



Shri Neminath Jain Brahmacharyashram (Jain Gurukul's)

**Karmveer Keshavlalji Harakchandji Abad Arts,
Shriman Motilalji Giridharilalji Lodha Commerce and
Shriman P.H. Jain Science College,**

Neminagar, Chandwad, Dist. Nashik - 423101, Maharashtra.
Affiliated to Savitribai Phule Pune University, Pune. Estd. 1970, AISHE Code : C-42199



- DST-FIST Sponsored College (2018-19) ● UGC-NSQF Courses (B. Voc. & C.C.)
- Best College Award – 2015-16 of Savitribai Phule Pune University, Pune

S. Y. B. Sc.

Semester-II

ANALOG CIRCUIT DESIGN

Electronic Science (EL-241): Paper-I



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S. Y. B. Sc. — Electronic Science

Paper-I: ANALOG CIRCUIT DESIGN

(EL-241)

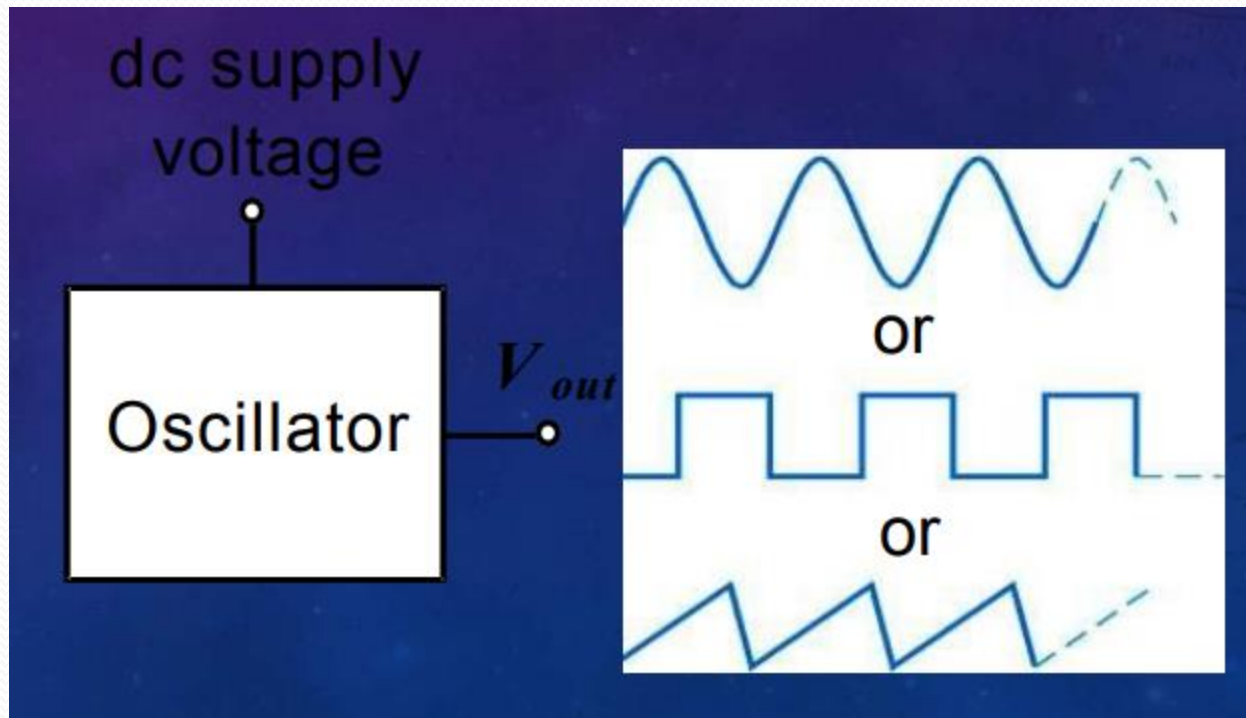
Unit – 3: Op-Amp based systems

Topics covered earlier:

1. Negative feedback
2. Types of feedback: Current shunt, current series, voltage shunt, voltage shunt
3. The effect of negative feedback: Gain stability, gain control, constant gain for all frequencies, increase in bandwidth, less amplitude distortion, less harmonic distortion, reduced noise, increased input impedance and decreased output impedance.
4. Differential Amplifier
5. Block diagram of Op-Amp
6. Adder using Op-Amp
7. Integrator, Differentiator
8. Active filters
9. Butterworth Approximation
10. Concept of positive feedback
11. Barkhausen criterion for oscillation

Oscillator Circuit:

