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

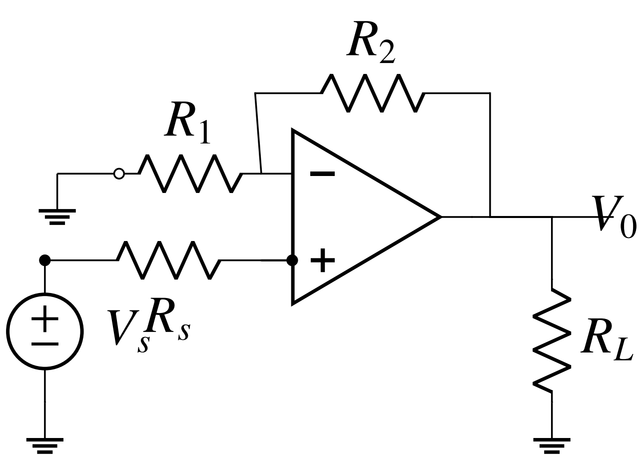

Fig. 5.0.1

amplifier be A. The equivalent circuit of the amplifier is in fig.5.0.1 From the equivalent circuit, Applying Ohms law,

$$V_0 = A(V_+ - V_-) \tag{5.0.1.1}$$

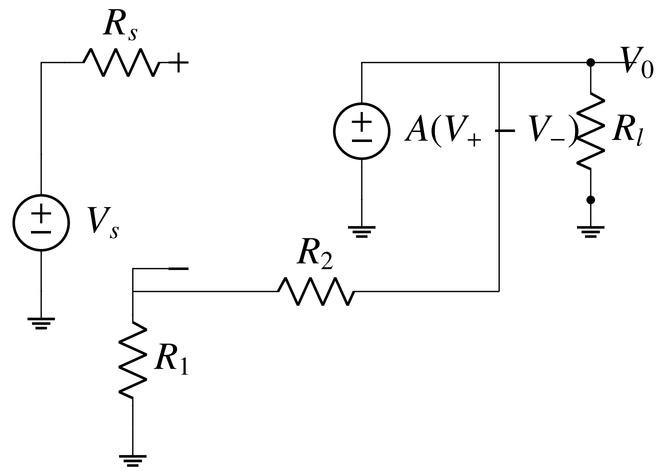

Fig. 5.0.1

Now,Applying voltage dividing rule

$$V_- = \left[\frac{R_1}{R_1 + R_2}\right] V_0 \tag{5.0.1.2}$$

Substituting in equ.5.0.1.1

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

$$\implies V_0 = AV_+ - A\left[\frac{R_1}{R_1 + R_2}\right] V_0 \tag{5.0.1.4}$$

$$A(V_+) = V_0 + A\left[\frac{R_1}{R_1 + R_2}\right] V_0 \tag{5.0.1.5}$$

But,

$$V_s = V_+ \tag{5.0.1.6}$$

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

$$V_0 = A\left[\frac{1}{1 + \frac{AR_1}{R_1+R_2}}\right] V_s \tag{5.0.1.7}$$

$$\text{Gain} = \frac{V_0}{V_s} = \left[\frac{A}{1 + \frac{AR_1}{R_1+R_2}}\right] \tag{5.0.1.8}$$

For a negative feedback system,

$$\frac{V_0}{V_i} = \frac{A}{1 + A\beta} \tag{5.0.1.9}$$

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

- Open loop gain = A
- Loop gain = P
- Amount of feedback = F

- Feedback factor = f

where

$$A = A \tag{5.0.1.10}$$

$$P = A\beta = A\frac{R_1}{R_1 + R_2} \tag{5.0.1.11}$$

$$F = 1 + A\beta = 1 + \frac{AR_1}{R_1 + R_2} \tag{5.0.1.12}$$

$$f = \beta = \frac{R_1}{R_1 + R_2} \tag{5.0.1.13}$$

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

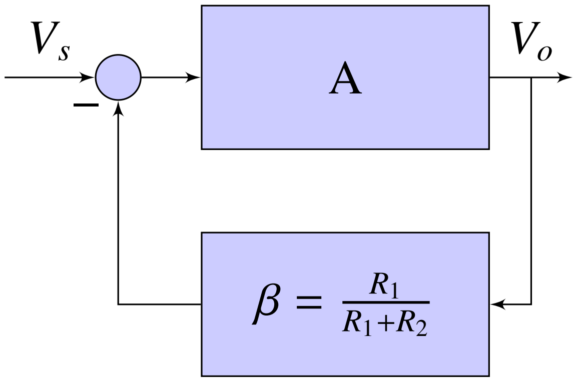

Fig. 5.0.1

$$f = \beta = \frac{R_1}{R_1 + R_2} \tag{5.0.1.14}$$

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

$$A_f = \frac{A}{1 + A\beta} \tag{5.0.2.1}$$

$$\tag{5.0.2.2}$$

For Af to be independent on A..,

$$A\beta >> 1 \tag{5.0.2.3}$$

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

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

Under such condition..,

$$A_f = \frac{1}{\beta} \tag{5.0.2.6}$$

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

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

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

$$A >> A_f \tag{5.0.2.9}$$

5.0.3. If the open loop voltage gain

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

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

$$A_f = \frac{A}{1 + A\beta} = \frac{A}{1 + \frac{AR_1}{R_1+R_2}} = 10 \tag{5.0.3.2}$$

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

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

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

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

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

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

$$F(dB) = 20log(F) \tag{5.0.4.1}$$

$$\text{where..,}F = 1 + A\beta \tag{5.0.4.2}$$

$$F = \frac{A}{A_f} \tag{5.0.4.3}$$

$$\text{where..,}A = 10^4 \tag{5.0.4.4}$$

$$A_f = 10 \tag{5.0.4.5}$$

$$F(dB) = 20log(\frac{10^4}{10}) = 20log(1000) \tag{5.0.4.6}$$

$$F(dB) = 60dB \tag{5.0.4.7}$$

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

$$A = 10^4 \tag{5.0.5.1}$$

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

$$A = (1 - 0.2)10^4 \tag{5.0.5.2}$$
$$= 8000 \tag{5.0.5.3}$$

For this value of A and ,

$$\frac{R_2}{R_1} = 9.010 \tag{5.0.5.4}$$

The value of Af can be solved as follows,

$$A_f = \frac{A}{1 + \frac{A}{1+\frac{R_2}{R_1}}} \tag{5.0.5.5}$$
$$A_f = \frac{8000}{1 + \frac{8000}{1+0.9010}} \tag{5.0.5.6}$$
$$A_f = 9.99749 \tag{5.0.5.7}$$

The percentage change in Af is..,

$$fractionalchange = \frac{10 - 9.99749}{10} \tag{5.0.5.8}$$
$$= 2.51x10^{-4} \tag{5.0.5.9}$$
$$\%changeinA_f = 0.00251 \tag{5.0.5.10}$$

Therefore Af decreases by 0.0025% when A decreases by 20%