

Simulation 7

Sine wave generation using Wien-bridge oscillator

Reference- Sedra and Smith (6th edition), chapter 17 p.p. 1342-1243

Introduction – Generation of sine wave can be accomplished by employing a positive-feedback loop. It consists of an amplifier and RC or LC frequency selective network. All oscillators are non-linear circuits. A positive-feedback loop that could generate sine wave is shown in Fig. 1.

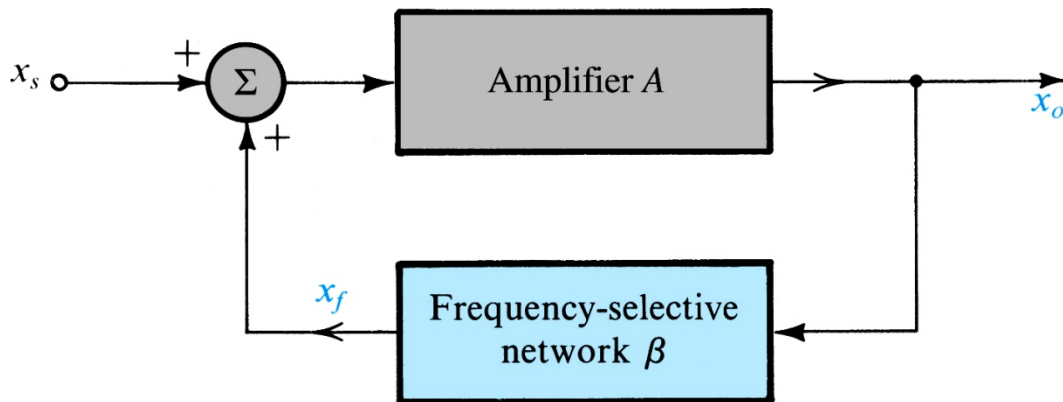


Fig. 1 – The basic structure of a sinusoidal oscillator

Here, a positive feedback loop is formed by an amplifier with gain A and a frequency-selective network with gain β . In this figure an input signal of X_s is shown but in actual oscillator no signal input is present. The amplifier, however, needs a DC supply for proper operation. The loop gain of this circuit in Fig. 1 is given by $-A(s)\beta(s)$.

For a sustained stable oscillation, the loop gain should be one; i.e. $1=A(s)\beta(s) = A(j\omega_0)\beta(j\omega_0)$. At the frequency ω_0 the phase of the loop gain should be zero and the magnitude of the loop gain should be unity. This is known as **Barkhausen criterion**. The frequency ω_0 should be unique otherwise we wouldn't have a pure sine wave.

One such example of a sine-wave oscillator that works according to the above principle is Wien-Bridge oscillator. This uses an OP-AMP and several R, C elements. The basic schematic is shown in Fig. 2.

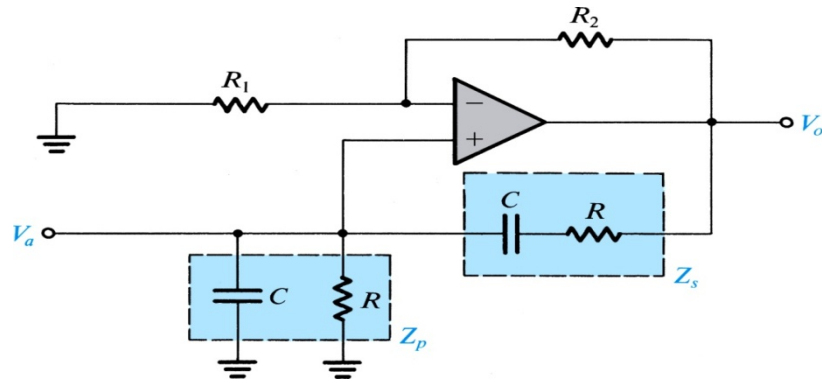


Fig. 2 - A Wien –Bridge oscillator without amplitude stabilization

The loop gain is given by ¹

$$L(j\omega) = \left[1 + \frac{R_2}{R_1} \right] \left[\frac{Z_p}{Z_p + Z_s} \right] = \frac{1 + R_2/R_1}{1 + Z_s Y_p} = \frac{1 + \frac{R_2}{R_1}}{3 + j \left(\omega CR - \frac{1}{\omega CR} \right)} \quad (1)$$

The first term in $L(j\omega)$ is the non-inverting amplifier gain $A = \left[1 + \frac{R_2}{R_1} \right]$. The second term involving Z is the feedback gain β .

When the phase of L is zero, the loop gain (L) is a real number. This condition is satisfied at $\omega_0 = 1/CR$. (2)

To obtain a sustained oscillation at this frequency, one should set the magnitude of the loop-gain to unity. This can be achieved by selecting

$$\frac{R_2}{R_1} = 2 \quad (3)$$

In order to ensure that the oscillation will start, we make R_2/R_1 slightly greater than 2. The circuit in Fig. 3 is a Wien-Bridge oscillator using an OP-AMP ($\mu A741$) from PSPICE “EVAL” library.

