

Oscillator

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1. Three identical inverting amplifier stages each characterized by a low frequency gain K and a single pole response with

$$f_{3dB} = 100kHz \quad (1.1)$$

are connected in a feedback loop with $H = 1$. What is the minimum value of K at which the circuit oscillates? What would the frequency of oscillation be?

2. Find $G(s)$.

Solution: \because the amplifier is inverting, the gain at the i th stage is

$$G_i(s) = \frac{-K}{1 + \frac{s}{2\pi f_{3dB}}} \quad (2.1)$$

$$= \frac{-K}{1 + \frac{s}{2\pi 10^5}} \quad (2.2)$$

upon substituting for the pole from Table 2. The open loop gain

Parameter	Value
f_{3dB}	100kHz
H	1

TABLE 2: INPUT TABLE

$$G(s) = \prod_{i=1}^3 G_i(s) \quad (2.3)$$

$$= - \left[\frac{K}{1 + \frac{s}{2\pi 10^5}} \right]^3 \quad (2.4)$$

3. Draw the block diagram for the feedback system .

Solution: See Fig. 3

4. Find the loop gain of the system.

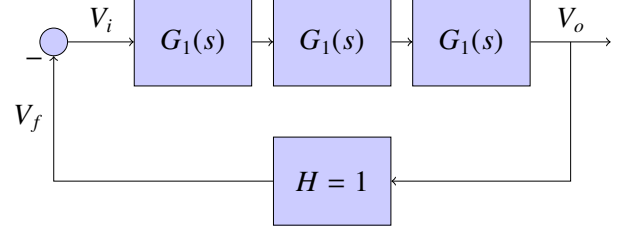


Fig. 3: CONTROL SYSTEM BLOCK

Solution: The loop gain is given by

$$L(s) = G(s)H \quad (4.1)$$

$$= - \left[\frac{K}{1 + \frac{s}{2\pi 10^5}} \right]^3 \quad (4.2)$$

$$(4.3)$$

5. Find the frequency of oscillation.

Solution: According to Barkhausen's criteria.,

- The magnitude of loop gain of the system at the oscillating frequency should be greater than or equal to 1.
- The phase angle of loop gain at the oscillating frequency must be equal to -180° degrees.

Let the frequency of oscillation is f_s .,

$$\angle LG(j\omega) = -180^\circ \quad (5.1)$$

$$-180^\circ - 3 \tan^{-1} \left[\frac{\omega_s}{2\pi 10^5} \right] = -180^\circ \quad (5.2)$$

$$-3 \tan^{-1} \left[\frac{\omega_s}{2\pi 10^5} \right] = -360^\circ \quad (5.3)$$

$$\frac{\omega_s}{2\pi 10^5} = \tan(120^\circ) \quad (5.4)$$

$$\Rightarrow \omega_s = 1.088 \times 10^6 \text{ rad/sec} \quad (5.5)$$

Thus, the frequency of oscillation is 1.088M rad/sec.

6. Find the minimum value of K .

Solution: We know the magnitude of loop gain is greater than or equal to 1. The range of K can

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be found as follows,

$$|LG(j\omega_s)| \geq 1 \quad (6.1)$$

$$\frac{K^3}{\left|1 + \frac{j\omega_s}{2\pi 10^5}\right|^3} \geq 1 \quad (6.2)$$

$$K^3 \geq \left|1 + \frac{j1.088 \times 10^6}{2\pi 10^5}\right|^3 \quad (6.3)$$

$$K^3 \geq |1 + j1.73|^3 \quad (6.4)$$

$$K^3 \geq 8 \quad (6.5)$$

$$K \geq 2 \quad (6.6)$$

Therefore, The minimum value of K is 2.

7. Design the three stage oscillator for the above given question.

Solution: Consider the circuit shown in the figure.7.

Considering the first stage.,

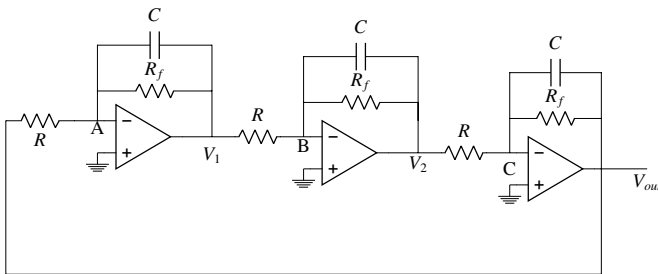


Fig. 7: 1

$$\frac{V_1}{V_{out}} = -\frac{R_f \parallel \frac{1}{sC}}{R} \quad (7.1)$$

$$\frac{V_1}{V_{out}} = -\frac{\frac{R_f}{R}}{1 + sCR_f} \quad (7.2)$$

Similarly for second stage.,

$$\frac{V_2}{V_1} = -\frac{\frac{R_f}{R}}{1 + sCR_f} \quad (7.3)$$

Similarly For third stage.,

$$\frac{V_{out}}{V_2} = -\frac{\frac{R_f}{R}}{1 + sCR_f} \quad (7.4)$$

Loop gain of the oscillator is computed as

follows.,

$$LG(s) = \frac{V_1}{V_{out}} \times \frac{V_2}{V_1} \times \frac{V_{out}}{V_2} \quad (7.5)$$

