Wien Bridge Oscillator

Introduction

Oscillators are circuits that produce periodic waveforms without any input signal. They generally use some form of active devices like transistors or OPAMPs as amplifiers with feedback network consisting of passive devices such as resistors, capacitors, or inductors.

Fig.1 demonstrates the a basic negative feedback system in which V_{IN} is the input voltage, V_{OUT} is the output voltage from the amplifier gain block (A), and β as the feedback factor, that is fed back to the summing junction. E represents the error signal that is equal to the summation of the feedback factor and the input voltage.

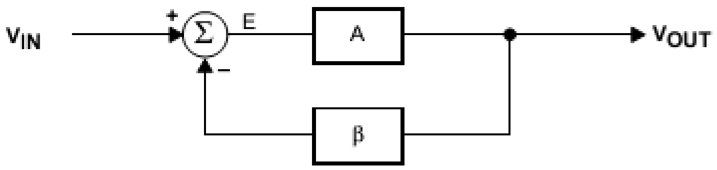

Figure 1 Basic block diagram explaining feedback

$$E = V_{in} - \beta V_{out}$$

$$V_{out} = AE = (V_{in} - \beta Vout)$$

$$A_f = \frac{V_{out}}{V_{in}} = \frac{A}{1+A\beta}$$

When $A\beta = 1$, i.e. the unity loop gain with phase shift of 180° provided by the feedback network ($A\beta = 1\angle{-180°}$), the denominator term becomes 0 and the gain with feedback, A_f, becomes infinite. This means infinitesimal signal (noise voltage) can provide an output voltage, and the circuit acts as an oscillator even without an input signal. This is Barkhausen Criterion for sustained oscillations.

This can be explained using control theory using following three conditions:

1. If the loop gain $A\beta < 1$, the poles of the transfer function A_f, lie in the left half of the s-Plane (real part σ being negative). The system oscillates but eventually they die out. (Refer Fig 2a)

2. If the loop gain $A\beta = 1$, the poles of the transfer function (which are complex conjugates with real part σ equal to zero) of the closed loop system lie on the jω axis. However, in reality, the nonlinearity of the circuit components eventually causes Aβ to become less than one and the oscillations cease out. (Refer Fig 2c)

3. If the loop gain $A\beta > 1$, the poles of the transfer function lie in the right half of s-plane (real part σ being positive) which make the system highly unstable causing the oscillations grow exponentially. (Refer Fig 2b)

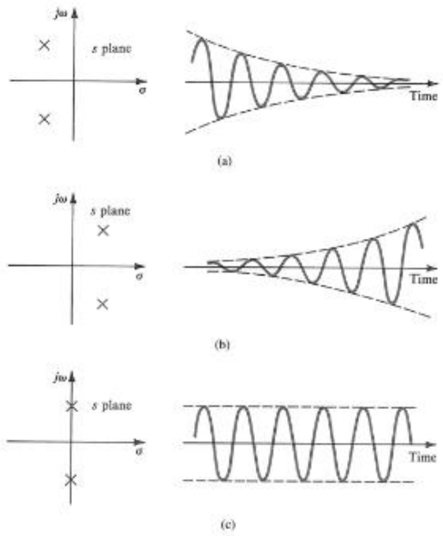

Figure 2 Stability based on location of poles and zeros

In practical circuits, however, it is found that for the loop gain Aβ, even if made equal to unity, the oscillations die out exponentially as the devices used for amplification are nonlinear in nature and cause the gain to reduce from their nominal value resulting in oscillations to cease. Hence the loop gain Aβ is made slightly greater than one to build up oscillations. The growing oscillations are then limited by the nonlinearity of the circuit elements. The automatic gain control circuits are also often used to stabilise the amplitude of oscillations to result in less distortion.
The feedback network is the frequency selective network. It uses either RC or LC components depending upon the desired range of frequencies. Generally RC (e.g. Wien Bridge oscillator, Phase shift oscillator, twin-T oscillator) network is used for audio frequency range and LC (e.g. Hartley, Colpitt, Clapp oscillator) for RF applications.

In this experiment we will study the Wien Bridge oscillator.

Wien Bridge Oscillator

The Wien bridge oscillator is one of the simplest oscillators. Fig.2 shows the basic Wien bridge circuit configuration. OPAMP is used as the amplifying device and the Wien bridge is used as the feedback element.

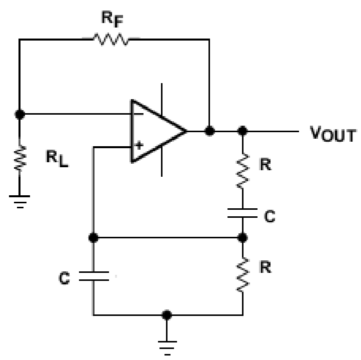

Figure 3 Wien Bridge Oscillator

The OPAMP is used in noninverting mode that provides a phase shift of 0^0. One can expect that the phase shift introduced by the feedback network also to be equal to 0^0 at the frequency of oscillations. The frequency of oscillations is,

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

The feedback network provides gain of 1/3. Hence, the amplifier gain in inverting mode should be slightly greater than 3.

Mathematical analysis.

We wish to derive the condition for sustained oscillation and the oscillating frequency.

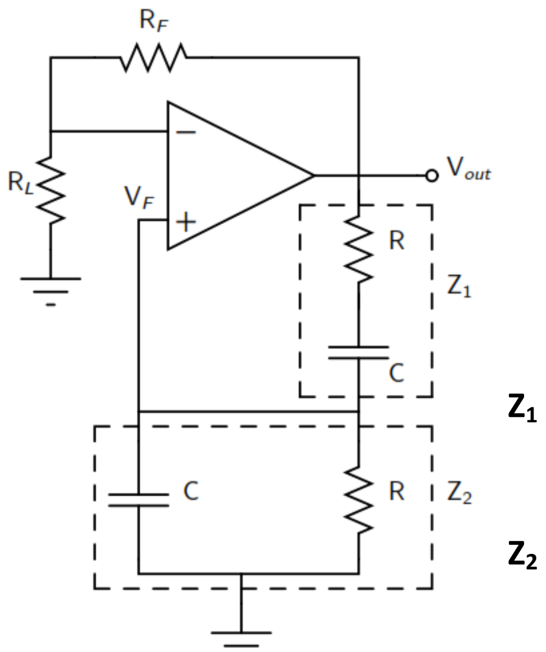

Figure 4 Wien Bridge Oscillator analysis

The feedback voltage V_f is given by,

$$V_f = \frac{Z_1}{Z_1+Z_2} V_{out} \quad (1)$$

where,

$$Z_1 = \frac{R}{1+RCS} \quad (2)$$

$$Z_2 = R + \frac{1}{Cs} \quad (3)$$

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,

$$V_f = \frac{j\omega CR}{1+3RCj\omega - C^2 R^2 \omega^2} V_{out} \qquad (4)$$

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

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

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

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

This implies that the non inverting gain of the amplifier should be slightly greater than 3 so that the loop gain condition is satisfied.