Unit IV

Oscillator and Multivibrators

Principle of Positive feedback, Concept of Stability in electronics circuits, Barkhausen criteria for oscillation, Principle of operation of RC Phase Shift, Wien Bridge, Colpitt‟s, Hartley, Crystal oscillators.

Principle of operation of Transistorized Astable, Bistable and Monostable multivibrator.

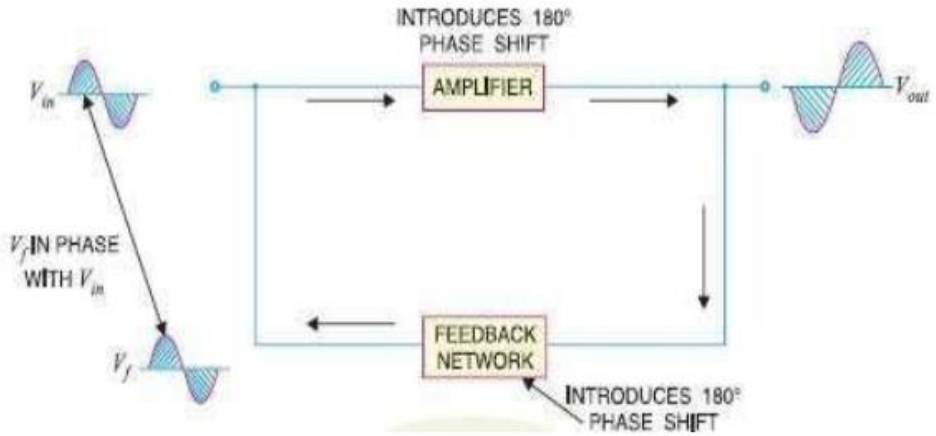
Introduction of Feedback Amplifiers:

The phenomenon of feeding a portion of the output signal back to the input circuit is known as feedback. The effect results in a dependence between the output and the input and an effective control can be obtained in the working of the circuit. Feedback is of two types.

- Positive Feedback
- Negative Feedback

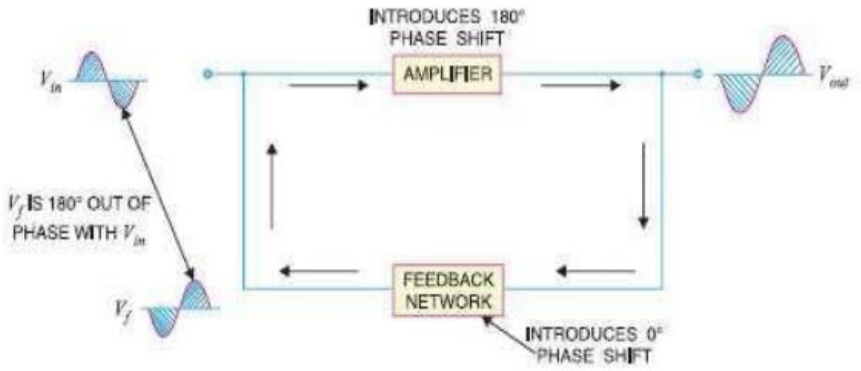
Positive or regenerate feedback:

- 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.



Negative or Degenerate feedback:

- In negative feedback, the feedback energy (voltage or current), is out of phase with the input signal and thus opposes it.
- Negative feedback reduces gain of the amplifier. It also reduce distortion, noise and instability.
- This feedback increases bandwidth and improves input and output impedances.
- Due to these advantages, the negative feedback is frequently used in amplifiers.



Comparison Between Positive and Negative Feed Back:

Sr. No.	Negative Feedback	Positive Feedback
1	Feedback energy is out phase with their input signal.	Feedback energy is in phase with the input signal.
2	Gain of the amplifier decreases.	Gain of the amplifier increases.
3	Gain stability increases.	Gain stability decreases.
4	Noise and distortion decreases.	Noise and distribution increases.
5	Increase the band width.	Decreases bandwidth.
6	Used in amplifiers.	Used in Oscillators.

Type of Oscillator:

There are many types of oscillators, but can broadly be classified into two main categories – **Harmonic Oscillators** (also known as Linear Oscillators) and **Relaxation Oscillators**.

In a harmonic oscillator, the energy flow is always from the active components to the passive components and the frequency of oscillations is decided by the feedback path. Whereas in a relaxation oscillator, the energy is exchanged between the active and the passive components and the frequency of oscillations is determined by the charging and discharging time-constants involved in the process.

Further, **harmonic oscillators produce low-distorted sine-wave outputs while the relaxation oscillators generate non-sinusoidal (sawtooth, triangular or square) wave-forms**.

The main types of Oscillators include:

RC Oscillators

- •Wien Bridge Oscillator
- •RC Phase Shift Oscillator

LC Oscillators

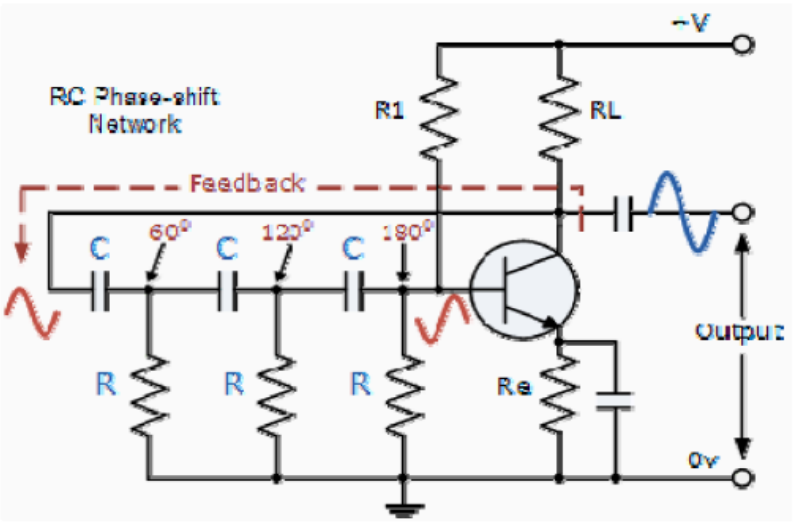
- •Hartley Oscillator
- •Colpitts Oscillator
- •Clapp Oscillator

