UNIT 4 - Wave Shaping & Multivibrator Circuits

Waveform Shaping Circuits:

RC CIRCUIT

The waveform shaping circuits like differentiating and integrating circuits are used in Multivibrators as triggering and synchronising pulse generators. The leading and trailing edge of trigger pulse are of utmost importance and the horizontal part of the pulse is not important in multivibrator applications. Triggering pulse for the multivibrator are to be reshaped using differentiating and integrating RC circuits.

Differentiating Circuit (High Pass RC Circuit)

- Consist of Series Capacitor & Shunt Resistor

Reactance of Capacitor \( X_C = \frac{1}{2\pi f C} \)

\( X_C \rightarrow \text{wire \& freq.} \)

- At high freq, capacity act as Short Circuit
- All higher freq components appear at tip with less attenuation than the lower freq components.

The circuit is called High Pass Filter.

The effect of Time Constant \( T = RC \) on the tip waveform for the pulse is shown in fig. 161 (c).

![Differentiating circuit](image)

**Effect of Delay Time Constant**

![Dip waveform with delay time constant](image)
With reducing time constant the pulse at the OLP becomes narrower with negligible sag. If the time constant is reduced sufficiently the OLP will be simply a series of alternate positive and negative spikes.

Mathematically, such a waveform is the first derivative of the input waveform i.e. \( V_o = \frac{dV_i}{dt} \) and hence the circuit is called differentiator. In general, the time constant of the differentiating circuit shall be small compared to the period of the input signal.

Integrating Circuit (low pass RC Circuit):

\[ \text{A simple Integrating Circuit} \]

- Consists of series Resistor + Shunt Capacitor.
- Cuts out low frequencies of the input signal and attenuates high freq.
- Below the reactance of capacitor \( C \) will be \( 1 \) for freq.

At very high freq, Capacitor acts as a virtual short circuit.

- Hence \( C \) is called a low pass filter.

It gives an OLP waveform similar to the time integral of the input waveform i.e.

\[ V_o = \frac{1}{RC} \int V_i \, dt \]

OLP is given by

\[ V_o = V_i \left[ 1 - e^{-\frac{t}{RC}} \right] \]

\( V_o \rightarrow \) OLP Voltage, \( V_i \rightarrow \) input voltage.

Time constant of Integrating Circuit shall be large compared with period of the input signal.
Rise time:

The rise time $t_r$ is the time taken for the voltage to rise from 10% to 90% of its final value.

In a low-pass RC circuit, it is found that the time required for $V_o$ to reach 10% of its final value is $0.1RC$.

And the time to reach 90% of its final value is $2.3RC$.

The rise time $t_r$ is proportional to the time constant $RC$ and inversely proportional to the rise time $t_r$ is given by:

$$t_r = RC \times \ln(2)$$

Peak response for $f_0 = \frac{1}{2\pi RC}$

Sag or tilt:

By shows the response to which exhibits a tilt when a step $V_i$ is applied to a high-pass RC circuit.

Since the capacitor is initially uncharged, the op-amp at $t = 0$ will be $V_i$. Hence,

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

At $t = T$, if time constant $RC$ is very large, $V_i RC << t$,

there is only a slight tilt to the op-amp pulse. At $t = T$,

$$V' = V_i \left(1 - \frac{t}{RC}\right)$$

Tilt or sag in time $t_i$ is given by:

$$\rho = \frac{V_i - V'}{V} \times 100 = \frac{t_i}{RC} \times 100 \%$$
Valid for the tilt of each half cycle of a symmetrical square wave of peak to peak value \( V \times \) period \( T \)

we get \( f_1 = \frac{V}{2T} \). If \( f = \frac{1}{4T} \) is the freq of square wave

we have 3 dB freq \( f_1 = \frac{1}{2\pi f_1 c_1} \)

\[
P = \frac{f x 100}{2 f_1 c_1} = \frac{100 x f}{2 f_1 (1)}
\]

Tilt x lower 3 dB freq - \( f_1 \)

**Duty Cycle**

ratio of on period \( T_{on} \) to total period \( T_{on + T_{off}} \)

Duty cycle = \( \frac{T_{on}}{T} \)

**RL Circuit:**

In an RL circuit, a resistor \( R \) and a capacitor \( C \) are replaced by an Inductor \( L \) and a Resistor \( R' \), respectively. The time constant \( L/R' \) is equal to the time constant \( R' C \). Then all the results derived in RL circuits are applicable and it is without any change in RL circuit.

