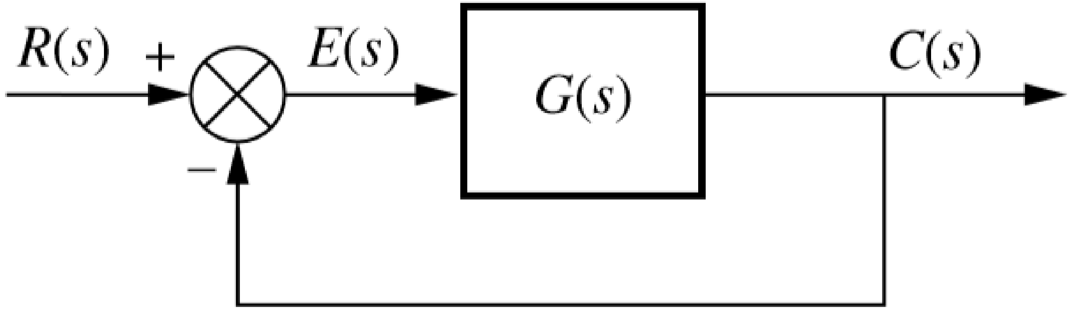
Review Questions of Root Locus, Bode Plots and Nyquist Plots

Root Locus

- Typically transient response and steady state response specifications will be given.
- Transient response – percentage overshoot, settling time, peak time etc.
- Steady state error – Positions constant (Kp), Velocity Constant (Kv), Acceleration Constant (Ka)
- Useful, in viewing compensation required to meet these requirements.
- May require a simple proportional or, PD or PI or PID to meet requirements.
- Not always possible to use PD, PI or PID so we use lead, lag and lead-lag compensators.

Consider the unity feedback system



$$G(s) = \frac{K}{(s+4)^3}$$

a. Find the location of the dominant poles to yield a 1.6 second settling time and an overshoot of 25%.

b. If a compensator with a zero at −1 is used to achieve the conditions of Part **a**, what must the angular contribution of the compensator pole be?

c. Find the location of the compensator pole.

d. Find the gain required to meet the requirements stated in Part **a**.

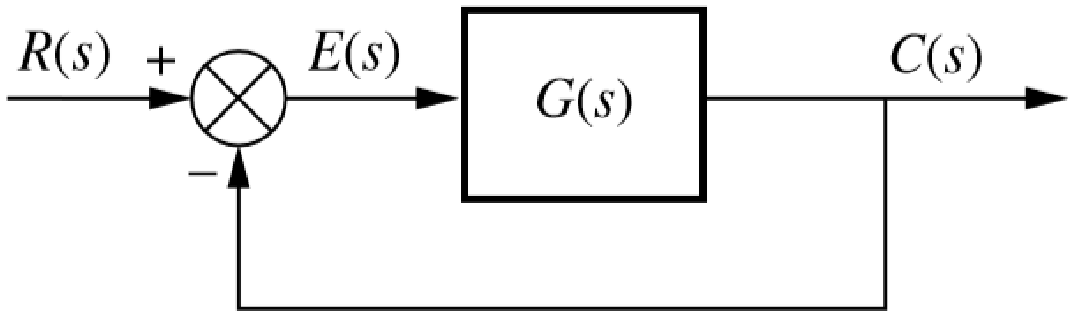
e. Find the location of other closed-loop poles for the compensated system.

f. Discuss the validity of your second-order approximation.

g. Use MATLAB or any other computer program to simulate the compensated system to check your design.

MATLAB
ML

Consider the unity feedback system



$$G(s) = \frac{K}{s(s+5)(s+11)}$$

do the following: [Section: 9.4]

a. Find the gain, K, for the uncompensated system to operate with 30% overshoot.