Crystal Oscillators

Barkhausen Criteria:

- The condition **Aβ=1** is known as Barkhausen criteria. It implies (1) Magnitude of the loop gain **Aβ = 1**
  (2) Phase shift over the loop = 0 0r 360 degrees.
- Frequency of the noise in the amplifier for which this criteria are satisfied, is the frequency of oscillations.
- By applying this criteria, we can even find the values of transistor parameters, like gain, required for setting in oscillations.

Basic RC Phase Shift Oscillator:



The **RC Oscillator** which is also called a **Phase Shift Oscillator**, produces a sine wave output signal using regenerative feedback from the resistor-capacitor combination. This

regenerative feedback from the RC network is due to the ability of the capacitor to store an electric charge, (similar to the LC tank circuit). This resistor-capacitor feedback network can be connected as shown above to produce a leading phase shift (phase advance network) or interchanged to produce a lagging phase shift (phase retard network) the outcome is still the same as the sine wave oscillations only occur at the frequency at which the overall phase-shift is 360o. By varying one or more of the resistors or capacitors in the phase-shift network, the frequency can be varied and generally this is done using a 3-ganged variable capacitor.

If all the resistors, R and the capacitors, C in the phase shift network are equal in value, then the frequency of oscillations produced by the RC oscillator is given as:

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

Where:

f is the Output Frequency in Hertz

R is the Resistance in Ohms

C is the Capacitance in Farads

N is the number of RC stages. (in our example N = 3)

Since the resistor-capacitor combination in the **RC Oscillator** circuit also acts as an attenuator producing an attenuation of -1/29th (Vo/Vi = β) per stage, the gain of the amplifier must be sufficient to overcome the losses and in our three mesh network above the **amplifier gain must be greater than 29**. The loading effect of the amplifier on the feedback network has an effect on the frequency of oscillations and can cause the oscillator frequency to be up to 25% higher than calculated. Then the feedback network should be driven from a high impedance output source and fed into a low impedance load such as a common emitter transistor amplifier but better still is to use an Operational Amplifier as it satisfies these conditions perfectly.

Wien Bridge Oscillator:

A Wien-Bridge **Oscillator** is a type of phase-shift oscillator which is based upon a Wien-Bridge network comprising of four arms connected in a bridge fashion. Here two arms are purely resistive while the other two arms are a combination of resistors and

capacitors. In particular, one arm has resistor and capacitor connected in series (R1 and C1) while the other has them in parallel (R2 and C2). 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.

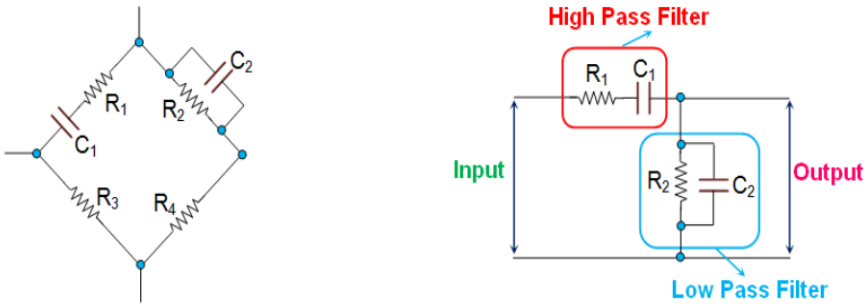


Figure 1 (a) Wien-Bridge Network (b) Two arms of the Wien-Bridge Network

In this circuit, at high frequencies, the reactance of the capacitors C1 and C2 will be much less due to which the voltage V0 will become zero as R2 will be shorted. Next, at low frequencies, the reactance of the capacitors C1 and C2 will become very high.

However even in this case, the output voltage V0 will remain at zero only, as the capacitor C1 would be acting as an open circuit. This kind of behavior exhibited by the Wien-Bridge network makes it a lead-lag circuit in the case of low and high frequencies, respectively.

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:

$$f_r = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$

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

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

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. In the case of **Wien-Bridge oscillator**, the Wien-Bridge network of Figure 1 will be used in the feedback path as shown in Figure 2. The circuit diagram for a Wein Oscillator using a BJT (Bipolar Junction Transistor) is shown below:

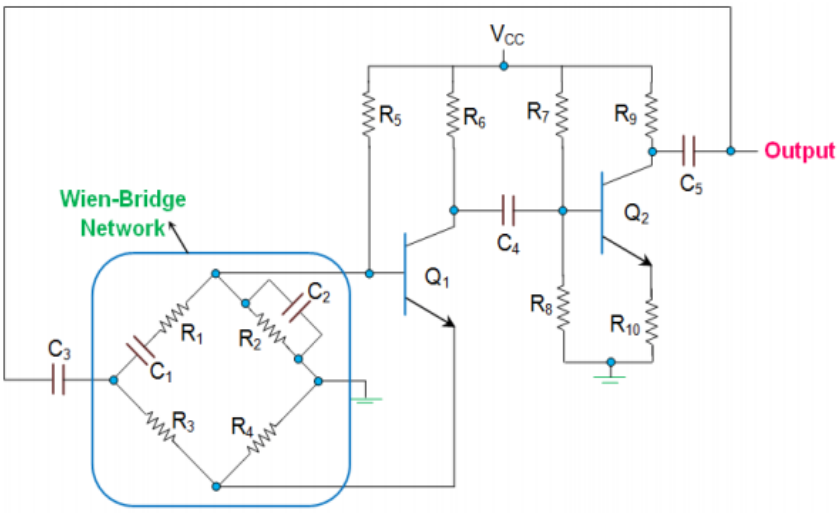


Figure 2 Wien-Bridge Oscillator Using BJT

In these oscillators, the amplifier section will comprise of two-stageamplifier formed by the transistors, Q1 and Q2, wherein the output of Q2 is back-fed as an input to Q1 via Wien-Bridge network (shown within the blue enclosure in the figure). Here, the noise inherent in the circuit will cause a change in the base current of Q1 which will appear at its collector point after being amplified with a phase-shift of 180o.