Whenever a large time constant is required, the RL circuit is rarely used because \( L \) should be large to get the large time constant \( L/R' \). Thus, RL circuit is used only if a small time constant is required.

**RL Circuit Types:**

1. High-pass RL circuit
2. Low-pass RL circuit.
High pass RL Circuit

The reactance of inductor is \( X_L = 2\pi f L \)

For dc \(IL = 0 \) \( ; X = 0 \)

For ac \( f \) \( > \) \( f_c \), reactance becomes zero

Inductor act as short circuit

And \( OLP \) falls to zero

Inductor act as short circuit for certain low freq. range.

- The circuit does not pass low freq. of \( OLP \)

Very high freq. Inductor open circuit

- All high freq. components appear at \( OLP \)

- Chir called as high pass filter

The time constant (T) for RL circuit \( L = \frac{1}{\pi f} \)

At instantaneous voltage \( \frac{dv}{dt} \) across any inductance in any circuit is not infinite, the current through an inductor does not change discontinuously. Therefore, an inductor act as an open circuit at the time of abrupt change in voltage.

[Diagram showing square wave response of high pass RL circuit with small time constant]
Low pass RL Circuit

- Consists of series inductor, shunt resistor.
- The current passes low frequencies of iLP as attenuated high freq. because reactance of inductor is \( \frac{1}{sL} \) for high freq.

High freq. - Inductor acts as open circuit, iLP falls to zero, low pass filter.

Suppose a voltage applied to LP RL circuit. iLP changes abruptly from 0 to a voltage. Current (I) can't change instantly (in circuit) \( \frac{dL}{dt} \) = 0. Voltage across inductor is zero.

\[ \frac{di}{dt} = 0 \Rightarrow \text{Voltage drop across inductor is zero.} \]

- Entire voltage \( V_A \) appears across iLP.
- iLP voltage decays exponentially from 0 to \( A_e \).

\[ V(t) = A(1 - e^{(-BC)t}) \]

To low pass RC circuit, the rise time is defined as time required by the iLP to rise from 10% of final value to 90% of final value.

\[ T_R = 2.2 \tau \]

when pulse iLP voltage of amplitude \( A \) and width \( \tau \) is applied to low pass RL circuit; it is observed that iLP is distorted. The distortion can be minimized by delay.

The rise time, compared to pulse width, is 

\[ T_R = 0.35 \tau \]

iLP is faithfully reproduced of iLP.
For square wave input voltage

- Square wave input with constant amplitude $A_1$ for the period $T_1$. It changes abruptly from $A_1$ to $A_2$ and remains at $A_2$ for the period $T_2$.

The period of square wave is $T = T_1 + T_2$.

The square wave is considered to be made up of pulses of alternating polarity. In one cycle, there exists a pulse width $T_1$ with amplitude $A_1$ and negative pulse of width $T_2$ with amplitude $A_2$.

Two constants are small: $\alpha_{1p} \approx 1$.

Square wave response of low pass RL circuit with small time constant.
Storage, Delay, Calculation of Transfer

Switching Time

When pulse is applied to input of transistor, the collector current does not respond directly to the input waveform.

- There will be little delay, because the transistor operates from cut-off to saturation and then returns to cut-off.

![Diagram of transistor circuit and waveform]

Transistor quickly cut

Delay time ($t_{d}$):

The collector current does not immediately respond to the input pulse. There is a delay and the time that elapses during this delay, together with time needed for the current to rise to 10% of its maximum (saturated) value is $t_{d}$. $t_{on} = V_{cc} / R_{e}$ is called delay time ($t_{d}$).

The reason for delay is that the transistor requires time to charge up the emitter junction transistor capacitance in order to bring the transistor to the active region from cut-off region.
Rise time (\(t_r\)):
The time required for \(\text{Collector Current}\) to rise from 10% to 90% of its max. value is called rise time (\(t_r\)).

Turn on time (\(t_{on}\)):
The sum of rise time \(t_r\) and delay time (\(t_d\)) is called turn on time:
\[ t_{on} = t_d + t_r \]

Storage time (\(t_s\)):
When the flip-flop returns back to its initial state at \(t = 0\), the Collector Current again fails to respond immediately. The interval which elapses before transition of flip voltage waveform and the time when Collector Current \(i_C\) dropped to 90% of its max. value is called storage time.

Fall time (\(t_f\)):
The time required for the Collector Current to fall from 90% to 10% of its max. value.

