WIEN BRIDGE OSCILLATOR

Generally in an oscillator, amplifier stage introduces 180° phase shift and feedback network introduces additional 180° phase shift, to obtain a phase shift of 360° (2TI radians) around a loop. This is required condition for any oscillator. But Wien bridge oscillator uses a non inverting amplifier and hence does not provide any phase shift during amplifier stage. As total phase shift required is 0° or 2 nn radians, in Wien bridge type no phase shift is necessary through feedback. Thus the total phase shift around a loop is 0°. Let us study the basic version of the Wien bridge oscillator and its analysis.

A basic Wien bridge used in this oscillator and an amplifier stage is shown in the Fig. 3.18.1.

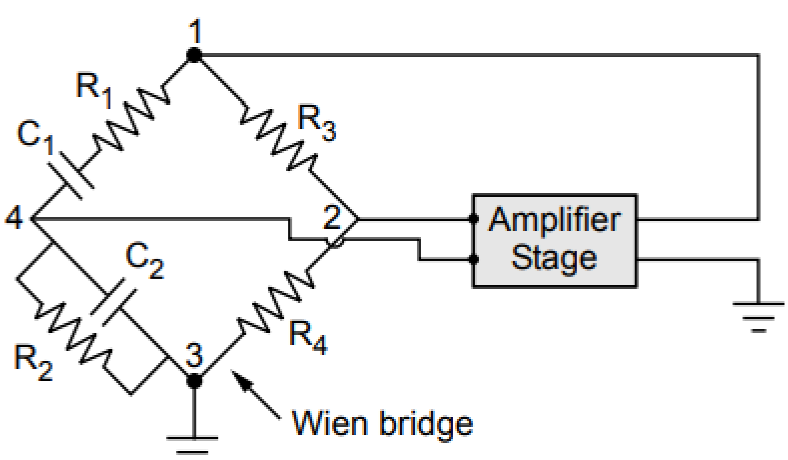

Fig. 3.18.1 Basic circuit of Wien bridge oscillator

The output of the amplifier is applied between the terminals 1 and 3, which is the input to the feedback network. While Fig. 3.18.1 Basic circuit of Wien bridge oscillator the amplifier input is supplied from the diagonal terminals 2 and 4, which is the output from the feedback network. Thus amplifier supplied its own input through the Wien bridge as a feedback network.

The two arms of the bridge, namely R_1 C_1 in series and R_2, C_2 in parallel are called frequency sensitive arms. This is because the components of these two arms decide the frequency of the oscillator. Let us find out the gain of the feedback network. As seen earlier input to the feedback network is between is 1 and 3 while output V_f of the feedback network is between 2 and 4. This is shown in the Fig. 3.18.2. Such a feedback network is called lead-lag network. This is because at very low frequencies it acts like a lead while at very high frequencies it acts like lag network.

