Lecture Notes

Unit:3

Timing Circuits and Oscillators

Topics Covered:

RC-timing circuits, IC 555 and its applications as astable and mono-stable multi-vibrators, positive feedback, Barkhausen's criteria for oscillation, R-C phase shift and Wein bridge oscillator.

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Timing Circuits & Oscillators

All Electrical or Electronic circuits or systems suffer from some form of "time-delay" between its input and output terminals when either a signal or voltage, continuous, (DC) or alternating (AC), is applied to it.

This delay is generally known as the circuits **time delay** or **Time Constant** which represents the time response of the circuit when an input step voltage or signal is applied. The resultant time constant of any electronic circuit or system will mainly depend upon the reactive components either capacitive or inductive connected to it.

Time constant has units of, **Tau –** τ

RC Timing Circuits

RC timing circuits are very important in electronics because they can be used to make time delay circuits and clock circuits. Clock circuits provide regular pulses that allow digital circuits to remain synchronized. Clock circuits are the heartbeat of our modern electronic world.

The "RC Timing Circuits" can have following:

- R - Resistance
- C - Capacitance
- Timing - the output of the circuit changes slowly over time, not instantly
- Network - a combination of several circuit components

RC Timing Circuits - a circuit containing a Resistor and a Capacitor where the output changes slowly with time.

When an **increasing DC voltage** is applied to a discharged Capacitor, the capacitor draws what is called a "**charging current**" and "charges up". When this **voltage is reduced**, the capacitor begins to **discharge** in the opposite direction. Because capacitors can store electrical energy they act in many ways like small batteries, storing or releasing the energy on their plates as required.

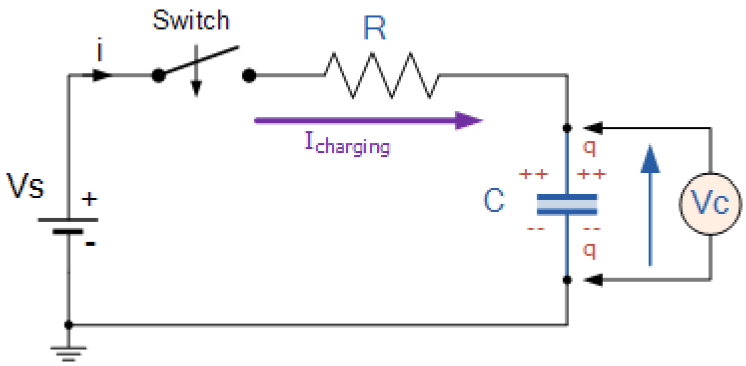
The electrical charge stored on the plates of the capacitor is given as: **Q = CV**. This **charging** (storage) and **discharging** (release) of a capacitors energy is **never instant** but takes a certain **amount of time** to occur with the time taken for the capacitor to charge or discharge to within a certain **percentage** of its **maximum supply** value being known as its **Time Constant** (τ).

If a **resistor is connected in series with the capacitor** forming an RC circuit, the capacitor will charge up gradually through the resistor until the voltage across it reaches that of the supply voltage. The time required for the capacitor to be fully charge is equivalent to about **5 time constants** or 5T. Thus, the transient response or a series RC circuit is equivalent to 5 time constants.

This **transient response time T**, is measured in terms of $\tau = R \times C$, in seconds, where R is the value of the resistor in ohms and C is the value of the capacitor in Farads. This then forms the basis of an RC charging circuit were 5T can also be thought of as "5 x RC".

RC Charging Circuit

The figure below shows a capacitor, (C) in series with a resistor, (R) forming a **RC Charging Circuit** connected across a DC battery supply (Vs) via a mechanical switch. at time zero, when the **switch is first closed**, the capacitor gradually charges up through the resistor until the voltage across it reaches the supply voltage of the battery. The manner in which the **capacitor charges** up is shown below.



Let us assume above, that the capacitor, C is fully "**discharged**" and the switch (S) is fully open. These are the **initial conditions** of the circuit, **then t = 0, i = 0** and **q = 0**. When the

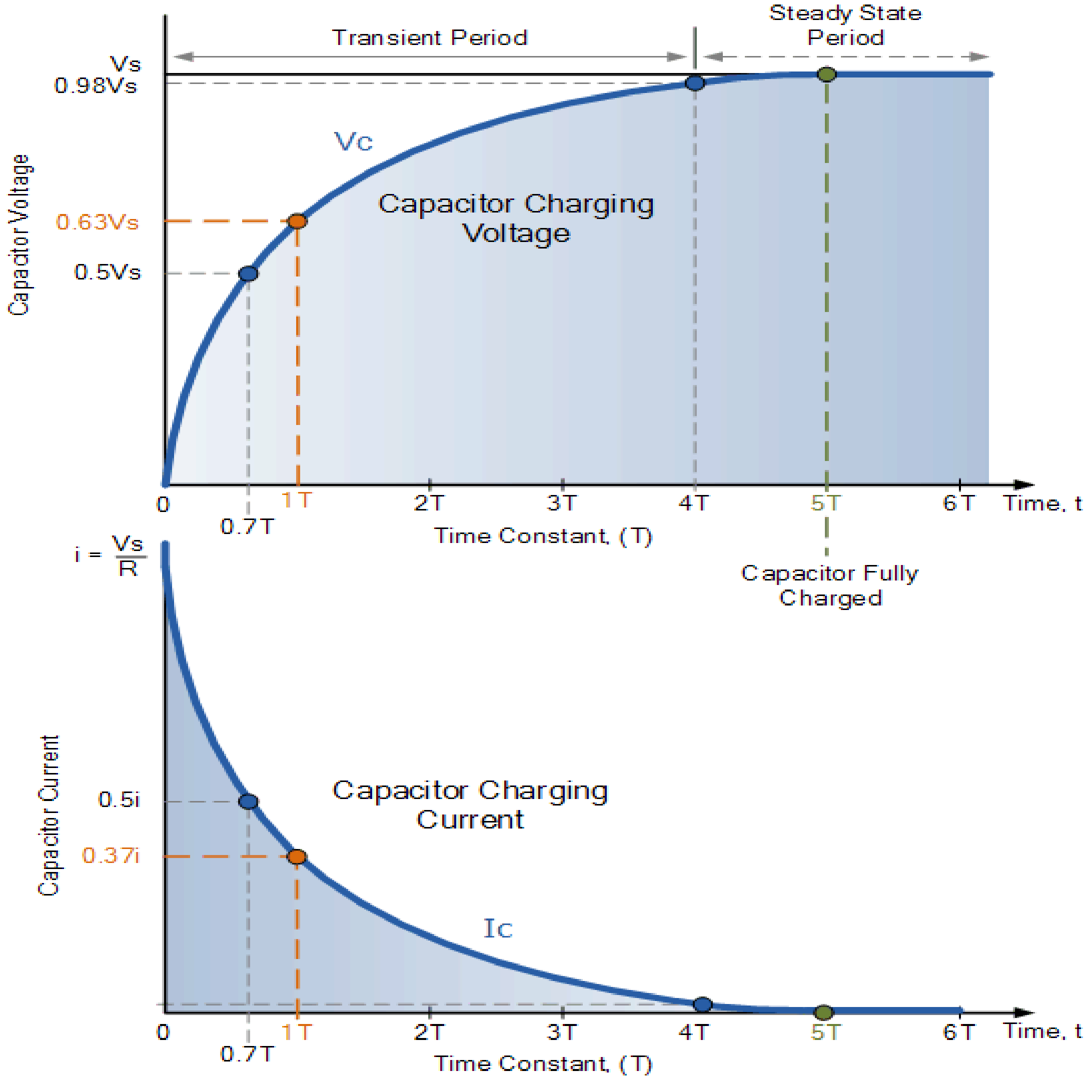
switch is closed the time begins at t = 0 and current begins to flow into the capacitor via the resistor.

