Chapter 7
(Chapter 8 in Text Book)

Signal generation

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Signal Generators Characteristics:

- Frequency should be **known** and **stable**.
- Signal Amplitude should be known and **controllable**.
- Signal should be **Free** of distortion.

The Sign-Wave Generators:

The basic Signal generator consists of two stages:

1- The **Oscillator**: Generate the signal with the specific shape and Frequency.

2. **Attenuator**: For design the signal amplitude.

SINUSOIDAL OSCILLATOR

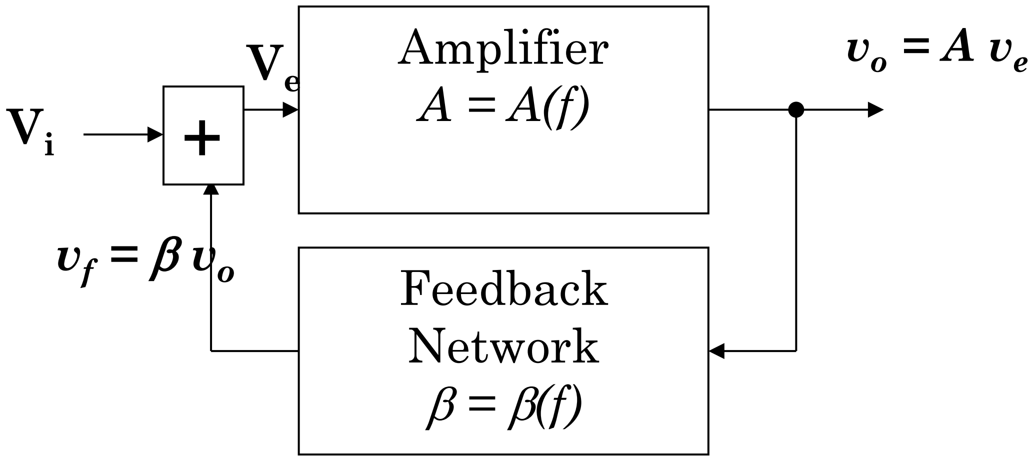
- Oscillator with LC Feedback
  - Colpitts Oscillator
  - Hartley Oscillator
- Crystal Controlled Oscillator

Sinusoidal oscillator

- Use positive feedback principle (feedback oscillator)

PRINCIPLE OF FEEDBACK OSCILLATOR

- Used to produce **sinusoidal** periodic signal
- Use positive feedback.
  - The output of the amplifier ***Vo*** is fed into the feedback network, amplified and fed back to the amplifier.



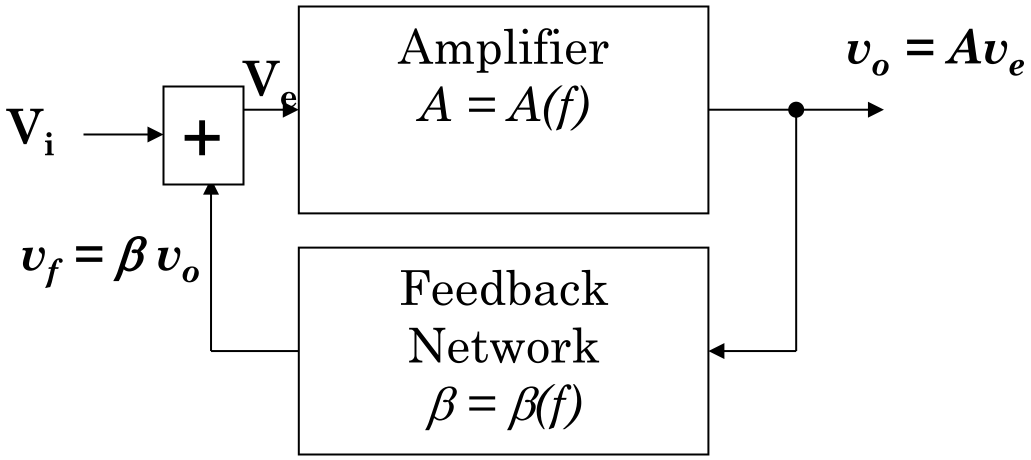
***A* is the gain of the amplifier and**

β* is the gain of the feedback network and both are dependent on frequency *f

PRINCIPLE OF FEEDBACK OSCILLATOR

- $v_e = v_i + \beta v_o = v_i + \beta A v_e$
- Oscillator **does not require** external input v_i

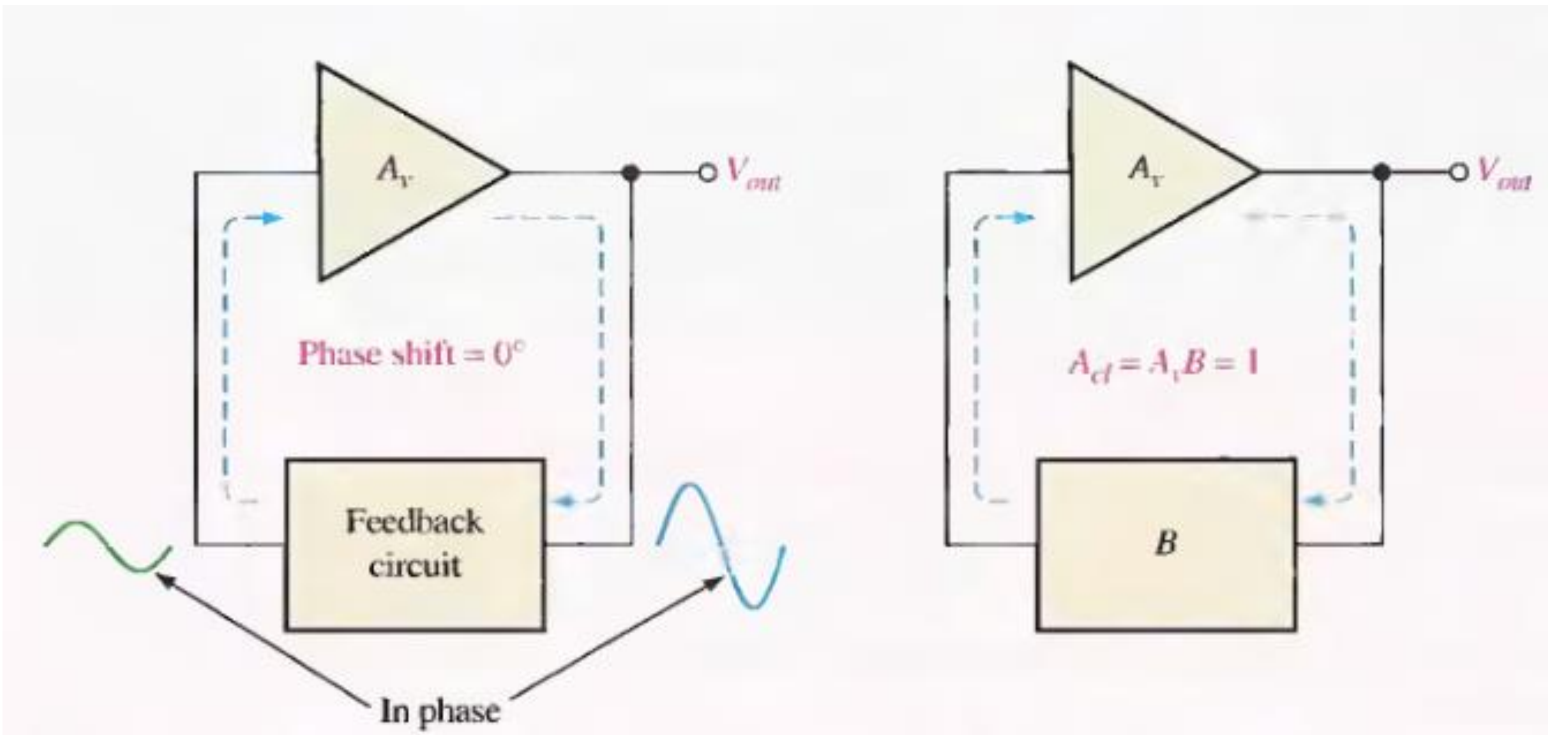
  >> $v_i = 0$ >> $\boldsymbol{\beta A = 1}$ **(requirement for oscillation)**
- $\boldsymbol{\beta A}$ is called the loop gain



