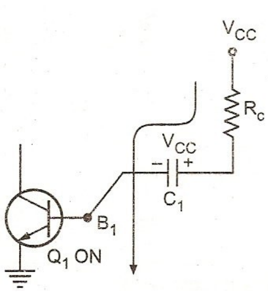
At start assume Q_2 is **ON** and Q_1 is **OFF**. Capacitor C_2 starts charging towards V_{CC} through path $R_C - C_2 - Q_2(ON)$ till finally the voltage across C_2 becomes equal to V_{CC} with proper polarity.

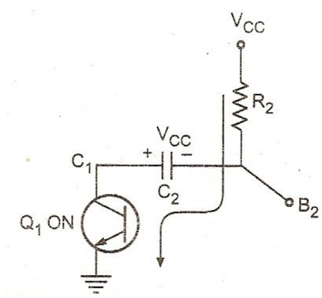
At the same time capacitor C_1 which is charged to V_{CC} in the earlier state, starts discharging through path $Q_2 - V_{CC} - R_1 - C_1$



The base of Q_1 is at $-V_{CC}$ at the beginning, but as C_1 starts discharging, it becomes less and less negative, i.e. becomes more positive and finally becomes equal to V_γ the cut-in voltage of Q_1. When $V_{B1} \geq V_\gamma$ transistor Q_1 starts conducting, so Q_1 becomes **ON** and Q_2 becomes **OFF.**

As Q_1 becomes **ON** and Q_2 becomes **OFF,** capacitor C_1 starts charging again through $R_C - C_1 - Q_1(ON)$ while C_2 starts discharging through path $V_{CC} - R_2 - C_2 - Q_1(ON)$





As C_2 discharges, V_{B2} the potential at B_2, becomes less negative i.e. it increases towards positive. When $V_{B2} \geq V_\gamma$ of Q_2 the Q_2 starts conducting, and thus, Q_2 becomes **ON** and Q_1 becomes **OFF.** The changes in the two states is automatic and without any external triggering signal.

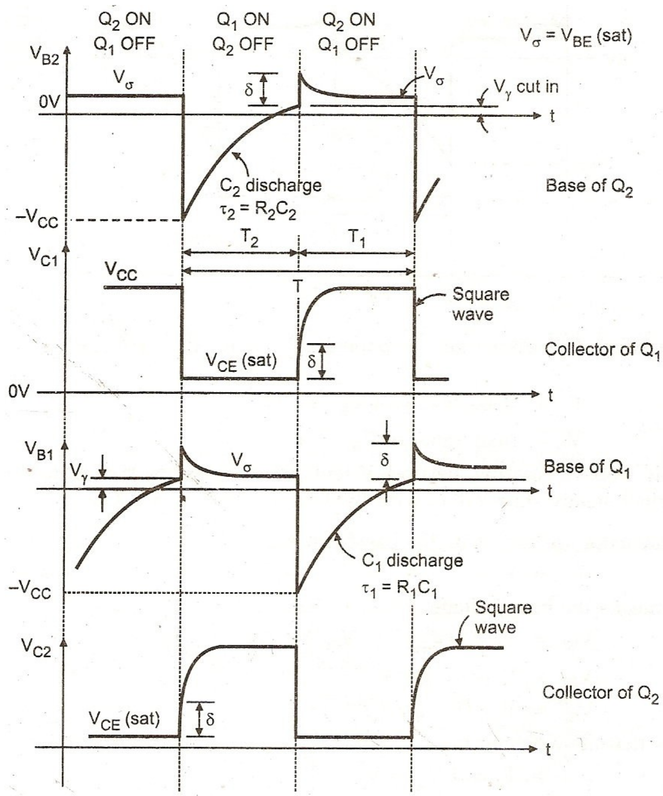
Waveforms of Astable Multivibrator at collectors of Q_1 and Q_2

