Experiment No. 9

WIEN BRIDGE OSCILLATOR USING OPAMP

AIM:

To design a Wien Bridge oscillator using op-amp for a given frequency of 1kHz.

THEORY:

An oscillator is a circuit that produces periodic electric signals such as sine wave or square wave. The application of oscillator includes sine wave generator, local oscillator for synchronous receivers etc. An oscillator consists of an amplifier and a feedback network.

1. 'Active device' i.e. opamp is used as an amplifier.
2. Passive components such as R-C or L-C combinations are used as feedback network.

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 β) = 1,

   where, A_v = Amplifier gain and
   β = Feedback gain.
2. Phase shift around the loop must be 360° or 0°.

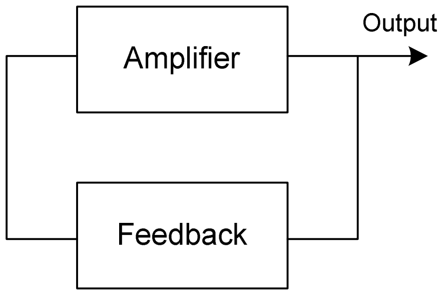


Fig 1. Basic oscillator block diagram

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.

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*).

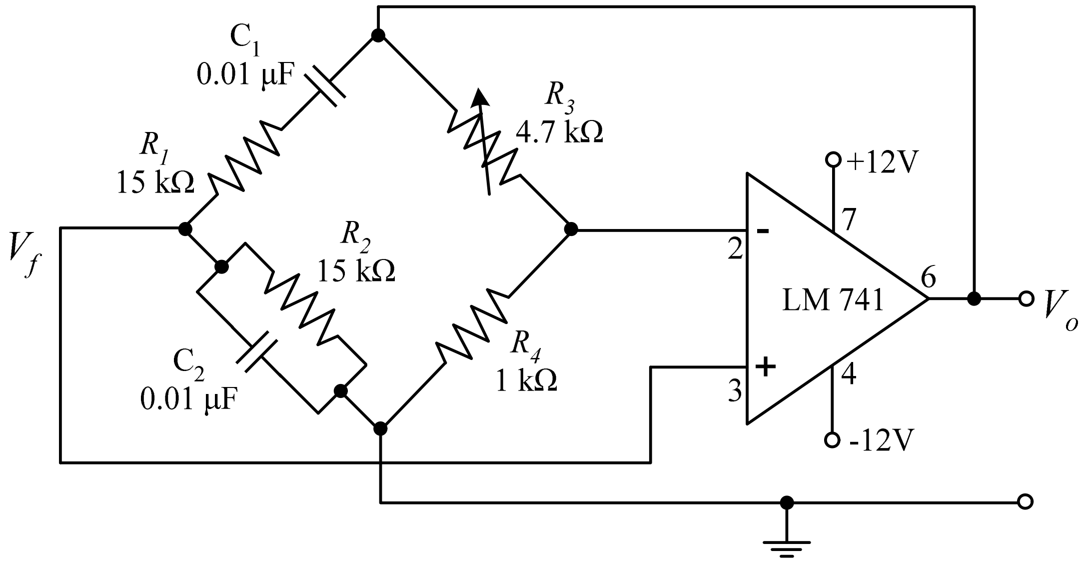


Fig 2 Circuit diagram of Wien bridge oscillator using opamp.

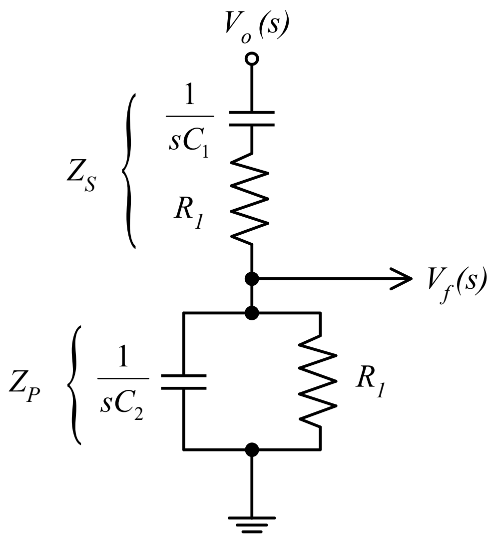


Fig 2 Circuit diagram of Wien bridge oscillator using opamp.

