ELECTRONIC DEVICES & CIRCUITS
Module 4

Oscillators

S3 CSE KTU

prepared by

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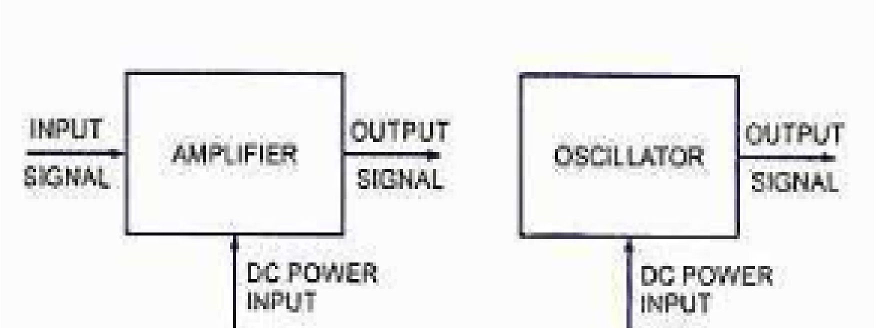
OSCILLATORS

- An oscillator can be described as a source of alternating voltage.
- An amplifier delivers an amplified version of input signal while oscillator generates an output waveform without an input signal.
- The additional power content in the output signal is supplied by an external DC power source.
- The oscillator requires no external signal to initiate or maintain the energy conversion process.
- Instead, an output signal is produced as long as a DC power source is connected.

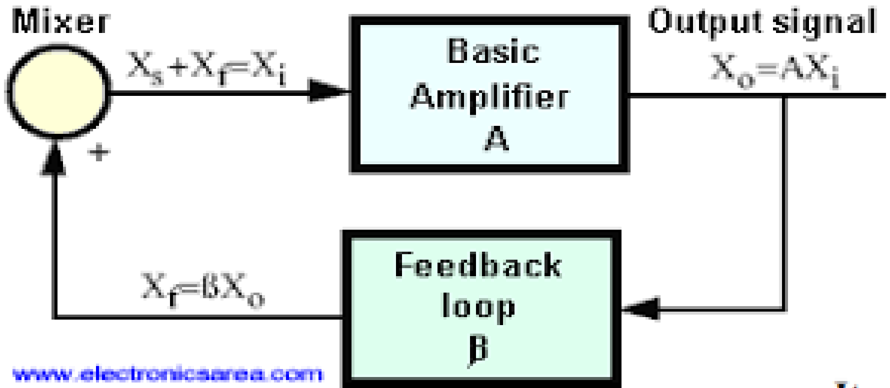


- Oscillators are amplifiers with positive feedback.

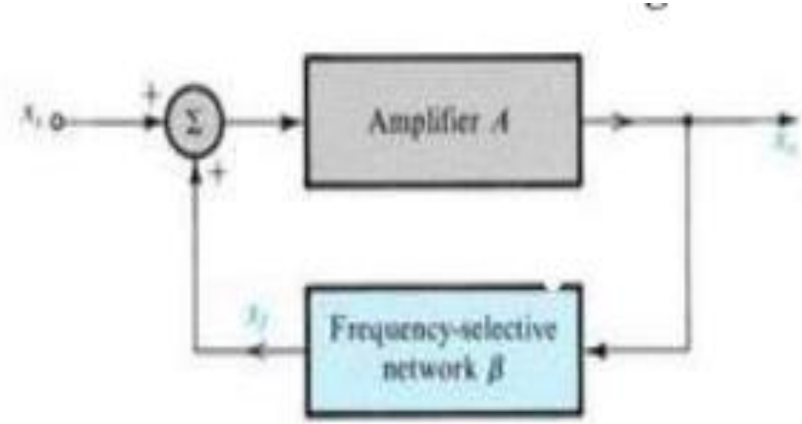
Depending on nature of o/p waveform oscillators are of 2 types

1.Sinusoidal Oscillators
2. Relaxation oscillators/Non sinusoidal Oscillators- square, triangular, sawtooth waveforms

1.Sinusoidal Oscillators -Principle



Basic structure of the sinusoidal oscillator



It consists of an amplifier to maintain the loop gain at unity and a frequency selective network to determine the frequency of oscillation.

