Control Systems

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Contents

***Abstract*—This manual is an introduction to control systems in feedback circuits. Links to sample Python codes are available in the text.**

Download python codes using

```
svn co https://github.com/gadepall/school/trunk/
    control/feedback/codes
```

1 Feedback Voltage Amplifier: Series-Shunt

2 Feedback Current Amplifier: Shunt-Series

2.1 Ideal Case

2.2 Practical Case

3 Feedback Current Amplifier: Example

4 Feedback Transconductance Amplifier: Series-Series

5 Op-Amp RC Oscillator Circuit

5.1. For the circuit in Fig. 5.1.1 (ignore the amplitude stabilization circuitry), find the loop gain GH by breaking the circuit at node X.

5.2. **Solution:** The equivalent control system representation of Oscillator circuit is shown in Fig. 5.2.2. Oscillator circuits do not have input. After removing the amplitude stabilization circuitry, when we break the loop at X, from Fig. 5.2.3 the value of gain

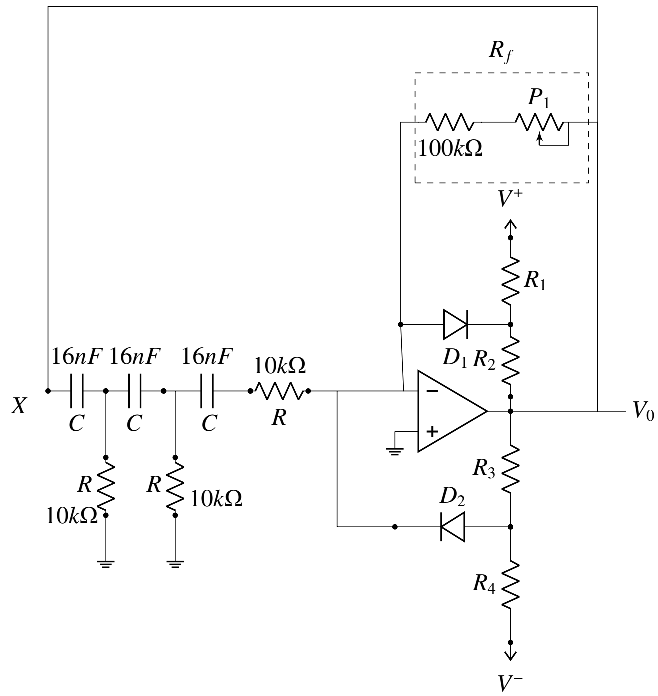

Fig. 5.1.1

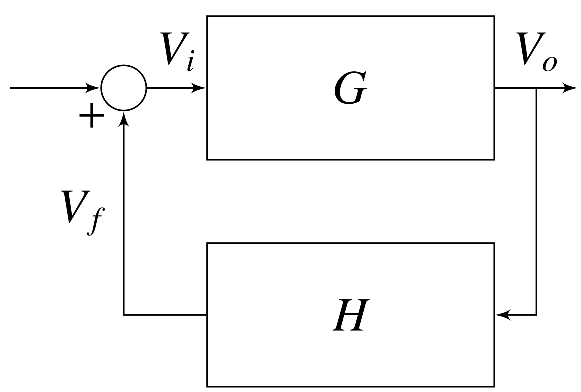

Fig. 5.2.2

$$GH = \frac{v_o(j\omega)}{v_x(j\omega)} \tag{5.2.1}$$

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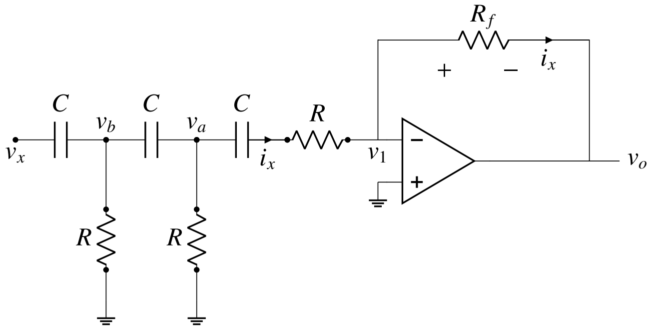

Fig. 5.2.3

$$v_1 = 0 \tag{5.2.2}$$

$$\implies v_o = -i_x R_f \tag{5.2.3}$$

$$v_a = (\frac{1 + sRC}{sC})i_x \tag{5.2.4}$$

$$\implies v_b = (R + \frac{3}{sC} + \frac{1}{s^2C^2R})i_x \tag{5.2.5}$$

$$\implies v_x = (R + \frac{6}{sC} + \frac{5}{s^2C^2R} + \frac{1}{s^3C^3R^2})i_x \tag{5.2.6}$$

$$\implies \frac{v_x}{i_x} = (R + \frac{6}{sC} + \frac{5}{s^2C^2R} + \frac{1}{s^3C^3R^2}) \tag{5.2.7}$$