Consider the feedback circuit shown in fig 3 On applying voltage divider rule,

$$V_f(s) = \frac{V_o(s) \times Z_P(s)}{Z_P(s) + Z_S(s)}$$

where, $Z_S(s) = R_1 + \frac{1}{sC_1}$ and $Z_P(s) = R_2 \parallel \frac{1}{sC_2}$

Let, $R_1 = R_2 = R$ and $C_1 = C_2 = C$. On solving,

$$\text{feedback gain, } \beta = \frac{V_f(s)}{V_o(s)} = \frac{RsC}{(RsC)^2 + 3RsC + 1} \qquad (1)$$

Since the op-amp is operated in the non-inverting configuration the voltage gain,

$$A_v = \frac{V_o(s)}{V_f(s)} = 1 + \frac{R_3}{R_4} \qquad (2)$$

Applying the condition for sustained oscillations, $A_v\beta = 1$

Substitute equations (1) & (2), we get,

$$\left(1 + \frac{R_3}{R_4}\right)\left(\frac{RsC}{(RsC)^2 + 3RsC + 1}\right) = 1$$

Substitute $s = j\omega$

$$\left(1 + \frac{R_3}{R_4}\right)\left(\frac{j\omega RC}{-R^2C^2\omega^2 + 3j\omega RC + 1}\right) = 1$$

$$\left(1 + \frac{R_3}{R_4}\right) j\omega RC = \left(-R^2C^2\omega^2 + 3j\omega RC + 1\right)$$

$$j\omega\left[\left(1 + \frac{R_3}{R_4}\right)RC - 3RC\right] = 1 - R^2C^2\omega^2$$

To obtain the frequency of oscillation equate the real part to zero.

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

$$\omega = \frac{1}{RC}$$

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

To obtain the condition for gain at the frequency of oscillation, equate the imaginary part to zero.

$$j\omega\left[\left(1 + \frac{R_3}{R_4}\right)RC - 3RC\right] = 0$$

$$j\omega\left(1 + \frac{R_3}{R_4}\right)RC = j\omega 3RC$$

$$\left(1 + \frac{R_3}{R_4}\right) = 3 \quad (\textit{gain of the amplifier})$$

$$\frac{R_3}{R_4} = 2$$

Therefore, $R_3 = 2\,R_4$ is the required condition.

SIMPLIFIED DESIGN:

Frequency of oscillation, $f = \dfrac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$

Let, $R_1 = R_2 = R$ and $C_1 = C_2 = C$

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

Given frequency, $f = 1$ kHz. assume C = 0.01µF

$$1000 = \frac{1}{2\pi R \times 0.01 \times 10^{-6}}$$

then $R = 15.9$ kΩ

Take $R_1 = R_2 = 15$ kΩ (nearest standard value)

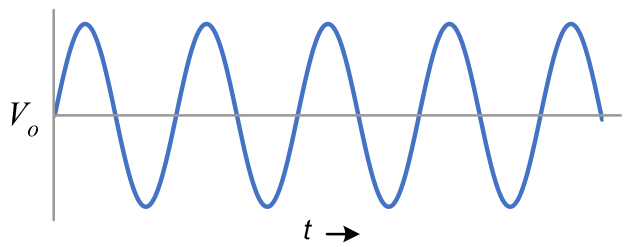
Also, $\dfrac{R_3}{R_4} = 2$

Let $R_4 = 1$ kΩ, then $R_3 = 2$ kΩ. (Use 4.7kΩ potentiometer for fine corrections).

PROCEDURE:

- Test the op-amp by giving a sine wave at the inverting terminal, ground at the non-inverting terminal to obtain a square wave at the output.
- Set up the circuit as shown in the figure.
- Obtain the sine wave at the output. Check for the frequency obtained.

OUTPUT (TO BE OBTAINED):



$f = 1$ kHz

RESULT:

A Wien bridge oscillator was designed and setup for a frequency of 1kHz and the output waveform is observed.