This is fed as an input to Q2 via C4 and gets further amplified and appears with an additional phase-shift of 180o. This makes the net phase-difference of the signal fed back to the Wien-Bridge network to be 360o, satisfying phase-shift criterion to obtain sustained oscillations.

However, this condition will be satisfied only in the case of resonant frequency, due to which the Wien-Bridge oscillators will be highly selective in terms of frequency, leading to a frequency-stabilized design.

RC Phase Shift Oscillator:

RC phase-shift oscillators use resistor-capacitor (RC) network (Figure 1) 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.

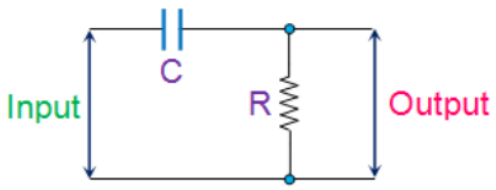


Figure 1 RC Phase-Shift Network

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

$$\varphi = tan^{-1}\frac{X_C}{R}$$

Where, XC = 1/(2πfC) 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 60o, as shown by Figure 2.

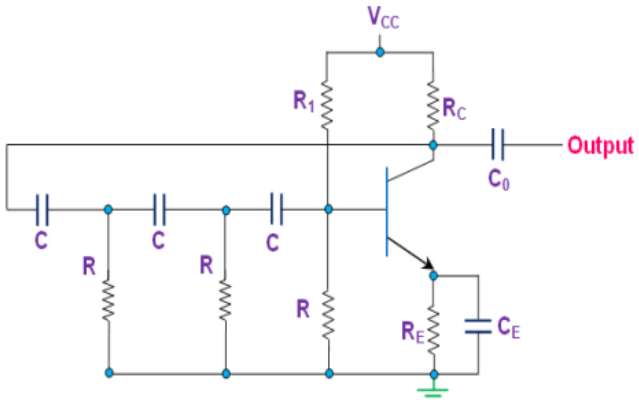


Figure 2 RC Phase-Shift Oscillator Using BJT

Here the collector resistor Rc limits the collector current of the transistor, resistors R1 and R (nearest to the transistor) form the voltage divider network while the emitter resistor RE improves the stability. Next, the capacitors CE and Co are the emitter bypass 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° during its course of travel from output terminal to the base of the transistor. Next, this signal will be shifted again by 180° by the transistor in the circuit due to the fact that the phase-difference between the input and the output will be 180° in the case of common emitter configuration. This makes the net phase-difference to be 360°, 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°. 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.

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, N is the number of RC stages formed by the resistors R and the capacitors C.

LC- Oscillators :

LC Oscillator	Z1	Z2	Z3
Hartley Oscillator	L	L	C
Colpitts Oscillator	C	C	L
Clapp Oscillator	C	C	L-C

Hartley Oscillator:

Hartley Oscillator is a type of harmonic oscillator which was invented by Ralph Hartley in 1915. These are the Tuned Circuit Oscillators which are used to produce the waves in

the range of **radio frequency and hence are also referred to as RF Oscillators**. Its frequency of oscillation is decided by its tank circuit which has a capacitor connected in parallel with the two serially connected inductors, as shown by Figure 1.

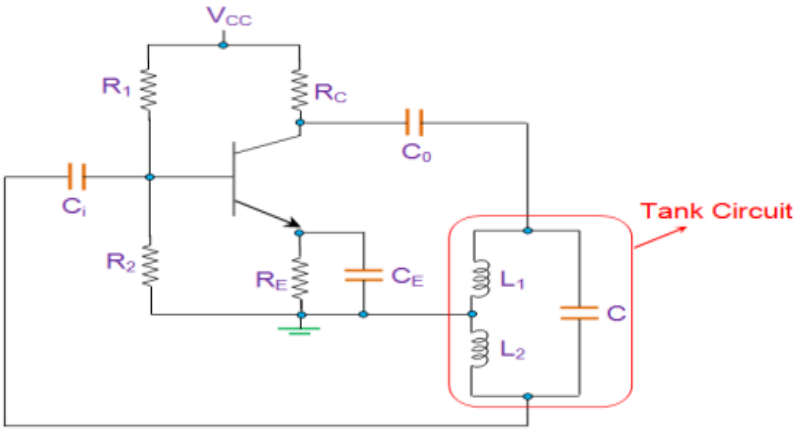


Figure 1 Hartley Oscillator

Here the RC is the collector resistor while the emitter resistor RE forms the stabilizing network. Further the resistors R1 and R2 form the voltage divider bias network for the transistor in common-emitter CE configuration. Next, the capacitors Ci and Co are the input and output decoupling capacitors while the emitter capacitor CE is the bypass capacitor used to bypass the amplified AC signals. All these components are identical to those present in the case of a common-emitter amplifier which is biased using a voltage divider network. However, Figure 1 also shows one more set of components viz., the inductors L1 and L2 and the capacitor C which form the tank circuit (shown in red enclosure).

