Contents

***Abstract*—This manual is an introduction to control systems based on GATE problems.Links to sample Python codes are available in the text.**

Download python codes using

1 Stability

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5 Feedback systems

5.0.1. The non-inverting op-amp configuration shown in fig.5.0.1 provides direct implementation of feedback loop.Assuming operational amplifier has infinite input resistance and zero output resitance.Find the expression for feedback factor. **Solution:** Let the gain of the operational amplifier be G. The equivalent circuit of the amplifier is in fig.5.0.1 From the equivalent circuit, Applying Ohms law,

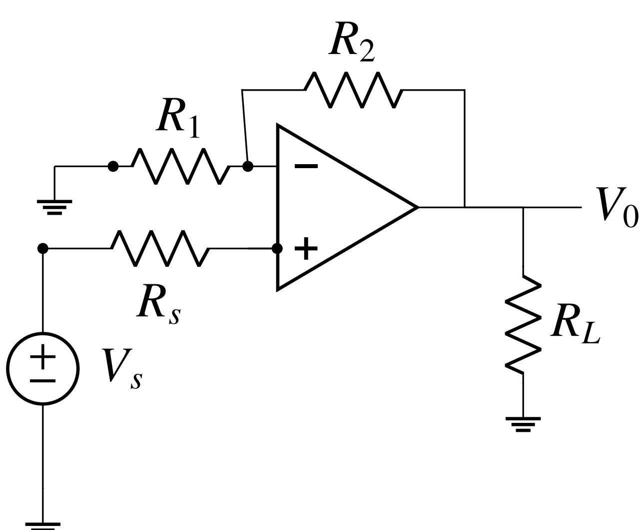

Fig. 5.0.1

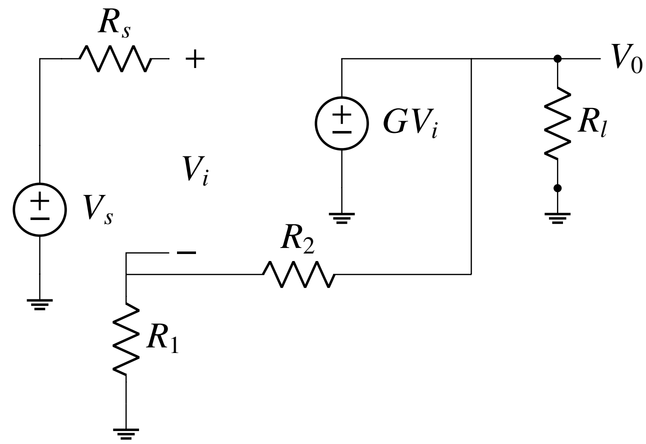

Fig. 5.0.1

$$V_0 = G(V_i) \tag{5.0.1.1}$$

$$\text{and,} V_i = V_+ - V_- \tag{5.0.1.2}$$

Now,Applying voltage dividing rule

$$V_- = \left[\frac{R_1}{R_1 + R_2}\right] V_0 \tag{5.0.1.3}$$

Substituting in equ.5.0.1.1

$$V_0 = G(V_+ - \left[\frac{R_1}{R_1 + R_2}\right] V_0) \tag{5.0.1.4}$$

$$\implies V_0 = GV_+ - G\left[\frac{R_1}{R_1 + R_2}\right] V_0 \tag{5.0.1.5}$$

$$G(V_+) = V_0 + G\left[\frac{R_1}{R_1 + R_2}\right] V_0 \tag{5.0.1.6}$$

But,

$$V_s = V_+ \tag{5.0.1.7}$$

because, no current flows through resistor,Rs Since,input resistance is given infinite in fig.5.0.1 The equation can be written as...,

$$V_0 = G\left[\frac{1}{1 + \frac{GR_1}{R_1+R_2}}\right] V_s \tag{5.0.1.8}$$

$$\text{Gain} = \frac{V_0}{V_s} = \left[\frac{G}{1 + \frac{GR_1}{R_1+R_2}}\right] \tag{5.0.1.9}$$

For a negative feedback system,

$$\frac{V_0}{V_i} = \frac{G}{1 + GH} \tag{5.0.1.10}$$

$$\text{where.,} H = \frac{R_1}{R_1 + R_2} \tag{5.0.1.11}$$

The equation.5.0.1.1 looks exactly similar to the Gain of a negative feedback system with

- Open loop gain = G
- Loop gain = P
- Amount of feedback = F
- Feedback factor = f
- closed loop gain = T

where

$$G = G \tag{5.0.1.12}$$

$$P = GH = G\frac{R_1}{R_1 + R_2} \tag{5.0.1.13}$$

$$F = 1 + GH = 1 + \frac{GR_1}{R_1 + R_2} \tag{5.0.1.14}$$

$$f = H = \frac{R_1}{R_1 + R_2} \tag{5.0.1.15}$$

Therefore,This operational amplifier can be modelled as a negative feedback system shown in the fig.5.0.1 So, the feedback factor f..,

