Wein-bridge oscillator

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1. For the Wein-bridge oscillator of Fig 1.1, use the expression for loop gain 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.

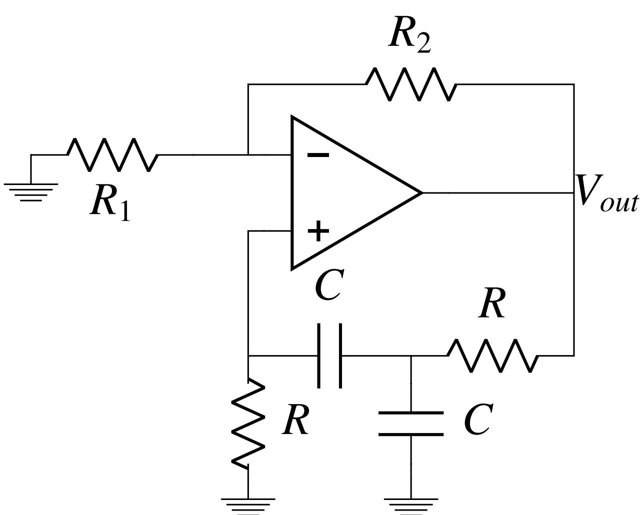

Fig. 1.1

2. Compare the basic structure for a sinusoidal oscillator with Wein-bridge oscillator and give expressions for G and H.
Solution:
Comparring Fig 1.1 and Fig 2.2, we get

$$G = 1 + \frac{R_2}{R_1} \tag{2.1}$$

$$H = \frac{Z_p}{Z_p + Z_s} \tag{2.2}$$

where,

$$Z_p = \frac{R}{RSC + 1} \tag{2.3}$$

$$Z_s = \frac{RSC + 1}{SC} \tag{2.4}$$

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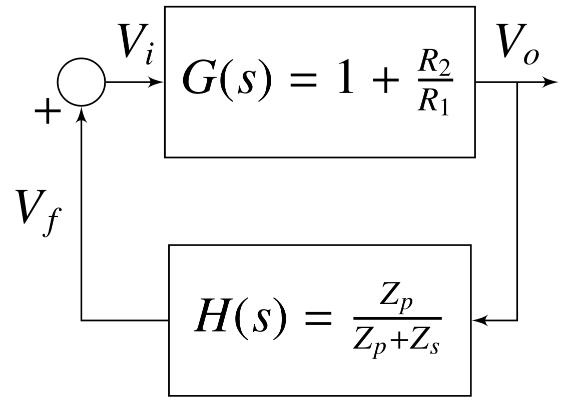

Fig. 2.2

3. Write the characteristic equation for Wein-bridge oscillator.
Solution:

$$1 - L(s) = 0 \tag{3.1}$$

$$1 - \frac{1 + \frac{R_2}{R_1}}{3 + sCR + \frac{1}{sCR}} = 0 \tag{3.2}$$

$$3 + sRC + \frac{1}{sCR} = 1 + \frac{R_2}{R_1} \tag{3.3}$$

$$3 - 1 + sRC + \frac{1}{sRC} - \frac{R_2}{R_1} = 0 \tag{3.4}$$

$$2s + s^2RC + \frac{1}{RC} - s\frac{R_2}{R_1} = 0 \tag{3.5}$$

$$s^2RC + s(2 - \frac{R_2}{R_1}) + \frac{1}{RC} = 0 \tag{3.6}$$

$$s^2 + s\frac{1}{RC}(2 - \frac{R_2}{R_1}) + \frac{1}{R^2C^2} = 0 \tag{3.7}$$

4. Write the general expression for the characteristic equation.
Solution:

$$s^2 + s\frac{\omega_0}{Q} + \omega_0^2 = 0 \tag{4.1}$$

5. State the **Barkhausen criterion** for sustained oscillations with frequency ω_0.
Solution:

$$L(j\omega_0) = G(j\omega_0)H(j\omega_0) = 1 \tag{5.1}$$

- That is, at ω_0 the phase of the loop gain should be zero and the magnitude of loop gain should be 1.
- Only for a ∞ gain,system will produce a finite output for zero input.