¹ Sedra/Smith, Microelectronic Circuits, 6th ed., ch.17

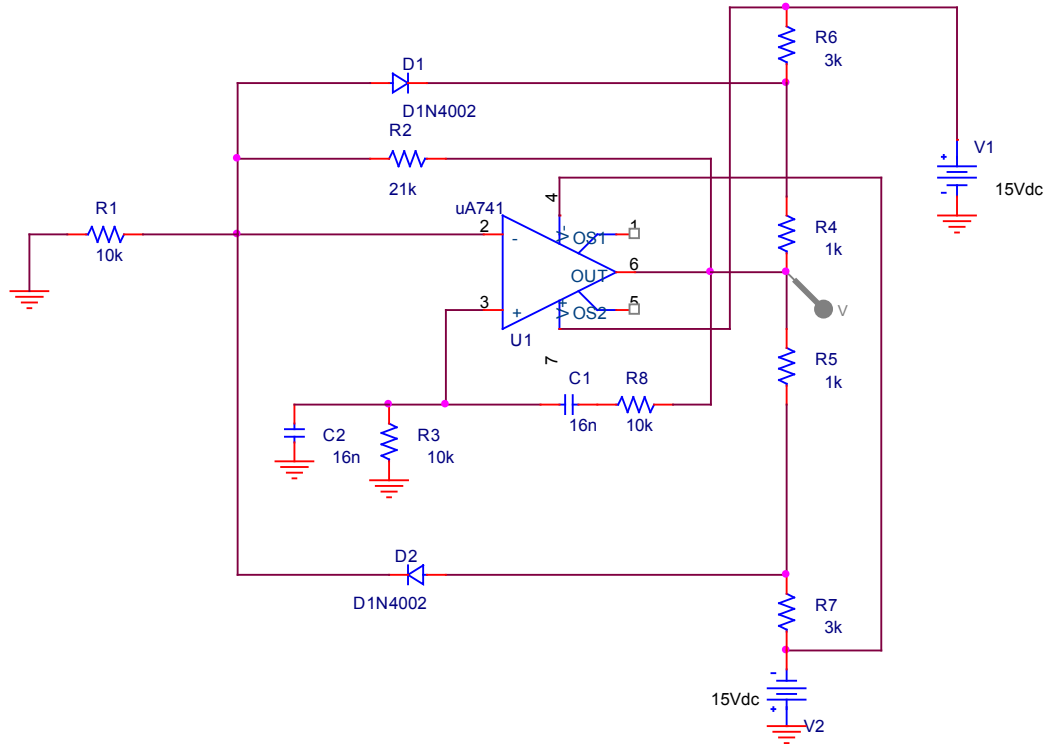


Fig. 3 – A Wien bridge oscillator with amplitude control

Note that in Figure 3, $R_2/R_1 = 2.1$. The diodes D1 and D2 in conjunction with R4, R5, R6, and R7 are there for amplitude control.

Simulation Procedure – Assemble the circuit in Fig. 3. For a correct simulation, all the ground points should be set to 0. Take note of the fact that pins 4 and 7 are connected to -15V and +15V respectively. Even though the connecting wires intersect other wires, there is no physical connection. You need to insure that while drawing the schematics. Do the following steps.

1. From PSPICE icon choose the analysis type – Time Domain
 - Run to time = 10ms
 - Start saving data after = 6ms
 - Maximum step size = 10us
 - Tick on “Skip the initial transient bias point calculation (SKIPBP)”
2. Run the simulation.
3. You would notice that the amplitude is increasing. This underscores the fact that in the beginning, the oscillator is not stable as the amplitude is not constant. Save this graph.
4. Now you need to edit the simulation profile (PSPICE → Edit Simulation Profile) and make the following changes.
 - analysis type – Time Domain

Run to time = 60ms

Start saving data after = 56ms

Maximum step size = 10us

Tick on "Skip the initial transient bias point calculation (SKIPBP)"

5. Run the simulation. You should have a stable oscillation. Save the graph and note down the amplitude and the frequency.
6. In figure 3, change C1 and C2 to 1.6nF. Run the simulation as in step 4. Note the oscillation frequency and amplitude. You may need to change "Run to time "to 56.5ms.

Questions –

1. Compare the theoretical frequency of the oscillation with the observed values.
2. If $R_2/R_1 = 2$ in Fig 3, do you get an oscillation?
3. Suggest a design for an oscillation frequency of 50 kHz.
4. Can you predict the amplitude of oscillation (as seen at the location of the voltage probe) for the circuit given in Fig.3? (*hint*: Read the analysis in Sedra/Smith's book)