When Q_1 is **OFF** and Q_2 is **ON,** C_1 discharges and V_{B1} increases. This increases exponentially with time constant $R_1 C_1$. When Q_1 is in saturation;

$$V_{B1} = V_{BE(sat)}$$
$$V_{C1} = V_{CE(sat)}$$
$$V_{C2} = V_{CC}$$

When Q_1 is **ON** and Q_2 is **OFF,** C_2 discharges and V_{B2} increases. This increases exponentially with time constant $R_2 C_2$. When Q_1 is in saturation;

$$V_{B2} = V_{BE(sat)}$$
$$V_{C1} = V_{CC}$$
$$V_{C2} = V_{CE(sat)}$$



Expression for time period

$$T_1 = 0.69 R_1 C_1$$
$$T_2 = 0.69 R_2 C_2$$ since $$T = T_1 + T_2 \Rightarrow T = 0.69(R_2C_2 + R_1C_1)$$

If $R_1 = R_2 = R \, and \, C_1 = C_2 = C \quad \Rightarrow T = 0.69(2RC) = 1.38RC$

Applications of Astable Multivibrator:

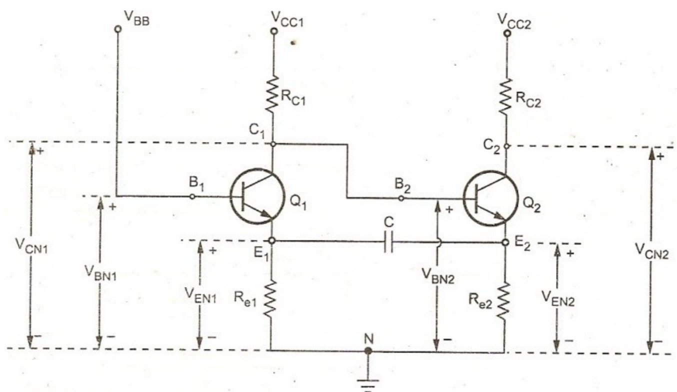
- Used as a square wave generator,
- Used as a voltage to frequency converter,
- Used as a clock for binary logic signals,
- Used in digital voltmeters and switched mode power supplies,
- As an oscillator to generate wide range of audio and radio frequencies.

Emitter Coupled Astable Multivibrators

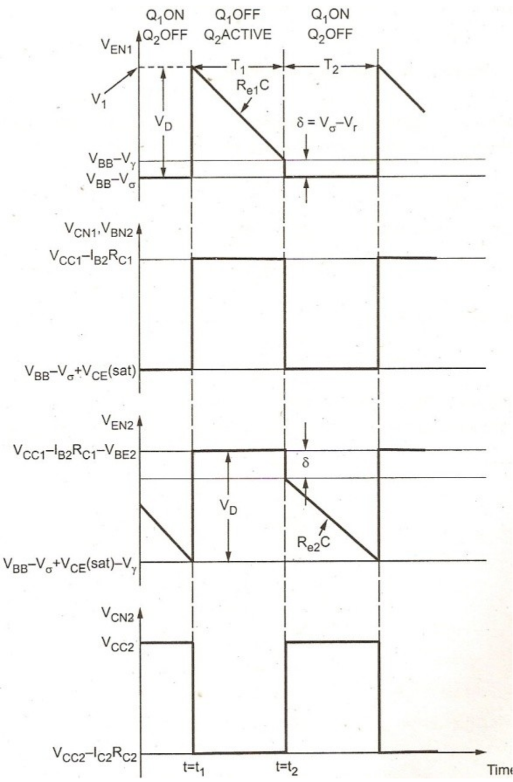
Construction:

The collector of Q_1 is connected to the base of Q_2, the capacitive coupling is used to connect emitters of Q_1 and Q_2. Additional resistances R_{e1} and R_{e2} are used in the emitter leg of Q_1 and Q_2 respectively.

The circuit has two quasi-stable states and it makes periodic switching between these states without any external trigger signal.



