Wien Bridge Oscillator: An oscillator is a circuit that produces periodic electric signals such as sine wave or square wave. Oscillators are circuits that produce periodic waveforms without any input signal. They generally use some form of active devices like transistors or OP-Amps as amplifiers with feedback network consisting of passive devices such as resistors, capacitors, or inductors.

The Wien Bridge is one of the simplest and best known oscillators and is used extensively in circuits for audio frequency sine wave oscillator of high stability and simplicity. The Wien Bridge Oscillator is so called because the circuit is based on a frequency-selective form of the Wheatstone bridge circuit (Wien-Bridge network). 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.

Here we are discussing wein bridge oscillator using 741 op amp IC. The op-amp used in this oscillator circuit is working as non-inverting amplifier mode. Here the feedback network need not provide any phase shift. The circuit can be viewed as a wein bridge with a series RC network in one arm and parallel RC network in the adjoining arm. Resistors Rin and Rf are connected in the remaining two arms. 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.

Figure 1a shows feedback bridge circuit which is used for the basic Wien Bridge circuit is connected between the amplifier input terminals and the output terminal. The bridge has a series RC network in one arm and a parallel RC network in the adjoining arm.

At the resonant frequency fr the phase shift is 0°. Consider the circuit below.

RC Phase Shift Network (Lead lag network)

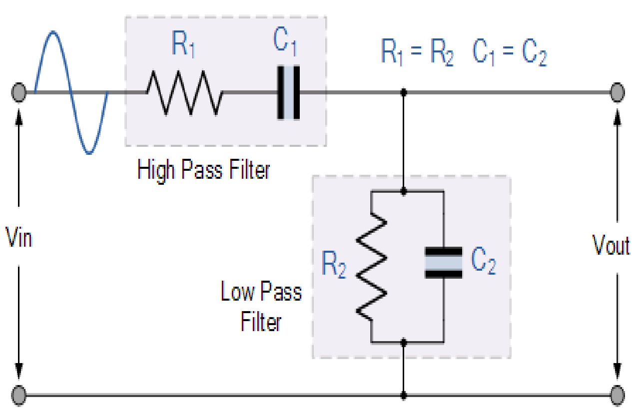

Figure 1a

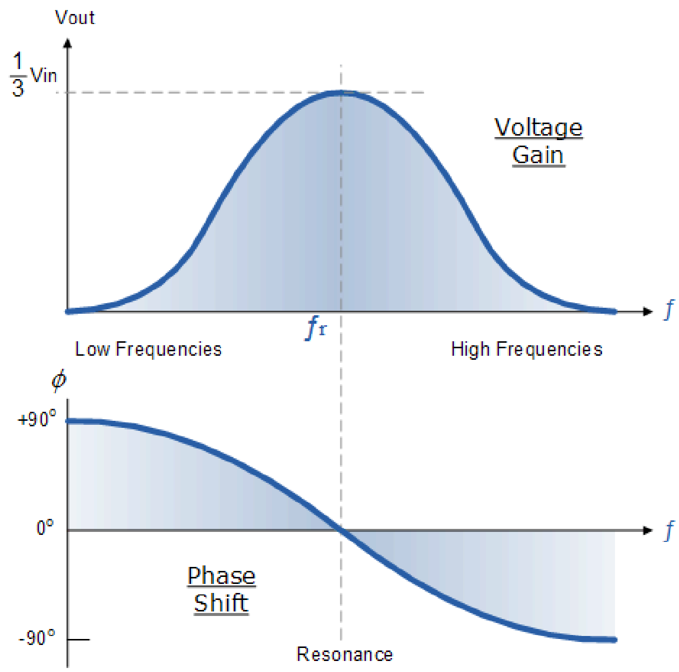

Figure 1b

The RC network consists of a series RC circuit connected to a parallel RC forming basically a High Pass Filter connected to a Low Pass Filter producing a very selective second-order frequency dependant Band Pass Filter with a high Q factor at the selected frequency, fr. At low frequencies (the circuit acts like a 'lead circuit') the reactance of the series capacitor (C1) is very high so acts a bit like an open circuit, blocking any input signal at V_{in} resulting in virtually no output signal, Vout. Likewise, at high frequencies (circuit acts as a 'lag circuit') 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*, (fr). At this resonant frequency, the circuit's 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 in fig 1b. Hence, this particular frequency is known as resonant frequency or oscillating frequency.