Turn off time (\(t_{off}\)):
The sum of Storage time \(t_s\) and fall time \(t_f\):
\[ t_{off} = t_s + t_f \]
- Used to improve switching times.
- BE junction of transistor is reverse biased before switch on. The delay is longer compared to the case when VBE is initially zero.
- Transistor base capacitance needs to charge to the reverse bias voltage to allow it to discharge before VBE becomes positive.
- Hence, to minimize turn on time, VBE should have a very small reverse bias value before switch on.
- To do so: reduce if the transistor is overdriven.
  1) if $I_t$ is made larger than minimum required for saturation.
  2) larger $I_t$, the junction capacitance charges faster, thus reducing the turn on time.

**Blind vs. overdriving:**
Storage time is extended by large current flow across the forward biased collector base junction when the transistor is in saturation.

Turn off time may be reduced by providing a large negative $V_{CE}$ voltage during switch off.
- This produces a reverse base current flow, causing junction capacitance to discharge rapidly.
- Also the turn on time because of initial reverse large reverse bias required for base emitter junction.
For faster switching, VBE preferably is to be fixed at zero volt, Ib is to be made large or switch on. A should be rapidly allowed to settle down to minimum value required for saturation.

Switch off - done by large reverse bias voltage which rapidly returns to zero.

\[ \text{Load achieve} = \frac{1}{11} \text{C} \]

Called speed up capacitor / commutation capacitor

- Speed up capacitor - \( \frac{1}{11} \) F or Fsp
- C is small, it becomes completely charged within delay time
- Will not affect rise time
- C is totally discharged during storage time, it will not result in significant improvement of fall time.

**Calculation of Speed up Capacitor:**

The capacitor charging current drops by 10% from its maximum level with the capacitor permitted to charge by 10% during the turn on time. C changes by 10% during the time of 0.1 Rs C.

\[ \text{ten} = 0.1 \text{Rs C} \]

\[ C = \frac{\text{ten}}{0.1 \text{ Rs}} \]
The max value of $C$ is depends on max freq of sle.

Transistor switch off; $C$ discharge through $R_B$

For perfect switching, $C$ must be arround 90%, discharged
during the time interval ble transistor switch(off xon)

- Time needed for capacitor to return to its discharge
  and is called settling time or recovery time of $C$.

- Transistor is off; capacitor discharge through $R_B$
  by 90% in time $t$ to $2.3 R_B C$.
  \[ t_{r_{f}} = 2.3 R_B C \]

**Diode Clipper:**

The circuit with which the waveform is shaped by removing (or clipping) a portion of the sle without distorting the remaining part of alternating waveform is called clipper.

Clipping circuits refer to as Voltage Type limiters, amplitude selector or slicers.

- Used in radar, digital computer, radio LV receiver.
**Clipping Circuits** employ the components like Diode, resistor, etc. battery.

**Purposes of Resistor**: Used to limit the current flowing through the diode - **FB**.

- To produce flat clip waveform at clipping load, value of \( R = \frac{R_f \times R_r}{R_f + R_r} \).
- \( R_f \) = Forward resistance.
- \( R_r \) = Reverse resistance.

4 types of clippers: 1) Positive clipper 2) Negative clipper 3) Biased clipper 4) Combination clipper.

**i) Positive clipper**

**Series Configuration**

**Shunt Configuration**

**Waveform Diagrams**
Negative Clipper

Positive Clipper

Biased Positive Clipper: with reverse polarity of battery
a) Biased Negative clipper:

When the input voltage $v_i > v_R$ the diode does not conduct and clipping takes place. When the input voltage $v_i < -v_R$ the diode conducts and clipping takes place.

![Diagrams showing clipping in biased negative clipper.]

b) Biased Negative clipper with reverse polarity of the battery:

![Diagrams showing clipping in biased negative clipper with reverse battery polarity.]

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Diode Comparator:

A non-linear circuit used to perform operations of clipping, may also be used to perform the operation of comparison, is called Comparator.

The Comparator Circuit compares an input voltage with reference voltage and, if the input voltage is higher than the reference voltage, the Comparator o/p is high. If the input voltage is lower than the reference voltage, the Comparator o/p is low. The Comparator o/p is independent of the input until it attains reference level.

If the input level becomes equal, there will be a sharp pulse at Comparator o/p.
\[ i_{\text{LP}} \text{ SLL = ramp} \]

- For \( t = t_1 \), \( V_i(t) = V_P + V_p \Rightarrow V_o = V_P \) until \( t = t_1 \).
- Beyond \( t = t_1 \), the SLP rises with \( i_{\text{LP}} \). If \( t > t_1 \), the device responds in the range \( \Delta V_o \) for a precise \( i_{\text{LP}} \) voltage \( \Delta V_p \) corresponding to \( \Delta t \).
- When \( V_P = 0 \), the SLP will respond every time the \( i_{\text{LP}} \) passes through zero, this arrangement is called a Zero Crossing detector.