Amplifiers and oscillators- comparison

1. No signal source Vs is required in oscillators . Only DC power source is needed.
   For amplifiers, both DC and ac signal source are necessary.
2. Positive feedback is necessary for oscillations to build up.
   Negative feedback is required for amplifier stability against Q-point variations..
3. For oscillator frequency selection, the feedback loop in oscillator consists of frequency dependent elements, ie , reactive elements .
   It can be combination of R &C, L&C or crystals

   The amplifier feedback network elements consists of only resistive elements for stabilizing the gain against frequency variations.

- A is the open loop gain of the amplifier.
- Without feedback, output voltage of amplifier is

$$V_0 = A \times V_{in}$$

And Vin =Vs

- Since positive feedback is used, feedback voltage V_f is added with input signal V_s
- Thus the input to the amplifier is $V_s + V_f$
- With feedback, the output voltage $V_o = A(V_s + V_f)$

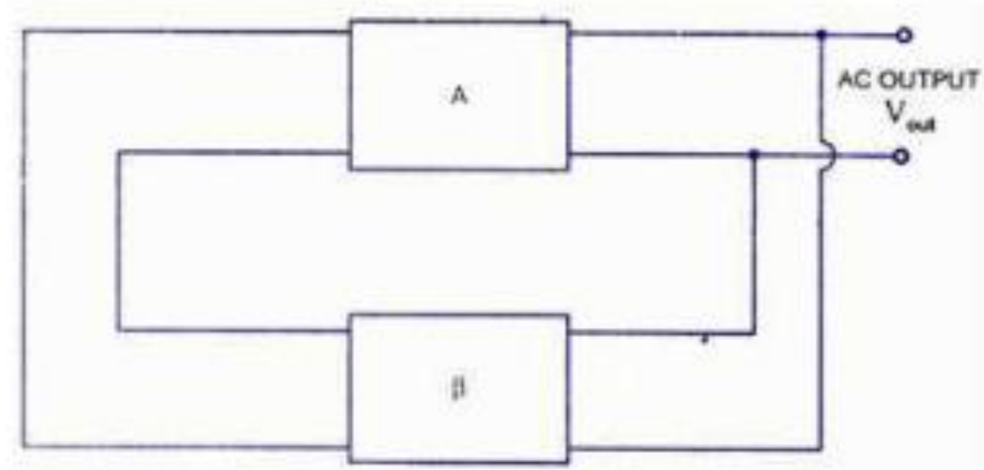
$$V_o = A(V_s + \beta V_o) \text{ because } V_f = \beta V_o$$

$$V_0 (1 - A\beta) = Av_s$$

$$\frac{V_o}{V_s} = \frac{A}{1 - A\beta}$$

- Which denotes the gain of the amplifier with feedback. **(positive**)

- Consider the case when the input signal V_{in} is removed and V_f is directly connected to the amplifier.



- This is the case of an oscillator that no input signal is applied to it.
- Then the condition for a non - zero output to exist can be derived from the equation $V_o / V_s = A / (1-A\beta)$, which is $V_s = 0$ (since there is no input for an oscillator) and V_o should be non zero.

$V_o(1-A\beta)$ =A V_s = 0 (since V Vs = 0

Since Vo should be non zero $(1-A\beta)$ = 0

This implies that Loop gain $A\beta = 1$ and $A\beta$ is in phase with input signal since