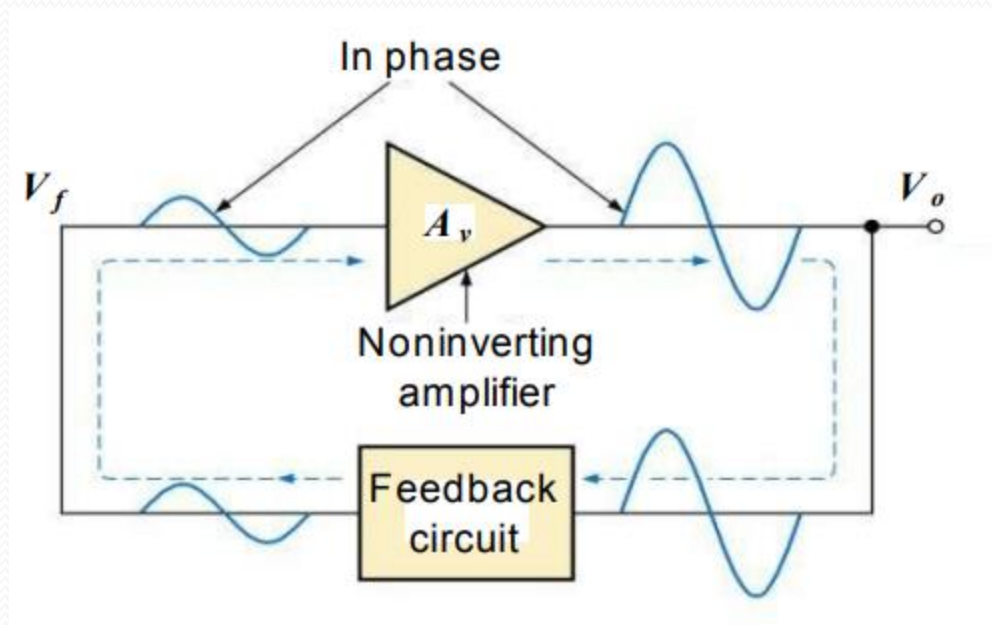
Oscillator is an electronic circuit that *generates a periodic waveform on its output without an external signal source*. It is used to convert dc to ac. The waveform can be sine wave, square wave, triangular wave, and sawtooth wave.



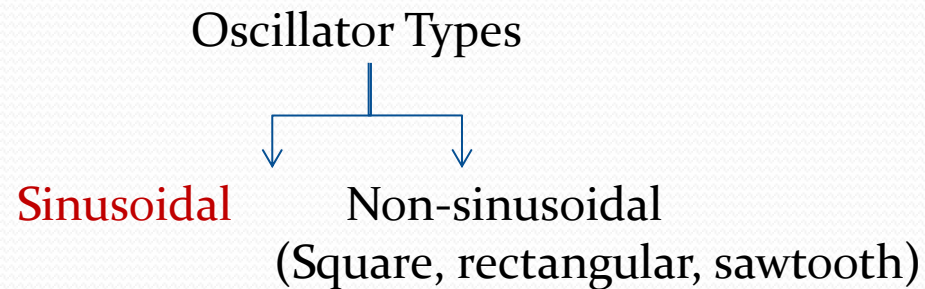
The feedback Oscillator

The **Feedback oscillator** is widely used for generation of sine wave signals. The positive (in phase) feedback maintains the oscillations

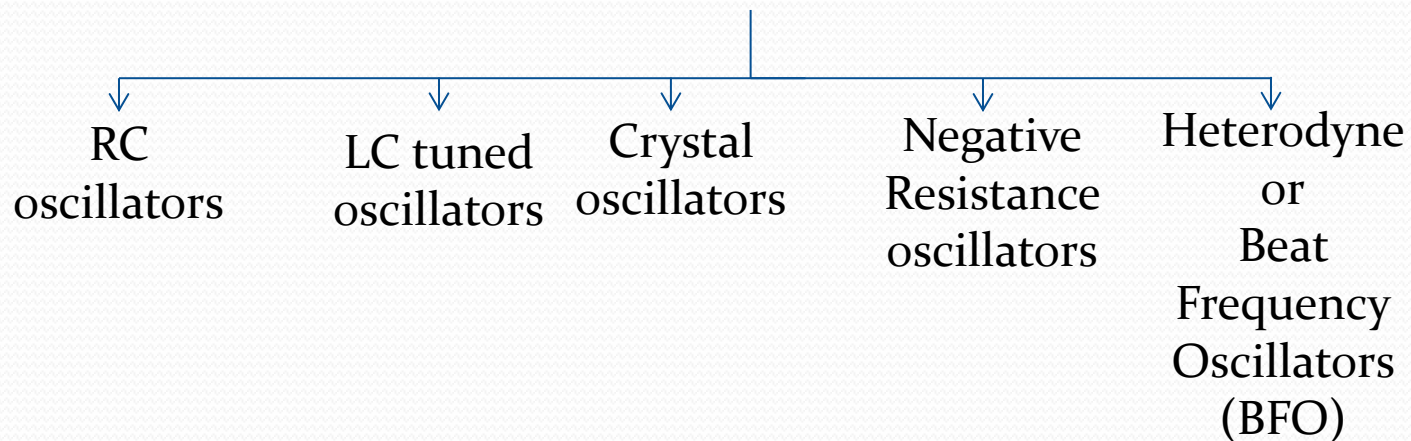
If the feedback circuit returns the signal out of phase, an inverting amplifier produces positive feedback.