From (5.2.3)

$$\frac{v_x}{v_o} = -\frac{R}{R_f}(1 + \frac{6}{sCR} + \frac{5}{s^2C^2R^2} + \frac{1}{s^3C^3R^3}) \tag{5.2.8}$$

$$\implies \frac{v_o}{v_x} = -\frac{R_f s^3C^3R^3}{R(s^3C^3R^3 + 6s^2C^2R^2 + 5sCR + 1)} \tag{5.2.9}$$

Substituting $s = j\omega$ gives us the transfer function

$$\frac{v_o}{v_x} = GH = \frac{\omega^2C^2R_fR}{(5 - \omega^2C^2R^2) + j(6\omega CR - \frac{1}{\omega CR})} \tag{5.2.10}$$

5.3. Find frequency of oscillation f_0.
5.4. **Solution:** For system to oscillate at a frequency ω_0,

$$L(j\omega_0) = G(j\omega_0)H(j\omega_0) = 1 \tag{5.4.1}$$

$$\implies \angle(G(j\omega_0)H(j\omega_0)) = 0 \tag{5.4.2}$$

$$\implies 6\omega_0 CR = \frac{1}{\omega_0 CR} \tag{5.4.3}$$

$$\implies \omega_0 = \frac{1}{\sqrt{6}CR} \tag{5.4.4}$$

$$\implies \omega_0 = 2551.55 rad/sec \tag{5.4.5}$$

$$\implies f_0 = 406.1 Hz \tag{5.4.6}$$

5.5. Find R_f for oscillation to begin.
5.6. **Solution:** From (5.4.1)

$$Re(G(j\omega_0)H(j\omega_0)) = 1 \tag{5.6.1}$$

$$\implies \frac{R_f\omega_0^2C^2R}{5 - \omega_0^2C^2R^2} = 1 \tag{5.6.2}$$

$$\implies R_f = 29R \tag{5.6.3}$$

$$\implies R_f = 290k\Omega \tag{5.6.4}$$

Thus, for the oscillations to begin,

$$R_f \geq 290k\Omega \tag{5.6.5}$$

5.7. Tabulate your results.
5.8. **Solution:** See table 5.8

Parameter	**Value**
ω_0	2551.55 rad/s
f_0	406.1 Hz
R_f	$290k\Omega$

TABLE 5.8: calculated parameters

5.9. Verify results using Spice Simulation.
5.10. **Solution:** Following readme provides instructions for simulation in spice

```
codes/ee18btech11050/spice/README.md
```

The following netlist simulates the given circuit in 5.1.1

```
codes/ee18btech11050/spice/
    ee18btech11050_sim.net
```

The following code plots the oscillator output from spice simulation, which is shown in fig 5.10.4

codes/ee18btech11050/spice/ee18btech11050_sim.py

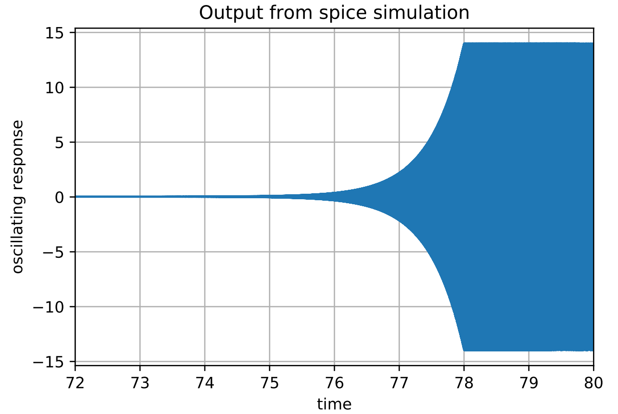

Fig. 5.10.4

The following code plots a part of spice output generated above, where a sinusoidal output can be clearly observed shown in fig 5.10.5

codes/ee18btech11050/spice/ee18btech11050_sim2.py

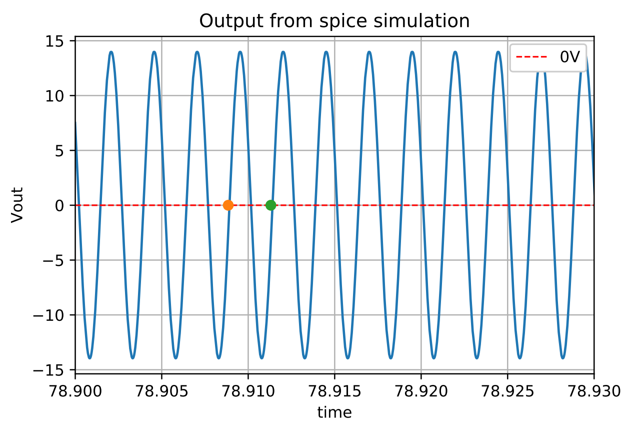

Fig. 5.10.5

From fig 5.10.5, time period is calculated from one cycle:

$$T = 78.91131 - 78.908846 = 0.002464sec \tag{5.10.1}$$

$$\implies f = 405.844Hz \tag{5.10.2}$$

Hence frequency is verified through spice simulation.