- Then the gain with feedback (closed loop gain) becomes infinite.
- Loop gain Aβ =1 implies that

$$|A\beta| = 1$$

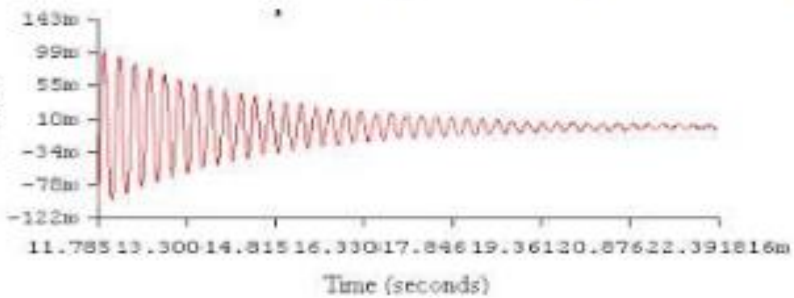
$$\angle A\beta = 0$$

- Thus the conditions for sustained oscillations are

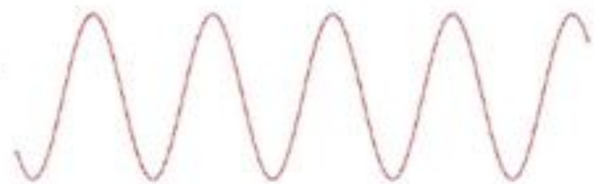
1. The magnitude of the loop gain Aβ of the circuit must be equal to unity.
2. The phase shift of the loop gain Aβ around the circuit must be 0 or 360^0

- These requirements are known as Barkhausen criteria.
- Barkhausen Criterion: A linear system will produce sustained oscillations only at frequencies for which the gain around the feedback loop is 1 and the phase shift around the feedback loop is ZERO or an integral multiple of 2π.
- In reality, no input signal is needed to start the oscillator going.
- Only the condition $A\beta = 1$ must be satisfied for self-sustained oscillations to result.
- In practice, $A\beta$ is made greater than 1 and the system will start oscillating by amplifying noise voltage, which is always present.

- The criterion $A\beta = 1$ is satisfied only at one frequency.
- Oscillations will not be sustained if $A\beta < 1$ or $A\beta > 1$
- Figure below shows the output for $A\beta < 1$ and $A\beta > 1$
- $A\beta < 1$



$A\beta = 1$



$A\beta > 1$

- If $A\beta$ is less than unity $A\beta V_{in}$ is less than V_{in} and the output signal will die out.
- If $A\beta > 1$, then $A\beta V_{in}$ is greater than V_{in} and the output voltage builds up gradually.
- If $A\beta = 1$, then the output voltage is sine wave under steady state conditions.

- **In practice, *Aβ* is made greater than 1 and the system will start oscillating by amplifying noise voltage, which is always present.**