6. 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.

7. Compare the equations 3.7 and 4.1 and give expressions for Q and ω_0
Solution:

$$\omega_0^2 = \frac{1}{R^2C^2} \tag{7.1}$$
$$\omega_0 = \frac{1}{RC} \tag{7.2}$$
$$\frac{\omega_0}{Q} = \frac{1}{RC}(2 - \frac{R_2}{R_1}) \tag{7.3}$$
$$Q = \frac{1}{(2 - \frac{R_2}{R_1})} \tag{7.4}$$
$$\tag{7.5}$$

8. Using Eq 7.4 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 $Q = \infty$

$$2 - \frac{R_2}{R_1} = 0 \tag{8.1}$$
$$\frac{R_2}{R_1} = 2 \tag{8.2}$$

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

$$\frac{R_2}{R_1} > 2 \tag{8.3}$$

9. Verify the above calculations using a Python code.
Solution:

```
codes/ee18btech11044/ee18btech11044_3_1.
    py
```

- This figure shows how the location of poles vary if $\frac{R_2}{R_1}$ is varied for a fixed ω_0.
- I have varied $\frac{R_2}{R_1}$ from -10 to 10.

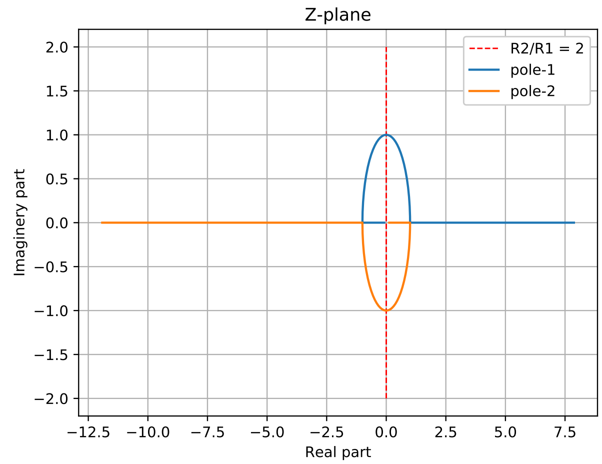

Fig. 9.3

10. Verify the output of the above transfer using a python code
Solution:
- In the real life oscillator generates a sinusoidal input utilizing the thermal noise in the circuit.
- In the python simulation, oscillator requires an input to generate the output as there is no thermal noise in the simulation.
- Any input will produce the same sinusoidal output in the simulation as you can see output for both step input and impulse input is same(Amplitude might differ but frequency will be the same).
- Please refer Fig10.4 for the output of the transfer function for a step input.
- Please refer Fig10.5 for the output of the transfer function for am impulse input.
- Code for generating step response

```
codes/ee18btech11044/
    ee18btech11044_pyst.py
```

- Code for generating impulse response

```
codes/ee18btech11044/
    ee18btech11044_pyim.py
```