Waveforms;



Expression for the Time Period

Assuming the supply voltages are large compared to junction voltages;

$$T = T_1 + T_2 \Rightarrow T = \left(R_{e1} + R_{e2}\right) C \ln\left(\frac{V_{CC1}}{V_{BB}}\right)$$

and

$$f = \frac{1}{T} = \frac{1}{\left(R_{e1} + R_{e2}\right) C \ln\left(\frac{V_{CC1}}{V_{BB}}\right)}$$

Te frequency is not dependent on transistor parameters, and if V_{CC1} and V_{BB} are selected such that they are proportional to each other the frequency can be made insensitive to supply voltages.

Advantages of Emitter Coupled Astable Multivibrator

- No external triggering signal is required. It is self starting,
- The output can be used to drive heavy loads without affecting the circuit performance,
- The distortion in the output waveform due to transients is absent,
- Easy to synchronize since the input terminal which is the base of Q_1 is isolated;
- A single capacitor C controls the frequency; hence it is easy to change frequency by varying C. In collector coupled, it is necessary to change both $C_1 \, and \, C_2$

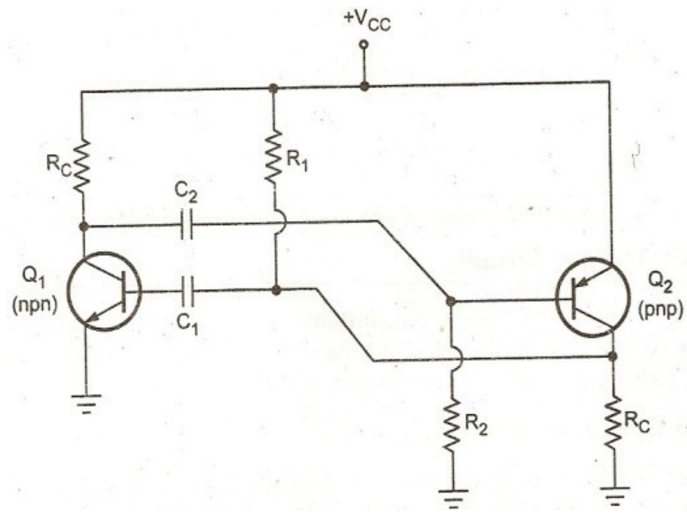
Disadvantages of Emitter Coupled Astable Multivibrator

- The number of components are more compared to the collector coupled circuit,
- The design is complicated; because the quiescent points of Q_1 and Q_2 are required to be designed such that Q_1 switches between **cut-off** and **saturation** while Q_2 switches between **cut-off** and **active region**.
- Emitter resistances R_{e1} and R_{e2} cannot differ much, hence with single capacitor C, widely different $T_1 \, and \, T_2$ cannot be obtained.
- As design is complicated and more components are required, it is more expensive.