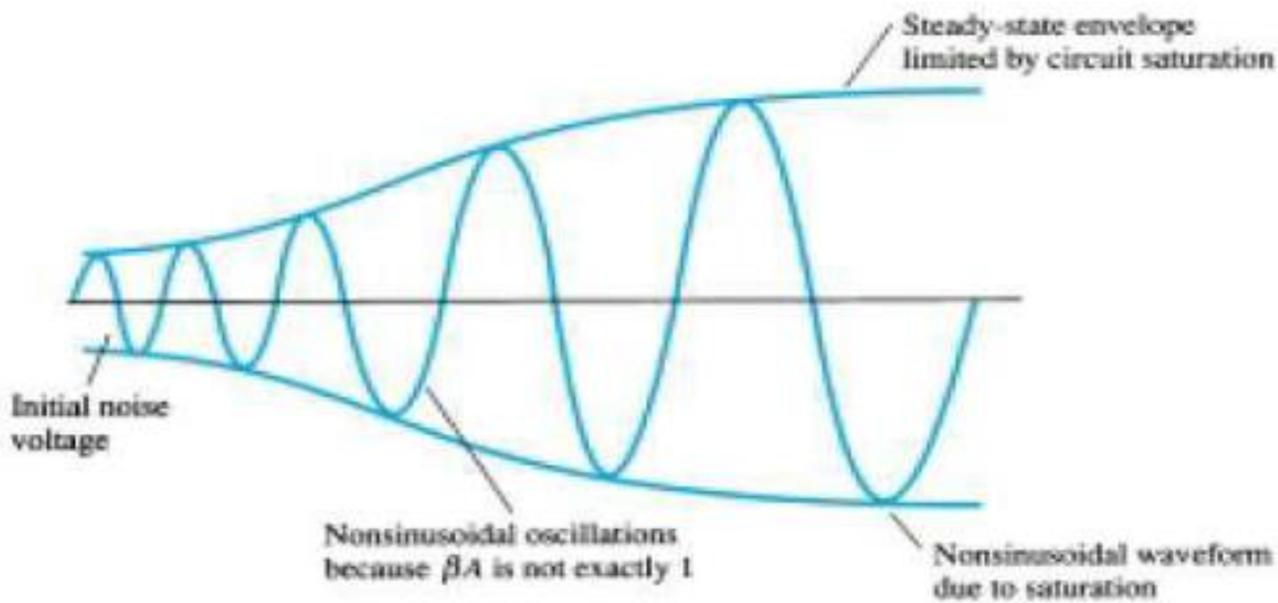
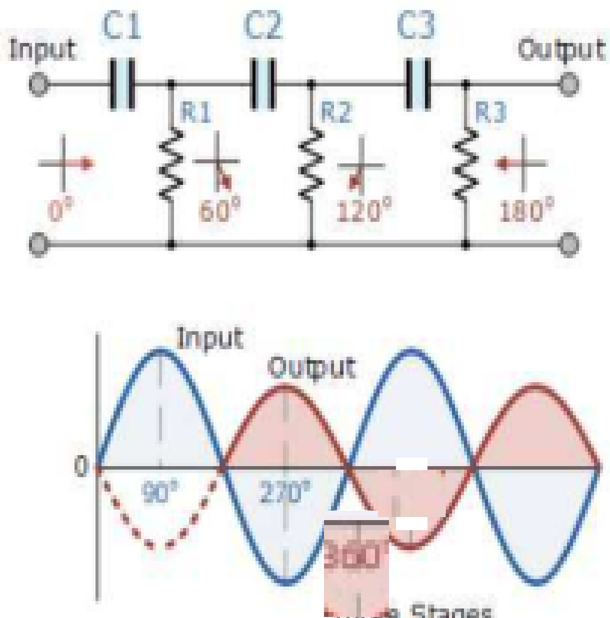


Figure 18.19 Buildup of steady-state oscillations.

- Passive components normally determine the frequency of oscillation.
- They also influence stability, which is a measure of change in output frequency with time, temperature or other factors.
- Passive devices may include resistors, inductors, capacitors, transformers and resonant crystals.
- An RC phase shift network which offers 180^0 phase shift is shown in the figure below.



