

# Wein-bridge oscillator

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For the Wein-bridge oscillator of Fig 0, use the expression for loop gain in (3.5) to find the poles of the closed-loop system. Give the expression for the pole, Q and use it to show that to locate the poles in the right half of s plane,  $\frac{R_2}{R_1}$  must be selected to be greater than 2.

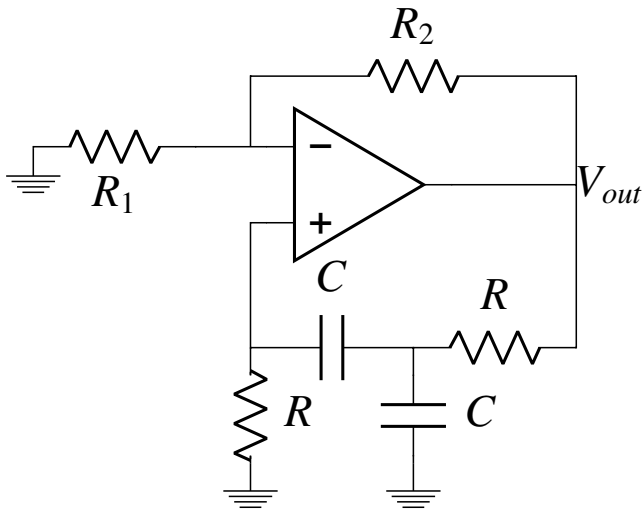


Fig. 0

- 1.
2. Compare the basic structure for a sinusoidal oscillator with Wein-bridge oscillator and give expressions for G and H.

**Solution:**

- Comparing Fig 0 and Fig 2, we get

$$G = 1 + \frac{R_2}{R_1} \quad (2.1)$$

$$H = \frac{Z_p}{Z_p + Z_s} \quad (2.2)$$

where,

$$Z_p = \frac{R}{RSC + 1} \quad (2.3)$$

$$Z_s = \frac{RSC + 1}{SC} \quad (2.4)$$

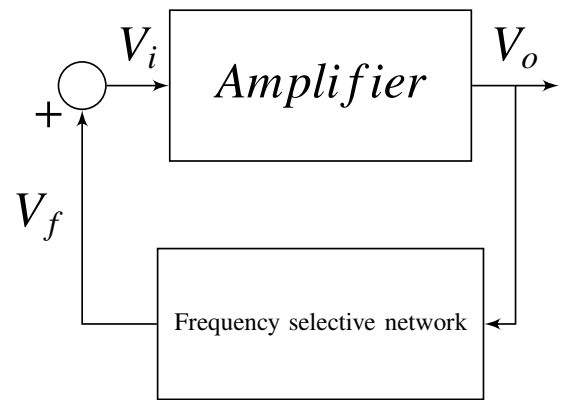


Fig. 2

3. Give the expression for loop gain for Wein-bridge oscillator.

**Solution:**

$$T(s) = A(s)\beta(s) \quad (3.1)$$

$$T(s) = \frac{1 + \frac{R_2}{R_1}}{1 + Z_s Y_p} \quad (3.2)$$

$$T(s) = \frac{1 + \frac{R_2}{R_1}}{1 + \left(\frac{sRC+1}{sC}\right)\left(\frac{sRC+1}{R}\right)} \quad (3.3)$$

$$T(s) = \frac{1 + \frac{R_2}{R_1}}{1 + \frac{s^2 R^2 C^2 + sRC + sRC + 1}{sRC}} \quad (3.4)$$

$$T(s) = \frac{1 + \frac{R_2}{R_1}}{3 + sCR + \frac{1}{sCR}} \quad (3.5)$$

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4. Write the characteristic equation for Wein-bridge oscillator.

**Solution:**

$$1 - T(s) = 0 \quad (4.1)$$

$$1 - \frac{1 + \frac{R_2}{R_1}}{3 + sCR + \frac{1}{sCR}} = 0 \quad (4.2)$$

$$3 + sRC + \frac{1}{sCR} = 1 + \frac{R_2}{R_1} \quad (4.3)$$

$$3 - 1 + sRC + \frac{1}{sCR} - \frac{R_2}{R_1} = 0 \quad (4.4)$$

$$2s + s^2RC + \frac{1}{RC} - s\frac{R_2}{R_1} = 0 \quad (4.5)$$

$$s^2RC + s(2 - \frac{R_2}{R_1}) + \frac{1}{RC} = 0 \quad (4.6)$$

$$s^2 + s\frac{1}{RC}(2 - \frac{R_2}{R_1}) + \frac{1}{R^2C^2} = 0 \quad (4.7)$$

5. Write the general expression for the characteristic equation.

**Solution:**

$$s^2 + s\frac{\omega_0}{Q} + \omega_0^2 = 0 \quad (5.1)$$

6. State the **Barkhausen criterion** for sustained oscillations with frequency  $\omega_0$ .

**Solution:**

$$T(j\omega_0) = G(j\omega_0)H(j\omega_0) = 1 \quad (6.1)$$

- That is, at  $\omega_0$  the phase of the loop gain should be zero and the magnitude of loop gain should be 1.
  - Only for a  $\infty$  gain, system will produce a finite output for zero input.
7. Give the definition of **Quality factor(Q)** and explain its significance.