Now from the Fig. 3.18.2, as shown,

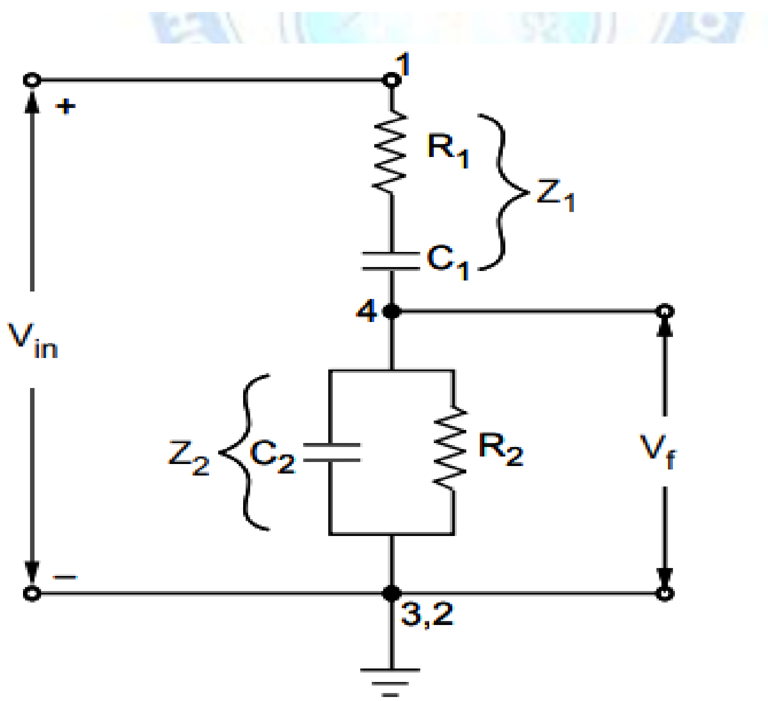

Fig. 3.18.2 Feedback network of Wien bridge oscillator

$$Z_1 = R_1 + \frac{1}{j\omega C_1} = \frac{1+j\omega R_1 C_1}{j\omega C_1}$$

$$Z_2 = R_2 \parallel \frac{1}{j\omega C_2} = \frac{R_2 \times \frac{1}{j\omega C_2}}{R_2 + \frac{1}{j\omega C_2}}$$

$$= \frac{R_2}{1+j\omega R_2 C_2}$$

Replacing $j\omega = s$,

$$Z_1 = \frac{1+sR_1C_1}{sC_1}$$

and $$Z_2 = \frac{R_2}{1+sR_2C_2}$$

$$I = \frac{V_{in}}{Z_1+Z_2}$$

and $$V_f = I Z_2 = \frac{V_{in} Z_2}{Z_1+Z_2}$$

$$\therefore \quad \beta = \frac{V_f}{V_{in}} = \frac{Z_2}{Z_1+Z_2} \qquad \ldots(3.18.2)$$

Substituting the values of Z_1 and Z_2,

$$\beta = \frac{\left[\frac{R_2}{1+sR_2C_2}\right]}{\left[\frac{1+sR_1C_1}{sC_1}\right]+\left[\frac{R_2}{1+sR_2C_2}\right]} = \frac{sC_1R_2}{(1+sR_1C_1)(1+sR_2C_2)+sC_1R_2}$$

$$= \frac{sC_1R_1}{1+s(R_1C_1+R_2C_2+C_1R_2)+s^2 R_1R_2C_1C_2}$$

Replacing s by $j\omega$, $s^2 = -\omega^2$

$$\therefore \quad \beta = \frac{j\omega C_1 R_2}{(1-\omega^2 R_1R_2C_1C_2)+j\omega(R_1C_1+R_2C_2+C_1R_2)} \qquad \ldots(3.18.3)$$

Rationalising the expression,

$$\beta = \frac{j\omega C_1R_2\left[(1-\omega^2R_1R_2C_1C_2)-j\omega(R_1C_1+R_2C_2+C_1R_2)\right]}{\left(1-\omega^2R_1R_2C_1C_2\right)^2+\omega^2\left(R_1C_1+R_2C_2+C_1R_2\right)^2}$$

$$\beta = \frac{\omega^2 C_1R_2(R_1C_1+R_2C_2+C_1R_2)+j\omega C_1R_2(1-\omega^2R_1R_2C_1C_2)}{\left(1-\omega^2R_1R_2C_1C_2\right)^2+\omega^2\left(R_1C_1+R_2C_2+C_1R_2\right)^2} \qquad \ldots(3.18.4)$$

To have zero phase shift of the feedback network, its imaginary part must be zero.

$$\therefore \quad \omega(1-\omega^2 R_1R_2C_1C_2) = 0$$

$$\therefore \quad \omega^2 = \frac{1}{R_1R_2C_1C_2} \quad \text{i.e.} \quad \omega = \frac{1}{\sqrt{R_1R_2C_1C_2}}$$

$$\therefore \quad \boxed{f = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}} \qquad \ldots(3.18.5)$$

This is the frequency of the oscillator and it shows that the components of the frequency sensitive arms are the deciding factors, for the frequency.