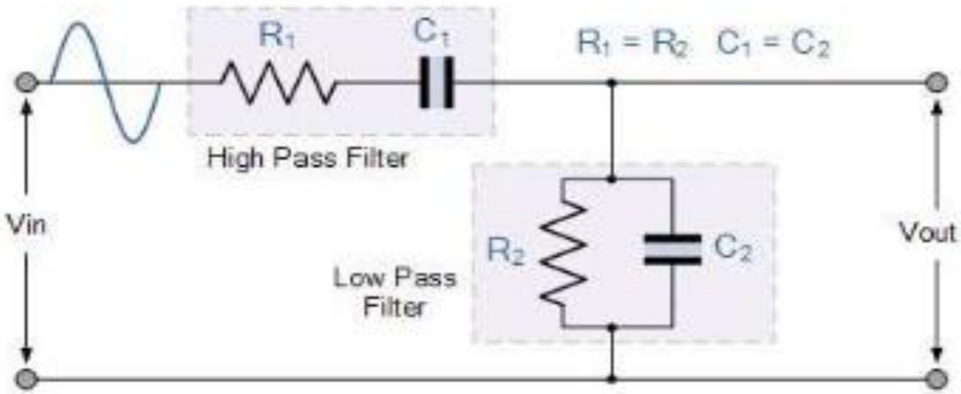
CLASSIFICATION OF OSCILLATORS

- Oscillators can be classified in a variety of different ways. Some of the more common classes are:
  - Operating frequency band (Audio, Radio).
  - Output waveform (Sine wave, Square wave, Triangle wave, Sawtooth wave).
  - Components used to set the frequency (RC, LC, crystal).
  - Configuration of those components (Phase Shift, Wein Bridge, Hartley, Colpitts).
  - Purpose of the oscillator (Local oscillator, Beat Frequency oscillator, system clock, signal generator, function generator).
  - Available tuning range (fixed, adjustable, wide range).
  - Technology used (Analog, Digital, CMOS).

WIEN BRIDGE OSCILLATOR

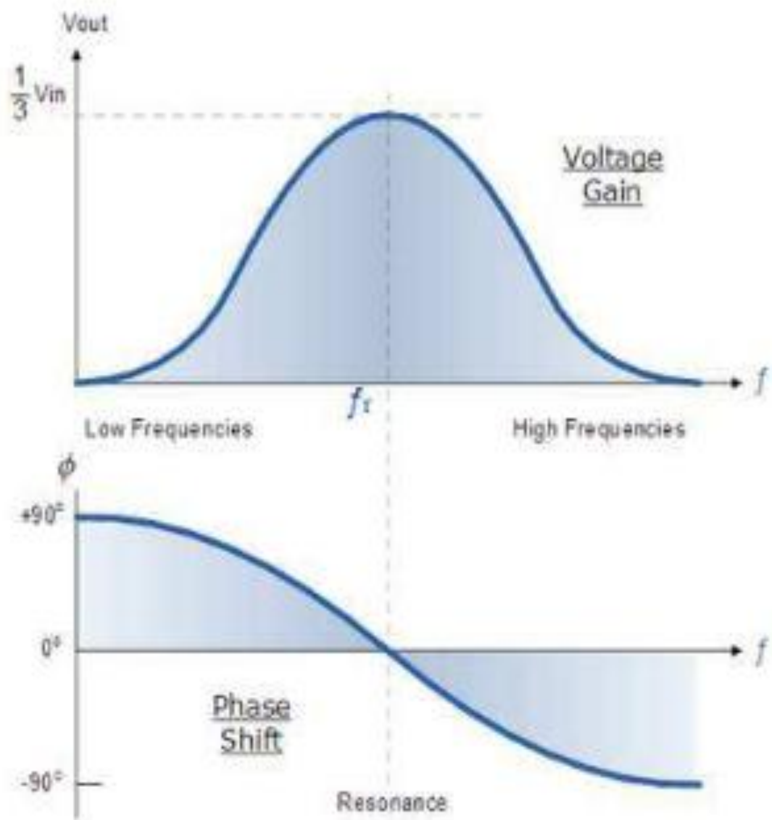
- The Wien Bridge Oscillator is so called because the circuit is based on a frequency-selective form of the Wheatstone bridge circuit.
- The Wien Bridge oscillator is a two-stage RC coupled amplifier circuit that has good stability at its resonant frequency, low distortion and is very easy to tune, making it a popular circuit as an audio frequency oscillator.
- This type of oscillator is simple in design, compact in size, and remarkably stable in its frequency output.
- This type of oscillator uses RC feedback network so it can also be considered as RC oscillator.