- Square wave from saw wave
- Timing markers generator from a saw wave
- Phase meter
- Amplitude distribution analyzer
- Pulse train Modulator
- Pulse Square wave, triangular wave generator
- A to D Converter
CLAMPER:

Clamping new shifts (Clamps) a signal to a different dc level (s) it introduces a dc level to an ac signal. Clamping new is also known as dc restorer.

- Apply - TV because to store dc at rf to video sll.

Components: diode, capacitor, resistor.

T = RC: large so voltage across capacitor does not discharge. When the diode is not conducting.

Vp = square wave with max. amplitude of V

- Diode conducts - Short circuit - Capacitor charge to Vdc.
  - Vo = 0V.

- Diode open - Op voltage - Vp - V - Vo = 0
  - Vo = -2V.

Diode FB - Short circuit - Capacitor charge up to level determined by

the voltage across the capacitor in open circuit.

Open circuit - Capacitor hold onto all its charge.

Total swing of Vp = Total swing of Vp + Vp.
Multivibrator:
The multivibrators are used to generate square or rectangular waveforms. They are two stage amplifiers connected back to back. The device are operated either as cut-off or saturation alternatively, so that the OP swings between $V_{cc}$ and $V_{ee}$ (sat) resulting in square or rectangular waveform.

Types of Multivibrator:

1. Types. They are:
   1) Asstable Multivibrator
   2) Monostable
   3) Bistable

Asstable Multivibrator:
- The circuit is not stable (i.e.) both the states of the multivibrator are quasi (semi) stable state. The multivibrator changes state on its own without the need for external triggering. Hence it is known as free running multivibrator, which generates square waveforms whose time period is decided by the circuit components.

Application: Square wave generator

Monostable Multivibrator:
- One stable state of one quasi stable state.
- Multivibrator requires an external trigger to change from the stable state to the quasi stable state.
- It remains in this state for a duration decided by the RC time constant and returns back to the stable state.

Since the circuit returns back to the original state after time duration $T$; it is also known as monoshot, single cycle, single step circuit, monoshot or univibrator.
It generates rectangular waveform, which can be used to gate other circuits. It is also called the gating circuit.

It is also known as delay circuit. Such a circuit generates a fast transition at a predetermined time after trigger input.

Bistable Multivibrator

- Two Stable States
- It remains in both states indefinitely unless altered by an external trigger. The bistable multivibrator is also known as Eccles-Jordan circuit, flip-flop or binary.

Applications:
1) Used in design of counters, shift registers, memories.
2) Generation of trains of pulse waveform.

Collector-Coupled Astable Multivibrator

An astable multivibrator has two quasi-stable states. The collector of each stage is connected to the base of the other stage through a capacitor. Due to this capacitive coupling, both the stages are alternately at cutoff and saturation regions, alternatively at regular time intervals, decided by the RC time constant of the circuit. Since the circuit keeps changing status on its own accord, it is also known as free running oscillator.
Astable Multivibrator

Waveform at base of $Q_1$, $Q_2$

Collector of $Q_1$, $Q_2$

$V_{cc}$

$V_{be}$

$V_{be}$ (up)

$V_{be}$ (down)

$V_{be}$ (up)

$V_{be}$ (down)

$V_{be}$ (up)

$V_{be}$ (down)

$V_{cc}$
- A stable or free running multivibrator generates square wave without any external triggering pulse.
- No stable state (i) it has two quasi stable state
- Switches back & forth from one state to the other.
- Remaining in each state for a time depending upon the discharging of capacitive circuit.
- Square wave is taken from collector points of Q1 or Q2.
- Supply voltage Vcc is applied, one transistor will conduct more than the other due to some circuit imbalance.
- Assume Q1 is Conducting, Q2 is Cut off.
  - Vc1 = Vcc (Sat) & Vc1 = Vcc
  - C1 charges exponentially with T = R1\ C1 through R1.
  - Vb1 + Vc1 towards Vcc
  - Vb2 (voltage) Q2 starts Conducting,
    - Vc2 = VCC (Sat) & Vb1 falls due to capacitive coupling, blw collector of Q2 + base of Q1,
- Q1 off, Q2 on.
  - Vb1 + Vc1 exponentially with R1 \ L2.
  - Vb1 = Vb1 (Sat) & Vc1 = VCC (Sat)
on time for $Q_1 = T_1 = B_1 C_1 \ln 2 = 0.693 R_1 C_1$

