Control Systems

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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

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

1 Compensators

1.1. For the control system shown in 1.1 write the steady state output for step input.
Solution:

$$\lim_{t\to\infty} y(t) = \lim_{s\to 0} sY(s) \tag{1.1.1}$$

$$\lim_{s\to 0} sY(s) = \lim_{s\to 0} \frac{sR(s)}{1+G(s)} \tag{1.1.2}$$

$$\lim_{s\to 0} sY(s) = \frac{1}{1+\lim_{s\to 0} G(s)} \tag{1.1.3}$$

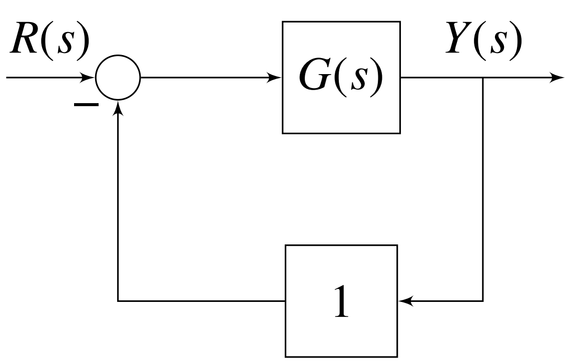

Fig. 1.1

1.2. What do you mean by steady state error and write the expression for steady state error for control system shown in 1.1 considering step input.
Solution: Steady-state error is the difference between the input and the output for a prescribed test input as time tends to infinity.

$$e_{ss} = \lim_{s\to 0} \frac{1}{1+G(s)} \tag{1.2.1}$$

1.3. Refer the definition and calculating phase margin in section 9.
Solution:

1.4. Write the general expression for the transfer function of a phase lead compensator.
Solution:

$$G_c(s) = K_{comp}\alpha\frac{(1+\frac{s}{z})}{(1+\frac{s}{p})} \tag{1.4.1}$$

$$\alpha = \frac{z}{p} \tag{1.4.2}$$

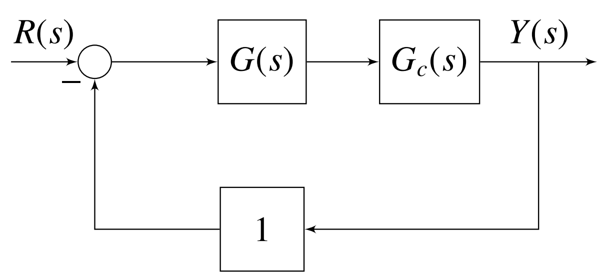

Fig. 1.4

1.5. What are the steps involved in designing a lead compensator, explain briefly.
Solution:
- Add poles at the origin so that steady state error (generally ramp input is taken) becomes finite.
- find the value of K_{comp} from the desired value of steady state error.
- Check whether the system satisfies the phase margin criterion.
- If not then calculate the additional phase to be added at w_{gc}. considering the small change in w_{gc}.

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- Now calculate α, z and p as we know the maximum phase and the frequency at which it occurs.
- If designed compensator does not satisfy the required criterion then add a bit more phase to compensate for shift in w_{gc}.

1.6. For a unity feedback system shown in Fig.1.2, $\frac{K}{s(s+1)}$. Design a lead compensator such that the phase margin of the system is 45° and appropriate steady state error is less than or equal to $\frac{1}{15}$ units of the final output value. Further the gain crossover frequency of the system must be less than 7.5rad/sec.

Solution: For the following reasons, i think this problem cannot be solved

- Let us find K_{comp} from the desired steady state error(generally step function or ramp function is considered as input).
- Using equations 1.1.3 and 1.2.1 steady state value for step input is 1 and steady state error for step input is 0.
- As the steady state error is always zero the value of K_{comp} can be anything.
- For ramp input, steady state error is finite but steady state value of output is infnity, so no value of K_{comp} can satisfy the desired steady state error condition.
- unique K_{comp} cannot be found which satisfies the desired conditions.
- Calculating the phase margin of given system is a necessary step as we would know the phase to be added to achieve the desired phase margin, but phase margin of given system cannot be calculated without the knowledge of K.

1.7. Plot how phase margin is varying as K is varying

Solution:

```
codes/EE18BTECH11044_2.py
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