On switching ON the power supply, the transistor starts to conduct, leading to an increase in the collector current, IC which charges the capacitor C. On acquiring the maximum charge feasible, C starts to discharge via the inductors L1 and L2. This charging and discharging cycles result in the damped oscillations in the tank circuit. The oscillation current in the tank circuit produces an AC voltage across the inductors L1 and L2 which are out of phase by 180o as their point of contact is grounded.

Further from the figure, it is evident that the output of the amplifier is applied across the inductor L1 while the feedback voltage drawn across L2 is applied to the base of the transistor. Thus one can conclude that the output of the amplifier is inphase with the tank circuit's voltage and supplies back the energy lost by it while the

energy fed back to amplifier circuit will be out-of-phase by 180o. The feedback voltage which is already 180o out-of-phase with the transistor is provided by an additional 180o phase-shift due to the transistor action. Hence the signal which appears at the transistor's output will be amplified and will have a net phase-shift of 360o.

At this state, if one makes the gain of the circuit to be slightly greater than the feedback ratio given by

$$\beta = \frac{L_1}{L_2};\ \textit{if the coils are wound on different cores}$$

$$\beta = \frac{L_1 + M}{L_2 + M}$$

(if the coils are wound on the same core with M indicating the mutual inductance) then the circuit generates the oscillations which can be sustained by maintaining the gain of the circuit to be equal to that of the feedback ratio. This causes the circuit in Figure 1 to act as an oscillator as it would then satisfy both the conditions of the Barkhausen criteria. The frequency of such an oscillator is given as

$$F = \frac{1}{2\pi\sqrt{L_{eff}C}}$$

Where

$$L_{eff}\ \textit{is the effective series inductance which is expressed as}$$

$$L_{eff} = L_1 + L_2;\ \textit{if the coils are wound on different cores}$$

$$L_{eff} = L_1 + L_2 + 2M;\ \textit{if the coils are wound on the same core}$$

Colpitts Oscillator:

Colpitts Oscillator is a type of LC oscillator which falls under the category of Harmonic Oscillator and was invented by Edwin Colpitts in 1918. Figure 1 shows a typical Colpitts oscillator with a tank circuit in which an inductor L is connected in parallel to the serial combination of capacitors C1 and C2 (shown by the red enclosure).

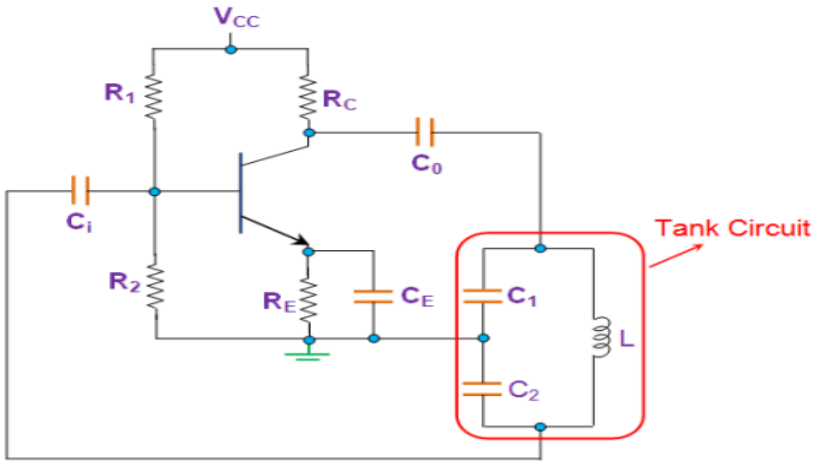


Figure 1 Colpitts Oscillator

Other components in the circuit are the same as that found in the case of common-emitter CE which is biased using a voltage divider network i.e. RC is the collector resistor, RE is the emitter resistor which is used to stabilize the circuit and the resistors R1 and R2 form the voltage divider bias network. Further, the capacitors Ci and Co are the input and output decoupling capacitors while the emitter capacitor CE is the bypass capacitor used to bypass the amplified AC signals.

Here, as the power supply is switched ON, the transistor starts to conduct, increasing the collector current IC due to which the capacitors C1 and C2 get charged. On acquiring the maximum charge feasible, they start to discharge via the inductor L. During this process, the electrostatic energy stored in the capacitor gets converted into magnetic flux which in turn is stored within the inductor in the form of electromagnetic energy. Next, the inductor starts to discharge which charges the capacitors once again. Likewise, the cycle continues which gives rise to the oscillations in the tank circuit. Further the figure shows that the output of the amplifier appears across C1 and thus is in-phase with the tank circuit's voltage and makes-up for the energy lost by re-supplying it. On the other hand, the voltage feedback to the transistor is the one obtained across the capacitor C2, which means the feedback signal is out-of-phase with the voltage at the transistor by 180o. This is due to the fact that the voltages developed across the capacitors C1 and C2 are opposite in polarity as the point where they join is grounded. Further, this signal is provided with an additional phase-shift of 180o by the transistor which results in a net phase-shift of 360o around the loop, satisfying the phaseshift criterion of Barkhausen principle.

At this state, the circuit can effectively act as an oscillator producing sustained oscillations by carefully monitoring the **feedback ratio given by (C1/C2).** The frequency of such a **Colpitts Oscillator** depends on the components in its tank circuit and is given by

$$F = \frac{1}{2\pi\sqrt{LC_{eff}}}$$

Where, the Ceff is the effective capacitance of the capacitors expressed as

$$\frac{C_1 C_2}{C_1 + C_2}$$

As a result, these oscillators can be tuned either by varying their inductance or the capacitance. However the variation of L does not yield a smooth variation. Hence they are usually tuned by varying the capacitances which are generally ganged, due to which a change in any one of them changes both of them.