off time for $Q_2 = T_2 = B_2 C_2 \ln 2 = 0.693 R_2 C_2$

$T_0 = T_1 + T_2 = 0.693 (B_1 C_1 + B_2 C_2)$

If $R_1 = R_2 = R$ ; $C_1 = C_2 = C$

$T = 1.386 R C \Rightarrow f = \frac{1}{T} = \frac{1}{1.386 R C}$

To ensure oscillations, the value of resistor should

satisfy following condition:

$R_1 \leq \text{hfe}_{(min)} R C_1 \leq R_2 \leq \text{hfe}_{(min)} R C_2$

$hfe_{(min)} - \text{ min. value of dc current gain of}
\quad \text{ transistor $Q_1 \& Q_2$.}$

Applications:

- Astable multivibrator used as square wave generator,
  - Voltage to frequency converter, and in pulse
    - Synchronization, as clock for binary logic signals.
  - It produces square waves, it is a source of
    - Production of harmonic frequencies of higher order
  - Used in construction of digital voltmeters & SMPS
  - It can be operated as an oscillator over
    - Wide range of audio & video frequency.
Emitter Coupled Asstable Multivibrator:

Due to the circuit symmetry of collector coupled asstable multivibrator, sometimes both the transistors Q1 and Q2 may be on or remain off. Therefore when supply voltage Vcc is supplied, the circuit may not start oscillating. By shorting the base and emitter terminals of one of the transistors for a short time, the oscillation can be started.

When one transistor starts conducting, the other transistor’s emitter voltage drops. As its base voltage decreases, the presence of RC eliminates the possibility of both transistors remaining on at the same time. In effect, the circuit oscillates. \( R_C = \frac{V_{cc}}{2I_E} \) and other components are also determined.

Mono-stable Multivibrator:

- One stable state
- One quasi stable state
- Also called a shot multivibrator / univibrator

- Remain in its stable state until an input pulse triggers
- Remains in its quasi stable state for some duration
determined by discharging the RC circuit and the circuit returns to its original stable state automatically.
It remains there until the next trigger is applied.

- Can't generate square waves.
- Only external trigger pulses will cause it to
  generate the rectangular wave.

- Consists of two identical transistors Q1, Q2.

- Equal collector resistance of PC1, PC2.

- The collector of Q2 is coupled to Q1 at the base Q1.

- The collector of Q2 acts as an attenuator in which Q1 is a
  small speed up capacitor to speed up transitions.

- Value of Q2 & VBB chosen so as to reverse bias Q1.

- The collector supply +Vcc x R will forward bias
  Q2 and keep it in the ON state.

- Then it becomes stable.

- Positive trigger pulse of short duration is sufficient
  to be applied to the base of Q2 through C1,
  magnitude is applied to the base of Q2, through C2,
  and hence decreasing the base of transistor Q1 starts conducting and thereby decreasing
  the voltage at its collector Vc1, which is coupled
  to the base of Q2 through capacitor C1.

- This decrease FB on Q2. Its Collector current decreases.

- The increasing positive potential on the collector of Q2 is
  further applied to the base of Q1 through R1. This further
  increase the base potential of Q1 to Q1 is quickly
  driven to saturation. Q2 is cut off.

- Capacitor C charges to +VCC.

- Capacitor C discharges through Q2 base as FB
  Collector current starts to flow into Q2.

- Q2 is quickly driven to saturation & Q1 is cut off.

- This is a stable state of circuit. It remains &
  this condition...
Duration of 1/v pulse of multivibrator
multivibrator = T = 0.693 \times RC

Applications:
- Function as adjustable pulse width generator
- Used to generate uniform width pulse from a variable width 'Up' pulse train
- Generate clean & sharp pulses from the distorted pulses
- Used as time delay unit since it produces a transition or fixed time after the trigger signal
Bistable Multivibrator:
- Also refer as Flip Flop, Eccles Jordan Circuit,
  Trigger circuit or binary.
- Has two stable state.
- A trigger pulse is applied to circuit will cause it
  to switch from one state to the other.
- Another trigger pulse to switch the circuit back to
  its original state.
- Uses two NPN Transistors.
- Qp (collector) of Q2 is coupled to Q1 through R3.
- Emitter of Q1 is coupled to the base of Q2 through R1.
- When abruptly changing pulse is applied to the circuit, the transition from one state to other should occur instantaneously.
- Transition time = time interval during which conduction transfers from one transistor to other should be small.
- Main purpose of C1 & Q2 = improve switching characteristics of circuit
- Allow fast rise & fall time, so freq not be distorted.
- C1, Q2 call as Commutating Capacitor.
- Speed up capaciton or transpose Capacitor.
- Q1 is switched on, one of transistor start conducting.