In practice, $R_1 = R_2 = R$ and $C_1 = C_2 = C$ are selected.

$$\therefore \quad f = \frac{1}{2\pi\sqrt{R^2 C^2}} \quad \text{i.e.} \quad \boxed{f = \frac{1}{2\pi RC}} \qquad \ldots (3.18.6)$$

At $R_1 = R_2 = R$ and $C_1 = C_2 = C$, the gain of the feedback network becomes,

$$\beta = \frac{\omega^2 RC(3RC) + j\omega RC\left(1-\omega^2 R^2 C^2\right)}{\left(1-\omega^2 R^2 C^2\right) + \omega^2 (3RC)^2}$$

Substituting $f = \frac{1}{2\pi RC}$ i.e. $\omega = \frac{1}{RC}$

We get the magnitude of the feedback network at the resonating frequency of the oscillator as,

$$\beta = \frac{3}{0 + \frac{1}{R^2C^2} \times (3RC)^2} = \frac{3}{9} = \frac{1}{3} \qquad \ldots (3.18.7)$$

The positive sign of β indicates that the phase shift by the feedback network is 0°. Now to satisfy the Barkhausen criterion for the sustained oscillations, we can write,

$$|A\beta| \geq 1 \quad \text{i.e.} \quad |A| = \geq \frac{1}{|\beta|} \geq \frac{1}{\left(\frac{1}{3}\right)}$$

$\therefore$ $\boxed{|A| \geq 3}$ ... Required amplifier gain without phase shift

If $R_1 \neq R_2$ and $C_1 \neq C_2$ then , $\boxed{f = \dfrac{1}{2\pi\sqrt{R_1R_2C_1C_2}}}$

Substituting in the equation (3.18.7) we get,

$$\beta = \frac{C_1R_2}{(R_1C_1 + R_2C_2 + C_1R_2)} \quad \text{and} \quad |A\beta| \geq 1$$

$$\therefore \quad \boxed{A \geq \frac{R_1C_1 + R_2C_2 + C_1R_2}{C_1R_2}} \quad \text{... (3.18.8)}$$

Another important advantage of the Wien bridge oscillator is that by varying the two capacitor values simultaneously, by mounting them on the common shaft, different frequency ranges can be provided.

1. Wien Bridge Oscillator using Op-amp

The Fig. 3.18.4 shows the Wien bridge oscillator using an op-amp.

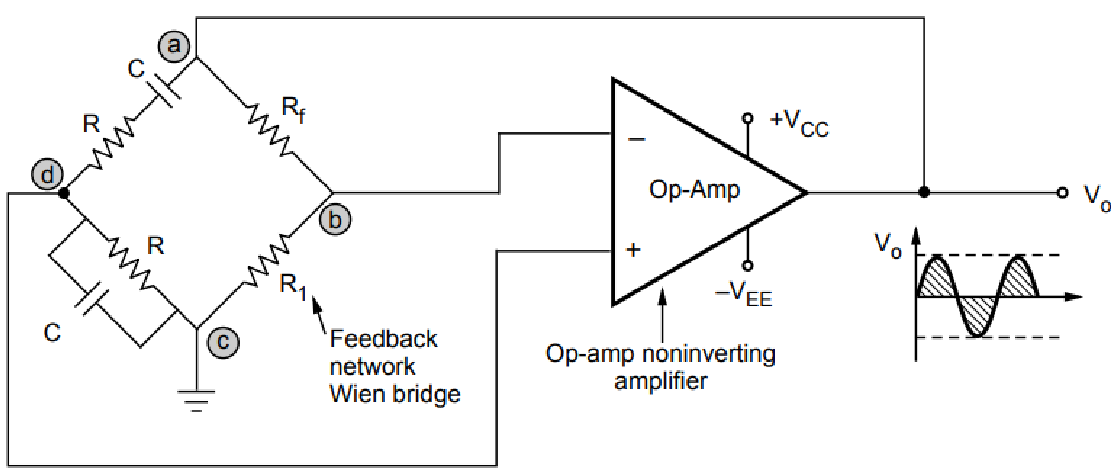

Fig. 3.18.4

The resistance R and capacitor C are the components of frequency sensitive arms of the bridge. The resistance R and R_1 form the part of the feedback path. The gain of noninverting op-amp can be adjusted using the resistance R and R_1. The gain of op-amp is,

