Wein Bridge Oscillator

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Redesign the circuit of Fig. 0 for operation at 10KHz using same values of resistance. If at 10KHz the op amp provides an excess phase shift (lag) of 5.7°, what will be the frequency of oscillation? Assume the phase shift introduced by the op amp remains constant for frequencies around 10KHz.)To restore operation to 10KHz, what change must be made in the shunt resistor of the wien bridge? Also, to what value must R_2/R_1 be changed ?
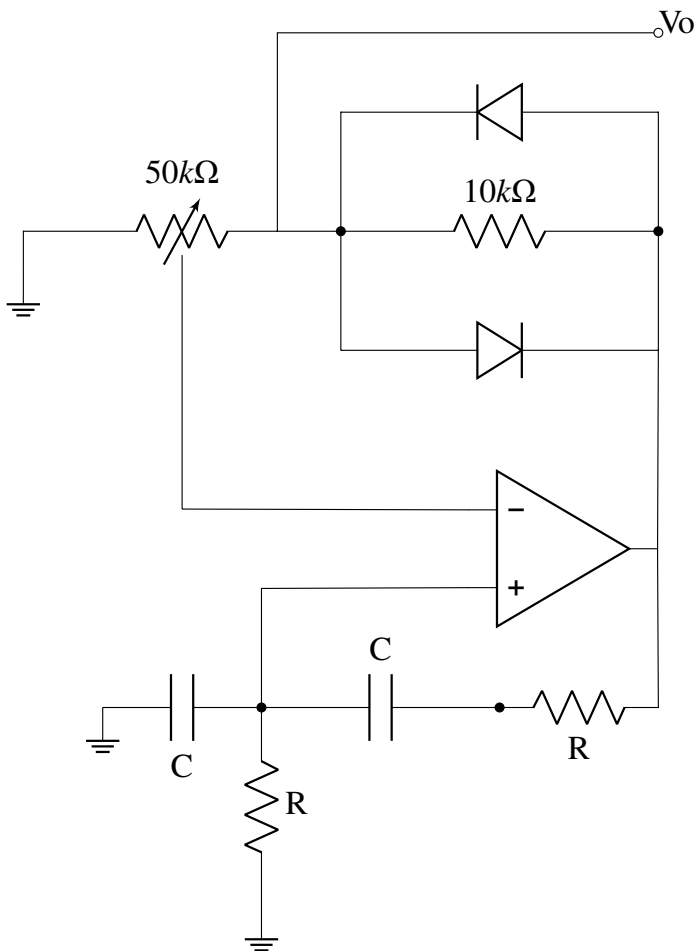

Fig. 0

1. Draw block diagram for the above circuit .
   Solution:

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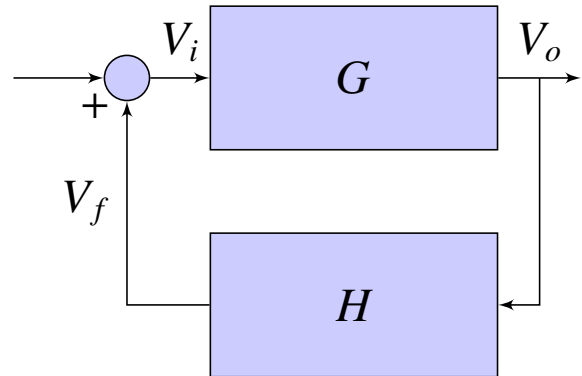

Fig. 1

2. Find G and draw circuit diagram for G .
   Solution:
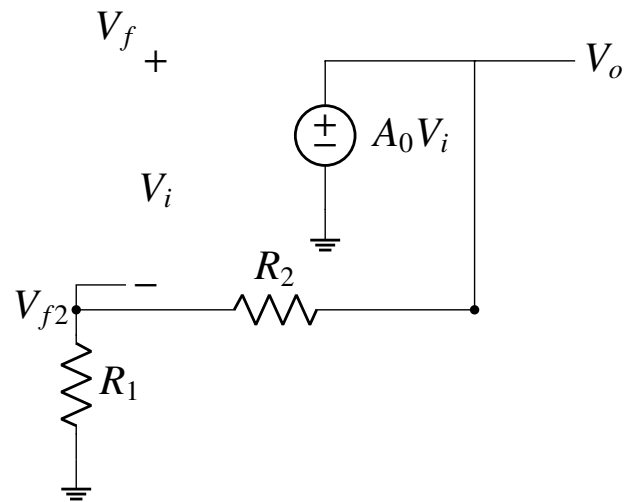

Fig. 2

from fig. 2

$$V_{f2} = \left(\frac{R_1}{R_1 + R_2}\right) V_o \qquad (2.1)$$

$$G_1 = \frac{V_{f2}}{V_o} = \left(\frac{R_1}{R_1 + R_2}\right) \qquad (2.2)$$

from fig 2 , A_o is the gain of amplifier, and G_1 is placed as negative feedback factor. Therefore