11. Simulate the circuit shown in Fig 1.1 using spice simulators. Plot the output generated using python.
Solution:

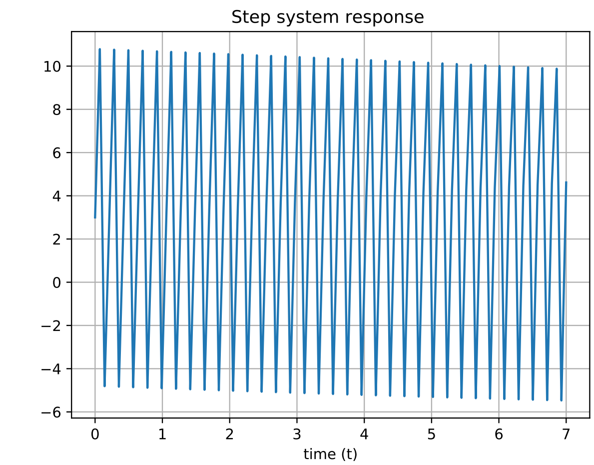

Fig. 10.4

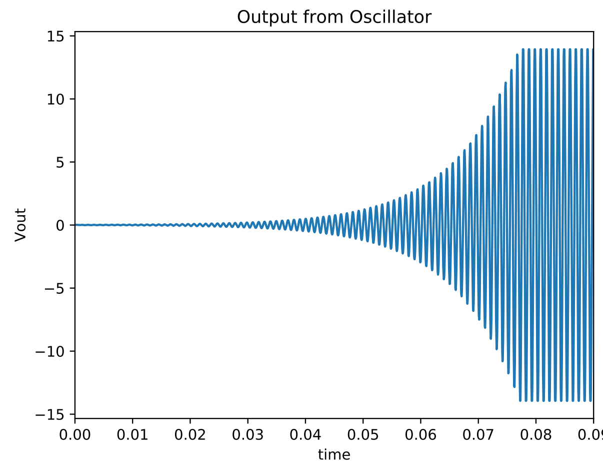

Fig. 11.6

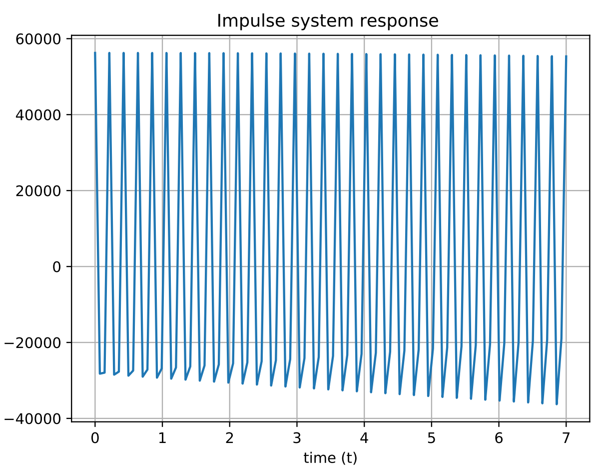

Fig. 10.5

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

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:

```
spice/ee18btech11044/ee18btech11044_spice.
    py
```

12. Tabulate the values of Resistors and Capacitors you have chosen for the simulation.
Solution:
Where, according to Fig 1.1

$$R_p = R_s = R \tag{12.1}$$
$$C_p = C_s = C \tag{12.2}$$

13. Calculate the frequency of sinusoidal generated for the combination of R and C chosen using Eq 7.2
Solution:
Frequency generated is given by

$$\omega_0 = \frac{1}{RC} \tag{13.1}$$
$$\omega_0 = 6250 rad/sec \tag{13.2}$$
$$f_0 = 995.22 Hz. \tag{13.3}$$

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 14.7.
    - Calculating the Time-period of the sinusoidal wave generated using the two points

marked in the Fig 14.7.

$$T_0 = 0.0856452 - 0.0846361 \tag{14.1}$$

$$f_0 = 1/T_0 \tag{14.2}$$

$$f_0 = 990.98Hz. \tag{14.3}$$

- We get the frequencies calculated from the formulae and the plot to be approximately same.
- Use this script to generate Fig 14.7

```
spice/ee18btech11044/
    ee18btech11044_spice_2.py
```

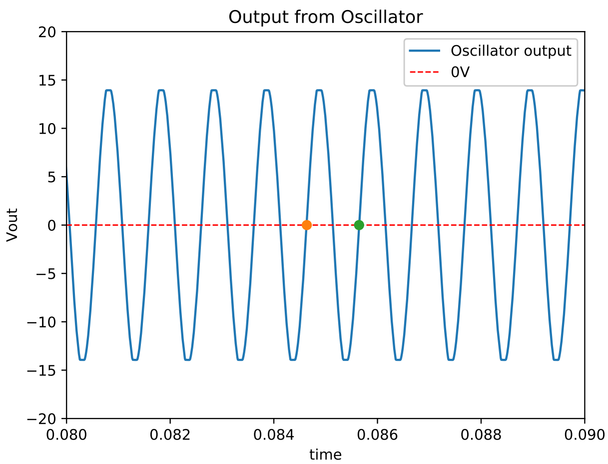

Fig. 14.7