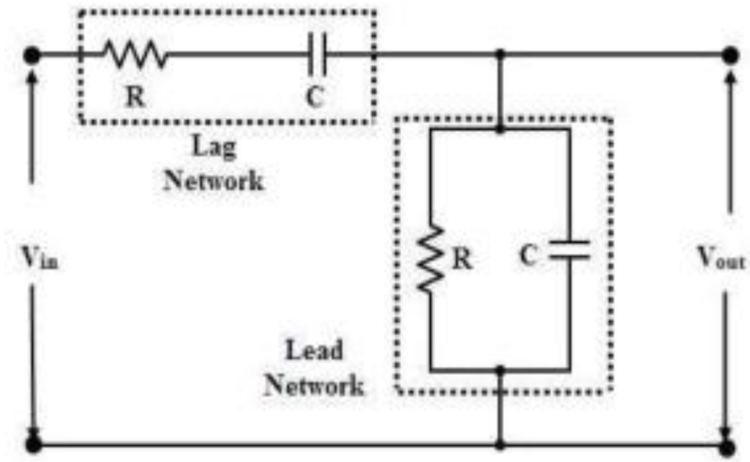
- **The Wien Bridge Oscillator uses a feedback circuit consisting of a series RC circuit connected with a parallel RC of the same component values producing a phase delay or phase advance circuit depending upon the frequency.**
- **At the resonant frequency f_r the phase shift is 0°.**
- **Consider the circuit below.**



At [illegible] resonant frequency, the circuits reactance equals its resistance, that is: $X_c = R$, 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 below.