Oscillator Circuits classification:

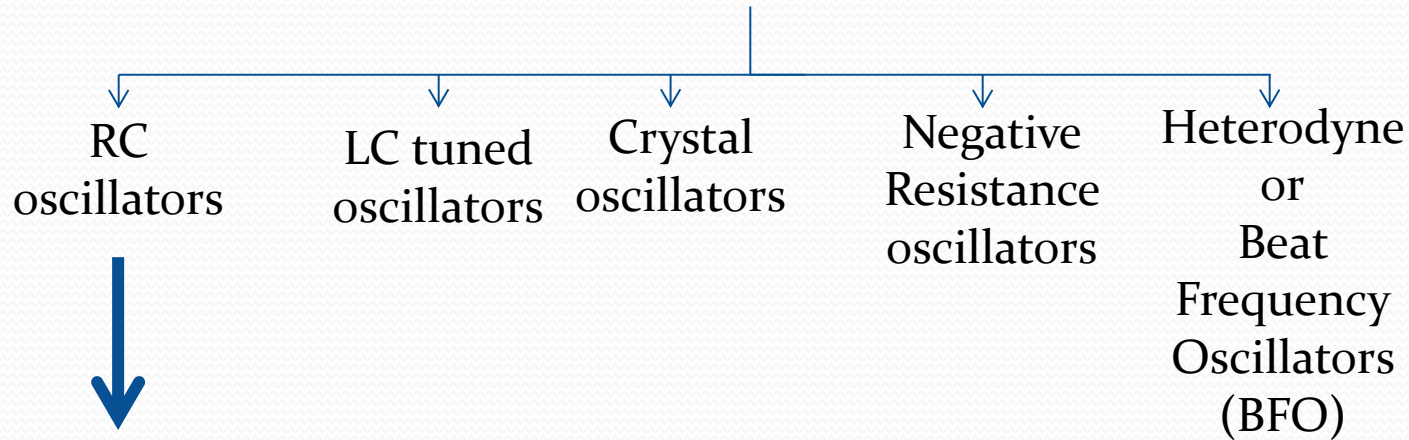


Sinusoidal Oscillators are subdivided into:



RC oscillators

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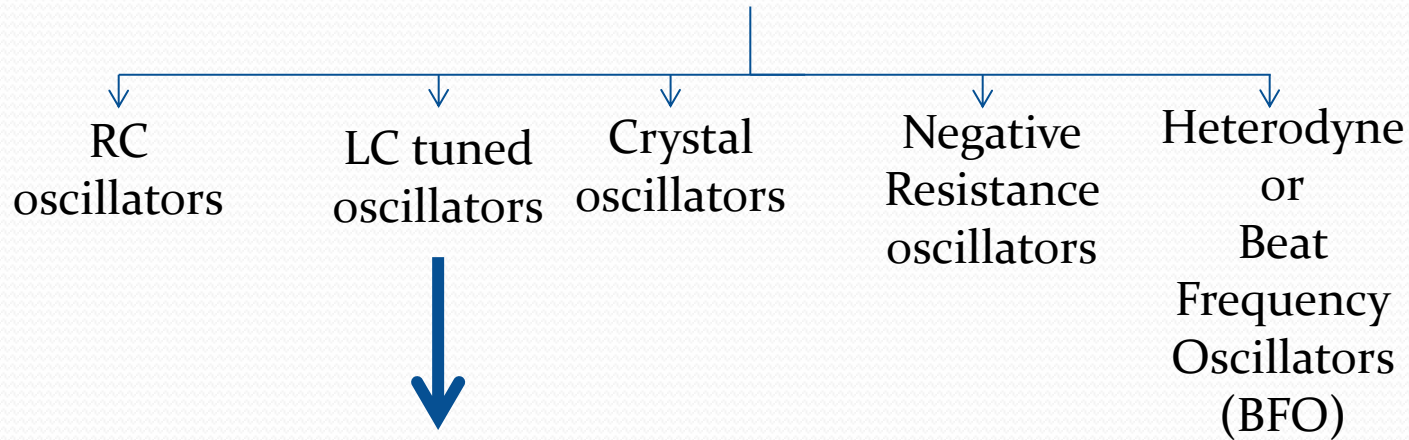


Examples of RC oscillators are:

- Wein Bridge
- Phase Shift
- Used to generate low or audio frequencies. These oscillators are limited to produce Frequencies less than 1 MHz.
- These oscillators consists of an Amplifier and a feedback network of resistors and Capacitors.
- Applying proper positive feedback, the output produced is sinusoidal waveform.