**Solution:**

- It is a parameter of an oscillatory system expressing the relationship between stored energy and energy dissipation.
  - The "purity" of output sine waves will be a function of the selectivity feedback network.
  - That is, higher the value of Q for frequency selective network, the less the harmonic content of sine wave produced.
8. Compare the equations 4.7 and 5.1 and give expressions for Q and  $\omega_0$

**Solution:**

$$\omega_0^2 = \frac{1}{R^2C^2} \quad (8.1)$$

$$\omega_0 = \frac{1}{RC} \quad (8.2)$$

$$\frac{\omega_0}{Q} = \frac{1}{RC}(2 - \frac{R_2}{R_1}) \quad (8.3)$$

$$Q = \frac{1}{(2 - \frac{R_2}{R_1})} \quad (8.4)$$

9. Using Eq 8.4 calculate the value of  $\frac{R_2}{R_1}$  for which poles lie on right hand of s-plane.

**Solution:**

Poles lie on imaginary axis for  $Q = \infty$

$$2 - \frac{R_2}{R_1} = 0 \quad (9.1)$$

$$\frac{R_2}{R_1} = 2 \quad (9.2)$$

$\therefore$  For poles to lie on right hand side of s-plane

$$\frac{R_2}{R_1} > 2 \quad (9.3)$$

10. Verify the above calculations using a Python code.

**Solution:**

codes/ee18btech11044\_3\_1.py

- This figure shows how the location of poles vary if  $\frac{R_2}{R_1}$  is varied for a fixed  $\omega_0$ .
- I have varied  $\frac{R_2}{R_1}$  from -10 to 10.

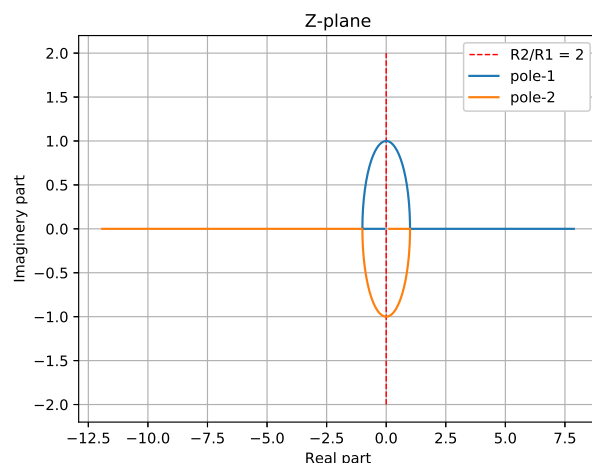


Fig. 10

11. Simulate the circuit shown in Fig 0 using spice simulators. Plot the output generated using python.

**Solution:**

You can find the netlist for the simulated circuit here:

spice/ee18btech11044/ee18btech11044.net

You can find the python script used to generate the output here:

codes/ee18btech11044/ee18btech11044\_spice.py

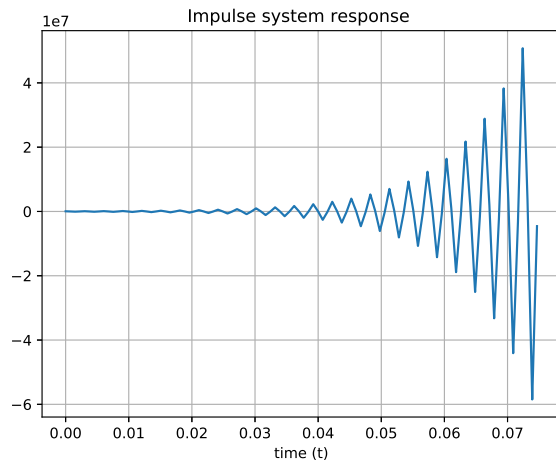


Fig. 11

12. Tabulate the values of Resistors and Capacitors you have chosen for the simulation.

**Solution:**

Parameter	Value
$R_1$	$10k\Omega$
$R_2$	$20.3k\Omega$
$R_p$	$10k\Omega$
$R_s$	$10k\Omega$
$C_s$	$16nF$
$R_p$	$10k\Omega$
$C_p$	$16nF$

TABLE 12

Where, according to Fig 0

$$R_p = R_s = R \quad (12.1)$$

$$C_p = C_s = C \quad (12.2)$$

13. Calculate the frequency of sinusoidal generated for the combination of R and C chosen using Eq 8.2

**Solution:**

Frequency generated is given by

$$\omega_0 = \frac{1}{RC} \quad (13.1)$$

$$\omega_0 = 6250 \text{ rad/sec} \quad (13.2)$$

$$f_0 = 995.22 \text{ Hz.} \quad (13.3)$$

14. Calculate the frequency of sinusoidal wave using plot generated from simulation.

**Solution:**

- Consider a part of plot generated from simulation shown in the Fig 14.
- Calculating the Time-period of the sinusoidal wave generated using the two points marked in the Fig 14.

$$T_0 = 0.0856452 - 0.0846361 \quad (14.1)$$

$$f_0 = 1/T_0 \quad (14.2)$$

$$f_0 = 990.98 \text{ Hz.} \quad (14.3)$$

- We get the frequencies calculated from the formulae and the plot to be approximately same.

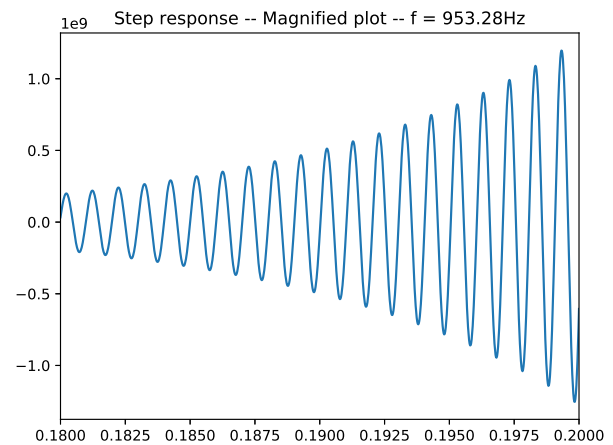


Fig. 14