

# Control Systems

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**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

### 3 FEEDBACK CURRENT AMPLIFIER: SHUNT-SERIES

3.0.1. A dc amplifier having a single-pole response with pole frequency 10Hz and unity-gain frequency of 1MHz is operated in a loop whose frequency-independent feedback factor is 0.01. Find the low-frequency gain, the 3-dB frequency, and the unity-gain frequency of the closed-loop amplifier. By what factor does the pole shift?

**Solution:** The open-loop gain of the amplifier is

$$G(s) = \frac{A_o}{1 + \frac{s}{\omega_p}} = \frac{A_o}{1 + \frac{s}{2\pi \cdot 10}} \quad (3.0.1.1)$$

Given that unity gain frequency is 1MHz  
Replacing  $s$  with  $j\omega$  in this equation.

$$\left| \frac{A_o}{1 + \frac{j \cdot 2\pi \cdot 10^6}{2\pi \cdot 10}} \right| = 1 \quad (3.0.1.2)$$

$$|A_o| = \left| 1 + \frac{2\pi \cdot 10^6}{2\pi \cdot 10} \right| \quad (3.0.1.3)$$

$$A_o \approx 10^5 \quad (3.0.1.4)$$

Block diagram for amplifier is

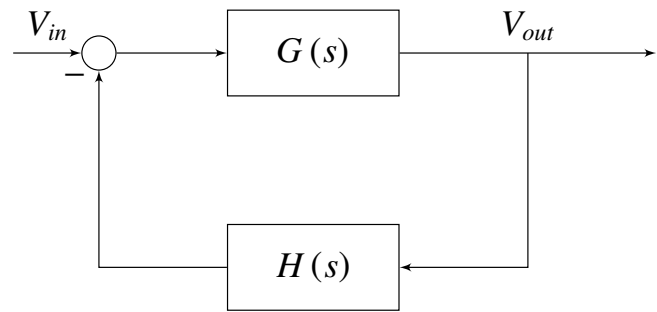


Fig. 3.0.1

Where  $G(s) = \frac{10^5}{1 + \frac{s}{10}}$

3.0.2. Find the low frequency gain of the closed-loop amplifier.

**Solution:** Given that frequency-independent feedback factor of amplifier is 0.01

$$H(s) = 0.01 \quad (3.0.2.1)$$

Closed loop gain of amplifier is given by

$$T(s) = \frac{G(s)}{1 + G(s)H(s)} \quad (3.0.2.2)$$

As frequency is low, substituting  $s = 0$

$$T(0) = \frac{G(0)}{1 + G(0)H(0)} \quad (3.0.2.3)$$

$$= \frac{10^5}{1 + 10^5 \cdot (0.01)} \quad (3.0.2.4)$$

$$= 99.900 \quad (3.0.2.5)$$

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3.0.3. Find the 3-dB frequency of the closed loop amplifier

**Solution:** Substituting  $G(s)$  and  $H(s)$  in (3.0.2.2)

$$T = \frac{\frac{A_o}{1+A_oH(s)}}{1 + \frac{s}{20\pi(1+A_oH(s))}} \quad (3.0.3.1)$$

$$\text{3-dB frequency} = \omega (1 + A_oH(s)) \quad (3.0.3.2)$$

$$= 20\pi \cdot (1 + 10^5 \cdot (0.01)) \quad (3.0.3.3)$$

$$= 62862.8 \text{ rad/s} = 10.01 \text{ kHz} \quad (3.0.3.4)$$

3.0.4. Find the unity gain frequency of the closed loop amplifier

**Solution:** Unity-gain frequency of the closed loop amplifier is obtained as follows

$$|T| = 1 \quad (3.0.4.1)$$

$$\frac{A_o}{1 + A_oH(s)} = \left| 1 + \frac{j\omega}{20\pi(1 + A_oH(s))} \right| \quad (3.0.4.2)$$

$$99.900 = \left| 1 + \frac{j\omega}{62862.8} \right| \quad (3.0.4.3)$$

$$\omega = 6279.649 \text{ Krad/s} = 999.94 \text{ kHz} \quad (3.0.4.4)$$

3.0.5. By what factor does the pole shift?

**Solution:** Open-loop pole is  $\omega$  and the Closed-loop pole is  $\omega (1 + A_oH(s))$

$$\text{Pole-shift Factor} = \frac{\omega (1 + A_oH(s))}{\omega} \quad (3.0.5.1)$$

$$= 1 + A_o\beta = 1001 \quad (3.0.5.2)$$