Syllabus: Oscillators: Positive feedback, Conditions for oscillation, BJT as an Oscillator (LC).

Oscillator

What is an Oscillator?

An **oscillator** is a circuit which produces a continuous, repeated, alternating waveform without any input. Oscillators basically convert unidirectional current flow from a DC source into an alternating waveform which is of the desired frequency, as decided by its circuit components.

1. **Block diagram of an amplifier stage with positive feedback**

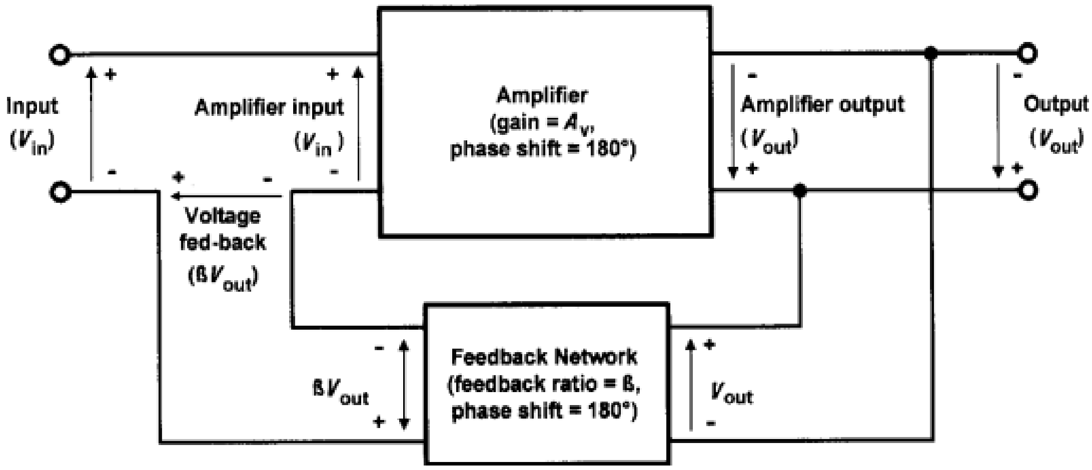


Figure 9.1 Amplifier with positive feedback applied

shows the block diagram of an amplifier stage with positive feedback applied. The amplifier provides a phase shift of 180° and the feedback network provides a further 180°. Thus the overall phase shift is 0°. If it is a CE configuration.

The overall voltage gain, G, is given by:

$$\text{Overall gain, } G = \frac{V_{out}}{V_{in}}$$

By applying Kirchhoff's Voltage Law

$$V_{in}' = V_{in} + \beta V_{out}$$

thus

$$V_{in} = V_{in}' - \beta V_{out}$$

and

$$V_{out} = A_v \times V_{in}$$

where Av is the internal gain of the amplifier.
Hence:

$$\text{Overall gain, } G = \frac{A_v \times V_{in}'}{V_{in}' - \beta V_{out}} = \frac{A_v \times V_{in}'}{V_{in}' - \beta(A_v \times V_{in}')}$$

$$\text{Thus, } G = \frac{A_v}{1 - \beta A_v}$$

Now consider what will happen when the loop gain βA_v **Where Aβ is the feedback factor or the loop gain.**, approaches unity (i.e., when the loop gain is just less than 1). The denominator (1-βAv) will become close to zero. This will have the effect of increasing the overall gain, i.e. the overall gain with positive feedback applied will be greater than the gain without feedback.

Barkhausen Criterion of oscillations.

If$A\beta = 1$, $G = \infty$. Thus the gain becomes infinity, i.e., there is output without any input. In another words, the amplifier works as an Oscillator.

The condition $A\beta = 1$ is called as Barkhausen Criterion of oscillations. This is a very important factor to be always kept in mind, in the concept of Oscillators.