Since the initial voltage across the capacitor is zero, **(Vc = 0) at t = 0** the capacitor appears to be a short circuit to the external circuit and the maximum current flows through the circuit restricted only by the resistor R. Then by using Kirchhoff's voltage law (KVL), the voltage drops around the circuit are given as:

$$V_S - R \times i(t) - V_C(t) = 0$$

The current now flowing around the circuit is called the **Charging Current** and is found by using Ohms law as: i = Vs/R.

RC Charging Circuit Curves



The capacitor (C), charges up at a rate shown by the graph. The rise in the RC charging curve is much steeper at the beginning because the charging rate is fastest at the start of charge but soon tapers off exponentially as the capacitor takes on additional charge at a slower rate.

As the capacitor charges up, the potential difference across its plates begins to increase with the actual time taken for the charge on the capacitor to reach 63% of its maximum possible fully charged voltage, in our **curve 0.63Vs**, being known as one full Time Constant, (T). **This 0.63Vs voltage point is given the abbreviation of 1T, (one time constant).**

The capacitor continues charging up and the voltage difference between Vs and Vc reduces, so too does the circuit current, i. Then at its final condition greater than five time constants (**5T**) when the capacitor is said to be fully charged

$$t = \infty, i = 0, q = Q = CV.$$

At infinity the charging **current finally diminishes to zero** and the **capacitor acts like an open circuit** with the supply voltage value entirely across the capacitor as

$$V_c = V_s.$$

So **mathematically** we can say that the time required for a capacitor to charge up **to one time constant, (1T)** is given as:

RC Time Constant, Tau

The RC time constant only specifies a rate of charge where, R is in Ω and C in Farads.

$$\tau \equiv R \times C$$

Since voltage V is related to charge on a capacitor given by the equation

$$V_c = Q/C$$

The voltage across the capacitor (Vc) at any instant in time during the charging period is given as:

$$V_C = V_S\,(1 - e^{(-t/RC)})$$

Where:

- **Vc** is the voltage across the capacitor
- **Vs** is the supply voltage
- **e** is an irrational number presented by Euler as: **2.7182**
- **t** is the elapsed time since the application of the supply voltage
- **RC** is the time constant of the RC charging circuit

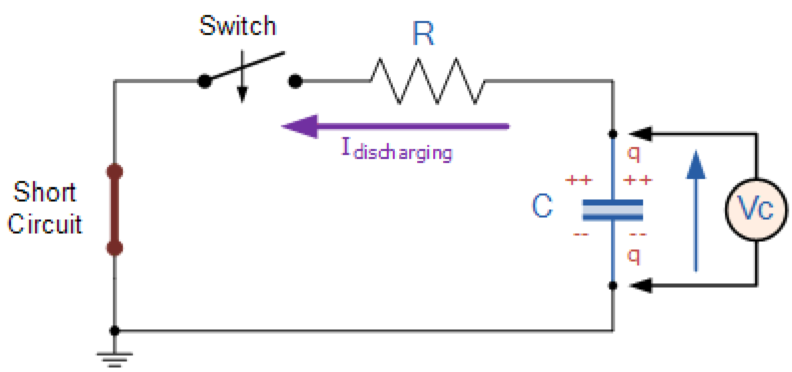
So in ***RC*** Charging Circuit ,a Capacitor, C charges up through the resistor until it reaches an amount of time equal to 5 time constants known as **5T**, and then remains fully charged as long as a constant supply is applied to it.

RC Discharging Circuit

When it fully charged capacitor is now disconnected from its DC battery supply voltage, the stored energy built up during the charging process would stay indefinitely on its plates, keeping the voltage stored across its connecting terminals at a constant value.

If the battery was replaced by a short circuit, when the switch is closed the capacitor would discharge itself back through the resistor, R as we now have a **RC discharging circuit**. As the capacitor discharges its current through the series resistor the stored energy inside the capacitor is extracted with the voltage **Vc** across the capacitor decaying to zero as shown below.

RC Discharging Circuit

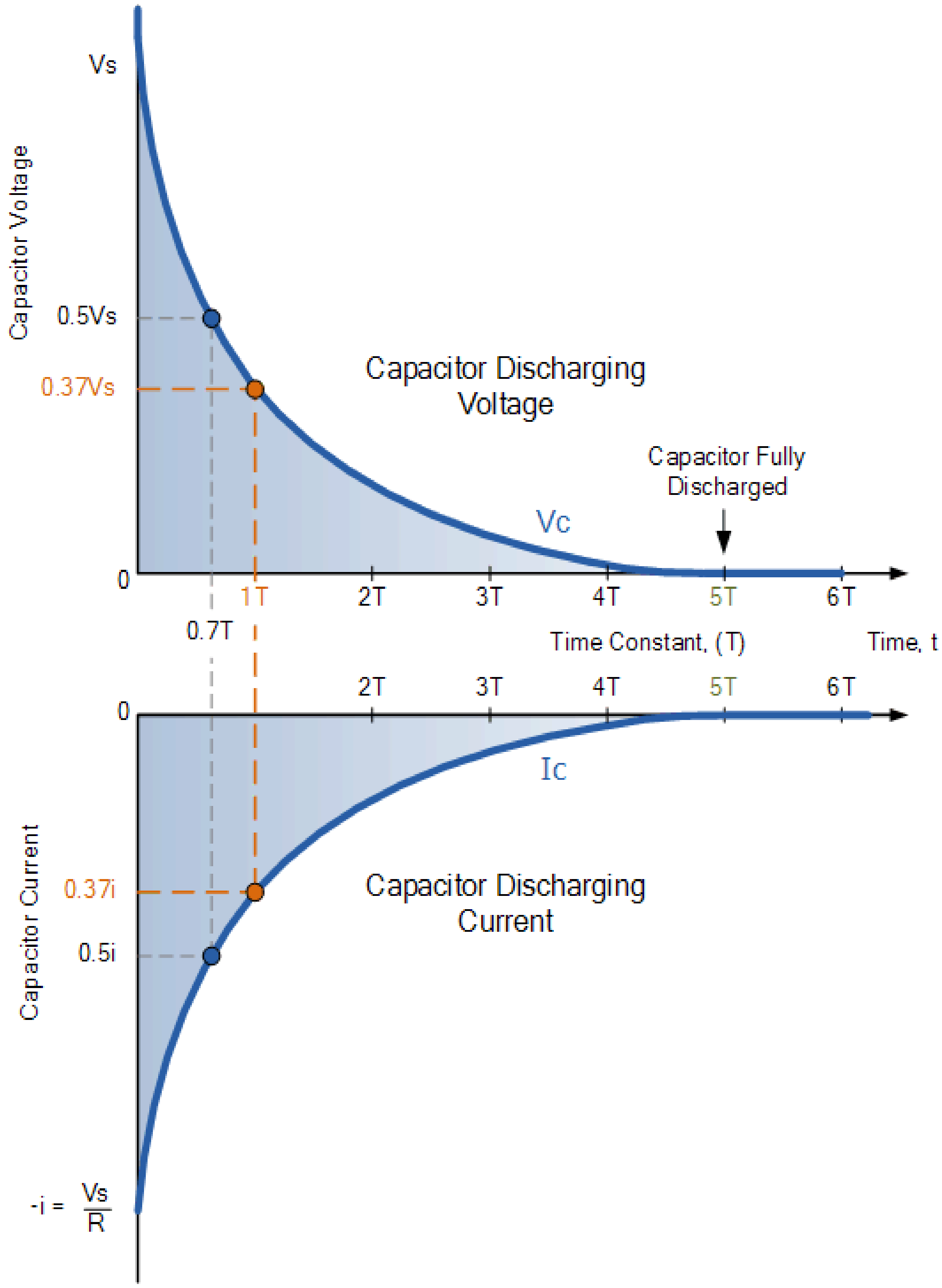


In a **RC Discharging Circuit** the time constant (τ) is still equal to the value of 63%. Then for a RC discharging circuit that is initially fully charged, the voltage across the capacitor after one time constant, 1T, has dropped by **63%** of its initial value which **is 1 – 0.63 = 0.37 or 37%** of its final value.