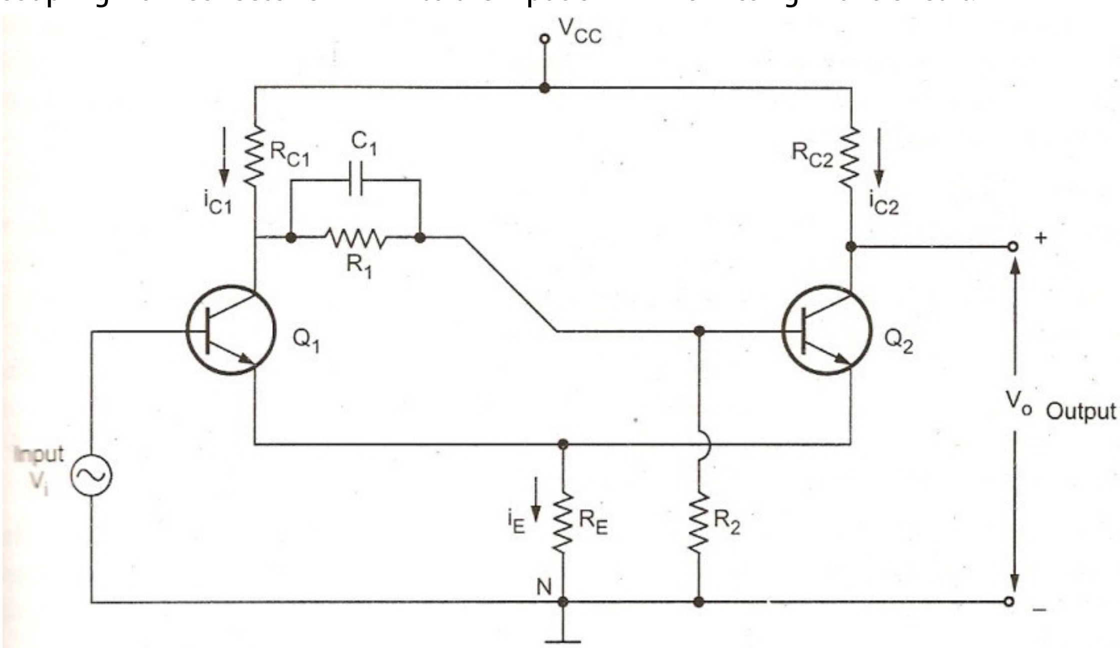
Complementary Multivibrators

A complementary multivibrator is obtained by replacing one of the transistors by its complimentary, so that one transistor is $n-p-n$ while the other is $p-n-p$.

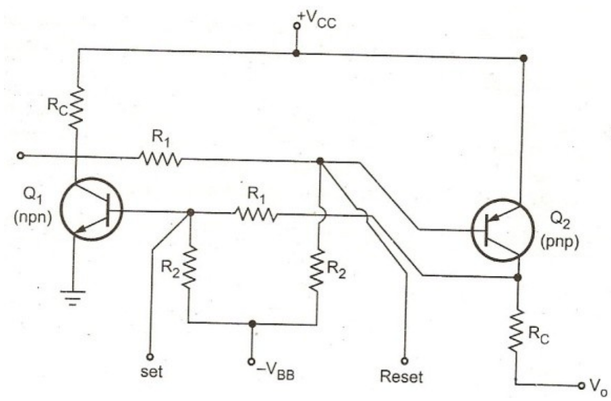
A. Complementary Astable Multivibrator:



coupling from collector of Q_2 to the input of Q_1 is missing in this circuit.