Nevertheless, the process is tedious and requires special largevalued capacitor. Thus, the Colpitts oscillators are seldom preferred in the applications where in the frequency varies but are more popular as fixed frequency oscillators due to their simple design. Further they offer better stability in comparison with the Hartley Oscillators as they are exempted from the mutual inductance effect present in-between the two inductors of the latter case.

Clapp Oscillator:

Clapp oscillator is a variation of Colpitts oscillator in which an additional capacitor (C3) is added into the tank circuit to be in series with the inductor in it, as shown by Figure 1.

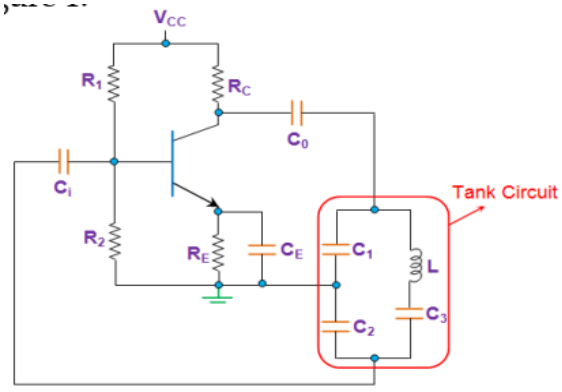


Figure 1 Clapp Oscillator

Apart from the presence of an extra capacitor, all other components and their connections remain similar to that in the case of Colpitts oscillator. Hence, the working of this circuit is almost identical to that of the Colpitts, where the feedback ratio governs the generation and sustainability of the oscillations. However the frequency of oscillation in the case of **Clapp oscillator** is given by

$$f = \frac{1}{2\pi\sqrt{L\left(\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}\right)}}$$

Usually the value of C3 is chosen to be much smaller than the other two capacitors. This is because, at higher frequencies, smaller the C3, larger will be the inductor, which eases the implementation as well as reduces the influence of stray inductance. Nevertheless, the value of C3 is to be chosen with utmost care. This is because, if it is chosen to be very small, then the oscillations will not be generated as the L-C branch will fail to have a net inductive reactance.

However, here it is to be noted that when C3 is chosen to be smaller in comparison with C1 and C2, the net capacitance governing the circuit will be more dependent on it. Thus the equation for the frequency can be approximated as

$$f = \frac{1}{2\pi\sqrt{LC_3}}$$

Further, the presence of this extra capacitance will make the **Clapp oscillator** preferable over Colpitts when there is a need to vary the frequency as is the case with **Variable Frequency Oscillator** (VCO). The reason behind this can be explained as follows. In the case of Colpitts oscillator, the capacitors C1 and C2 need to be varied inorder to vary its frequency of operation. However during this process, even the feedback ratio of the oscillator changes which in turn affects its output waveform.

One solution to this problem is to make both C1 and C2 to be fixed in nature while achieve the variation in frequency using a separate variable capacitor. As could be guessed, this is what the C3 does in the case of **Clapp oscillator**, which inturn makes it more stable over Colpitts interms of frequency.

The frequency stability of the circuit can be even more increased by enclosing the entire circuit in a chamber with constant temperature and by using a Zener diode to ensure constant supply voltage.

In addition, it is to be noted that the values of the capacitors C1 and C2 are prone to the effect of stray capacitances unlike that of C3. This means that the resonant frequency of the circuit would be affected by the stray capacitances if one had a circuit with just C1 and C2, as in the case of Colpitts oscillator. However if there is C3 in the circuit, then the changes in the values of C1 and C2 would not vary the resonant frequency much, as the dominant term would then be C3.

Next, it is seen that the **Clapp oscillators** are comparatively compact as they employ a relatively small capacitor to tune the oscillator over a wide frequency band. This is because, here, even a slight change in the value of the capacitance varies the frequency of the circuit upto a great extent. Further they exhibit high Q-factor with a high L/C ratio and lesser circulating current in comparison with Colpitts oscillators. Lastly it is to be noted that these oscillators are highly reliable and are hence preferred inspite of having a limited range of frequency of operation.

Crystal Oscillators:

Crystal Oscillators can be designed by connecting the crystal into the circuit such that it offers low impedance when operated in series-resonant mode (Figure 2a) and high impedance when operated in anti-resonant or parallel resonant mode (Figure 2b).

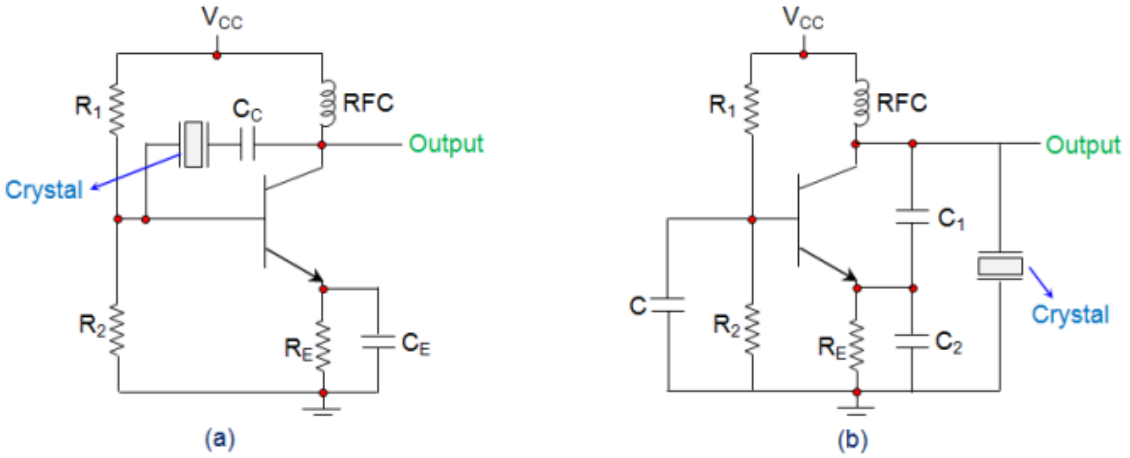


Figure 2 Crystal Oscillator Operating in (a) Series Resonance (b) Parallel Resonance

In the circuits shown, the resistors R1 and R2 form the voltage divider network while the emitter resistor RE stabilizes the circuit. Further, CE (Figure 2a) acts as an AC bypass capacitor while the coupling capacitor CC (Figure 2a) is used to block DC signal propagation between the collector and the base terminals. Next, the capacitors C1 and C2 form the capacitive voltage divider network in the case of Figure 2b.