LC oscillators

Sinusoidal Oscillators are subdivided into:

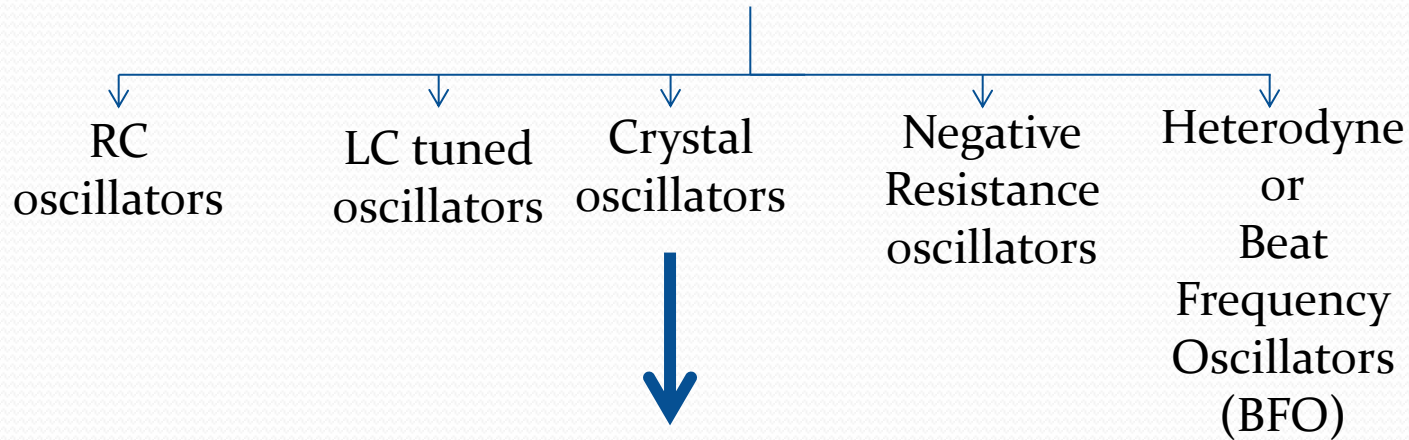


Examples of LC oscillators are:

- Hartley oscillator
- Colpitts oscillator
- Used to generate high frequencies or radio frequencies (RF).
- These oscillators consists of transistor with two reactive elements i.e. Capacitors (C) & Inductor (L)

Crystal oscillators

Sinusoidal Oscillators are subdivided into:

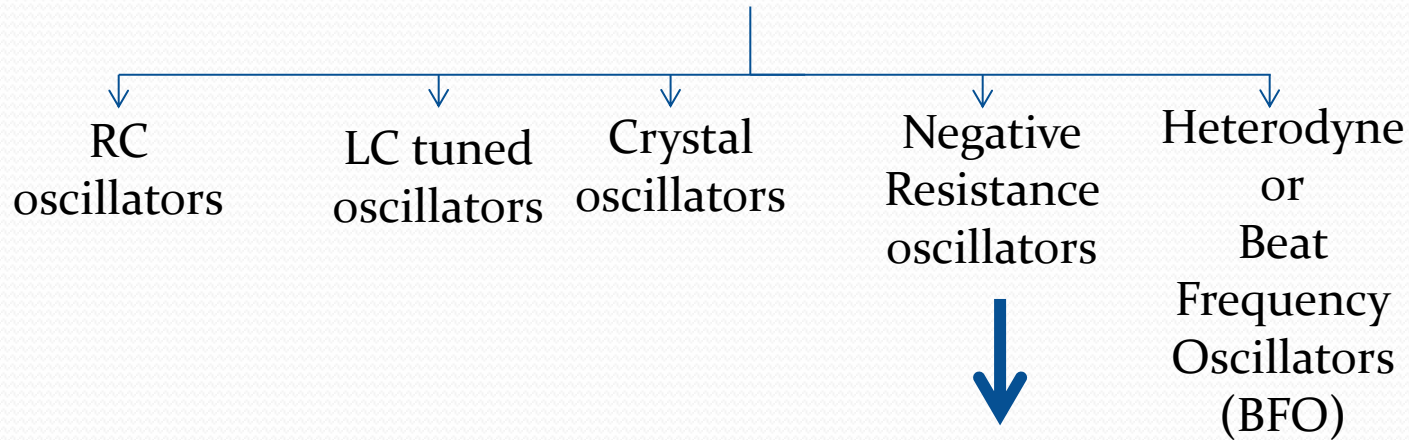


Examples of Crystal oscillators are:

- **Pierce oscillator**
- Used to generate accurate and stable frequencies.
- These oscillators are used in transmitters and receivers in communications, wrist watches, and other critical timing applications where accurate clock frequency is needed.