Thus the time constant of the circuit is given as the time taken for the capacitor to discharge down to within 63% of its fully charged value. So one time constant for an RC discharge circuit is given as the voltage across the plates representing 37% of its final value, with its final value being zero volts (fully discharged), and in our curve this is given as **0.37Vs.**

As the capacitor discharges, it does not lose its charge at a constant rate. At the start of the discharging process, the initial conditions of the circuit are**: t = 0, i = 0** and **q = Q.** The voltage across the capacitors plates is equal to the supply voltage and $V_C = V_S$. As the voltage at **t = 0** across the capacitors plates is at its highest value, maximum discharge current therefore flows around the **RC** circuit.

RC Discharging Circuit Curves



When the switch is first closed, the capacitor starts to discharge as shown. The rate of decay of the **RC discharging curve is steeper at the beginning** because the discharging rate is fastest at the start, but then **tapers off exponentially as the capacitor loses charge** at a slower rate. As the **discharge continues, V_C reduces resulting in less discharging current**.

We saw in the previous RC charging circuit that the voltage across the capacitor, C is equal to 0.5Vc at 0.7T with the steady state fully discharged value being finally reached at 5T.

For a RC discharging circuit, the voltage across the capacitor (V_C) as a function of time during the discharge period is defined as:

$$V_C = V_S \times e^{-t/RC}$$

Where:

- $\mathbf{V_c}$ is the voltage across the capacitor
- $\mathbf{V_s}$ is the supply voltage
- **t** is the elapsed time since the removal of the supply voltage
- **RC** is the time constant of the RC discharging circuit

Just like the previous RC Charging circuit, we can say that in a **RC Discharging Circuit** the time required for a capacitor to discharge itself down to one time constant is given as:

$$\tau \equiv R \times C$$

Where, **R is in Ω and C in Farads.**

555 Timer I'C

The 555 Timer is a commonly used IC designed to produce a variety of output waveforms with the addition of an external RC network.

The basic **555 timer** gets its name from the fact that there are three internally connected 5kΩ resistors which it uses to generate the two comparators reference voltages.

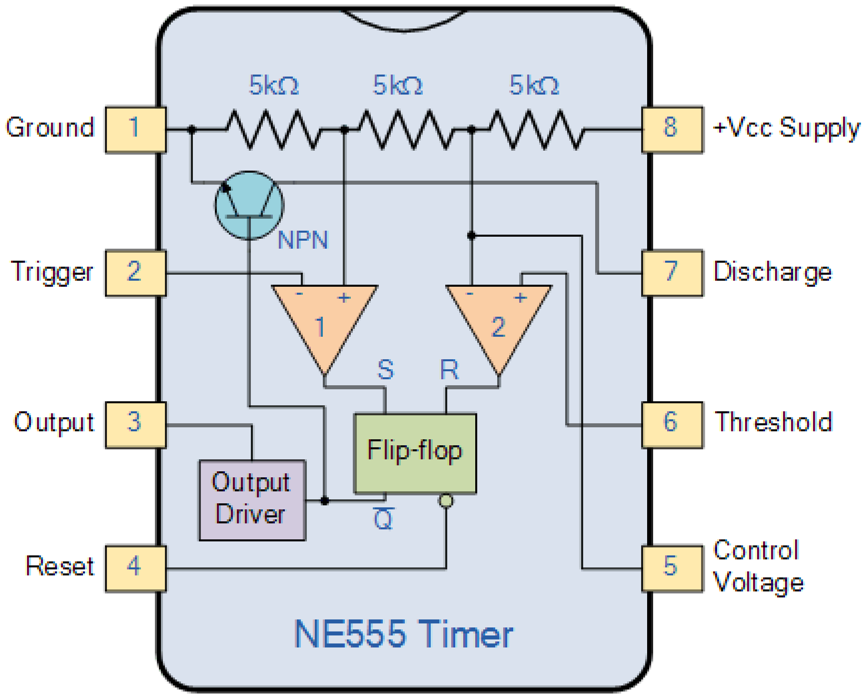
The 555 timer IC is a very cheap, popular and useful precision timing device which can act as either a simple timer to generate single pulses or long time delays, or as a relaxation oscillator producing a string of stabilised waveforms of varying duty cycles from 50 to 100%.

The single 555 Timer chip in its basic form is a **Bipolar 8-pin mini Dual-in-line Package** (DIP) device consisting of some **25 transistors, 2 diodes** and about **16 resistors arranged to form two comparators, a flip-flop and a high current output stage**.

The 555 timer chip is extremely robust and stable device that can be operated either as a very accurate **Monostable**, **Bistable** or **Astable Multivibrator** to produce a variety of applications such as one-shot or delay timers, pulse generation, LED and lamp flashers, alarms and tone generation, logic clocks, frequency division, power supplies and converters etc.

A simplified "block diagram" representing the internal circuitry of the **555 timer** is given below with a brief explanation of each of its connecting pins to help provide a clearer understanding of how it works.

555 Timer Block Diagram



- **Pin 1**. – **Ground**, The ground pin connects the 555 timer to the negative (0v) supply rail.

- **Pin 2.** – **Trigger**, The negative input to comparator No 1. A negative pulse on this pin "sets" the internal Flip-flop when the voltage drops below 1/3Vcc causing the output to switch from a "LOW" to a "HIGH" state.

- **Pin 3**. – **Output**, The output pin can drive any TTL circuit and is capable of sourcing or sinking up to 200mA of current at an output voltage equal to approximately Vcc – 1.5V so small speakers, LEDs or motors can be connected directly to the output.

- **Pin 4**. – **Reset**, This pin is used to "reset" the internal Flip-flop controlling the state of the output, pin 3. This is an active-low input and is generally connected to a logic "1" level when not used to prevent any unwanted resetting of the output.

- **Pin 5**. – **Control Voltage**, This pin controls the timing of the 555 by overriding the 2/3Vcc level of the voltage divider network. By applying a voltage to this pin the width of the output signal can be varied independently of the RC timing network. When not used it is connected to ground via a 10nF capacitor to eliminate any noise.

- **Pin 6.** – **Threshold**, The positive input to comparator No 2. This pin is used to reset the Flip-flop when the voltage applied to it exceeds 2/3Vcc causing the output to switch from "HIGH" to "LOW" state. This pin connects directly to the RC timing circuit.

- **Pin 7.** – **Discharge**, The discharge pin is connected directly to the Collector of an internal NPN transistor which is used to "discharge" the timing capacitor to ground when the output at pin 3 switches "LOW".

- **Pin 8.** – **Supply +Vcc**, This is the power supply pin and for general purpose TTL 555 timers is between 4.5V and 15V.

The most common use of the 555 timer oscillator is as a simple astable oscillator by connecting two resistors and a capacitor across its terminals to generate a fixed pulse train with a time period determined by the time constant of the RC network. But the 555 timer oscillator chip can also be connected in a variety of different ways to produce Monostable or Bistable multivibrators as well as the more common Astable Multivibrator.