At Resonance, $R = X_c$

$$R = \frac{1}{2\pi f_r C}$$

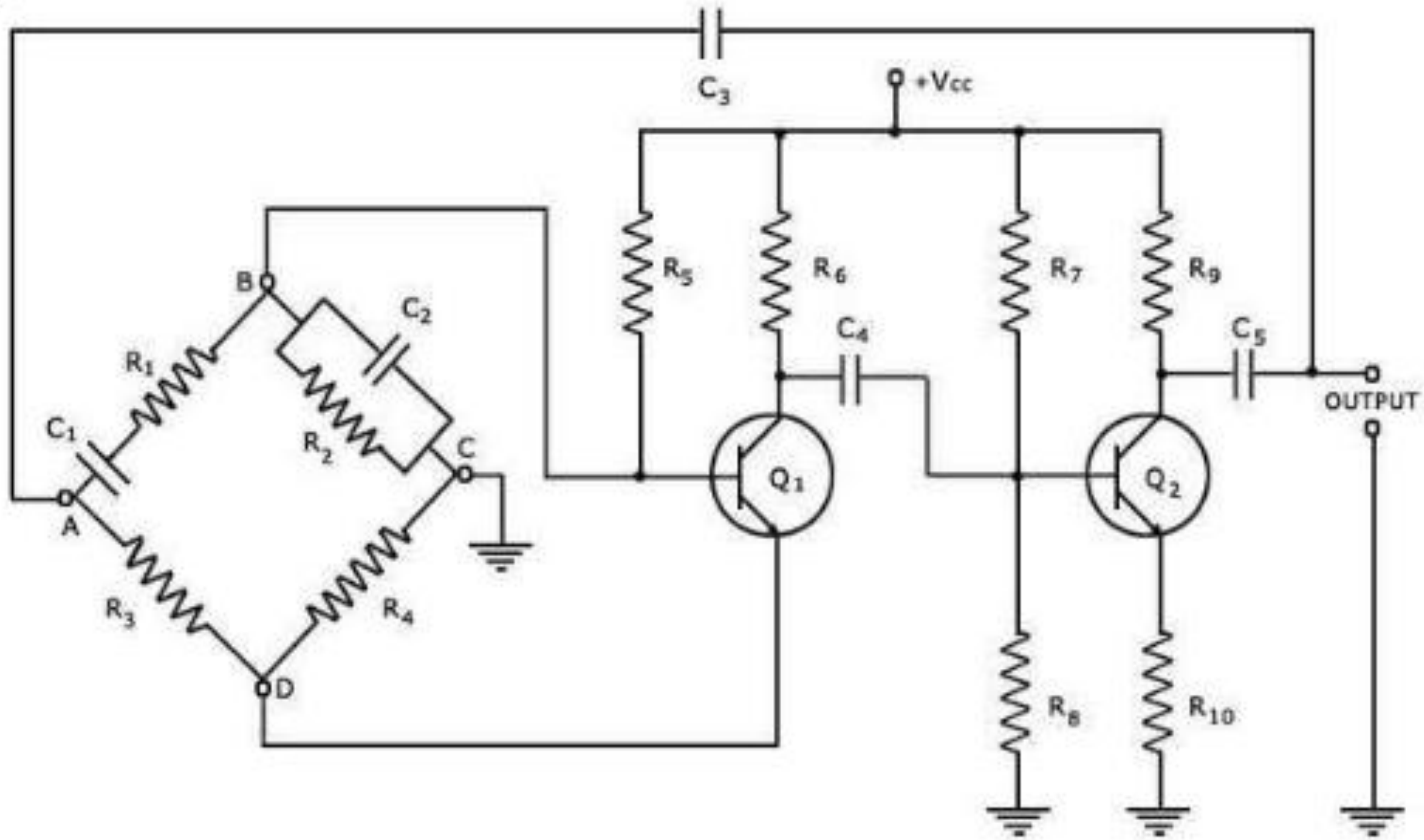
$$f_r = \frac{1}{2\pi RC}$$

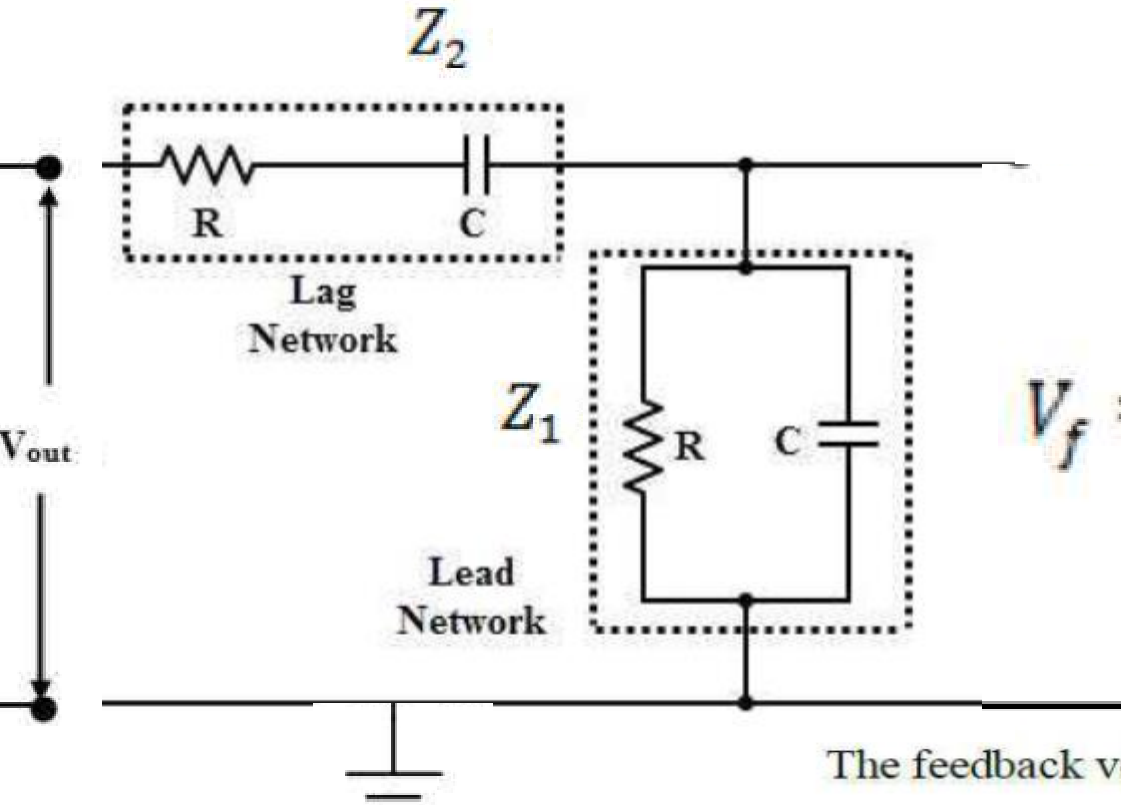
Wien Bridge Oscillator Frequency

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

Where:
f_r is the Resonant Frequency in Hertz
R is the Resistance in Ohms
C is the Capacitance in Farads

- The circuit diagram of Wien bridge oscillator is shown in the figure below.