$$LG(s) = \left[-\frac{\frac{R_f}{R}}{1 + sCR_f} \right]^3 \quad (7.6)$$

Comparing with the equation.4.3

$$\frac{R_f}{R} = K \quad (7.7)$$

$$CR_f = \frac{1}{2\pi 10^5} \quad (7.8)$$

For the circuit to oscillate,

$$K \geq 2 \quad (7.9)$$

$$R_f \geq 2R \quad (7.10)$$

Choose

$$R = 1000\Omega \quad (7.11)$$

$$\Rightarrow R_f = 2000\Omega \quad (7.12)$$

$$\Rightarrow C = 7.9577 \times 10^{-10} F \quad (7.13)$$

Parameter	Value
R	1000Ω
R_f	2000Ω
C	7.9577×10^{-10}

TABLE 7

8. Verify the above result using the ngspice simulation.

Solution: Follow the instructions of the following README file.

spice/ee18btech11031/README

Connect the circuit shown in fig.7:1 in ngspice. The following netlist file is connected accordingly

spice/ee18btech11031/gvv_ngspice.net

This netlist file results in a sinusoidal wave with particular frequency. The following code generates the graph shown in fig.8

spice/ee18btech11031/
ee18btech11031_ngspice.py

9. Find the frequency of sinusoid obtained from the simulation.

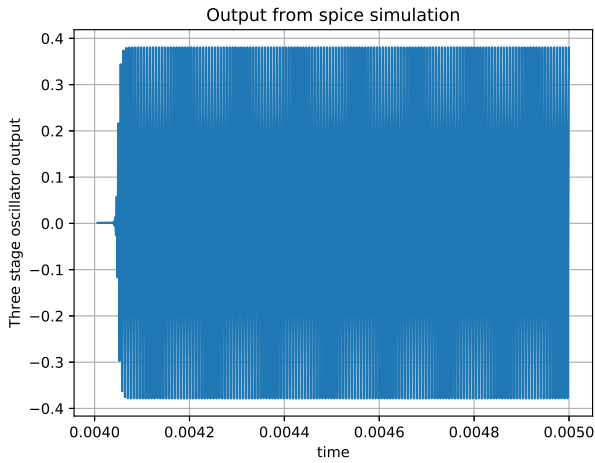


Fig. 8: Output of three stage oscillator

Solution: The following Netlist file is to generate the output from 4.22msec to 4.26msec

```
spice/ee18btech11031/gvv_ngspice2.net
```

The following code generates the variation of output voltage with respect to time.

```
spice/ee18btech11031/
ee18btech11031_ngspice_2.py
```

The data obtained from the above netlist file is plotted in the figure.9. The frequency obtained

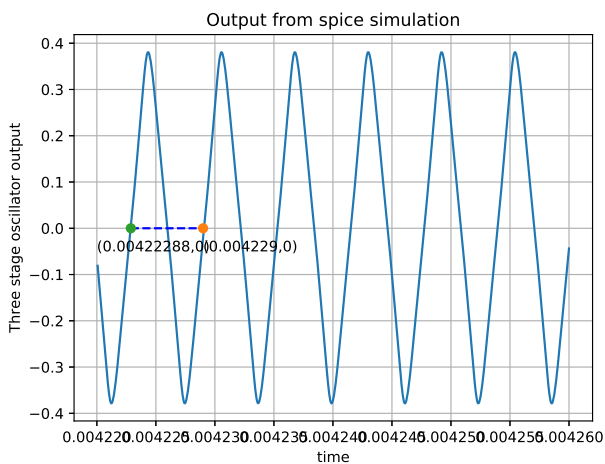


Fig. 9: Output of three stage oscillator

in simulation is as follows.,

$$T_s(spice) = 4.229 \times 10^{-3} - 4.2228 \times 10^{-3} \quad (9.1)$$

$$T_s(spice) = 6.2 \times 10^{-6} \quad (9.2)$$

$$\Rightarrow F_s(spice) = 0.1612 \text{ MHz} \quad (9.3)$$

$$\Rightarrow \omega_s(spice) = 1.012 \text{ Mrad/sec} \quad (9.4)$$

But the obtained value in equation.5.5 is 1.088MHz. Thus, the frequency obtained in the spice simulation is approximately equal to the calculated frequency.