Table for experiment to draw lead lag network study: (Take reading for frequency 1 KHz and 5 KHz)

	Frequency	Vin (Amplitude)	Vout (Amplitude)		

Wien-Bridge oscillators can even be designed using Op-Amps as a part of their amplifier section, as shown in Figure. The Op-Amp is required to act as a non-inverting amplifier as the Wien-Bridge network offers zero phase-shift. Further, from the circuit, it is evident that the output voltage is fed back to both inverting and non-inverting input terminals. At resonant frequency, the voltages applied to the inverting and non-inverting terminals will be equal and in-phase with each other. However, even here, the voltage gain of the amplifier needs to be greater than 3 to start oscillations and equal to 3 to sustain them. In general, these kinds of Op-Amp-based **Wien Bridge Oscillators** cannot operate above 1 MHz due to the limitations imposed on them by their open-loop gain. The circuit is observed like a Wien bridge on RC series network of one arm and the parallel RC network in for another arm. The resistor Ri and Rf are connected to the left two arms.

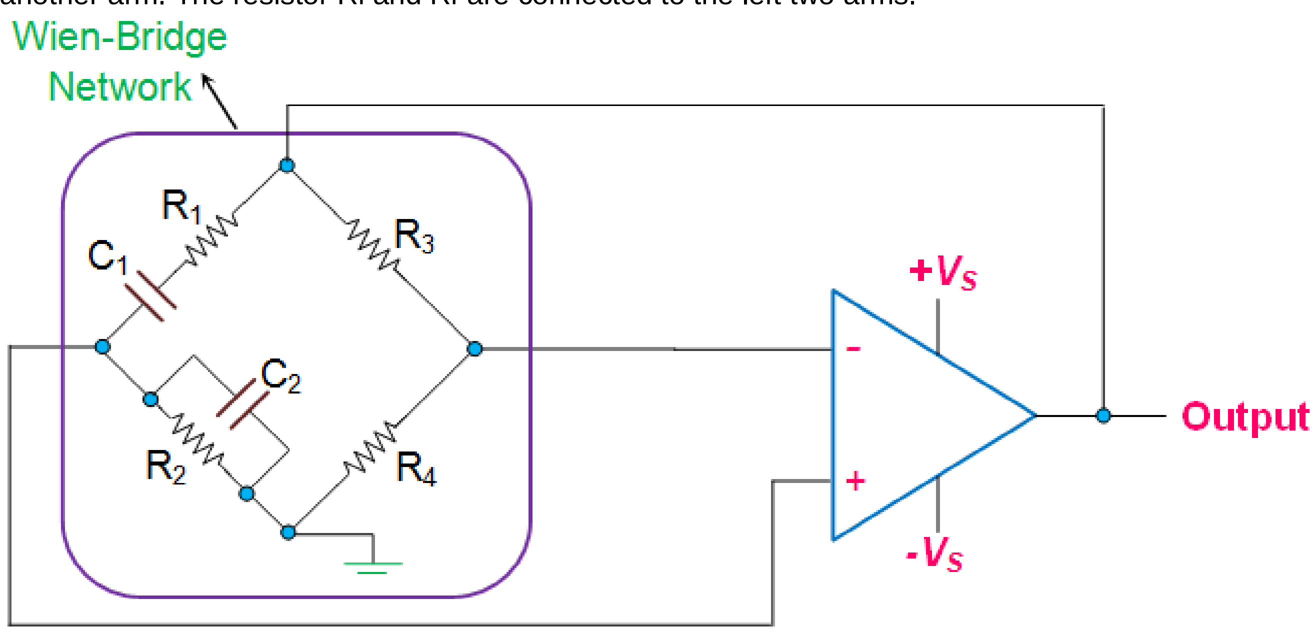

Figure 3 Wien-Bridge Oscillator Using an Op-Amp

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 phase angle criterion for oscillation is that the total phase shift around the circuit must be 0°. This condition occurs only when the bridge is balanced, that is at resonance. The frequency of oscillation Fo is exactly the resonant frequency of the balanced Wien Bridge One of the simplest sine wave oscillators which uses a RC network circuit to produce a sinusoidal output waveform, is called a Wien Bridge Oscillator.