The feedback voltage V_f is given by,

$$V_f = \frac{Z_1}{Z_1+Z_2} V_{out} \tag{1}$$

where,

$$Z_1 = \frac{R}{1+RCS} \tag{2}$$

$$Z_2 = R + \frac{1}{Cs} \tag{3}$$

Substituting these values in Eq.1 we get,

$$V_f = \frac{\frac{R}{1+RCs}}{\frac{R}{1+RCs} + R + \frac{1}{Cs}} V_{out}$$

Substituting the value of s=jω and simplifying we get,

$$V_f = \frac{j\omega CR}{1+3RCj\omega - C^2R^2\omega^2} V_{out}$$

To ensure phase shift of 0^0 by the feedback network,

$$1 - C^2R^2\omega^2 = 0$$

This leads to $\omega = \frac{1}{RC} \Rightarrow f = \frac{1}{2\pi RC}$

This happens for $V_f = \frac{V_{out}}{3}$

- **It is essentially a two-stage amplifier with an R-C bridge circuit.**
- **R-C bridge circuit (Wien bridge) is a lead-lag network.**
- **The phase'-shift across the network lags with increasing frequency and leads with decreasing frequency.**
- **By adding Wien-bridge feedback network, the oscillator becomes sensitive to a signal of only one particular frequency.**
- **This particular frequency is that at which Wien bridge is balanced and for which the phase shift is 0°.**
- **If the Wien-bridge feedback network is not employed and output of transistor Q_2 is fedback to transistor Q_1 for providing regeneration required for producing oscillations, the transistor Q_1 will amplify signals over a wide range of frequencies and thus direct coupling would result in poor frequency stability.**
- **Thus by employing Wien-bridge feedback network frequency stability is increased.**

- **This bridge circuit can be used as feedback network for an oscillator, provided that the phase shift through the amplifier is zero.**
- **The two transistors Q_1 and Q_2 causes a total phase shift of 360° and ensure proper positive feedback.**
- **The feedback network has an attenuation of 1/3.**
- **Thus, in this case, voltage gain A, must be equal to or greater than 3, to sustain oscillations.**
- **WORKING**
- **The circuit is set in oscillation by any random change in base current of transistor Q_1, that may be due to noise inherent in the transistor or variation in voltage of dc supply.**
- **This variation in base current is amplified in collector circuit of transistor Q_1 but with a phase-shift of 180°, the output of transistor Q_1 is fed to the base of second transistor Q_2 through capacitor C_4.**

- **Now a still further amplified and twice phase-reversed signal appears at the collector of the transistor Q_2.**
- **Having been inverted twice, the output signal will be in phase with the signal input to the base of transistor Q_1.**
- **A part of the output signal at transistor Q_2 is fedback to the input points of the bridge circuit (point A-C).**
- **A part of this feedback signal is applied to emitter resistor R_4 where it produces degenerative effect (or negative feedback).**
- **Similarly, a part of the feedback signal is applied across the base-bias resistor R_2 where it produces regenerative effect (or positive feedback).**
- **At the rated frequency, effect of regeneration is made slightly more than that of degeneration so as to obtain sustained oscillations.**
- **We can change the frequency range of the oscillator by switching into the circuit different values of resistors R_1 and R_2.**

- **Advantages**

1. Provides a stable low distortion sinusoidal output over a wide range of frequency.
2. The frequency range can be selected simply by using decade resistance boxes.
3. The frequency of oscillation can be easily varied by varying capacitances C_1 and C_2 simultaneously.
4. The overall gain is high because of two transistors.

- **Disadvantages**

1. The maximum frequency output of a typical Wien bridge oscillator is only about 1 MHz.
2. The circuit needs two transistors and a large number of other components.
3. The maximum frequency output is limited because of amplitude and the phase-shift characteristics of amplifier.