Negative resistance oscillators

Sinusoidal Oscillators are subdivided into:



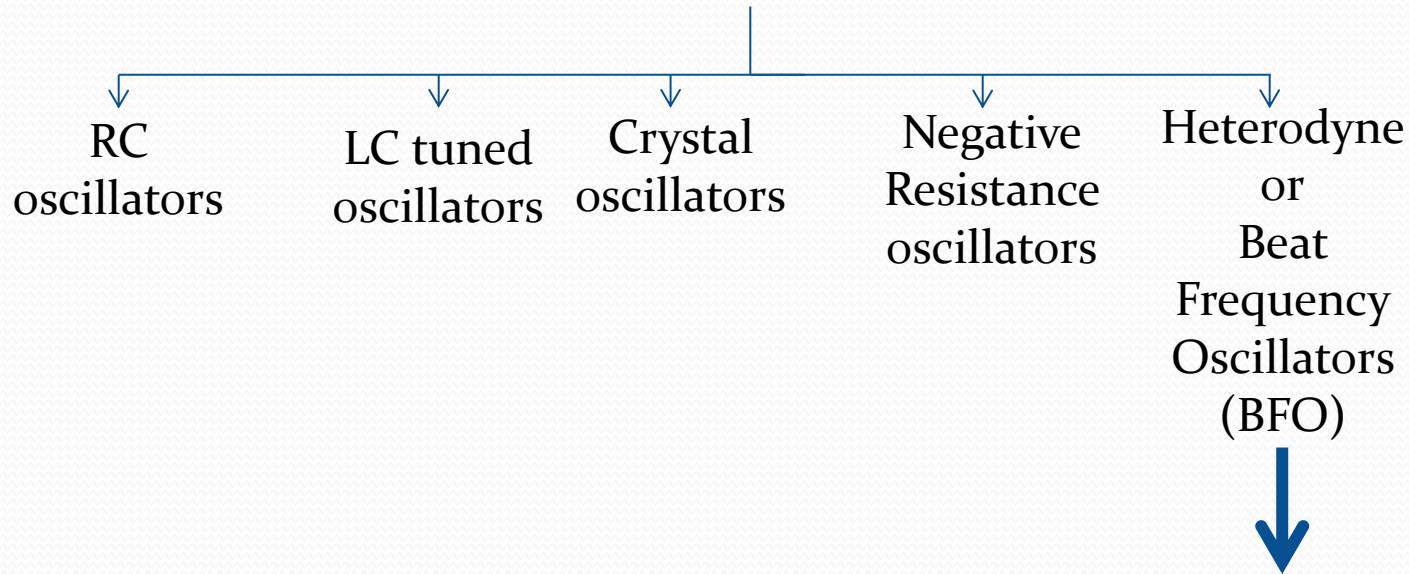
Examples of Negative resistance oscillators are:

- **Tuned Diode oscillator**

Used to generate very high frequency nearly 10 GHz

BFO oscillators

Sinusoidal Oscillators are subdivided into:

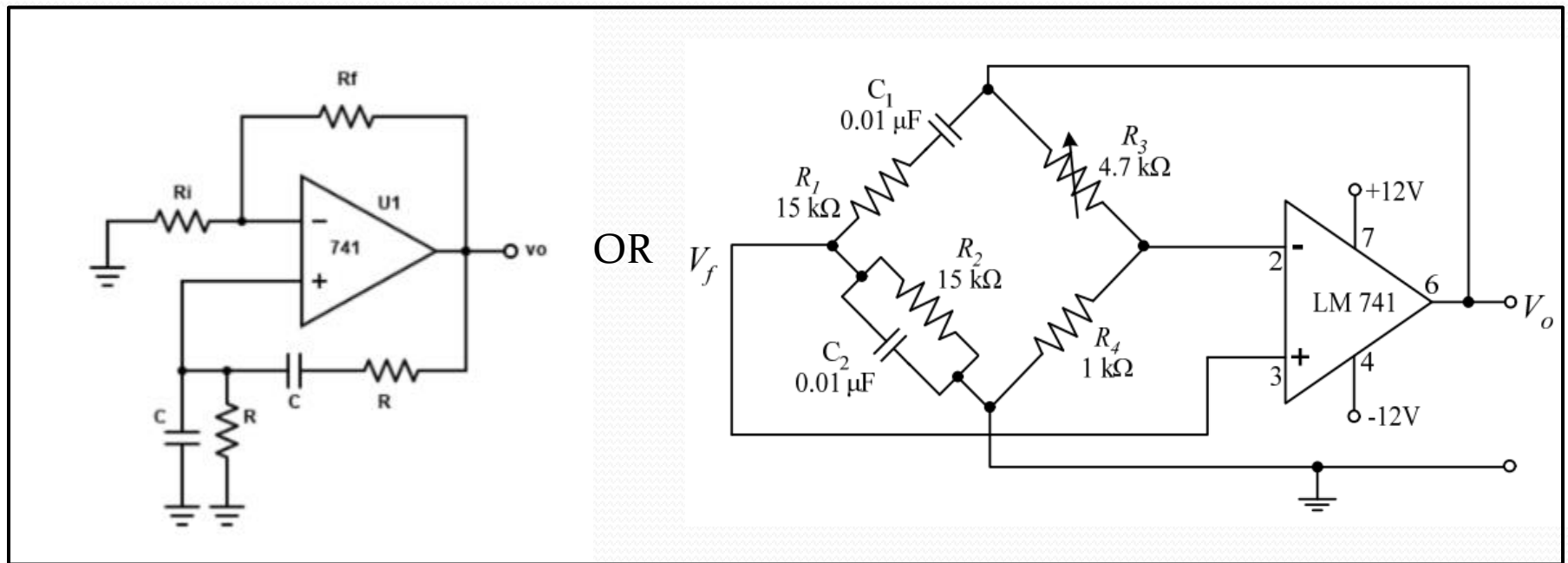


The primary function of a heterodyne oscillator in a superheterodyne receiver is to shift the frequency of the incoming radio signal to a fixed intermediate frequency (IF).

A heterodyne oscillator, or local oscillator (LO), is a key component in superheterodyne receivers, which uses a tunable oscillator to mix the incoming radio signal with a signal of a different frequency, creating a "beat" or "heterodyne" frequency that's easier to amplify and filter.

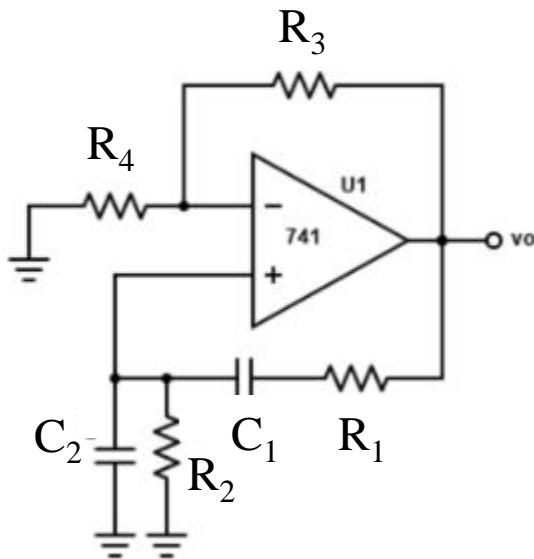
Wein Bridge Oscillator

A **Wien bridge oscillator** is a type of electronic oscillator that [generates sine waves](#). It can generate a large range of frequencies. The oscillator is based on a bridge circuit originally developed by [Max Wien in 1891](#) for the measurement of impedances. The bridge [comprises four resistors and two capacitors](#). The oscillator can also be viewed as a positive gain amplifier combined with a bandpass filter that provides positive feedback.



To start the oscillation with the constant amplitude, positive feedback is not the only sufficient condition. Oscillator circuit must satisfy the following two conditions known as **Barkhausen conditions**:

1. Magnitude of the loop gain ($A_v\beta$) = 1, where, A_v = Amplifier gain and β = Feedback gain.
2. Phase shift around the loop must be 360° or 0° .



Wien bridge oscillator is an audio frequency sine wave oscillator of high stability and simplicity. The feedback signal in this circuit is connected to the non-inverting input terminal so that the op-amp is working as a non-inverting amplifier. Therefore, the feedback network need not provide any phase shift. The circuit can be viewed as a Wien bridge with a series combination of R_1 and C_1 in one arm and parallel combination of R_2 and C_2 in the adjoining arm. Resistors R_3 and R_4 are connected in the remaining two arms. The condition of zero phase shift around the circuit is achieved by balancing the bridge. i.e. $R_1 = R_2 = R$ and $C_1 = C_2 = C$