Barkhausen Criterion for Oscillation

Imply that the loop gain is a real number

Imply that the loop gain magnitude equal 1



$$\beta(j\omega_o)\,A(j\omega_o) = 1$$

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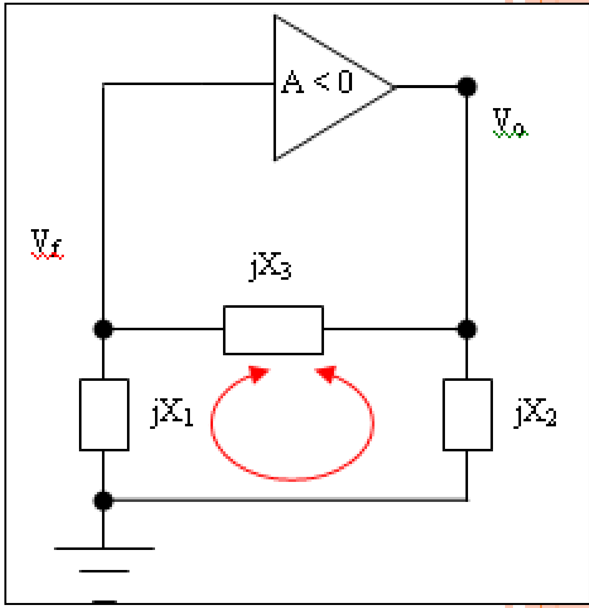
Frequency Stability

- Frequency stability is the ability of an oscillator to oscillate **at an exact** frequency.
- The oscillation frequency is a function of circuit components
- Crystal oscillators are far more stable than RC or LC oscillator, especially at higher frequencies.

Colpitts Oscillator

- If X1 and X2 are **capacitors**, the circuit is called a **Colpitts oscillator**.

$$X_1 = -\frac{1}{\omega_o C_1} \qquad X_2 = -\frac{1}{\omega_o C_2} \qquad X_3 = \omega_o L_3$$



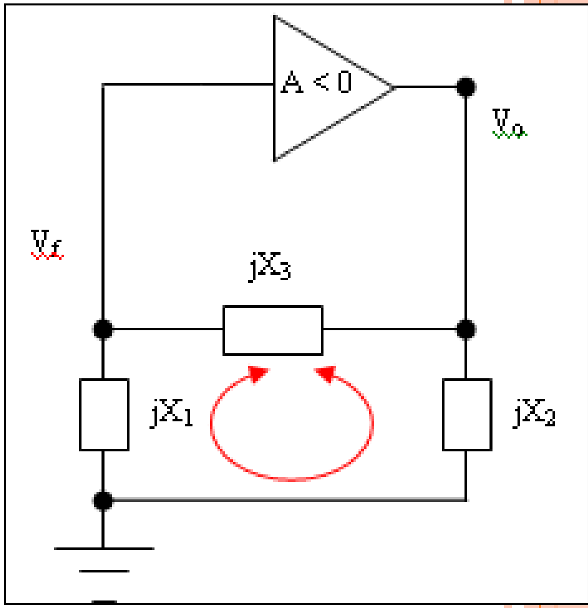
$$X_1 + X_2 + X_3 = -\frac{1}{\omega_o C_1} - \frac{1}{\omega_o C_2} + \omega_o L_3 = 0$$

$$\Leftrightarrow f_o = \frac{1}{2\pi\sqrt{L_3 C_T}} \qquad \text{where } C_T = \frac{C_1 C_2}{C_1 + C_2}$$

- β = -X1/X2= -C2/C1 and the required amplifier gain at resonant frequency is A = -C1/C2.

HARTLEY OSCILLATOR

- If X1 and X2 are **inductors**, the circuit is called a **Hartley oscillator**



$$X_1 = \omega_o L_1 \qquad X_2 = \omega_o L_2 \qquad X_3 = -\frac{1}{\omega_o C_3}$$

$$X_1 + X_2 + X_3 = \omega_o L_1 + \omega_o L_2 - \frac{1}{\omega_o C_3} = 0$$

$$\Leftrightarrow f_o = \frac{1}{2\pi\sqrt{L_T C_3}} \qquad \text{where } L_T = L_1 + L_2$$

β= -X1/X2 = -L1/L2 and the required amplifier gain at resonant frequency is A = -L2/L1.

Wein Bridge Oscillator

Feedback Oscillator

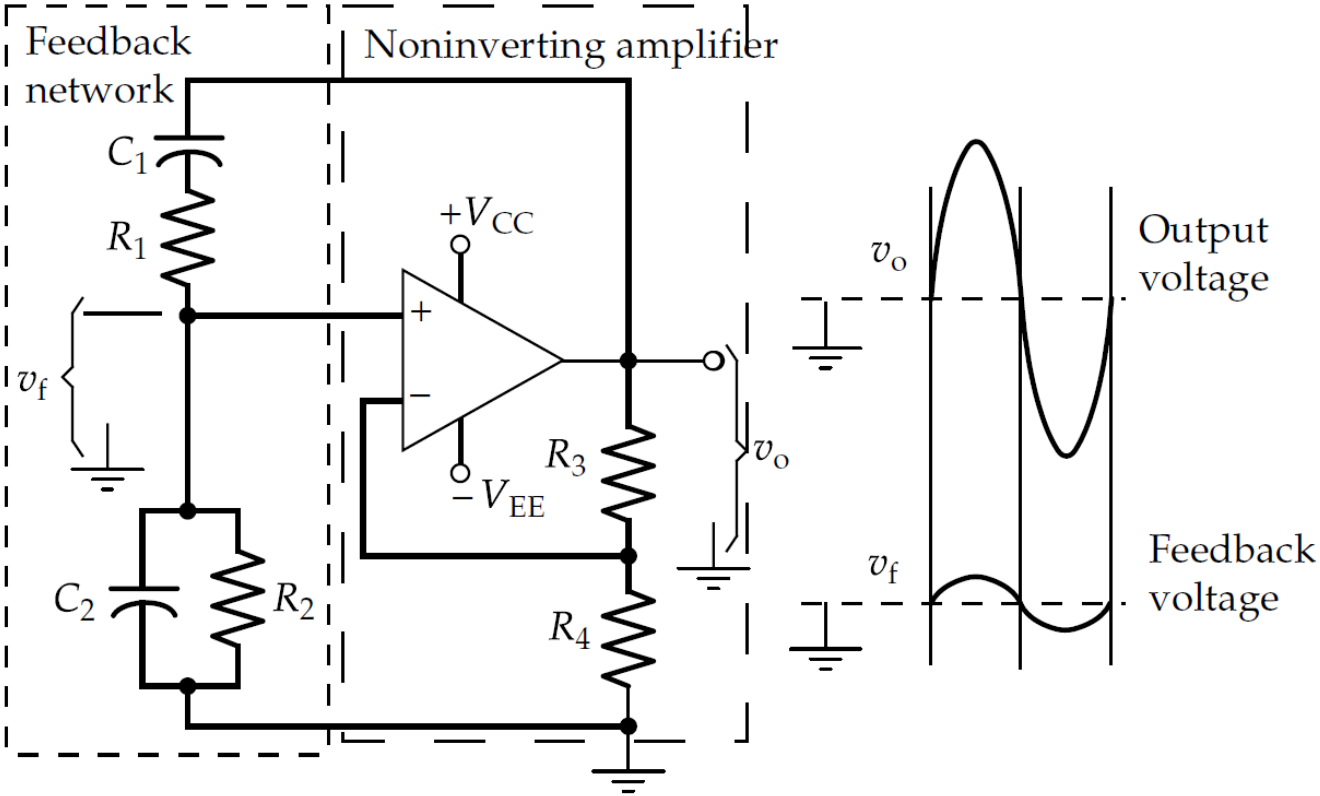


Figure 13-1 The Wein bridge oscillator circuit produces a sine-wave output with a frequency of $f = 1/(2\pi\, C\, R)$, where $R = R_1 = R_2$, and $C = C_1 = C_2$.