$A = 1 + R_f / R_1$

To satisfy Barkhausen criterion that $A\beta \geq 1$ it is necessary that the gain of the noninverting op-amp amplifier must be minimum 3.

$$\therefore \; |A| \geq 3 \quad \text{i.e} \quad 1 + \frac{R_f}{R_1} \geq 3 \quad \text{i.e.} \quad \boxed{\frac{R_f}{R_1} \geq 2}$$

Thus ratio of R_f and R_1 must be greater than or equal to 2.

The frequency of oscillations is given by,

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

The feedback is given to the noninverting terminal of op-amp which ensures zero phase shift. It is used popularly in laboratory signal generators.

If in a Wien bridge feedback network, two resistances are not equal i.e. they are R_1 and R_2 while two capacitors are not equal i.e. they are C_1 and C_2 then the frequency of oscillations is given by,

$$\therefore \quad \boxed{f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}}$$

With $R_1 = R_2 = R$ and $C_1 = C_2 = C$ we get it as $1/2\pi RC$ as stated earlier.

The simplified circuit diagram of the Wien bridge oscillator is shown in the Fig. 3.18.5.

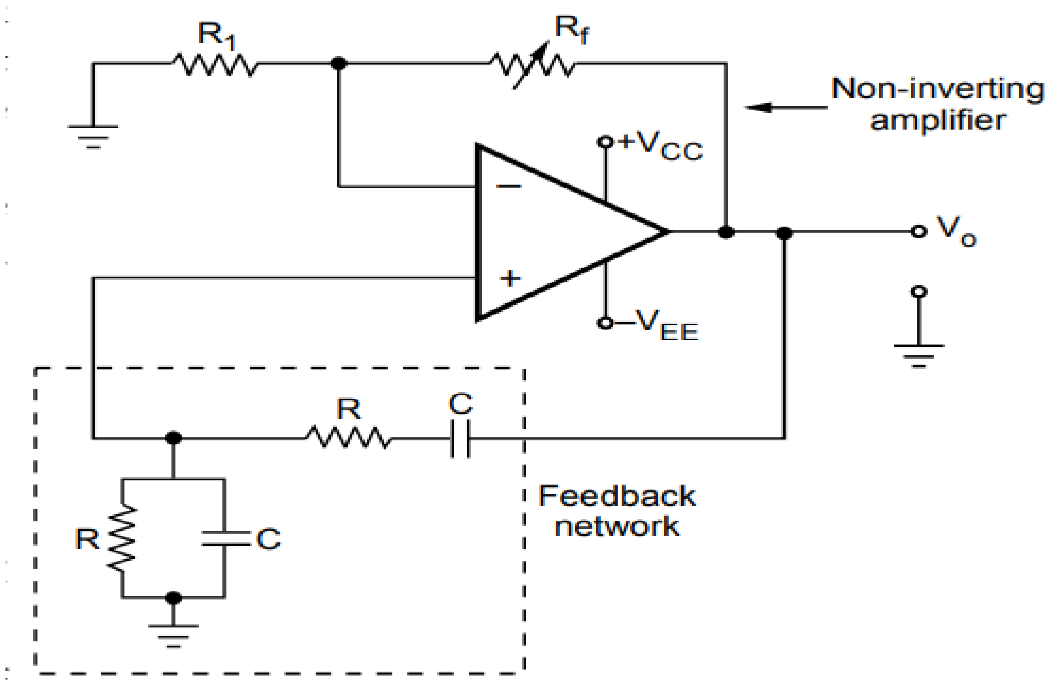

Fig. 3.18.5 Simplified diagram of Wien bridge oscillator

2. Advantages

The various advantages of Wien bridge oscillator are,

1. By varying the two capacitor values simultaneously, by mounting them on the common shaft, different frequency ranges can be obtained.