In addition, there is also a Radio Frequency Coil (RFC) in the circuits (both in Figure 2a and 2b) which offers dual advantage as it provides even the DC bias as well as frees the circuit-output from being affected by the AC signal on the power lines.

On supplying the power to the oscillator, the amplitude of the oscillations in the circuit increases until a point is reached wherein the nonlinearities in the amplifier reduce the loop gain to unity. Next, on reaching the steady-state, the crystal in the feedback loop highly influences the frequency of the operating circuit. Further, here, the frequency will self-adjust so as to facilitate the crystal to present a reactance to the circuit such that the Barkhausen phase requirement is fulfilled.

In general, the frequency of the crystal oscillators will be fixed to be the crystal's fundamental or characteristic frequency which will be decided by the physical size and shape of the crystal. However, if the crystal is non-parallel or of non-uniform thickness, then it might resonate at multiple frequencies, resulting in harmonics. Further, the crystal oscillators can be tuned to either even or odd harmonic of the fundamental frequency, which are called Harmonic and Overtone Oscillators, respectively. An example for this is the case where the parallel resonance frequency of

the crystal is decreased or increased by adding a capacitor or an inductor across the crystal, respectively.

Applications:

Crystal oscillators are compact in size and are of low cost due to which they are extensively used in electronic warfare systems, communication systems, guidance systems, microprocessors, microcontrollers, space tracking systems, measuring instruments, medical devices, computers, digital systems, instrumentation, phase locked loop systems, modems, sensors, disk drives, marine systems, telecommunications, engine controlling systems, clocks, Global Positioning Systems (GPS), cable television systems, video cameras, toys, video games, radio systems, cellular phones, timers, etc.

A colpitts oscillator has a coil with an inductance of 50 μH and is tuned by a capacitor 400 pF across amplifier input & 200 pF across the output. Then the frequency of oscillation & the minimum gain for maintaining oscillations?

(A) 1.95 MHz, 3 (B) 1.95 MHz, 2

(C) 2.9 MHz, 3 (D) 2.9 MHz, 2

For colpitts oscillator

$$f_0 = \frac{1}{2\pi\sqrt{LC_{eq}}}, \quad C_{eq} = \frac{C_1C_2}{C_1 + C_2}$$

$$C_{eq} = \frac{400 \times 200}{600} = 133.33 \text{ pF}$$

$$f_0 = \frac{1}{2\pi\sqrt{50 \times 133.33 \times 10^{-18}}}$$

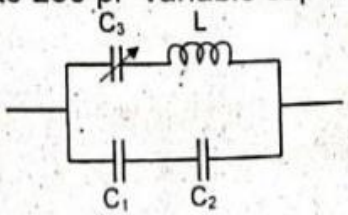
$$= 1.95 \text{ MHz}$$

For maintaining oscillations, $A\beta \geq 1$

$$A_{loop} = A_{v0} \cdot \frac{C_2}{C_1} = 1$$

$$A_{v0} = \frac{C_1}{C_2} = \frac{400}{200} = 2 \quad \text{Choice (B)}$$

A clapp oscillator has the following circuit components C_1 = 5000 pF, C_2 = 500 pF, L = 50 μH and C_3 is a 50 to 250 pF variable capacitor.



Find out the tuning frequency range?

(A) 1.98 to 10.34 MHz

(B) 2.34 to 11.56 MHz

(C) 3.35 to 12.5 MHz

(D) 5.34 to 15.4 MHz

$$f_0 = \frac{1}{2\pi\sqrt{LC_{eq}}}, \quad \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$C_{eq} = \frac{5000 \times 500 \times 50}{5000 \times 500 + 5000 \times 50 + 500 \times 50}$$

$= 45.045$ pF for C_3 = 50 pF

$$f_0 = \frac{1}{2\pi\sqrt{50 \times 45.045 \times 10^{-18}}}$$

= 3.35 MHz

C_{eq} = 161.29 pF for C_3 = 250 pF

Then f_0 = 12.5 MHz Choice (C)

Multivibrators

A MULTIVIBRATOR is an electronic circuit that generates square, rectangular, pulse waveforms, also called nonlinear oscillators or function generators. Multivibrator is basically a two amplifier circuits arranged with regenerative feedback.

There are three types of Multivibrator:

Astable Multivibrator: Circuit is not stable in either state—it continuously oscillates from one state to the other. (Application in Oscillators)

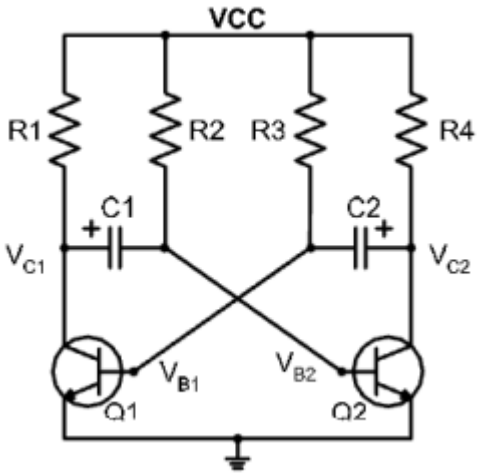
Monostable Multivibrator: One of the state is stable but the other is not. (Application in Timer)

Bistable Multivibrator: Circuit is stable in both the state and will remain in either state indefinitely. The circuit can be flipped from one state to the other by an external event or trigger. (Application in Flip flop)

Astable Multivibrators

The astable circuit has no stable state. With no external signal applied, the transistors

alternately switch from cutoff to saturation at a frequency determined by the RC time constants of the coupling circuits. Astable multivibrator circuit consist of two cross coupled RC amplifiers.