Wein Bridge Oscillator

Feedback Oscillator

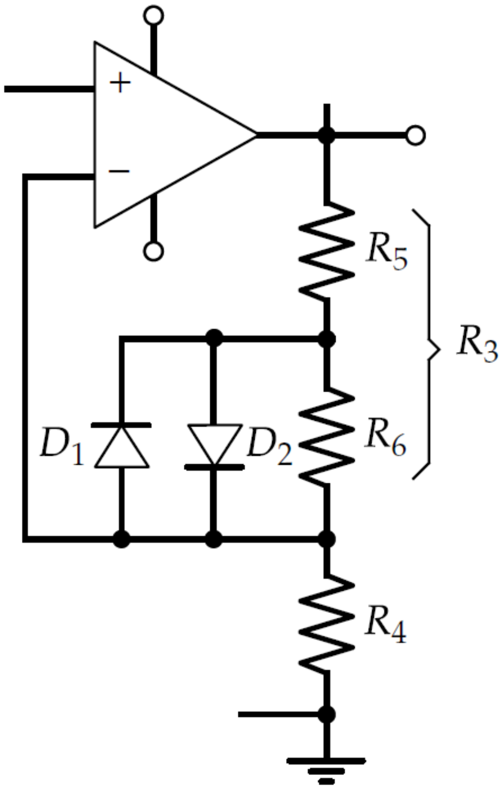


Figure 13-2 Including the diode circuit in a Wein bridge oscillator stabilizes the output amplitude by reducing the gain of the amplifier at high output amplitudes.

Pulse Shaping

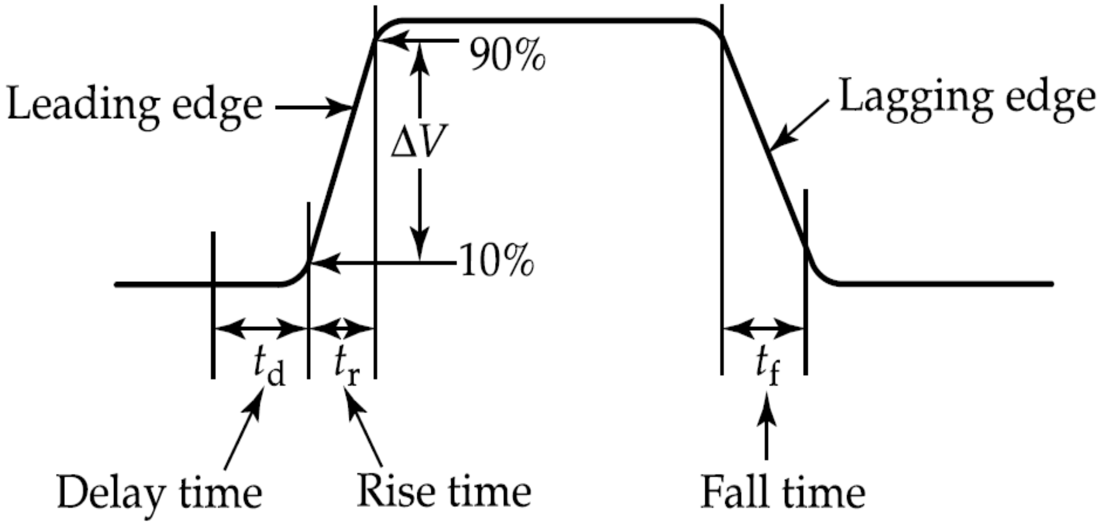
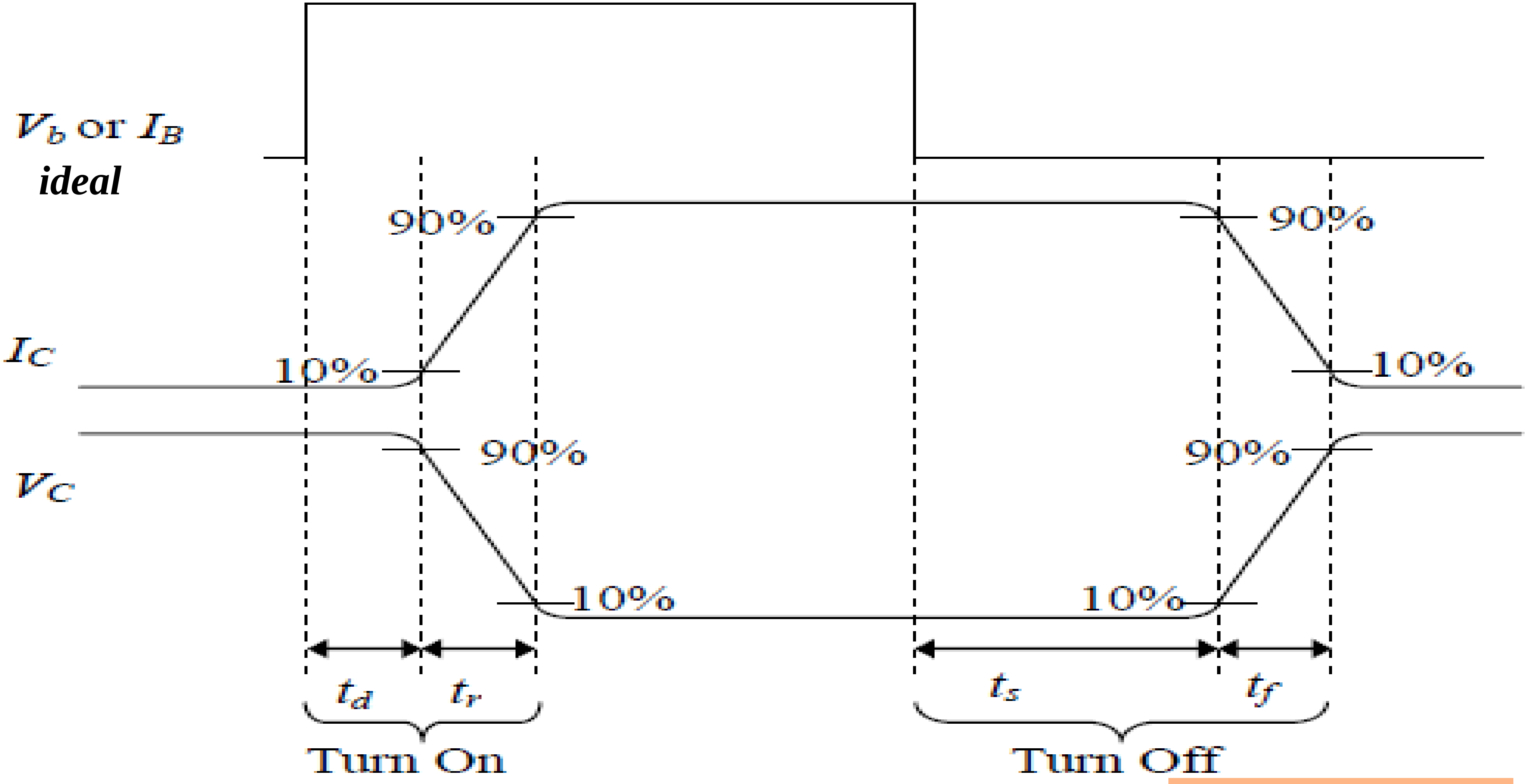


Figure 13-17 Many pulse generators have facilities for adjustment of pulse rise time and fall time. Delay time may also be adjustable.