For sinusoidal oscillations to begin, the voltage gain of the Wien Bridge circuit must be equal to or greater than **3**, ($Av \geq 3$). For a non-inverting op-amp configuration, this value is set by the feedback resistor network of R3 and R4 and is given as:

$$A_V = \frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_3}{R_4} = 3 \text{ or more}$$

If we choose a value for resistor R3 of say, 100kΩ's, then the value of resistor R4 is calculated as:

$$1 + \frac{R_3}{R_4} = 3$$

$$\therefore R_4 = \frac{R_3}{(3-1)} = \frac{R_3}{2} = \frac{1}{2}R_3$$

$$\text{if } R_3 = 100k\Omega, \text{ then } R_4 = 50k\Omega$$

While a gain of 3 is the minimum value required to ensure oscillations, in reality a value a little higher than that is generally required. If we assume a gain value of **3.1** then resistor R4 is recalculated to give a value of 47kΩ's. This gives the final Wien Bridge Oscillator circuit.

Design for 1KHz wein bridge Oscillator:

The required frequency of oscillation fo=1kHz

we have,

$$f_0 = \frac{1}{2\pi RC}$$

Take C=0.1µF, then R=1.6kΩ   (Use 1.5kΩ standard)

Gain of the amplifier section is given by,

$$G = 1 + \frac{R_f}{R_i} = 3$$

Take Ri=1kΩ, then Rf=2.2kΩ (Use 4.7kΩ Potentio meter for fine corrections)

Working of Wein Bridge Oscillator

- The feedback signal in this oscillator circuit is connected to the non-inverting input terminal so that the op-amp works as a non-inverting amplifier.
- The condition of zero phase shift around the circuit is achieved by balancing the bridge, zero phase shift is essential for sustained oscillations.
- The frequency of oscillation is the resonant frequency of the balanced bridge and is given by the expression fo = 1/2πRC
- At resonant frequency (ƒo), the inverting and non-inverting input voltages will be equal and "in-phase" so that the negative feedback signal will be cancelled out by the positive feedback causing the circuit to oscillate.
- From the analysis of the circuit, it can be seen that the feedback factor β= 1/3 at the frequency of oscillation. Therefore for sustained oscillation, the amplifier must have a gain of 3 so that the loop gain becomes unity.
- For an inverting amplifier the gain is set by the feedback resistor network Rf and Ri and is given as the ratio -Rf/Ri.

for oscillations to occur in a Wien Bridge Oscillator circuit the following conditions must apply.

- With no input signal a Wien Bridge Oscillator produces continuous output oscillations.
- The Wien Bridge Oscillator can produce a large range of frequencies.
- The Voltage gain of the amplifier must be greater than 3.
- The RC network can be used with a non-inverting amplifier.
- The input resistance of the amplifier must be high compared to R so that the RC network is not overloaded and alter the required conditions.
- The output resistance of the amplifier must be low so that the effect of external loading is minimized.
- Some method of stabilizing the amplitude of the oscillations must be provided. If the voltage gain of the amplifier is too small the desired oscillation will decay and stop. If it is too large the output will saturate to the value of the supply rails and distort.
- With amplitude stabilization in the form of feedback diodes, oscillations from the Wien Bridge oscillator can continue indefinitely.