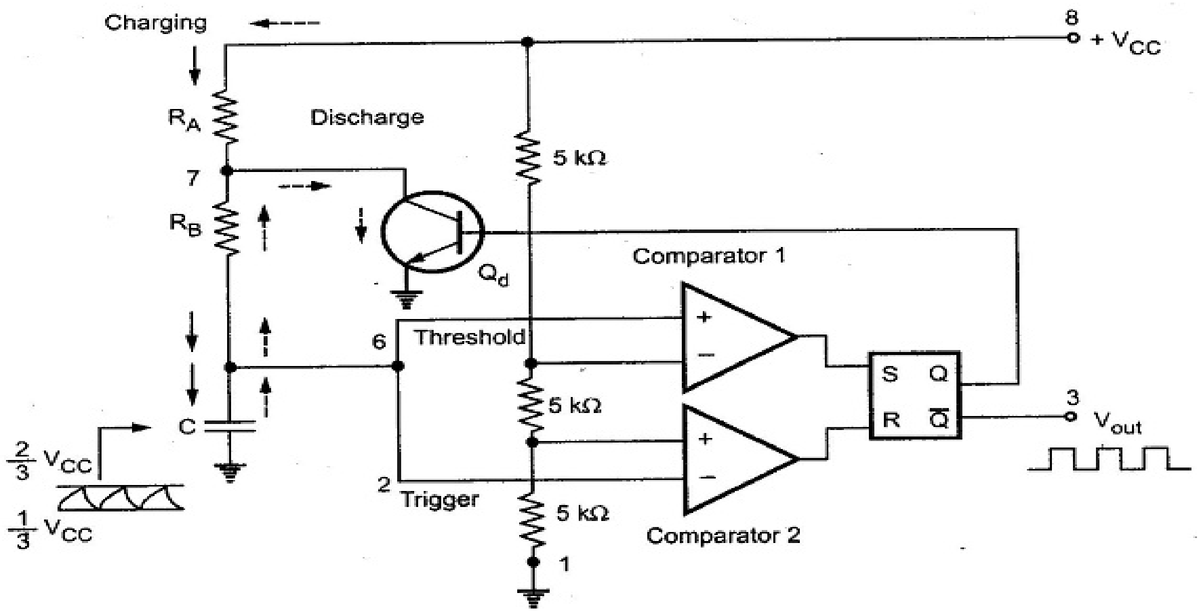
Multivibrator

Multivibrators produce an output wave shape resembling that of a symmetrical or asymmetrical square wave and as such are the most commonly used of all the square wave generators. Multivibrators belong to a family of oscillators commonly called "**Relaxation Oscillators**".

Astable Multivibrator Using IC 555:

Astable Multivibrators are free running oscillators which oscillate between two states continually producing two square wave output waveforms. In electronic circuits, astable multivibrators are also known as **Free-running Multivibrator** as they do not require any additional inputs or external assistance to oscillate. Astable oscillators produce a continuous square wave from its output or outputs, (two outputs no inputs) which can then be used to flash lights or produce a sound in a loudspeaker.

Fig. below showing the operation of Astable Multivibrator Using IC 555. The threshold input is connected to the trigger input. Two external resistances R_A, R_B and a capacitor C is used in the circuit.



This circuit has no stable state. The circuits changes its state alternately. Hence the operation is also called free running non-sinusoidal oscillator.

Working of Astable Multivibrator using IC 555:

When the flip-flop is set, **Q is high** which drives the transistor **Qd** in saturation and the capacitor gets discharged. Now the capacitor voltage is nothing but the trigger voltage. **So while discharging, when it becomes less than 1/3 VCC, comparator 2 output goes high**. **This resets the flip-flop hence Q goes low and Q goes high.**

The **low Q** makes the **transistor off**. Thus **capacitor starts charging** through the resistances **RA, RB and VCC**. The charging path is shown by thick arrows in the above fig.

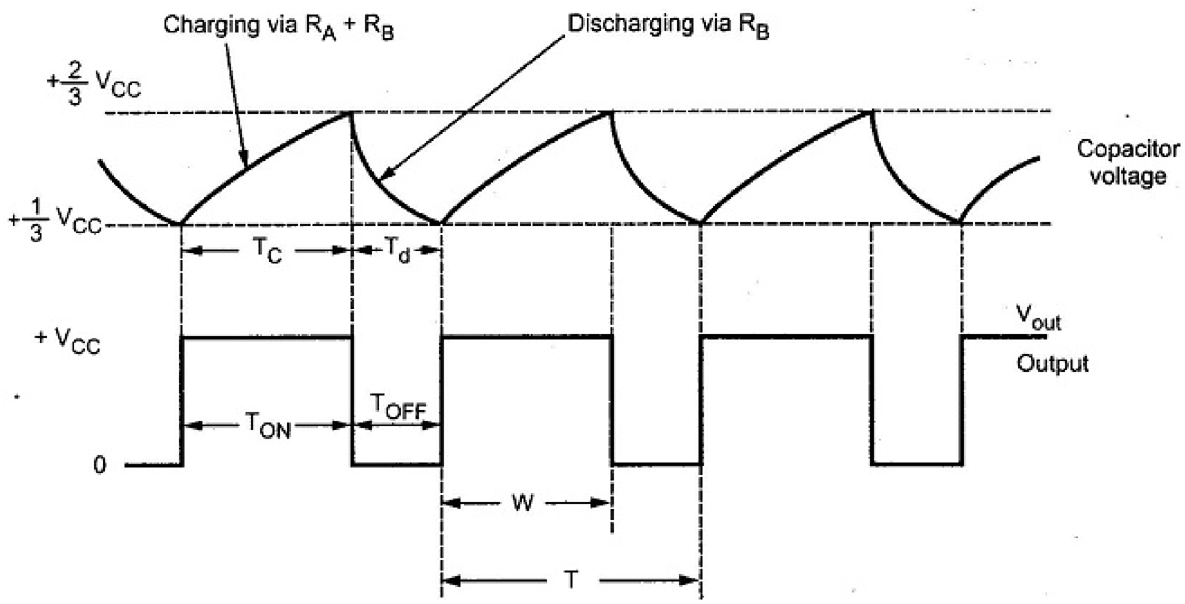
As total resistance in the **charging path is (RA + RB),** the charging time constant is **(RA + RB) C**.

Now the capacitor voltage is also a threshold voltage. **While charging, capacitor** voltage increases i.e. the threshold voltage increases. When it **exceeds 2/3 VCC**, then the **comparator 1 output goes high** which sets the flip-flop. The flip-flop output Q becomes high and output at pin 3 i.e. **Q becomes low**.

High Q drives transistor Qd in saturation and **capacitor starts discharging through resistance RB and transistor Qd**. This path is shown by dotted arrows in the above fig. Thus **the discharging time constant is RB C.** When capacitor voltage becomes **less than 1/3 VCC**, comparator 2 output goes high, **resetting** the flip-flop.

This cycle repeats.

Thus when capacitor is charging, output is high while when it is discharging the output is low. The output is a rectangular wave. The capacitor voltage is exponentially rising and falling. The waveforms of Astable Multivibrator Using IC 555 are shown in the Fig. below



Duty Cycle of Astable Multivibrator:

Generally the charging time constant is greater than the discharging time constant. Hence at the output, the waveform is not symmetric. The high output remains for longer period than low output. The ratio of high output period and low output period is given by a mathematical parameter called **duty cycle**. **It is defined as the ratio of ON time i.e. high output to the total time of one cycle.**

W = time for output is high = T_{ON}

T = time of one cycle

D = duty cycle = W/T

% D = W/T x 100%

The charging time for the capacitor is given by,

T_c = Charging time = $0.693 (R_A + R_B) C$

While the discharge time is given by,

T_d = Discharging time = $0.693 R_B C$

Hence the time for one cycle is

$$\mathbf{T = T_c + T_d = 0.693\,(R_A + R_B)\,C + 0.693\,R_B\,C}$$

$$\mathbf{= 0.693\,(R_A + 2\,R_B)\,C}$$

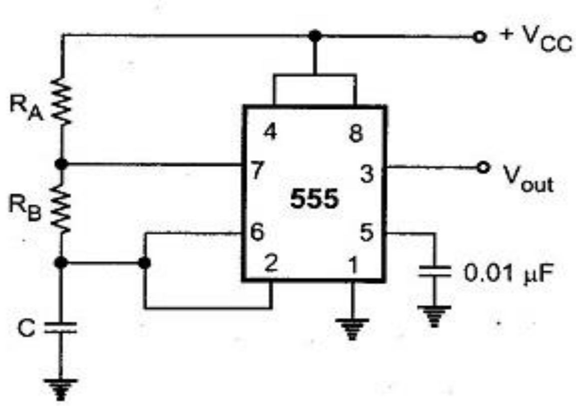
While

$$\mathbf{W = T_c = 0.693\,(R_A + R_B)\,C}$$

While the frequency of oscillations is given by,

If $\mathbf{R_A}$ is much smaller than $\mathbf{R_B}$, duty cycle approaches to 50% and output waveform approaches to square wave.