BJT Switching Time

Two important points about the output waveforms:

- There is a **delay** between each input transition and each output transition.
- The output transitions are **not instantaneous** (vertical). It takes some ***measurable amount of time*** for the transitions to occur.



Rise Time, Delay Time, Storage Time and Fall Time in BJT switching operation

- **Delay time** (*td*) - the time required for a *BJT* to come out of cutoff.

In term of *IC*, it is the time required for *IC* to reach 10% of its maximum value.

In term of *VC*, it is the time required for *VC* to drop to 90% of its maximum value.

- **Rise time** (*tr*) - the time required for a *BJT* to go from cutoff to saturation.

In term of *IC*, it is the time required for *IC* to rise from 10% to 90% of its maximum value.

In term of *VC*, it is the time required for *VC* to drop from 90% to 10% of its maximum value.

- **Storage time** (*ts*) - the time required for a *BJT* to come out of saturation.

In an extreme case this storage time may be two or three times the rise or fall time.

- **Fall time** (*tf*) -the time required for a *BJT* to make the transition from saturation to cutoff.

In terms of *IC*, it is the time required for *IC* to drop from 90% to 10% of its maximum value.

In term of *VC*, it is the time required for *VC* to increase from 10% to 90% of its maximum value.

***Propagation Delay*:**

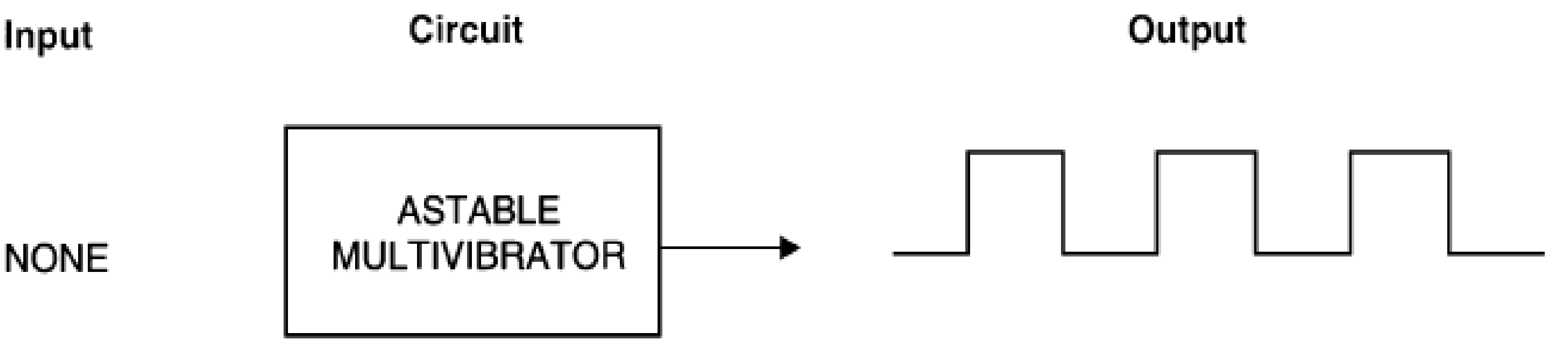
***The* overall time delay between *input* and *output* transitions**

The maximum **switching frequency** for the device,

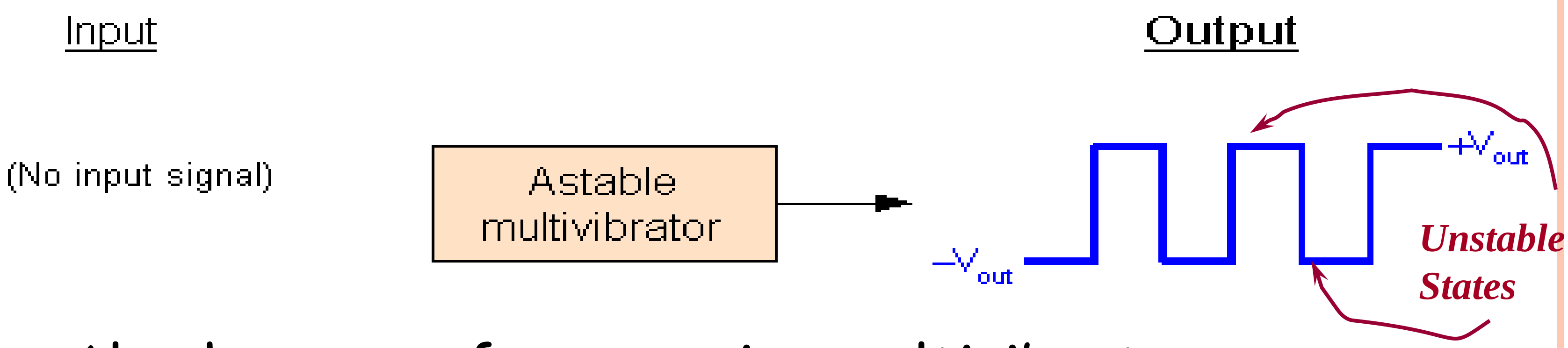
$$f_{\max} = \frac{1}{t_d + t_r + t_s + t_f}$$

Multivibrators

1. **Solid-state Multivibrators** (**The 555 Timer**)
2. **Transistor multivibrator**



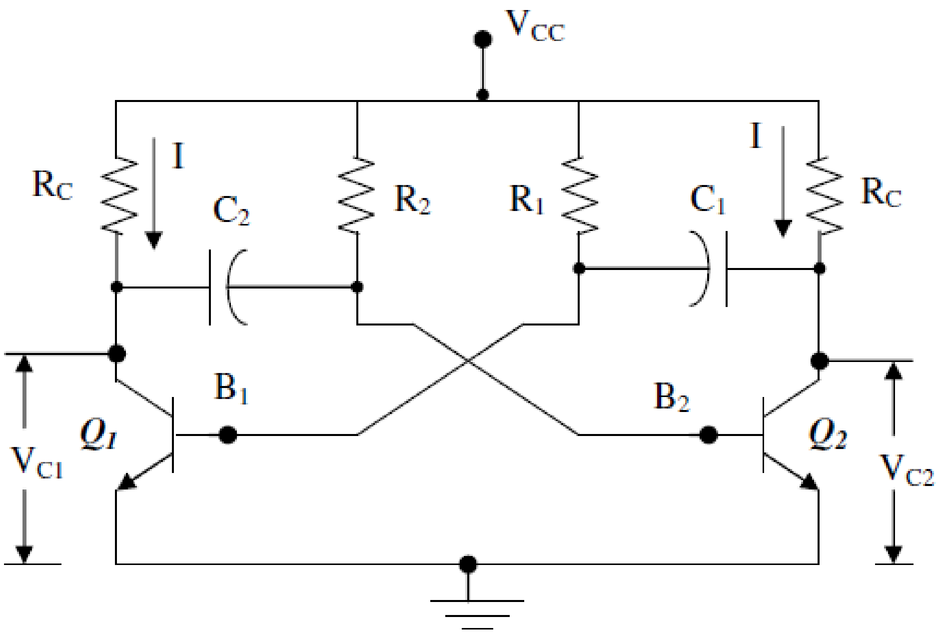
Astable Multivibrator



- Also known as free-running multivibrator
- Has no stable output state
- Output switches back & forth between high & low states without input signal