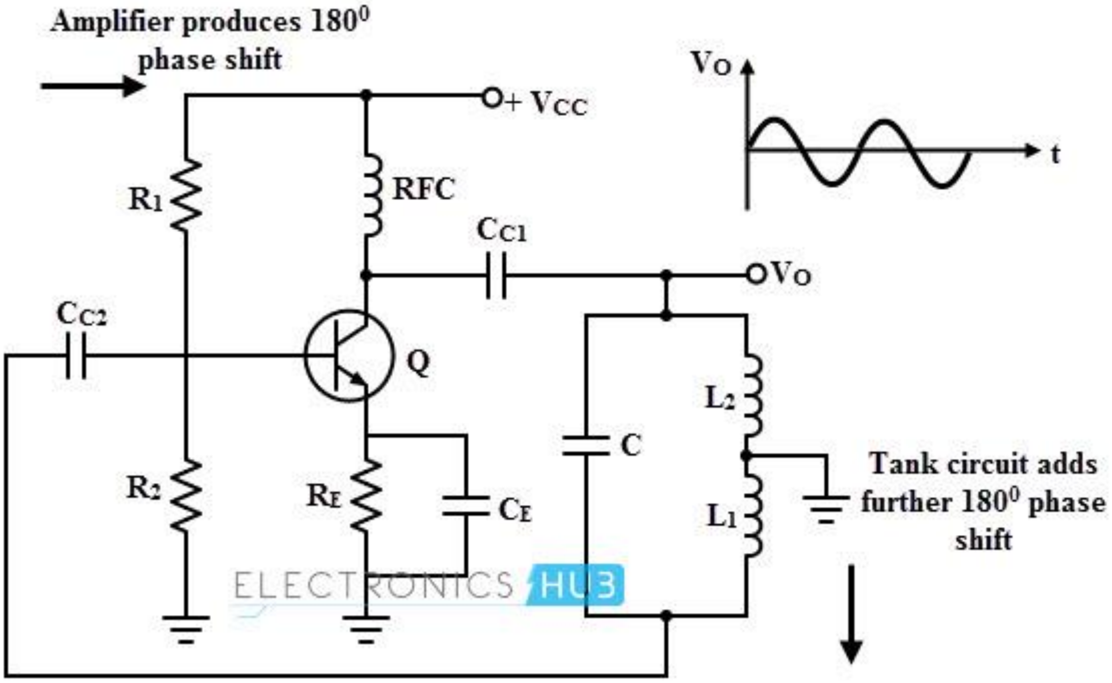
2. **Conditions for oscillation**

The conditions for oscillation are:

(a) the feedback must be positive (i.e. the signal fed back must arrive back in-phase with the signal at the input);

(b) the overall loop voltage gain must be greater than 1 (i.e. the amplifier's gain must be sufficient to overcome the losses associated with any frequency selective feedback network).

3. **Hartley Oscillator**



The Hartley oscillator is one of the classical LC feedback circuits and used to generate high frequency waveforms or signals.

The circuit diagram of a Hartley oscillator is shown in figure below. An NPN transistor connected in common emitter configuration serves as active device in amplifier stage. R1 and R2 are biasing resistors and RFC is the radio frequency choke which provides the isolation between AC and DC operation. At high frequencies, the reactance value of this RFC choke is very high; hence it can be treated as open circuit. The reactance is zero for DC condition hence causes no problem for DC capacitors. CE is the emitter bypass capacitor and RE is also a biasing resistor. Capacitors CC1 and CC2 are the coupling capacitors.

1. When the DC supply (Vcc) is given to the circuit, collector current starts raising and begins the charging of the capacitor C.
2. Once C is fully charged, it starts discharging through L1 and L2 and again starts charging.

3. This back-and-fourth voltage waveform is a sine wave which is a small and leads with its negative alteration.
4. The sine wave generated by the tank circuit is coupled to the base of the transistor through the capacitor CC1.
5. Since the transistor is configured as common-emitter, it takes the input from tank circuit and inverts it to a standard sine wave with a leading positive alteration.
6. The frequency of oscillations of this circuit is