Schematic Diagram of 555 Timer Astable Multivibrator:



It shows only the external components R_A, R_B and C. The pin 4 is tied to pin 8 and pin 5 is grounded through a small capacitor.

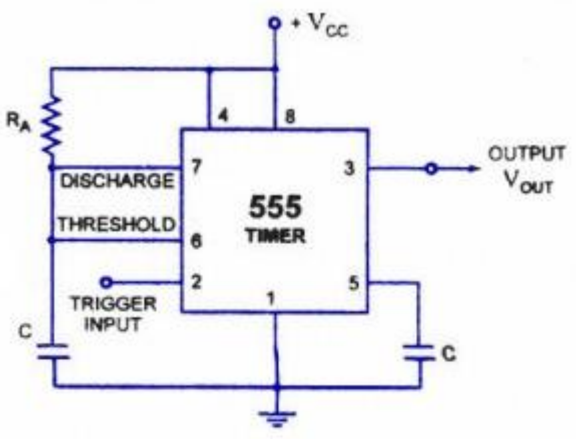
The important application of astable multivibrator is voltage controlled oscillator (VCO).

Application of Astable Multivibrator using IC 555:

- **Square wave generation**
- **FSK generator**
- **Voltage controlled oscillator (VCO)**

Monostable Multivibrator Using IC 555:

***A* monostable multivibrator *(MMV)* often called a one-shot multivibrator,** is a pulse generator circuit in which the duration of the pulse is determined by the R-C network,connected externally to the **555 timer**



Circuit of The Timer 555 as a Monostable Multivibrator

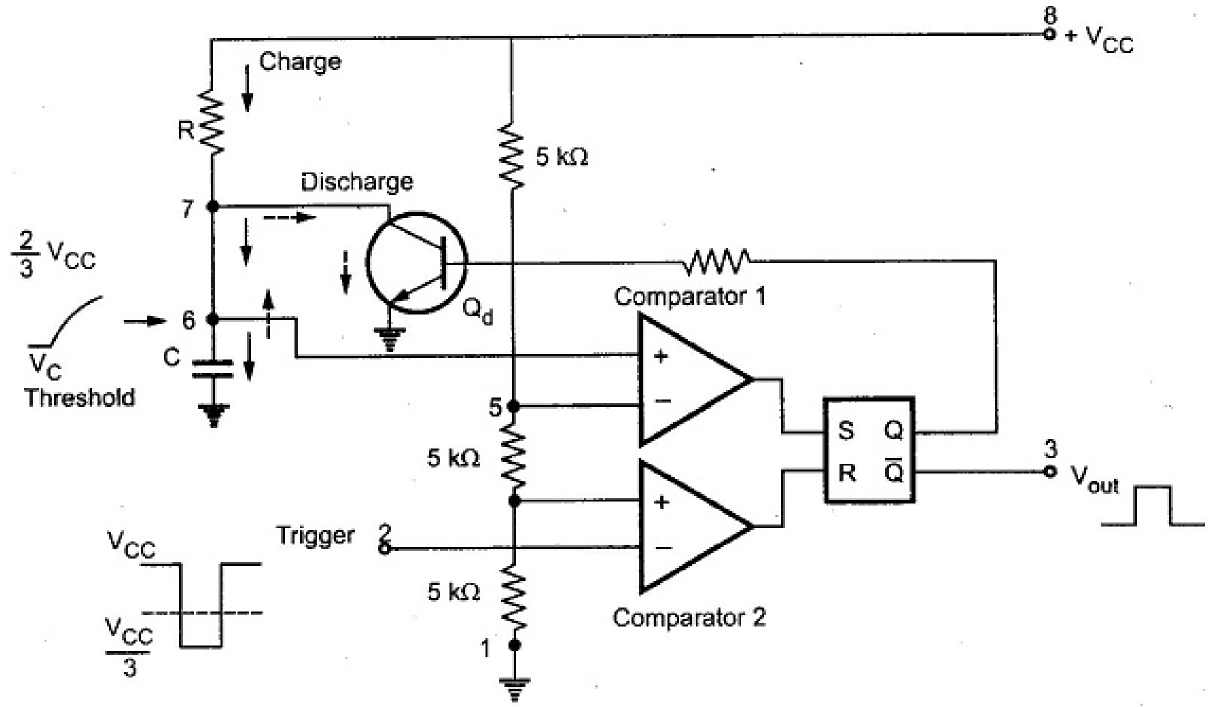
As the name specifies, a monostable multivibrator has only one stable state. When a trigger input is applied, a pulse is produced at the output and returns back to the stable state after a time interval. The duration of time for which the pulse is high will depend on the timing circuit that comprises of a resistor (R) and a capacitor (C).

The details of the connection are as follows. The pins 1 and 8 are connected to ground and supply (VCC) respectively. Output is taken at pin 3. To avoid accidental reset of the circuit, pin 4 is connected to the VCC. Pin 5, which is the control voltage input, should be grounded when not in use. To filter the noise, it is connected to the ground via a small capacitor of capacitance 0.01µF. Pin 6 (threshold) is shorted to pin 7. A resistor R_A is connected between pins 6 and 8. At pins 7 a discharge capacitor is connected while pin 8 is connected to supply V_{CC}.

Monostable Multivibrator Operation

The flip-flop is initially set i.e. Q is high. This drives the transistor Q_d in saturation. The capacitor discharges completely and voltage across it is nearly zero. the output at pin 3 is low.

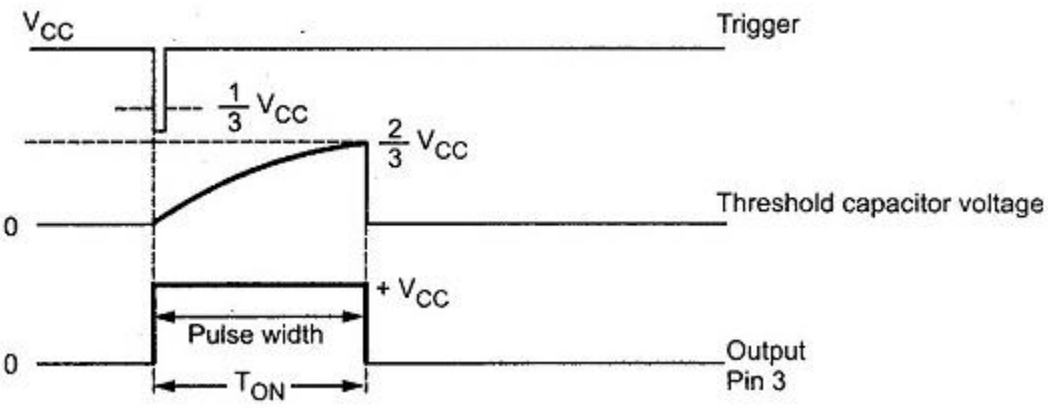
When a trigger input, a low going pulse is applied, then circuit state remains unchanged till trigger voltage is greater than 1/3 V_{cc}. When it becomes less than 1/3 V_{cc}, then comparator 2 output goes high. This resets the flip-flop so Q goes low and Q goes high. Low Q makes the transistor Q_d off. Hence capacitor starts charging through resistance R, as shown by dark arrows in the Fig. below.