Transistor Astable Multivibrator

- Has 2 outputs, no input
- Output alternates between 2 different output voltage levels when device is on
- Output remains at each voltage level for a limited period of time
- Output is continuous square or rectangular waveforms



Period, *T* is approximately:

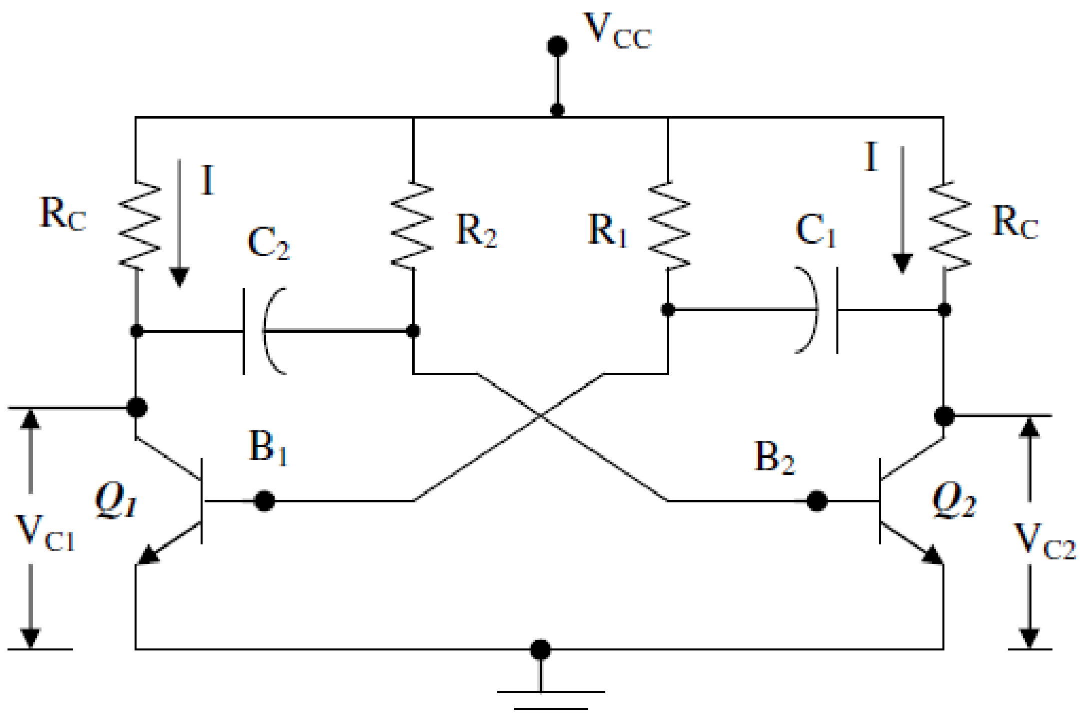
$$T = T_1 + T_2 = 0.693(R_1C_1 + R_2C_2)$$

Exercise:

Analyze the operation of Transistor Astable Multivibrator

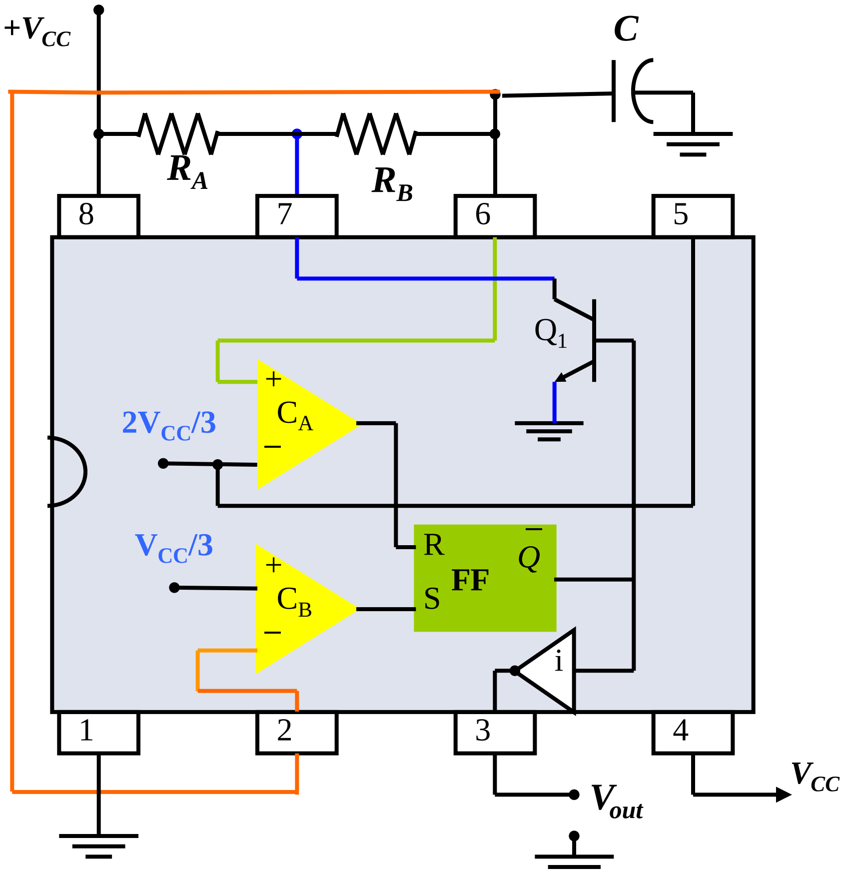
Steps:

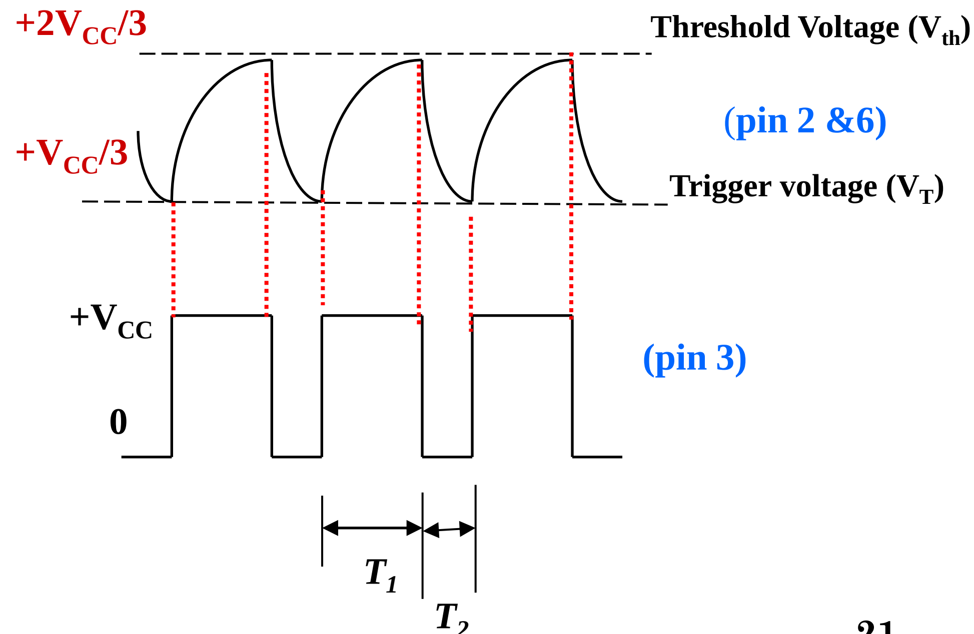
- **Assume one Q ON and the other OFF**
- **Trace the charging and discharge of C1, C2.**