Consists of two amplifying devices cross-coupled by resistors and capacitors.

Typically, R2 = R3, R1 = R4, C1 = C2 and R2 >> R1.

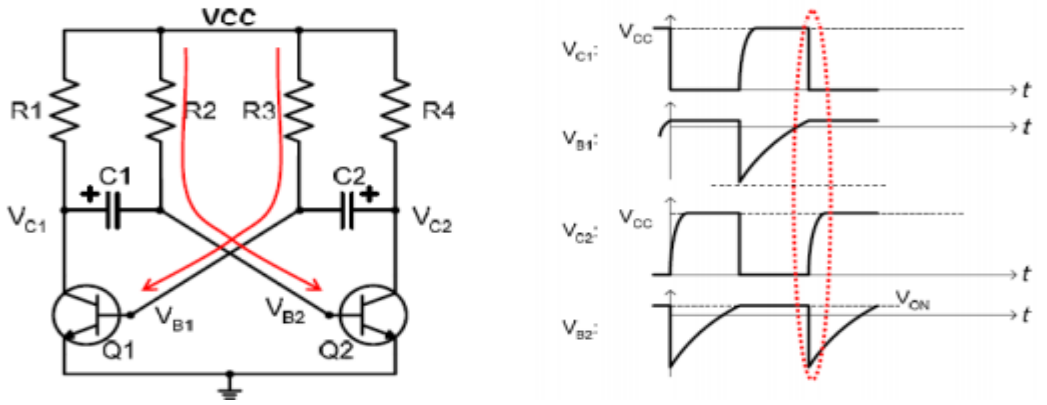
The circuit has two states

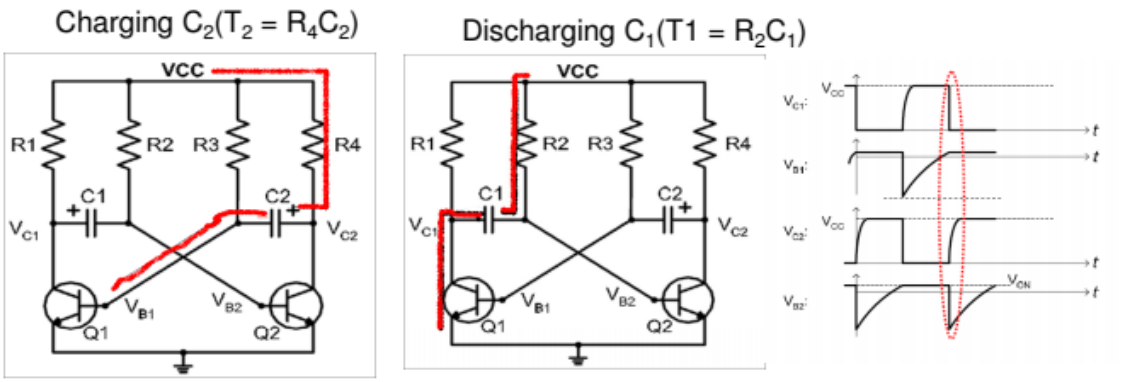
State 1: VC1 LOW, VC2 HIGH, Q1 ON (saturation) and Q2 OFF.

State 2: VC1 HIGH, VC2 LOW, Q1 OFF and Q2 ON (saturation).

It continuously oscillates from one state to the other.

When the circuit is first powered up, neither transistor is ON. Both VB1 and VB2 rise via base resistor R3 and R2 respectively. Any one of the transistor will conduct faster than other due to some circuit imbalance. We can not say which transistor will turn on first so for analysis purpose we assume Q1 conducts first and Q2 off (C1 is fully charged). Since Q1 conducts and Q2 off hence Vc1 = 0V and Vc2 = VCC. - state1





Since Q1 conducts and Q2 off hence Vc1 = 0V and Vc2 = VCC. Due to higher voltage at Vc2, capacitor C2 will be charged via R4 (low resistance path because R4 <R2). C1 (which was charged earlier, and can not hold the charge for indefinite period) starts discharging via R2 (high resistance path because R2>R1). Time taken to discharge C1(T1 = R2C1) > time taken to charge C2 (T2 =R4C2) When C2 is fully charged then left plate of C2 will be at –Vcc which switch off the Q1. When C1is fully discharged then left plate of C1 will be at +Vcc which switch on the Q2. – State 2

When VB2 reaches Von, the circuit enters in state 1 again, and the process repeats

Switching time & Frequency for Astable Multivibrators

- Time period of wave depends only upon the discharge of capacitors C_1 and C_2.
- Consider V_{B2} during discharge of C_2: $V_{B2} = V_{CC} - i_{C1}R_2$
- Since the capacitor C_1 charged up to V_{CC}, the initial discharge current will be

$$i_{C1} = \frac{V_{CC} + V_{CC}}{R_2}$$ Current decays exponentially with a time constant of R_2C_1

$$V_{B2} = V_{CC} - 2V_{CC}(e^{-t/R_2C_1})$$ **Transistor will switch when V_{B2} = 0V (actually 0.7V for Si which is small compare to V_{CC})**

$$0 = V_{CC} - 2V_{CC}(e^{-t/R_2C_1}) \qquad 2e^{-t/R_2C_1} = 1 \qquad t = T_2 = R_2C_1\ln(2)$$

where T2 is the off time for transistor Q_2

- Similarly off time for transistor Q_1 can be obtained.