The Frequency of oscillation is given as,

$$f = \frac{1}{2\pi RC} \text{ Hz}$$

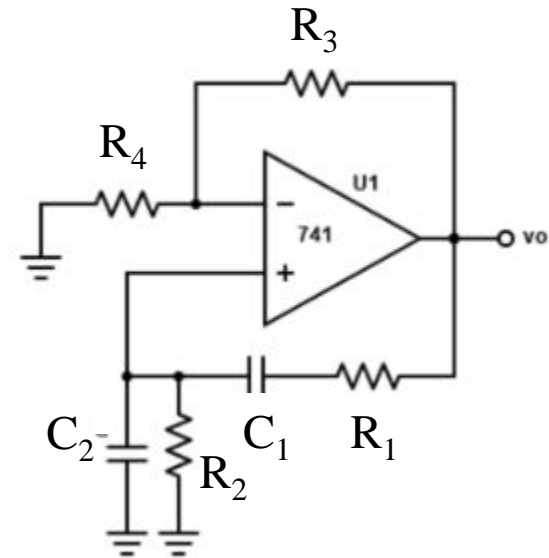
Assume that the resistors are equal in value and the capacitors are equal, at the oscillation frequency, $f = \frac{1}{2\pi RC}$ Hz the gain required for sustained oscillations is given by

$$A_v = \frac{1}{\beta} = 3$$

i.e. $1 + \frac{R_f}{R_1} = 3$

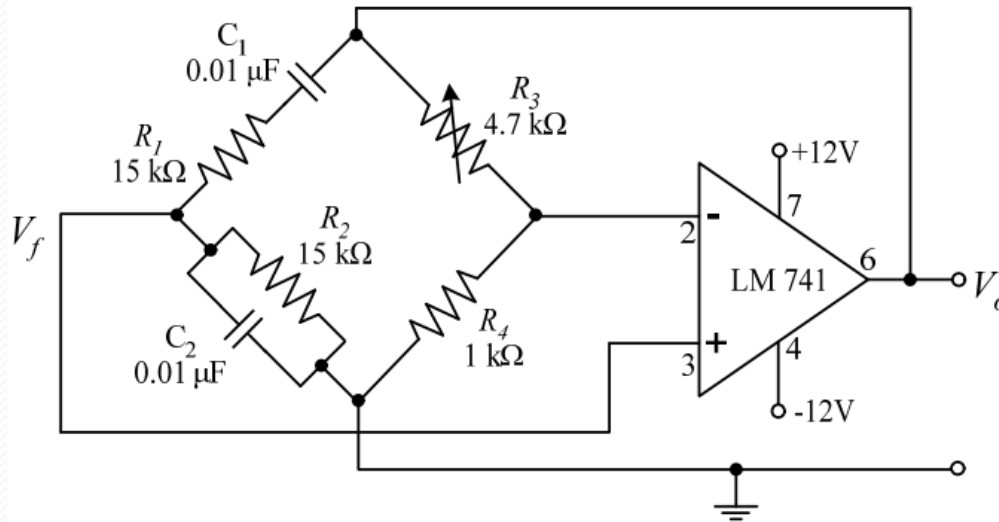
$$R_f = 2 R_1$$

The voltage gain of the amplifier must be equal to or Greater than three “Gain ≥ 3 ” for sustained oscillations.



The series and parallel combination of RC network form a lead-lag circuit. At high frequencies, the reactance of capacitor C_1 and C_2 approaches zero. This causes C_1 and C_2 appears short. Here, capacitor C_2 shorts the resistor R_2 . Hence, the output voltage V_o will be zero since output is taken across R_2 and C_2 combination. So, at high frequencies, circuit acts as a 'lag circuit'. At low frequencies, both capacitors act as open because capacitor offers very high reactance. Again, output voltage will be zero because the input signal is dropped across the R_1 and C_1 combination. Here, the circuit acts like a 'lead circuit'. But at one particular frequency between the two extremes, the output voltage reaches to the maximum value. At this frequency only, resistance value becomes equal to capacitive reactance and gives maximum output. Hence, this frequency is known as oscillating frequency (f).

Example: For following circuit, calculate the oscillation frequency.