total G is given as

$$G = \frac{A_0}{1 + A_0 G_1} \tag{2.3}$$

$$= \frac{1}{\frac{1}{A_0} + G_1} \tag{2.4}$$

$$\implies G \approx \frac{1}{G_1}, \quad A_0 \to \infty \tag{2.5}$$

$$\text{or, } G = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1} \tag{2.6}$$

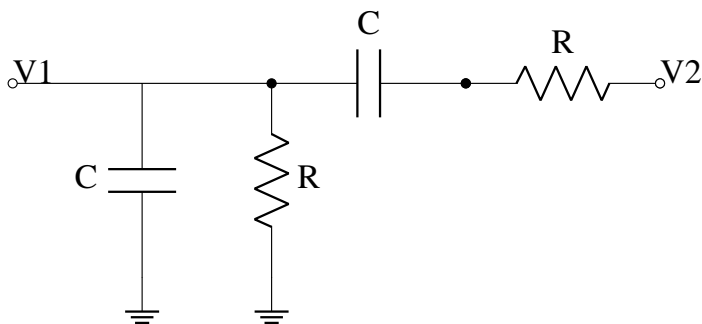3. Find H and draw circuit diagram for H
   Solution:

Fig. 3

from fig 3

$$V_1 = \frac{R \parallel \frac{1}{sC}}{\left(R \parallel \frac{1}{sC}\right) + R + \frac{1}{sC}} V_2 \tag{3.1}$$

$$H = \frac{1}{3 + j\left(\omega CR - 1/\omega CR\right)} \tag{3.2}$$

4. Find frequency of oscillation when the excess phase shift (*lag*) is 5.7°
   Solution: The loop gain of wein bridge oscillator$L(j\omega)$ is

$$L(j\omega) = H(j\omega) G(j\omega) \tag{4.1}$$

$$L(j\omega) = \frac{1 + R_2/R_1}{3 + j\left(\omega CR - 1/\omega CR\right)} \tag{4.2}$$

The phase shift of loop is

$$\phi(\omega) = \tan^{-1}\left(\frac{\omega CR - 1/\omega CR}{3}\right) \tag{4.3}$$

The loop gain will be a real number (i.e., the phase will be zero) at the frequency

$$\omega = \frac{1}{CR} \tag{4.4}$$

Differentiating $\phi(\omega)$ with ω

$$\frac{\partial \phi(\omega)}{\partial \omega} = \frac{-1}{1 + \left(\frac{\omega CR - 1/\omega CR}{3}\right)^2} \frac{\partial\left(\omega CR - 1/\omega CR\right)}{\partial \omega} \tag{4.5}$$

And since $\omega = 1/CR$ upon evaluating

$$\frac{\partial \phi(\omega)}{\partial \omega} = \frac{-2CR}{3} = \frac{-2}{3\omega} \tag{4.6}$$

$$\text{and } \Delta\omega = \frac{\Delta\phi}{\frac{\partial\phi(\omega)}{\partial\omega}} \tag{4.7}$$

$$\Delta\omega = \frac{-0.1}{-2/3\omega} \ (5.7° = 0.1 rad/s) \tag{4.8}$$

$$\Delta\omega = 0.15\omega \tag{4.9}$$

So, the frequency of oscillation is

$$\omega - \Delta\omega = 10 - 0.15x10 \tag{4.10}$$

$$= 8.15 kHz \tag{4.11}$$

5. What change must be made in the shunt resistor of the wien bridge, to restore the frequency of oscillation ?
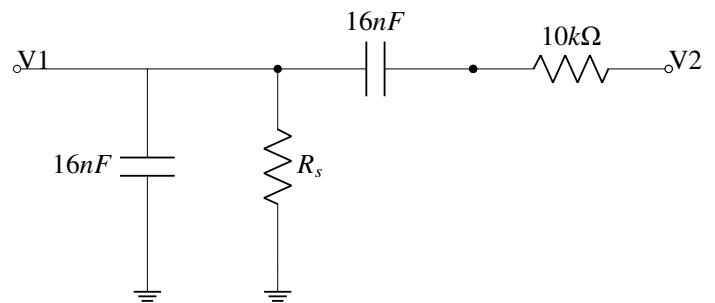   **Solution:** Assuming the parallel R $= R_s$ as shunt shown in Fig 5