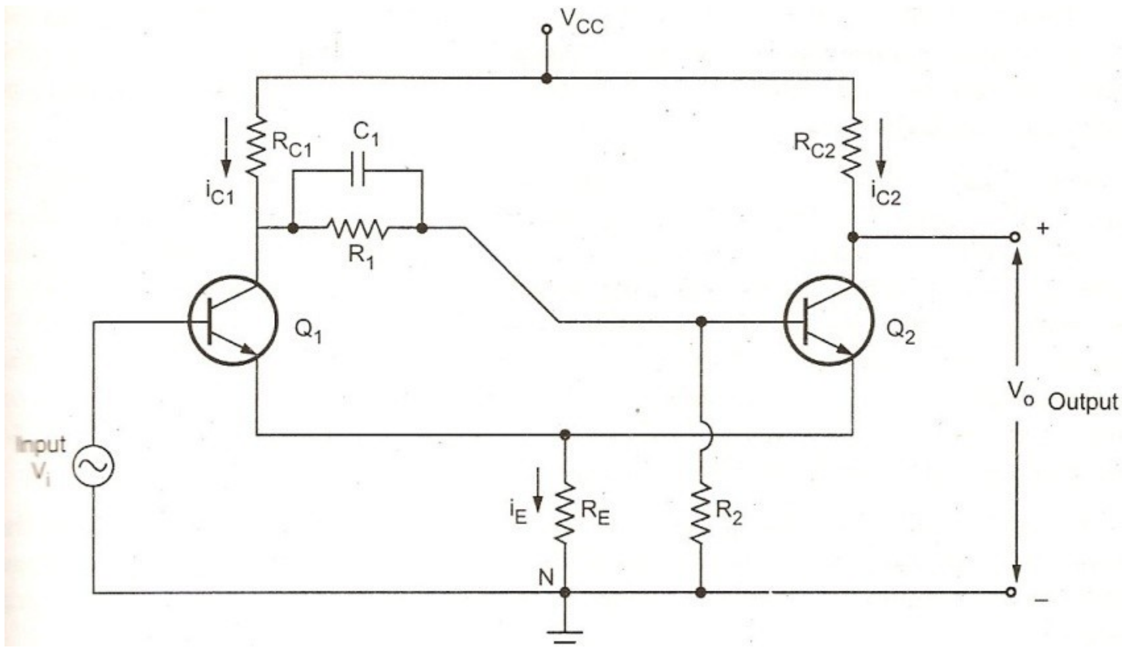


The emitter of the two transistors are connected to each other and grounded through



2. Schmitt Trigger Circuit

Schmitt trigger looks like a basic bistable configuration but it differs by the fact that the coupling from collector of Q_2 to the input of Q_1 is missing in this circuit.



The emitter of the two transistors are connected to each other and grounded through resistance R_E . The feedback is obtained through the resistance R_E . There exist two stable states of the output of the circuit. The resistance R_{C1} is kept smaller than R_{C2} so that regeneration cannot take place.

Operation of the circuit:

Let a sinusoidal input voltage V_i be applied to the circuit. Assume Q_2 is conducting and saturated. And as $V_i=0$ at start, Q_1 is cut-off, hence current $i_{C1}=0$ while $i_{C2}=\max$.

Neglecting base current of Q_2 ; $i_{C2}=i_E$ flowing through R_E . The drop across R_E is $i_{C2}R_E$

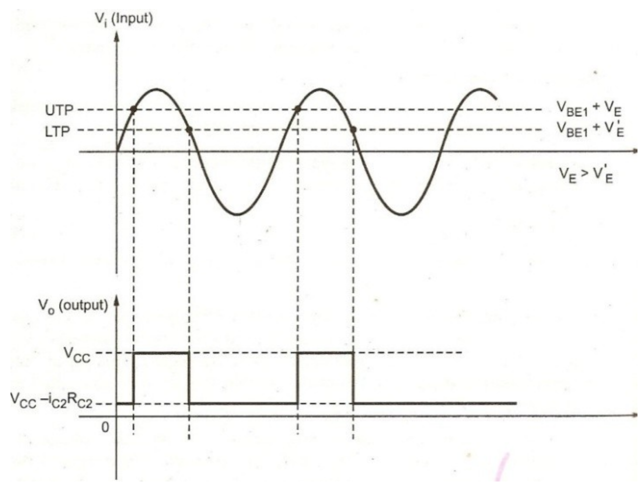
Therefore; $V_O=V_{CC}-i_{C2}R_C$

This drop across R_E raises the emitter voltage of Q_1 and reverse biases transistor Q_1 .

Then V_i increases and to make Q_1 ON, it must increase to the level equal to cut-in voltage V_{BE1} of Q_1 , plus the amount by which emitter voltage is raised V_E . When

$V_i = V_{BE1} + V_E$ transistor Q_1 gets driven to active region; This input voltage level is the **upper threshold point** (**UTP**) of the Schmitt trigger.

As Q_1 is **ON**, i_{C1} starts flowing. Due to drop across R_{C1} base voltage of Q_2 reduces and as the process is regenerative, Q_1 is driven into **saturation** and simultaneously Q_2 is **cu-off**. The output remains constant in a stable state i.e. $V_O = V_{CC}$. This level will not change automatically.



By this time, the collector current of Q_1 is i_{C1} , neglecting base current $i_E = i_{C1}$ which causes a drop of $V_E^{'}$ across R_E . When V_i starts decreasing, the base voltage of Q_1 starts decreasing, and when it reaches the level of $V_{BE1} + V_E^{'}$, then Q_1 stops conducting. This makes Q_2 **ON**, and instantaneously Q_2 goes into **saturation** and the output level reduces to $V_{CC} - i_{C2} R_{C2}$.

The level of V_i at which Q_1 becomes OFF and Q_2 **ON** is the **lower threshold point (LTP)**

Transfer Characteristics of Schmitt trigger