The flip-flop is initially set i.e. Q is high. This drives the transistor Qd in saturation. The capacitor discharges completely and voltage across it is nearly zero. the output at pin 3 is low.

When a trigger input, a low going pulse is applied, then circuit state remains unchanged till trigger voltage is greater than 1/3 Vcc. When it becomes less than 1/3 Vcc, then comparator 2 output goes high. This resets the flip-flop so Q goes low and Q goes high. Low Q makes the transistor Qd off. Hence capacitor starts charging through resistance R.

The voltage across capacitor increases exponentially. This voltage is nothing but the threshold voltage at pin 6. When this voltage becomes more than 2/3 V_{cc} , then comparator 1 output goes high. This sets the flip-flop i.e. Q becomes high and low. This high Q drives the transistor Q_d in saturation. Thus capacitor C quickly discharges through Q_d as shown in figure below.



So it can be noted that V_{out} at pin 3 is low at start, when trigger is less than 1/3 V_{cc} it becomes high and when threshold is greater than 2/3 V_{cc} again becomes low, till next trigger pulse occurs. So a rectangular wave is produced at the output. The pulse width of this rectangular pulse is controlled by the charging time of capacitor. This depends on the time constant RC. Thus RC controls the pulse width.

Derivation of Pulse Width:

The voltage across capacitor increases exponentially and is given by

$$V_C = V\left(1 - e^{-t/CR}\right)$$

If
$$V_C = 2/3\ V_{CC}$$

then
$$\frac{2}{3}V_{CC} = V_{CC}\left(1 - e^{-t/CR}\right)$$

$$\frac{2}{3} - 1 = -e^{t/CR}$$

$$\frac{1}{3} = e^{-t/CR}$$

$$-\frac{t}{CR} = -1.0986$$

$$t = +1.0986\ CR$$

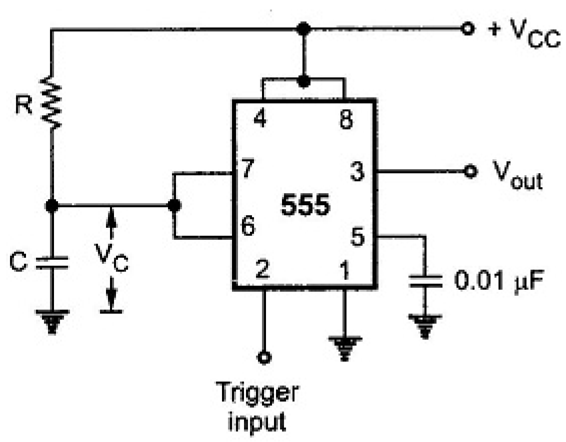
$$t \approx 1.1\ CR$$

Where C in farads, R in ohms, t in seconds.

Thus, we can say that voltage across capacitor will reach 2/3 Vcc in approximately 1.1 times, time constant i.e. 1.1 RC

Thus the pulse width denoted as W is given by, **W = 1.1 RC**

Schematic Diagram:



Generally a schematic diagram of the Monostable Multivibrator Using IC 555 circuits is shown which does not include comparators, flip-flop etc. It only shows the external components to be connected to the 8 pins of Monostable Multivibrator Using IC 555.

The external components R and C are shown. To avoid accidental reset, pin 4 is connected to pin 8 which is supply $+V_{cc}$. To have the noise filtering of control voltage, the pin 5 is grounded through a small capacitor of 0.01 tF.

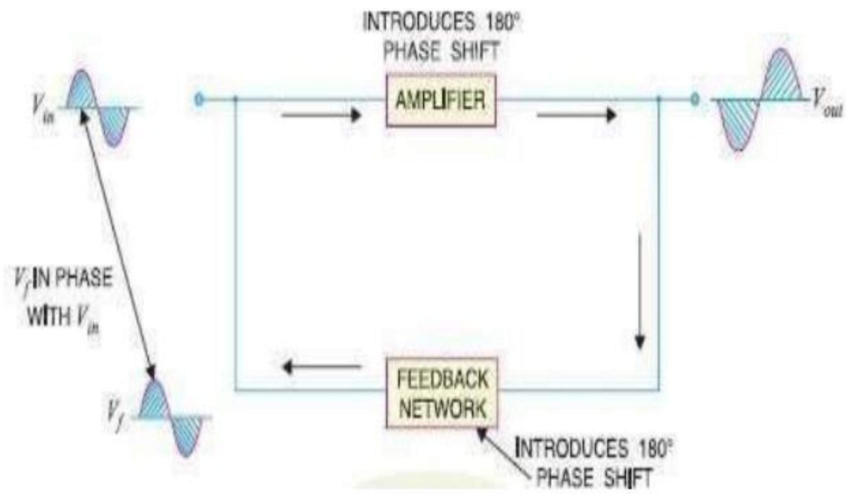
Applications:

The various applications of monostable circuit are,

- Frequency divider
- Pulse width modulation
- Linear ramp generator
- Pulse position modulation
- Missing pulse detector
- Timer in relay

Positive feedback

In positive feedback, the feedback energy (voltage or currents), is in phase with the input signal and thus aids it. Positive feedback increases gain of the amplifier also increases distortion, noise and instability. Because of these disadvantages, positive feedback is seldom employed in amplifiers. But the positive feedback is used in oscillators.



In the above figure, the gain of the amplifier is represented as A. The gain of the amplifier is the ratio of output voltage Vo to the input voltage Vi . The feedback network extracts a voltage

$$Vf = \beta\ Vo$$

From the output Vo of the amplifier. This voltage is subtracted for negative feedback, from the signal voltage Vs .Now,

$$Vi=Vs + Vf =Vs+\beta Vo$$

The quantity $\beta = Vf/Vo$ is called as feedback ratio or feedback fraction.

The output Vo must be equal to the input voltage (Vs + βVo) multiplied by the gain A of the amplifier.

Hence,

$$(Vs + \beta Vo) A = Vo$$

$$AVs + A\beta Vo = Vo$$

$$AVs = Vo (1-A\beta)$$

$$Vo/Vs = A/(1-A\beta)$$

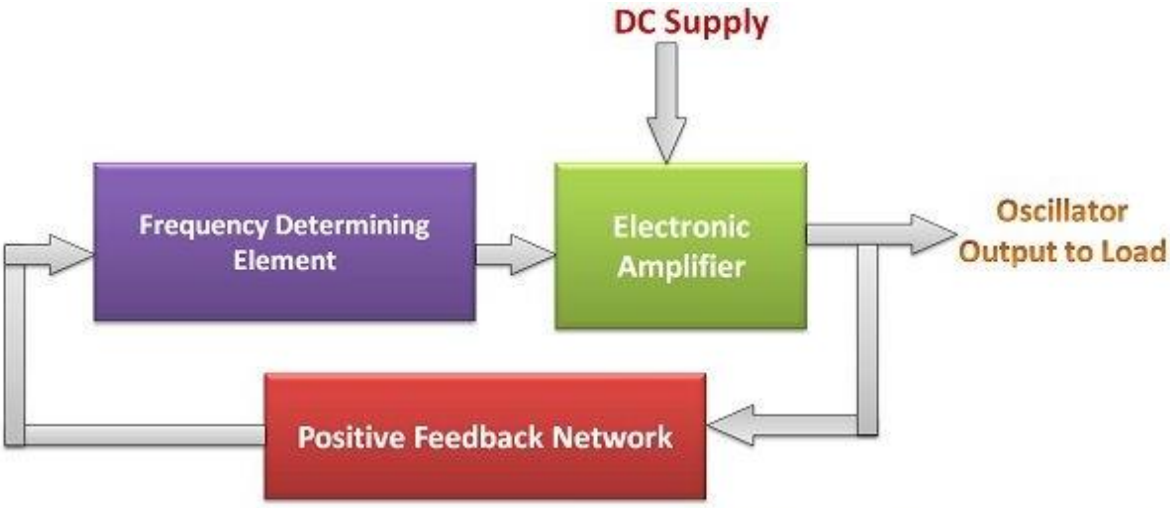
Therefore, the gain of the amplifier with feedback is given by

$$Af = A/(1-A\beta)$$

Oscillator

Definition: Oscillator is a circuit which utilizes positive feedback amplifier to generate sinusoidal waveforms of fixed amplitude and frequency. It is the major source of power in electrical and electronic instruments. The amplifier provided with the positive feedback can generate the sinusoidal signal even in the absence of any input. These signals are termed as oscillations, and hence the device is known as an oscillator.