$$t = T_1 = R_3C_2\ln(2)$$

- Total time period T:

$$T = T_1 + T_2 = [R_3C_2 + R_2C_1]\ln(2) = 0.694(R_3C_2 + R_2C_1)$$

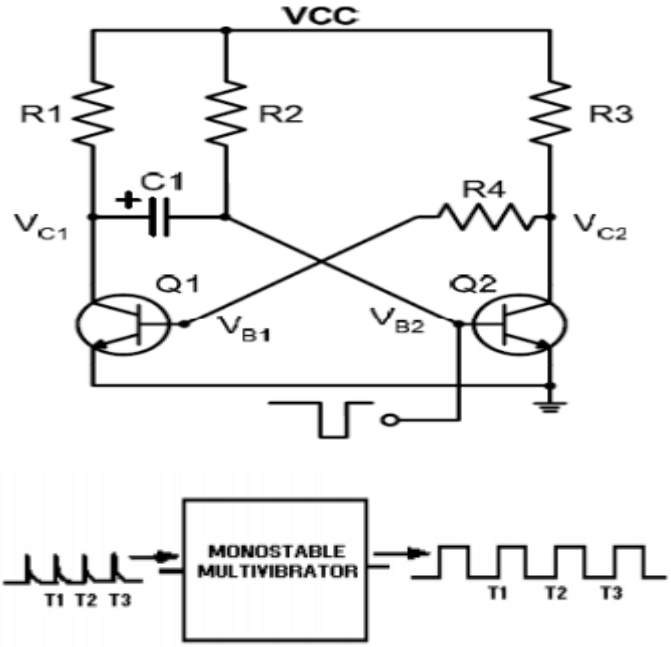
- If R2 = R3 = R, C1 = C2 = C then $T = 1.4RC$
- Frequency of oscillation is given by

$$f = \frac{1}{T} = \frac{0.7}{RC}$$

Monostable Multivibrators:

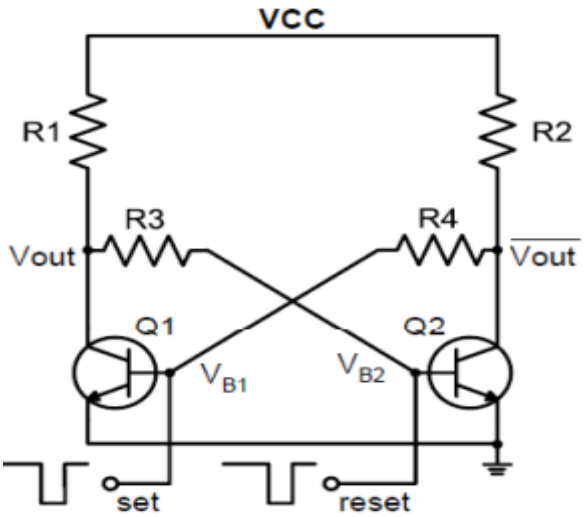
One of the state is stable but the other is not. For that capacitive path between VC2 and VB1 removed. In stable state any one transistor conducts and other is off. Application of external trigger change the state. When the external signal goes high VB2 charges up to VCC through R2 After a certain time T, VB2=VON, Q2 turns on VC2 pulled to 0V, Q1

turns off. Enters state 1 and remains there When VB2 is momentarily pulled to ground by an external signal VC2 rises to VCC Q1 turns on VC1 pulled to 0V.



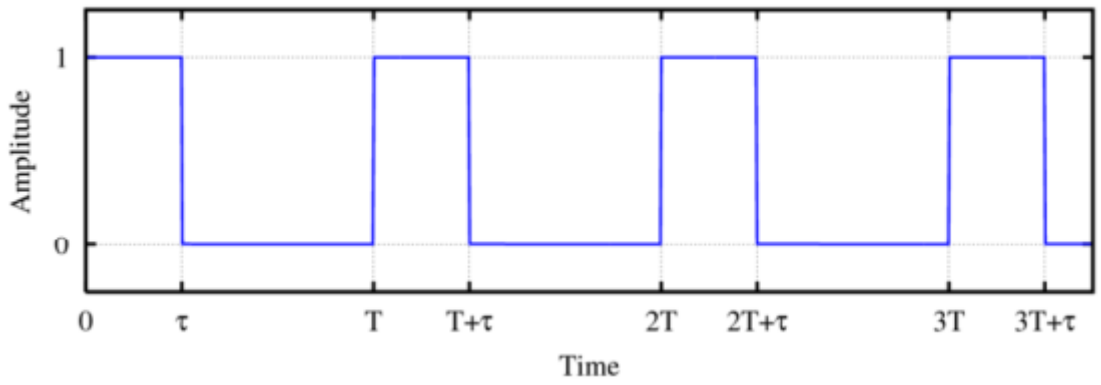
Bistable Multivibrators :

Both capacitors removed Stable for either state 1 or 2 Can be forced to either state by Set or Reset signals If Set is low, Q1 turns off VC1 (Vout) and VB2 rises towards VCC Q2 turns on VC2 pulled to 0V. VB1 is latched to 0V, Circuit remains in state 2 until Reset is low If Reset is low Similar operation Circuit remains in state 1 until Set is low Behave as an RS flip-flop (memory element).



Some Important terms:

Duty Cycle duty cycle is defined as the ratio of pulse duration to pulse period.



The pulse duration is τ; this is how long the pulse remains high (amplitude=1in the figure).The pulse period is T ; this is the duration of one complete cycle, and is just the inverse of the frequency in Hz (*f = 1/T).*

$$D = \tau / T$$