SOLID-STATE ASTABLE (FREE-RUNNING) MULTIVIBRATOR

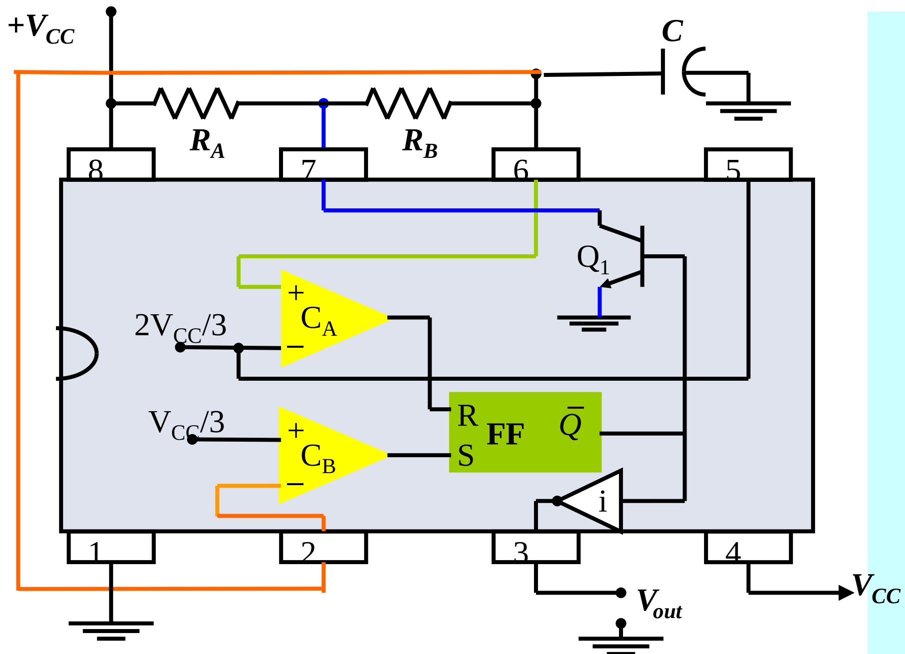
- connecting two resistors and one capacitor to the IC.
- no input trigger.
- It has no stable output state.
- Basically it generates square waves





Brief Analysis of solid-state Astable Multivibrator

- Capacitor is connected to both trigger i/p (pin 2) & threshold input (pin 6).
- Assume output from the FF is low, causing pins 3 & 7 open & the C charges via R_A & R_B toward the threshold voltage $V_{th} = 2V_{CC}/3$.
- When V_C charges to 2/3 V_{CC}, both inputs are high & causes the output from the timer goes low (pin3).
- pin 7 is now acting as a short to ground & will allow the capacitor to discharge. When V_C discharges down to trigger voltage of 1/3 V_{CC}, both inputs will be low & causes the output to go high & pin 7 to return to the open condition, & the cycle restarts again.
- If the capacitor is caused to charge & discharge between (2/3 V_{cc}) & (1/3 V_{cc}), the output will be steady train of pulses.



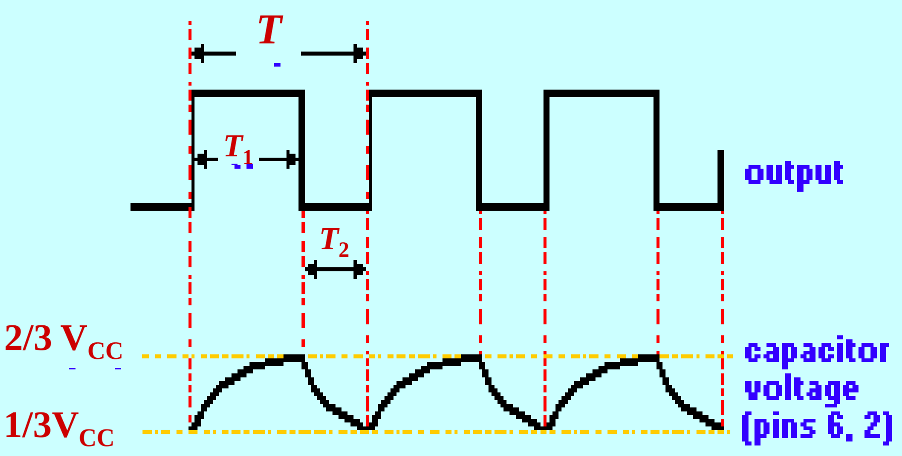


Fig. 10

Design Equations

- The capacitor charging time (pulse width) $T_1 = 0.693\,(R_A + R_B)\,C_1$

- The capacitor discharging time $T_2 = 0.693\,R_B\,C_1$

- Time period $T = T_1 + T_2 = 0.693\,(R_A + 2R_B)\,C_1$

- The charging time constant > discharging time constant, the output is not symmetrical; the high state lasts longer than the low state.