2. The perfect sine wave output is possible.

3. It is useful audio frequency range i.e. 20 Hz to 100 kHz.

3. Wien Bridge Oscillators Design

Select the capacitor value much larger than the stray capacitance, about 0.01 to 0.05 μF. From the equation of frequency, obtain the value of R.

$R = 1 / 2\pi fC$

Then for noninverting amplifier,

$R_f = 2 R_1$

Choose R_1 and design the value of R_f. Keep R_f variable for fine adjustments.

Example 3.18.1 ***Design the Wien bridge oscillator circuit to have output frequency of 5 kHz.***

Solution : Choose C = 0.01 μF

$$\therefore \quad R = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 5 \times 10^3 \times 0.01 \times 10^{-6}} = \mathbf{3.183\ k\Omega}$$

$$\text{Now} \quad R_f = 2 R_1$$

$$\text{Choose} \quad R_1 = \mathbf{1\ k\Omega}$$

$$\therefore \quad R_f = \mathbf{2\ k\Omega}$$

Use standard value of 2.2 k2 to have $A_{CL} > 3$. The designed circuit is shown in the Fig. 3.18.6.

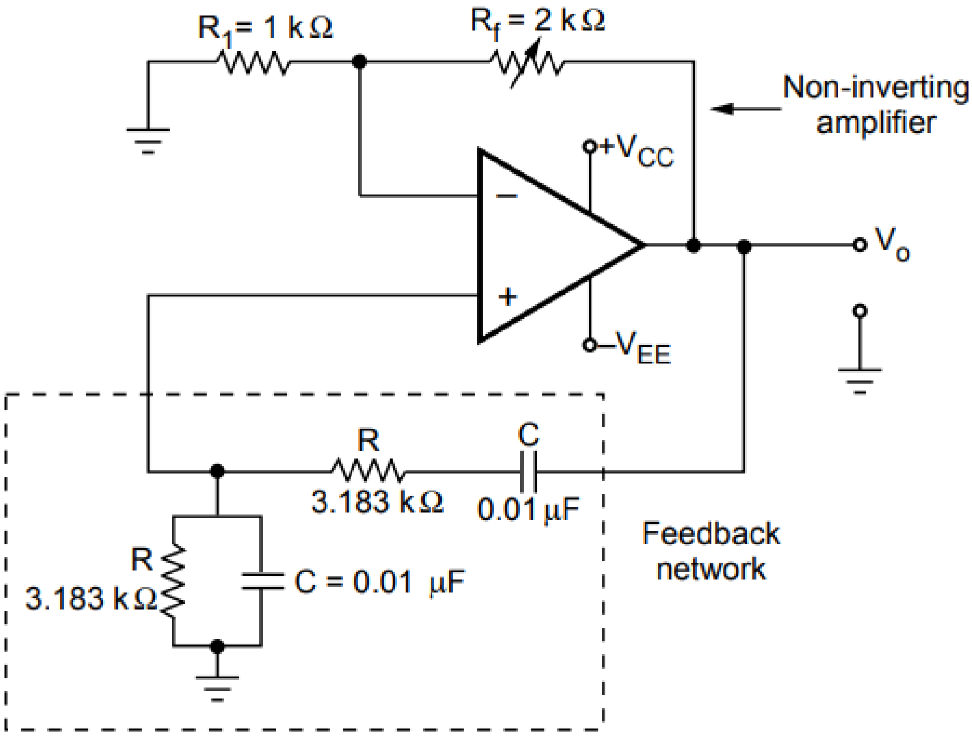
R1= 1 kΩ
Rf = 2 kΩ
Non-inverting
amplifier
+VCC
−
+
Vo
−VEE
R
3.183 kΩ
C
0.01 μF
Feedback
network
R
3.183 kΩ
C = 0.01 μF

Fig. 3.18.6