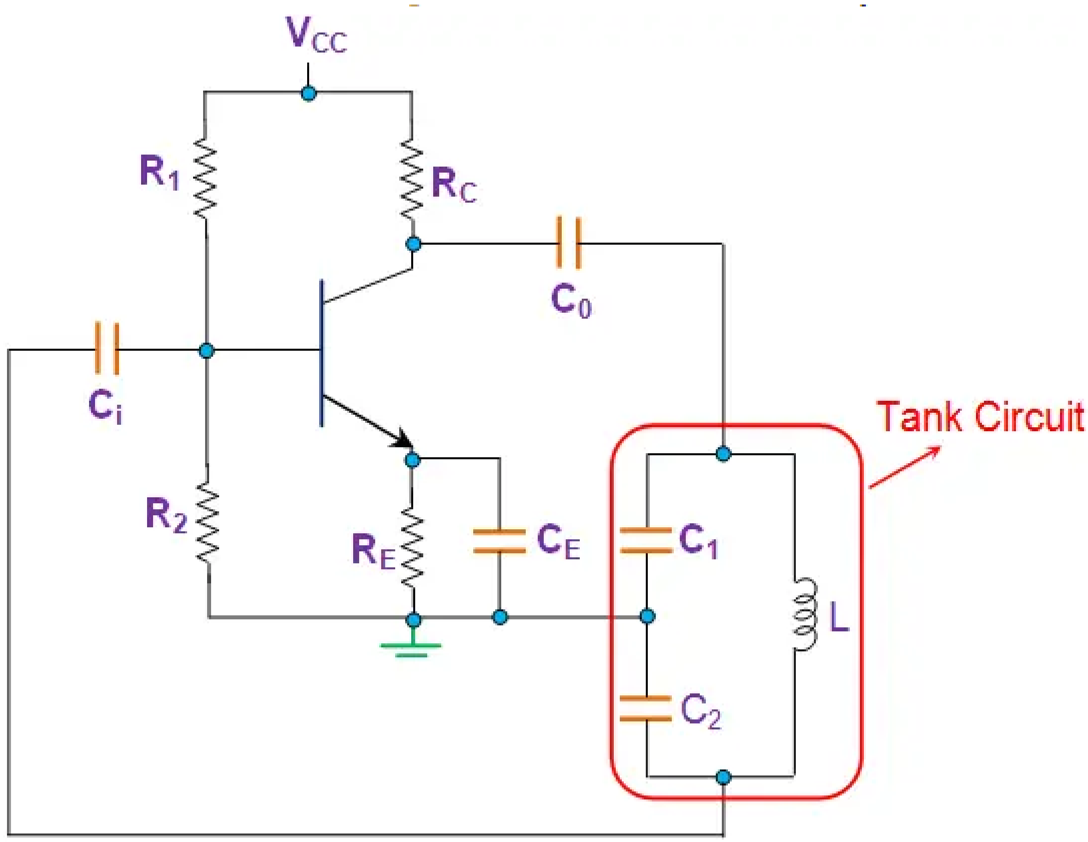
   $$fo = 1/ (2\pi \sqrt{} (Leq\ C))$$

   Where Leq is the total inductance of coils in the tank circuit and is given as
   Leq = L1 + L2 + 2M

7. Thus the transistor provides amplification as well as inversion to amplify and correct the signal generated by the tank circuit. The mutual inductance between the L1 and L2 provides the feedback of energy from collector-emitter circuit to base-emitter circuit.

4. Colpitts Oscillator:

1. A Colpitts Oscillator is a type of LC oscillator. Figure 1 shows a typical Colpitts oscillator with a tank circuit.
2. An inductor L is connected parallel to the serial combination of capacitors C1 and C2 (shown by the red enclosure).
3. 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.
4. Further, the capacitors Ci and Co are the input and output coupling capacitors while the emitter capacitor CE is the bypass capacitor used to bypass the amplified AC signals.
5. Here, as the power supply is switched ON, the transistor starts to conduct, increasing the collector current I_C due to which the capacitors C1 and C2 get charged.
6. On acquiring the maximum charge, they start to discharge via the inductor L.
7. During this process, the electrostatic energy stored in the capacitor gets converted into magnetic flux, which is stored within the inductor in the form of electromagnetic energy.
8. Next, the inductor starts to discharge, which charges the capacitors once again.
9. Likewise, the cycle continues, which gives rise to the oscillations in the tank circuit.
10. On the other hand, the voltage feedback to the transistor is obtained across the capacitor C2, which means the feedback signal is out-of-phase with the voltage at the transistor by 180^o.
11. 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.
12. Further, this signal is provided with an additional phase-shift of 180^o by the transistor which results in a net phase-shift of 360^o around the loop, satisfying the phase-shift criterion of Barkhausen principle.


V_{CC}
R_1
R_C
C_0
C_i
Tank Circuit
R_2
R_E
C_E
C_1
L
C_2