Circuit and derives the expression for the unknown element at balance:

Wien Bridge has a series RC combination in one and a parallel combination in the adjoining arm. Wien's bridge shown in fig . its basic form is designed to measure f r e qu ency. It can also be used for the instrument of an unknown capacitor with great accuracy,

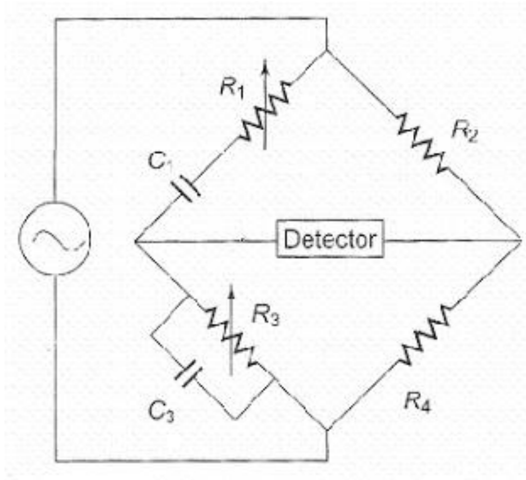

fig 2.1 Wein's Bridge

The impedance of one arm is $$Z_1 = R_1 - j/\omega C_1$$

The admittance of the parallel arm is $$Y_3 = 1/R_3 + j\ \omega\ C_3$$

Using the bridge balance equation, we have

We have $$Z_1\ Z_4 = Z_2\ Z_3$$

Therefore $$Z_1\ Z_4 = Z_2/Y_3, \text{ i.e. } Z_2 = Z_1\ Z_4\ Y_3$$

$$R_2 = R_4\left(R_1 - \frac{j}{\omega C_1}\right)\left(\frac{1}{R_3} + j\omega C_3\right)$$

$$R_2 = \frac{R_1 R_4}{R_3} - \frac{j R_4}{\omega C_1 R_3} + j\ \omega\ C_3\ R_1\ R_4 + \frac{C_3 R_4}{C_1}$$

$$R_2 = \left(\frac{R_1 R_4}{R_3} + \frac{C_3 R_4}{C_1}\right) - j\left(\frac{R_4}{\omega C_1 R_3} - \omega C_3 R_1 R_4\right)$$

Equating the real and imaginary terms we have as,

$$R_2 = \frac{R_1 R_4}{R_3} + \frac{C_3 R_4}{C_1} \quad \text{and} \quad \frac{R_4}{\omega C_1 R_3} - \omega C_3 R_1 R_4 = 0$$

Therefore,

$$\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1}$$

.... (1.1)

And,

$$\frac{1}{\omega C_1 R_3} = \omega C_3 R_1 \qquad \text{.................(1.2)}$$

$$\omega^2 = \frac{1}{C_1 R_1 R_3 C_3}$$

$$\omega = \frac{1}{\sqrt{C_1 R_1 C_3 R_3}}$$

$$\omega = 2\pi f$$

$$f = \frac{1}{2\pi\sqrt{C_1 R_1 C_3 R_3}} \qquad \text{............(1.3)}$$

If R1 = R2 = R and C1 = C2 = C

Than frequency f = 1 / 2 πRC

The two conditions for bridge balance, (1.1) and (1.3), result in an expression determining the required resistance ratio R2 / R4 and another express determining the frequency of the applied voltage. If we satisfy Eq. (1.1) an also excite the bridge with the frequency of Eq. (1.3), the bridge will be balanced.

In most Wien bridge circuits, the components are chosen such that R 1 = R3 = R and C1 = C3 = C. Equation (1.1) therefore reduces to R2IR4 =2 at Eq. (1.3) to f= 1/2ΠRC, which is the general equation for the frequency of fl bridge circuit.

The bridge is used for measuring frequency in the audio range. Resistances R1 and R3 can be ganged together to have identical values. Capacitors C1 and C3 are normally of fixed values

The audio range is normally divided into 20 - 200 and 2 k - 20 kHz range In this case, the resistances can be used for range changing and capacitors, and C3 for fine frequency control within the range.

The bridge can also be use for measuring capacitance. In that case, the frequency of operation must be known. The bridge is also used in a harmonic distortion analyzer, as a Notch filter, an in audio frequency and radio frequency oscillators as a frequency determine element. An accuracy of 0.5% - 1% can be readily obtained using this bridge. Because it is frequency sensitive, it is difficult to balance unless the waveform of the applied voltage is purely sinusoidal.