- The duty cycle defined as

$$D = (T_1 / T) \times 100\%$$

- The output frequency is

$$f_o = 1.44 / [(R_A + 2R_B)C_1]$$

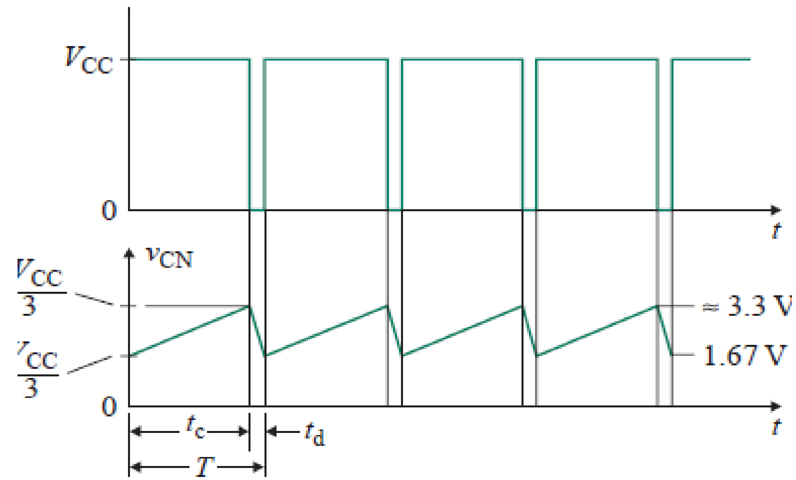
- The duty cycle is

$$D = [(R_A + R_B)/(R_A + 2R_B)] \times 100\%$$

Applications of Astable Multivibrator

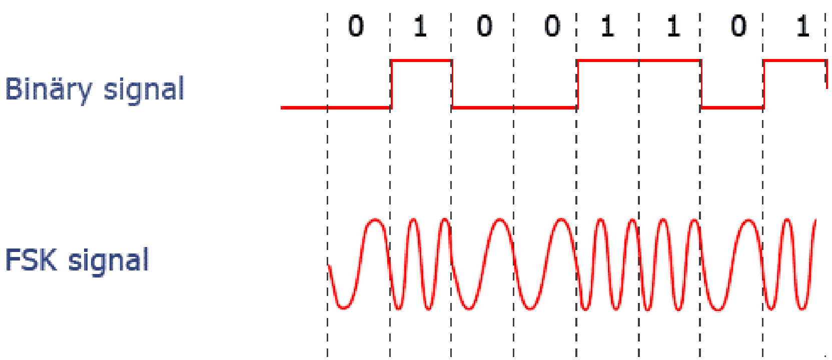
- ***Square-Wave Generator.***

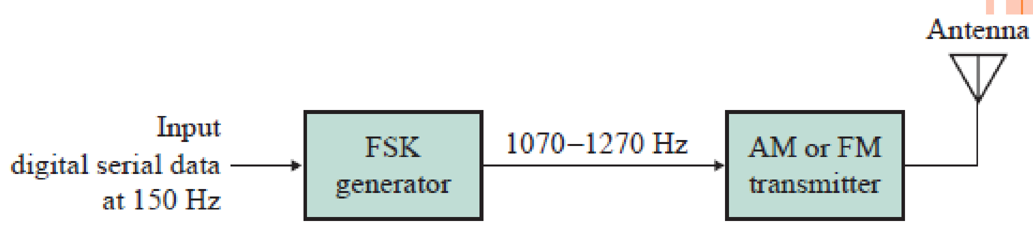
- ***Ramp Generator***



(b) Waveforms

- ***FSK (frequency-shift keying) Modulator***



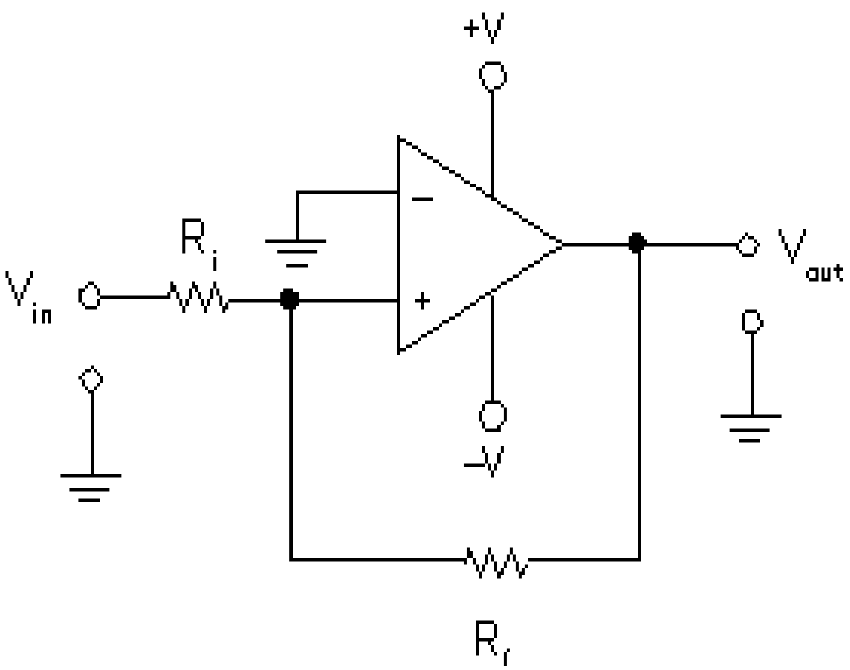


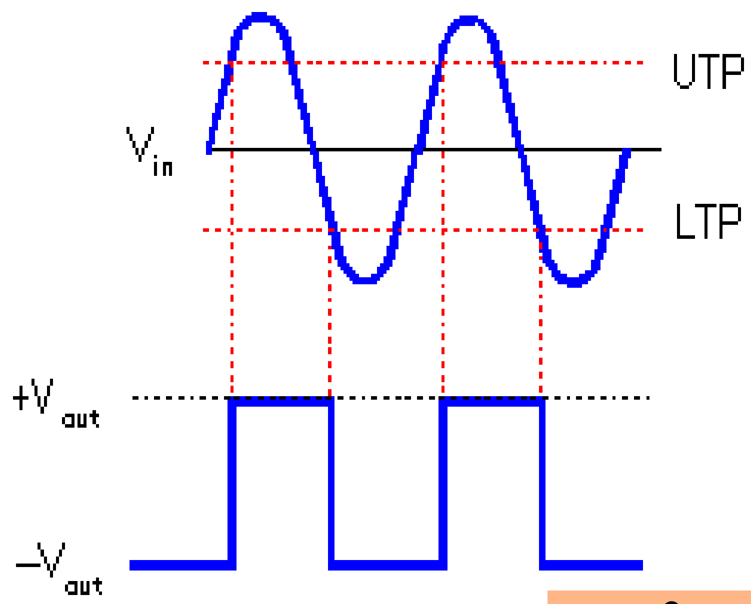
(a) AM/FM transmitter

Schmitt Trigger Circuit

Schmitt Trigger Circuit

- **A Schmitt Trigger can be considered as a comparator with variable threshold or reference voltage.**
- **It is often known as a squaring circuit. It is used to convert a regular or irregular waveform into a square or pulse waveform.**
- **Its input signal is a varying AC voltage.**
- **Its output has two opposite stable states i.e. High and Low.**





Schmitt Trigger Circuit

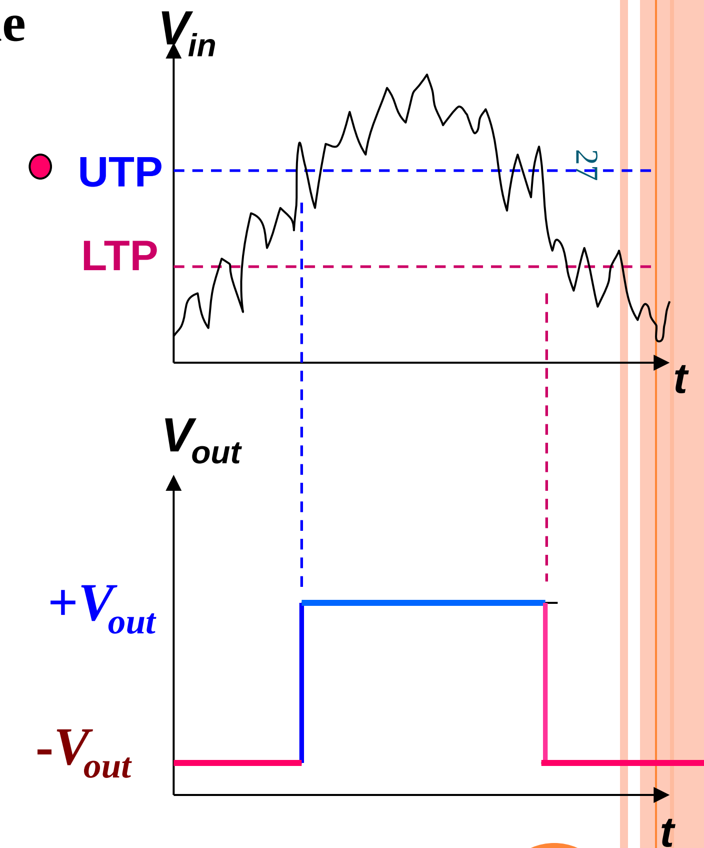
The input/output waveforms are described as follows:

1) When the input makes a **positive-going** transition **past** a ***specified voltage***, the output of the Schmitt trigger goes from ($-V_{out}$ to $+V_{out}$).