Answer: $R_1 = R_2 = 15 \text{ k}\Omega$ & $C_1 = C_2 = 0.01 \mu\text{F}$

The frequency of oscillation is given as, $f = \frac{1}{2\pi RC} \text{ Hz}$

$$f = \frac{1}{6.28 \times 15 \times 10^3 \times 0.01 \times 10^{-6}}$$

$$f = \frac{1 \times 10^3}{6.28 \times 0.15}$$

$$f = \frac{1 \times 10^3}{0.942}$$

$$f = 1 \times 0.061 \times 10^3 \text{ Hz} \approx 1 \text{ KHz}$$

The Gain is given as,

$$1 + \frac{R_f}{R_1} = 1 + \frac{4.7 \text{ k}\Omega}{1 \text{ k}\Omega}$$

$$= 1 + 4.7$$

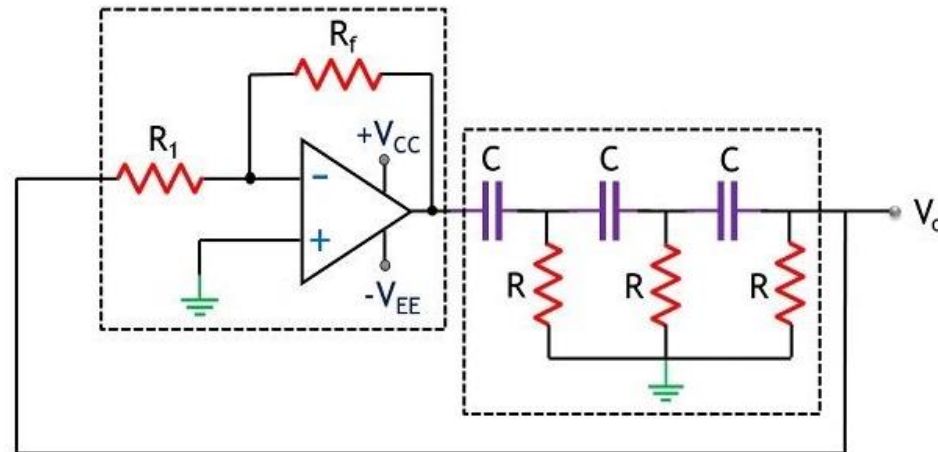
$$= 5.7$$

i.e. gain is > 3

Phase shift oscillator

Phase shift is any change that occurs in the phase of quantity, or in the phase difference between two or more quantities. Sometimes it is referred to as Phase-shift or Phase-offset because it represents a “shift” from zero phase.

A phase-shift oscillator is a linear electronic oscillator circuit that produces a sine wave output. It consists of an inverting amplifier element such as a transistor or op-amp with its output fed back to its input through a phase-shift network consisting of resistors and capacitors in a ladder network.

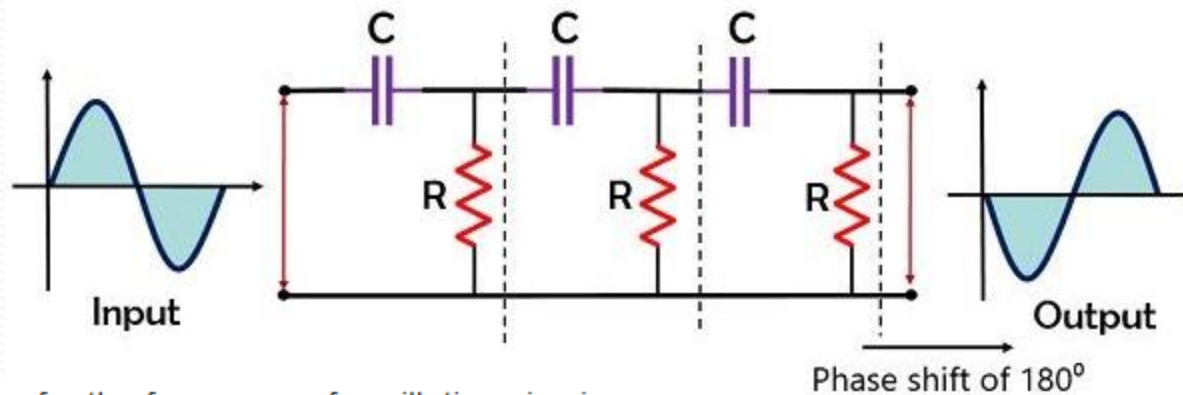


Circuit of Phase Shift Oscillator using Op-amp

The circuit shown above indicates that the feedback is connected to the inverting X input of the operational amplifier which produces the required 180° phase shift. Another 180° phase shift is produced through the three stage RC phase shift network which gets combined with feedback phase shift and produces 360° or 0° phase shift which is the required condition for sustained oscillations. RC oscillators with four stages are generally used because available op-amp came in quad IC packages.

As we have already discussed that to have the overall phase shift of 360° around the loop, the feedback circuit must provide a phase shift of 180° . And in case of 3 RC stages, each stage must provide a phase shift of 60° .

It is to be noted here that the values of resistance and capacitance must be the same for each stage. So that each section of the feedback circuit produces a desired phase shift for a particular frequency.



The expression for the frequency of oscillations is given as

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

: N is the total number of stages

Thus for 3 stages, the frequency of oscillations will be

$$f = \frac{1}{2\pi RC\sqrt{6}}$$

At this frequency, the Gain must be ≥ 29



- Thank you