Application:
- Memory elements in Shift register, Counter.
- Generate square wave of symmetrical shape by sending regular triggering pulse to the up.
- By adjusting the freq of up triggering pulse, the width of square wave can be altered.
- Used as freq divider.
A CLP waveform for Bistable Multivibrator
Schmitt Trigger:
- Wave shaping circuit
- Used for generation of a square wave from sine wave input
- It is a bistable circuit in which two transistor switches are connected regeneratively.

Fig: Symmetrical triggering through diodes at R1P & R1P of amplifier.


1. Consists of $Q_1$, $Q_2$ (Transistors) coupled through an Emitter resistor $R_E$. $R_1$, $R_2$ form a voltage divider across $V_{cc}$ and $GND$. This provides a small $V_E$ to $B$ junction of transistor $Q_2$.

2. Supply on, with no $I_{in}$, transistor $Q_2$ starts conducting. The rise in $I_{in}$ current (as $I_C$) of $Q_2$ causes voltage drop across $R_E$ as $V_{RE} = I_C R_E$.

3. Voltage provided by $R_E$ across Emitter-base junction of $Q_1$ and it is driven into cut-off state.

4. $Q_1$ is OFF, voltage at Collector rises to $V_{cc}$.

5. Collector of $Q_1$ is coupled to the base of $Q_2$ through $R_1$, the $V_E$ of transistor $Q_2$ is increased.

6. $Q_2$ is driven into saturation.

7. $V_{C1} = V_{cc}$ then $V_{C1} = V_{CC} (sat) + V_{BE}$

8. If $V_{in}$ apply to base $Q_1$.

9. When voltage increases above zero, nothing will happen until it reaches $V_TN$ (Upper Trigger Level).

10. $V_{in} > V_TN$, $V_{in} < V_{BE1}$, $Q_1$ Conducts.

11. Point at which $Q_1$ starts conducting is known as Upper Trigger Point.

12. $Q_1$ Conducts, $V_C < V_{cc}$.

13. Collector of $Q_1$ is coupled to base of $Q_2$ if $V_E$ of $Q_2$ is reduced.

14. $V_E$ is reversed bias of transistor $Q_1$ is reduced and it conducts most which drives $Q_2$ to nearer to cut-off.
Collector Voltage ann. \( V_{CE} = V_{CE} \text{(sat)} + V_{BE} \)

- \( V_{CC} = V_{CC} \).
- \( V_{CE} \) will continue to conduct till \( V_{CE} \) crosses \( V_{CC} \).

\[ V_{CE} = V_{CE} \text{(sat)} + V_{BE} \]

\[ V_{CE} = V_{CC} \]

- \( E_{1} \) is in reverse bias.

- \( V_{CE} = V_{CC} \), \( E_{B} \) junction of \( Q_{1} \) becomes reverse bias \( (R_{B}) \).

\( V_{CC} \) starts rising towards \( V_{CC} \).

- \( Q_{2} \) starts conducting.

- The point at which \( Q_{2} \) starts conducting is called lower trigger point \( (LTP) \).

- \( Q_{2} \) \( (sat) \); \( E_{1} \) \( (cut \; off) \).

- \( V_{CE} = V_{CC} \); \( V_{CE} = V_{CE} \text{(sat)} + V_{BE} \)

- No change in state will occur during the negative half cycle of input voltage.

- Hysteresis Voltage \( (V_{H}) = UTP - LTP \).

\( V_{H} \) - known as dead zone of Schmitt trigger.

- The hysteresis of LT voltage from UT voltage is known as hysteresis.

Application:
- Hysteresis eliminated by \( R_{C1} = R_{C2} \).

- Used for wave shaping circuit.

- Used for generation of rectangular waveform with sharp edges from sine wave and any other waveform.

- Used as voltage comparator.

- Hysteresis in Schmitt trigger is valuable as it can condition noisy signal for using digital circuit.

- Noise does not cause false triggering and so the output will be free from noise.
Schmidt Trigger

Key Hysteresis of Schmidt Trigger