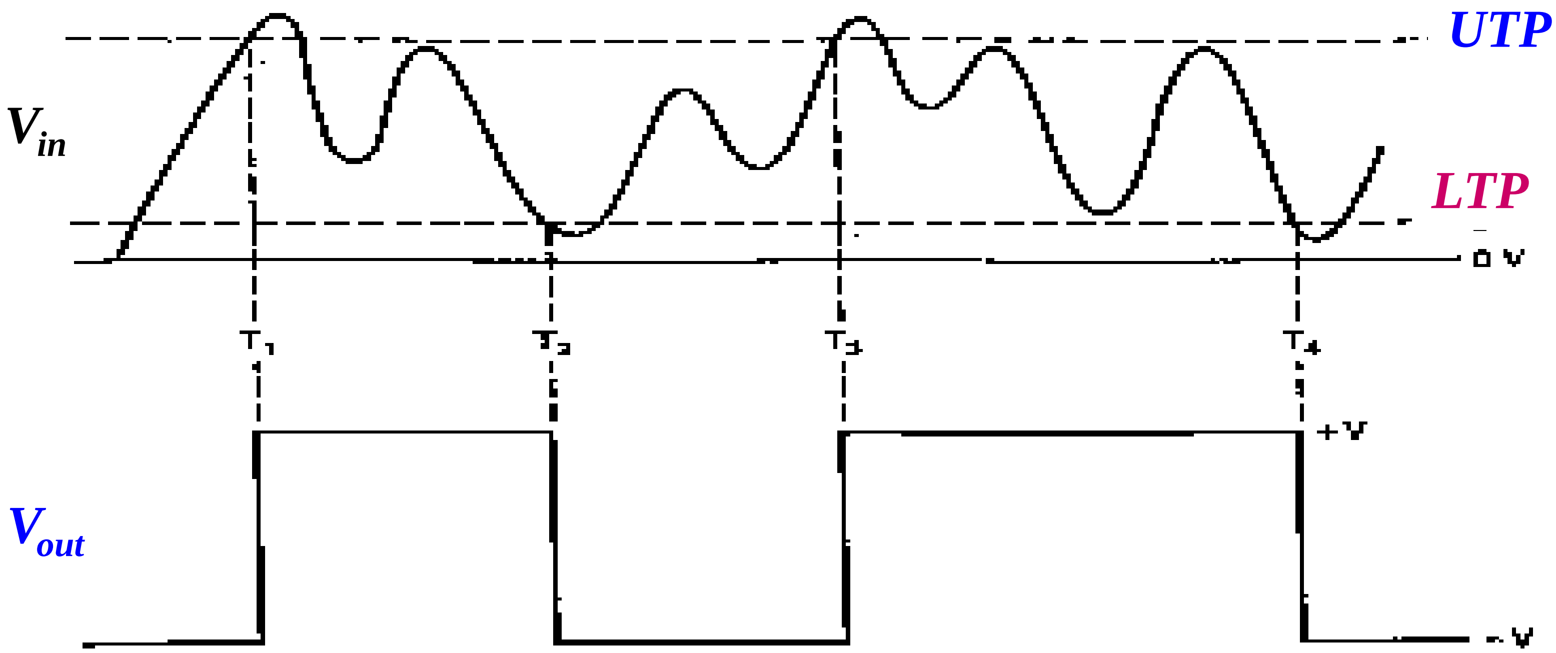
The input voltage at which this change occurs is called the ***Upper Trigger Point (UTP)***.

2) When the input makes a **negative-going** transition **past a *specified voltage***, the output of the Schmitt trigger goes from ($+V_{out}$ to $-V_{out}$).

The input voltage at which this change occurs is called the ***Lower Trigger Point (LTP)***.



- **Input voltage levels that fall between these two trigger points *do not affect the output of the Schmitt trigger*.**
- **Once the UTP is exceeded, the output will not change its state until the input makes a negative-going transition that passes the LTP. The opposite is also true for the LTP .**
- **The voltage difference between the UTP and LTP = hysteresis.**



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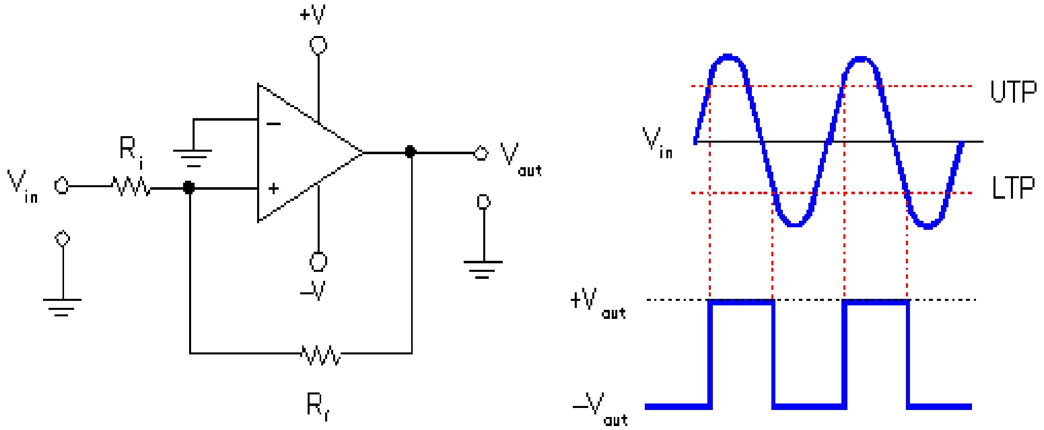
Some of the Schmitt Trigger Characteristics:

- ✓ ***UTP*** and ***LTP*** levels are determined **by** the component values in the circuit such as the R_i, R_f, $+V$.
- ✓ ***UTP*** and ***LTP*** values may or **may not be equal**
- ✓ ***LTP*** value can never be greater (more positive) than ***UTP*** .

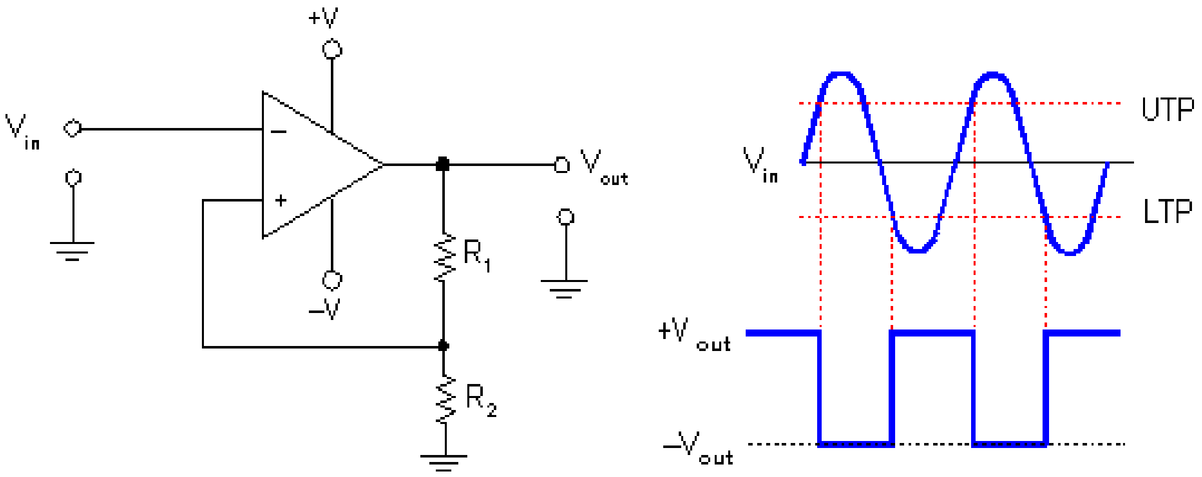
- ✓ The output from a Schmitt trigger changes when:
  - The ***UTP*** is reached by a ***positive****-going transition.*
  - The ***LTP*** is reached by a ***negative****-going transition.*

Schmitt Trigger Circuits

- ***(I) Noninverting Schmitt Triggers***



- ***(II) Inverting Schmitt Triggers***



Signal Frequency

- A **frequency Synthesizer** is an electronic system for generating any of a range of **frequencies** from a single fixed time-base or oscillator.

$$f_2 = N.f_1 \quad , f1: input \;\; f2: output$$

- **Frequency Divider**

- **Sweep Generator**

is a electronic test equipment which creates an **electrical waveform** with a **linearly varying** frequency and a **constant** amplitude

ELECTRONICALLY TUNED SWEEP GENERATOR-BLOCK DIAGRAM