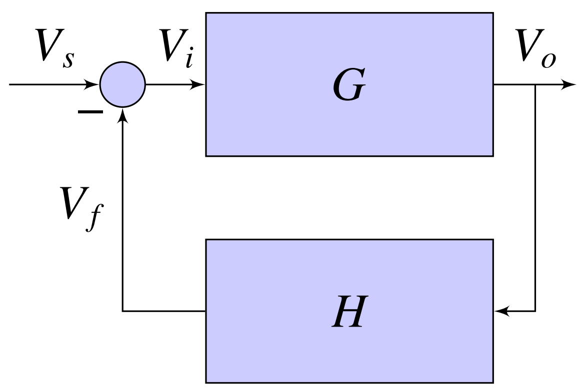

Fig. 5.0.1

$$f = H = \frac{R_1}{R_1 + R_2} \tag{5.0.1.16}$$

5.0.2. Find the condition under which closed loop gain T is almost entirely determined by the feedback network. **Solution:** For T to entirely dependent on feedback network, it should be independent on G(open loop gain) T is given by..,

$$T = \frac{G}{1 + \frac{GR_1}{R_1+R_2}} \tag{5.0.2.1}$$

$$\tag{5.0.2.2}$$

For T to be independent on G..,

$$GH >> 1 \tag{5.0.2.3}$$

$$G\frac{R_1}{R_1 + R_2} >> 1 \tag{5.0.2.4}$$

$$G >> 1 + \frac{R_2}{R_1} \tag{5.0.2.5}$$

Under such condition..,

$$T = \frac{1}{H} \tag{5.0.2.6}$$

$$T = \frac{R_1 + R_2}{R_1} \tag{5.0.2.7}$$

$$T = 1 + \frac{R_2}{R_1} \tag{5.0.2.8}$$

so, the necessary condition for Af depend only on feedback network is

$$G >> T \tag{5.0.2.9}$$

5.0.3. If the open loop voltage gain

$$G = 10^4 \tag{5.0.3.1}$$

Find the ratio of R2 and R1 to obtain a closed loop gain of 10. **Solution:** The closed loop gain gain T is given by

$$T = \frac{G}{1 + GH} = \frac{G}{1 + \frac{GR_1}{R_1+R_2}} = 10 \tag{5.0.3.2}$$

$$\text{where..,} G = 10^4 \tag{5.0.3.3}$$

$$10 = \frac{10^4}{1 + \frac{10^4}{1+\frac{R_2}{R_1}}} \tag{5.0.3.4}$$

$$\implies 1 + \frac{R_2}{R_1} = \frac{10^4}{\frac{10^4}{10} - 1} \tag{5.0.3.5}$$

$$1 + \frac{R_2}{R_1} = 10.010 \tag{5.0.3.6}$$

$$\frac{R_2}{R_1} = 9.010 \tag{5.0.3.7}$$

5.0.4. What is the amount of feedback in decibels? **Solution:** The value of F in decibals is given by

$$F(dB) = 20log(F) \quad (5.0.4.1)$$
$$\text{where..,}F = 1 + GH \quad (5.0.4.2)$$
$$F = \frac{G}{T} \quad (5.0.4.3)$$
$$\text{where..,}G = 10^4 \quad (5.0.4.4)$$
$$T = 10 \quad (5.0.4.5)$$
$$F(dB) = 20log(\frac{10^4}{10}) = 20log(1000) \quad (5.0.4.6)$$
$$F(dB) = 60dB \quad (5.0.4.7)$$

5.0.5. If G decreases by 20%,what is the corresponding decrease in T? **Solution:** Given

$$G = 10^4 \quad (5.0.5.1)$$

If G decrease by 20% then, the value of G is..,

$$G = (1 - 0.2)10^4 \quad (5.0.5.2)$$
$$= 8000 \quad (5.0.5.3)$$

For this value of G and ,

$$\frac{R_2}{R_1} = 9.010 \quad (5.0.5.4)$$

The value of T can be solved as follows,

$$T = \frac{G}{1 + \frac{G}{1+\frac{R_2}{R_1}}} \quad (5.0.5.5)$$
$$T = \frac{8000}{1 + \frac{8000}{1+0.9010}} \quad (5.0.5.6)$$
$$T = 9.99749 \quad (5.0.5.7)$$

The percentage change in T is..,

$$fractionalchange = \frac{10 - 9.99749}{10} \quad (5.0.5.8)$$
$$= 2.51x10^{-4} \quad (5.0.5.9)$$
$$\%changeinT = 0.00251 \quad (5.0.5.10)$$

Therefore T decreases by 0.0025% when G decreases by 20%