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. Note that oscillator circuits do not have a input. After removing the amplitude stabilization circuitry, when we break the loop at X, the value of gain

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

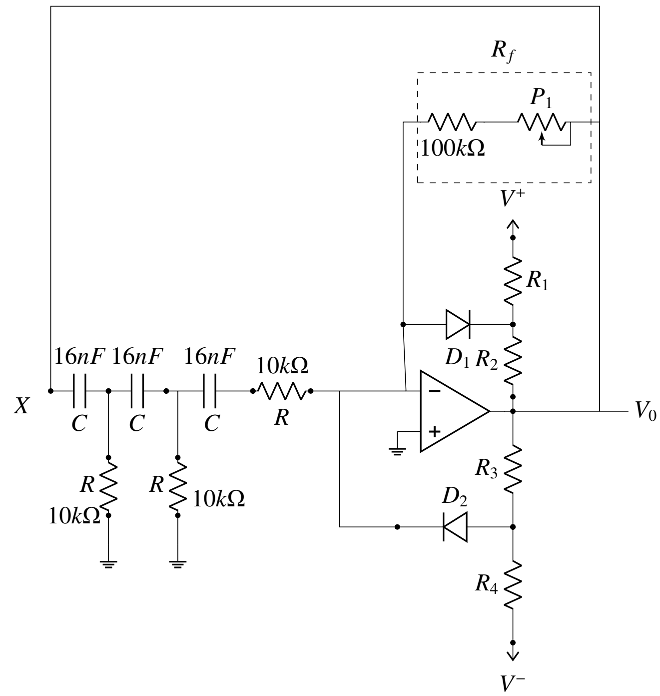

Fig. 5.1.1

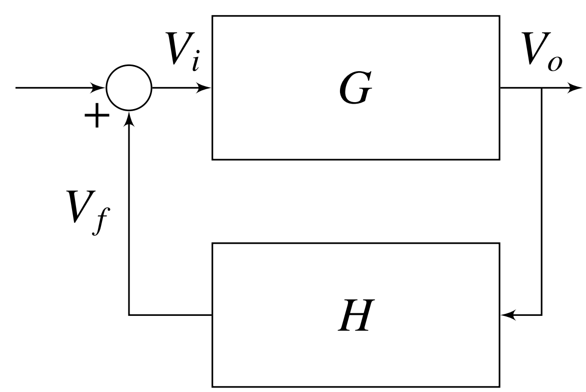

Fig. 5.2.2

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from Fig. 5.2.3

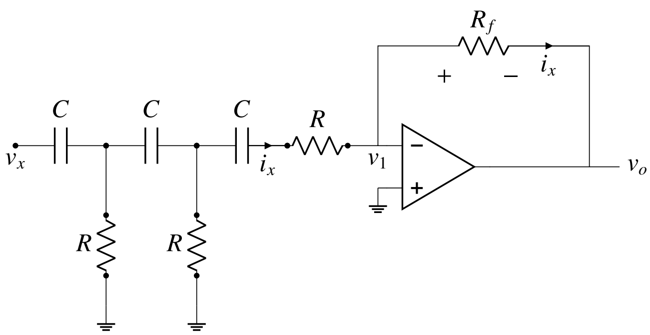

Fig. 5.2.3

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

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

Considering the circuit between node X and inverting terminal of op-amp,

$$\frac{v_x}{i_x} = (R + \frac{6}{sC} + \frac{5}{s^2C^2R} + \frac{1}{s^3C^3R^2}) \tag{5.2.4}$$

From (5.2.3)

$$\frac{v_x}{v_o} = -\frac{R}{R_f}(1 + \frac{6}{sCR} + \frac{5}{s^2C^2R^2} + \frac{1}{s^3C^3R^3}) \tag{5.2.5}$$

$$\implies \frac{v_o}{v_x} = -\frac{R_f s^3C^3R^3}{R(s^3C^3R^3 + 6s^2C^2R^2 + 5sCR + 1)} \tag{5.2.6}$$

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

$$\frac{v_o}{v_x} = GH = \frac{\omega^2C^2R_fR}{(5 - \omega^2C^2R^2) + j(6\omega CR - \frac{1}{\omega CR})} \tag{5.2.7}$$

5.3. Find frequency of oscillation f_0.

5.4. **Solution:** For system to oscillate at a frequency f_0,

$$GH = 1 \tag{5.4.1}$$

$$\implies \angle(GH) = 0 \tag{5.4.2}$$

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

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

$$\implies f_0 = 406.1Hz \tag{5.4.5}$$

5.5. Find R_f for oscillation to begin.

5.6. **Solution:** From (5.4.1)

$$Re(GH) = 1 \tag{5.6.1}$$

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

$$\implies R_f = 290k\Omega \tag{5.6.3}$$

Thus, for the oscillations to begin, R_f should be slighty greater than $290k\Omega$.

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