Fig. 5

Feedback loop gain $\beta(s)$

$$\beta(s) = \frac{R_s \parallel \frac{1}{sC}}{\left(R_s \parallel \frac{1}{sC}\right) + R + \frac{1}{sC}} \tag{5.1}$$

$$\beta(s) = \cfrac{1}{2 + \frac{R}{R_s} + j\left(\omega CR - \frac{1}{\omega CR_s}\right)} \qquad (5.2)$$

So, phase shift $\phi(\omega)$ is

$$\phi(\omega) = -\tan^{-1}\left(\cfrac{\omega CR - \frac{1}{\omega CR_s}}{2 + \frac{R}{R_s}}\right) \qquad (5.3)$$

from 5.3 we can find value of R_s when $\omega = \frac{1}{RC}$

$$R_s = 0.75R \qquad (5.4)$$
$$R_s = 7.5k\Omega \qquad (5.5)$$

6. Also, to what value must R_2/R_1 be changed ?

Solution: Substituting the values of R and R_s in 5.1 we get

$$\beta(j\omega) = \frac{1}{3.35} \qquad (6.1)$$

we know the loop gain $L(j\omega)$ is

$$L(j\omega) = \frac{1 + R_2/R_1}{\beta(j\omega)} \qquad (6.2)$$

Condition for oscillation is $1 - L(s) = 0$

$$1 + \frac{R_2}{R_1} = 3.35 \qquad (6.3)$$
$$\frac{R_2}{R_1} = 2.35 \qquad (6.4)$$

7. Verify and compare the oscillator results using ngspice .

Solution:
- Refer to Fig. 7 for the spice simulation output.
- original netlist simulated circuit here:

  codes/ee18btech11049/ee18btech11049_1.net

- You can find the python script for the above, used to generate the output here:

  spice/ee18btech11049/ee18btech11049_1.py
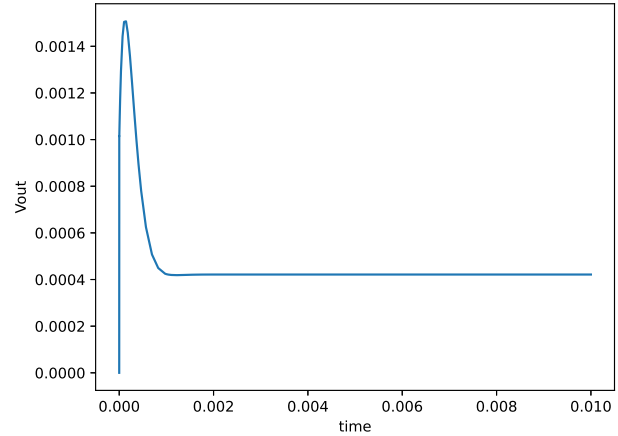
8. Re-designed output .

Fig. 7: Simulation result

- Refer to Fig. 7 for the spice simulation output.
- original netlist simulated circuit here:

  codes/ee18btech11049/ee18btech11049_2.net

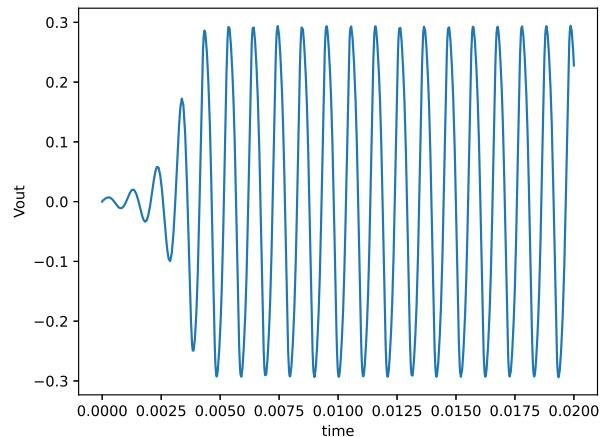- You can find the python script for the above, used to generate the output here:

  spice/ee18btech11049/ee18btech11049_2.py

Fig. 8: Simulation result