The oscillator does not generate the energy of its own, to generate oscillation but uses DC source to convert the DC power into AC. Therefore it is also termed as an inverter which is the opposite of rectifier.



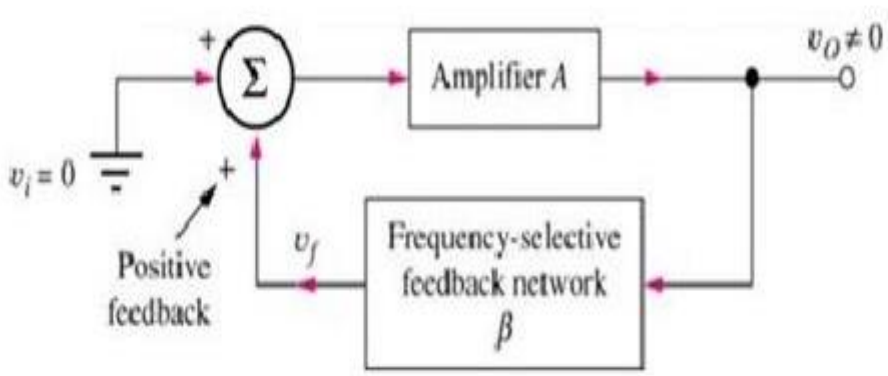
BLOCK DIAGRAM OF AN OSCILLATOR

Barkhausen Criteria

Conditions which are required to be satisfied to operate the circuit as an oscillator are called as "Barkhausen criterion" for sustained oscillations.

The Barkhausen criteria should be satisfied by an amplifier with positive feedback to ensure the sustained oscillations.

For an oscillation circuit, there is **no input signal** "V_s", hence the feedback signal V_f itself should be **sufficient to maintain the oscillations**.



The Barkhausen criterion states that:

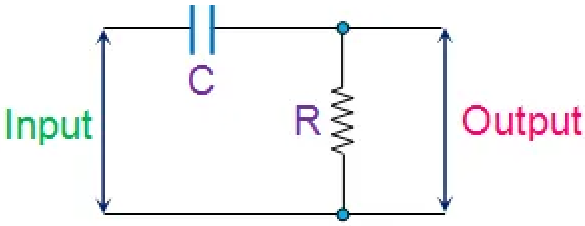
• The loop gain is equal to unity in absolute magnitude, that is, | β A | = 1 and

• The phase shift around the loop is zero or an integer multiple of 2π: ∠ β A = 2 π n, n ∈ 0, 1, 2,….

The product β A is called as the "loop gain".

RC Phase Shift Oscillator

RC phase-shift oscillators use resistor-capacitor (RC) network to provide the phase-shift required by the feedback signal. They have excellent frequency stability and can yield a pure sine wave for a wide range of loads.



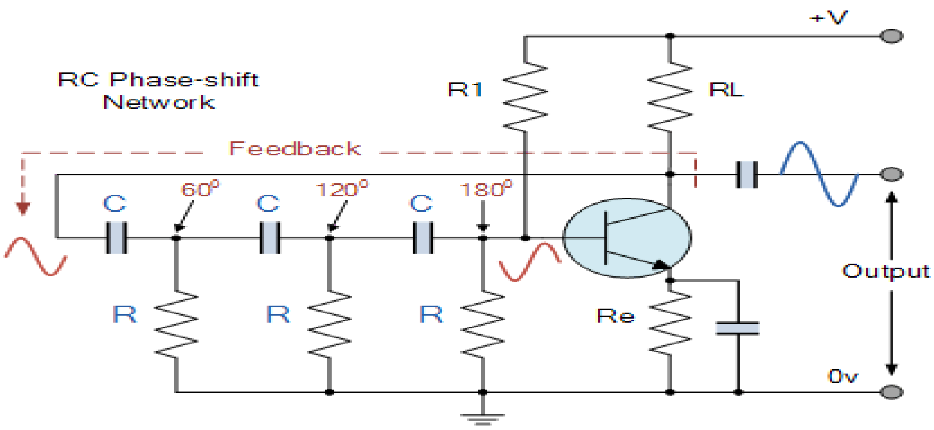
Ideally a simple RC network is expected to have an output which leads the input by 90°.

However, in reality, the phase-difference will be less than this as the capacitor used in the circuit cannot be ideal. Mathematically the phase angle of the RC network is expressed as

Where, $X_C = 1/(2\pi fC)$ is the reactance of the capacitor C and R is the resistor.

In oscillators, these kind of RC phase-shift networks, each offering a definite phase-shift can be cascaded so as to satisfy the phase-shift condition led by the Barkhausen Criterion.

One such example is the case in which **RC phase-shift oscillator** is formed by cascading three RC phase-shift networks, each offering a phase-shift of 60°, as shown figure below.



Here the collector resistor RC limits the collector current of the transistor, resistors R_1 and R (nearest to the transistor) form the voltage divider network while the emitter resistor R_E improves the stability. Next, the capacitors **C_E** and **C_o** are the emitter by-pass capacitor and the output DC decoupling capacitor, respectively.

Further, the circuit also shows three RC networks employed in the feedback path.

This arrangement causes the output waveform to shift by 180^o during its course of travel from output terminal to the base of the transistor. Next, this signal will be shifted again by **180^o** by the transistor in the circuit due to the fact that the phase-difference between the input and the output will be **180^o** in the case of common emitter configuration. This makes the net phase-difference to be **360^o**, satisfying the phase-difference condition.

One more way of satisfying the phase-difference condition is to use four RC networks, each offering a phase-shift of 45^o. Hence it can be concluded that the **RC phase-shift oscillators** can be designed in many ways as the number of RC networks in them is not fixed. However it is to be noted that, although an increase in the number of stages increases the frequency stability of the circuit, it also adversely affects the output Frequency of the oscillator due to the loading effect.

Frequency of RC Phase Shift Oscillator

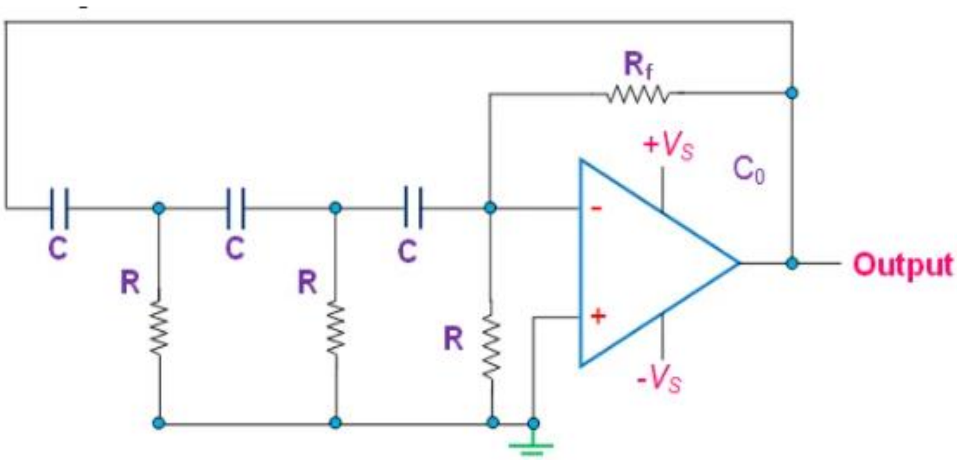
The generalized expression for the frequency of oscillations produced by a **RC phase-shift oscillator** is given by

$$f = \frac{1}{2\pi RC\sqrt{2N}}$$

Where,

- f is the oscillators output frequency in Hertz
- R is the feedback resistance in Ohms
- C is the feedback capacitance in Farads
- N is the number of RC feedback stages.

Further, as is the case for most type of oscillators, even the RC phase-shift oscillators can be designed using an OpAmp as its part of the amplifier section shown in figure below. Nevertheless, the mode of working remains the same while it is to be noted that, here, the required phase-shift of 360º is offered collectively by the RC phase-shift networks and the Op-Amp working in inverted configuration.



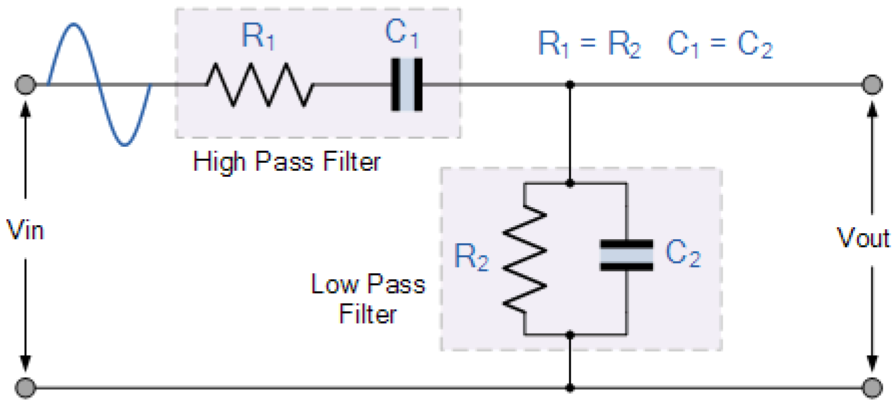
Further, it is to be noted that the frequency of the RC phase-shift oscillators can be varied by changing either the resistors or the capacitors. However, in general, the resistors are kept constant while the capacitors are gang-tuned.

Wien Bridge Oscillator

The Wien Bridge oscillator is a two-stage RC coupled amplifier circuit that has good stability at its resonant frequency, low distortion and is very easy to tune making it a popular circuit as an audio frequency oscillator but the phase shift of the output signal is considerably different from the previous phase shift **RC Oscillator**.

The **Wien Bridge Oscillator** uses a feedback circuit consisting of a series RC circuit connected with a parallel RC of the same component values producing a phase delay or phase advance circuit depending upon the frequency.

This indicates that these two arms of the network behave identical to that of high pass filter or low pass filter, mimicking the behavior of the circuit shown by Figure below.



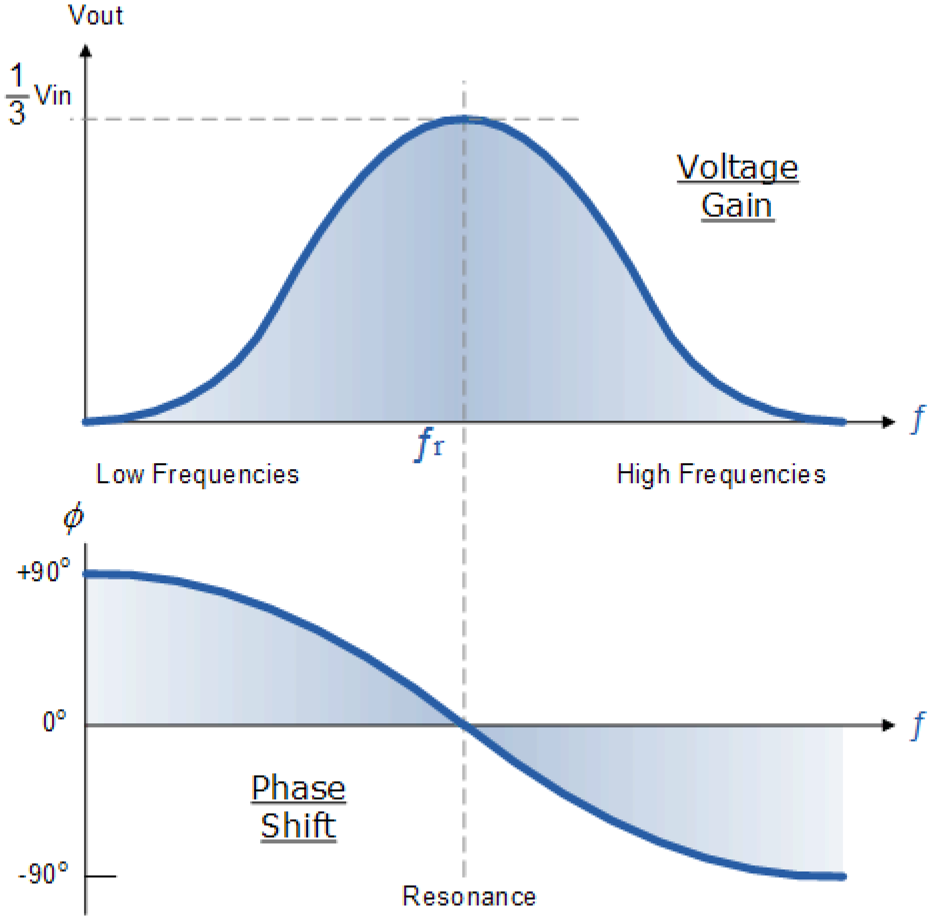
In this circuit,

- At low frequencies the reactance of the series capacitor (C1) is very high so acts a bit like an open circuit, blocking any input signal at **Vin** resulting in virtually no output signal, **Vout.**

- At high frequencies, the reactance of the parallel capacitor, (C2) becomes very low, so this parallel connected capacitor acts a bit like a short circuit across the output, so again there is no output signal.

So there must be a frequency point between these two extremes of C1 being open-circuited and C2 being short-circuited where the output voltage, **V_{OUT}** reaches its maximum value. The frequency value of the input waveform at which this happens is called the oscillators Resonant Frequency, **(*f*r).**

At this resonant frequency, the circuits reactance equals its resistance, that is: **Xc = R,** and the phase difference between the input and output equals zero degrees. The magnitude of the output voltage is therefore at its maximum and is equal to one third (1/3) of the input voltage as shown.



It can be seen that at very low frequencies the phase angle between the input and output signals is "Positive" (Phase Advanced), while at very high frequencies the phase angle becomes "Negative" (Phase Delay). In the middle of these two points the circuit is at its resonant frequency, (fr) with the two signals being "in-phase" or 0°. We can therefore define this resonant frequency point with the following expression.

Wien Bridge Oscillator Frequency Calculation

Nevertheless, amidst these two high and low frequencies, there exists a particular frequency at which the values of the resistance and the capacitive reactance will become equal to each other, producing the maximum output voltage.

This frequency is referred to as resonant frequency. The resonant frequency for a Wein Bridge Oscillator is calculated using the following formula:

$$f_r = \frac{1}{2\pi\sqrt{R_1 C_1 R_2 C_2}}$$

$$if\ R_1 = R_2 = R\ and\ C_1 = C_2 = C$$

$$then\ f_r = \frac{1}{2\pi RC}$$

Further, at this frequency, the phase-shift between the input and the output will become zero and the magnitude of the output voltage will become equal to one-third of the input value. In addition, it is seen that the Wien-Bridge will be balanced only at this particular frequency.

ASSIGNMENT:1

- *Find applications, Advantages and Disadvantages of RC-Phase Shift Oscillator.*
- *Explain Advantages and Disadvantages of Wein Bridge Oscillator.*

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