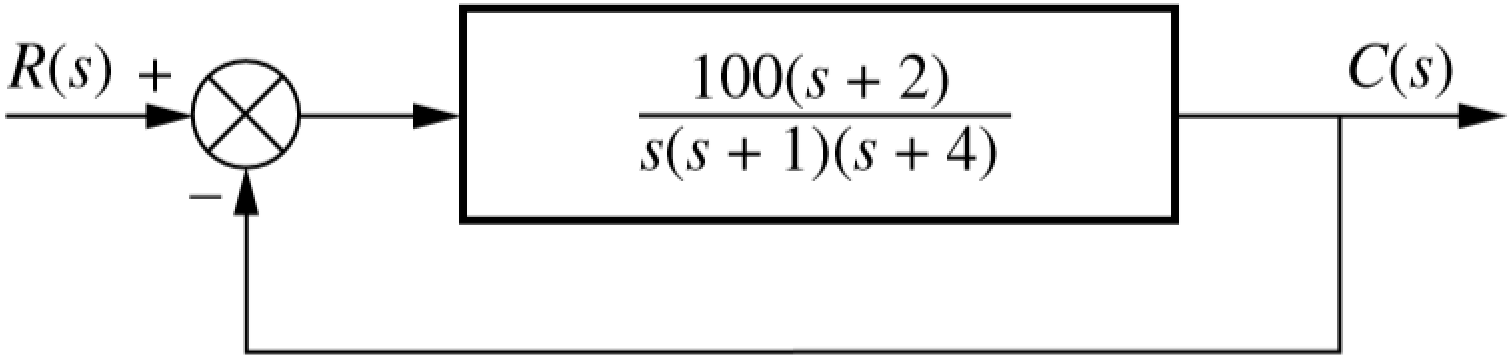
b. Find the peak time and K_v for the uncompensated system.

c. Design a lag-lead compensator to decrease the peak time by a factor of 2, decrease the percent overshoot by a factor of 2, and improve the steady-state error by a factor of 30. Specify all poles, zeros, and gains.

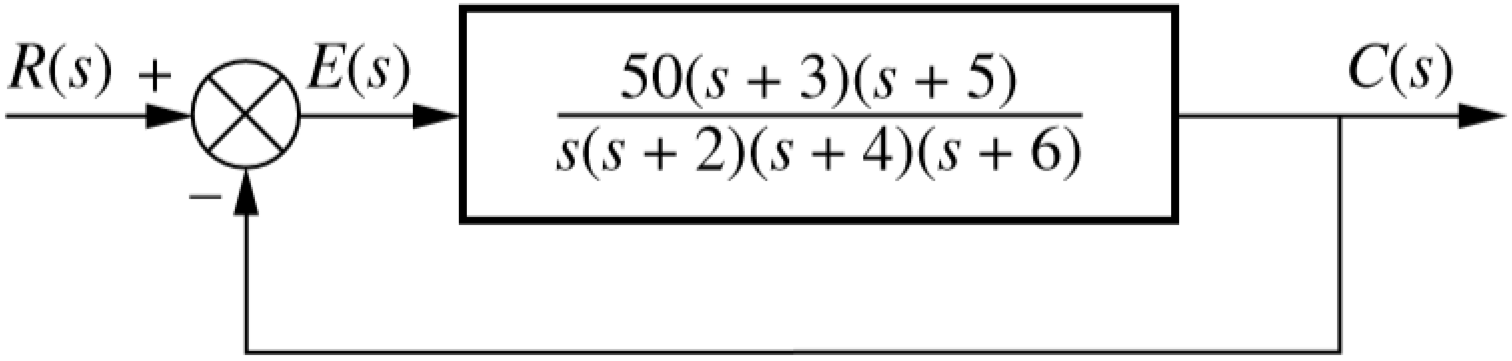
Bode Plot

- Useful in viewing compensators. More natural way.
- Exact knowledge of TF is required.
- Specifications may be in the form of PM and GM.
- From there one may check for the transient response requirement.

Using Bode plots, estimate the transient response of the systems

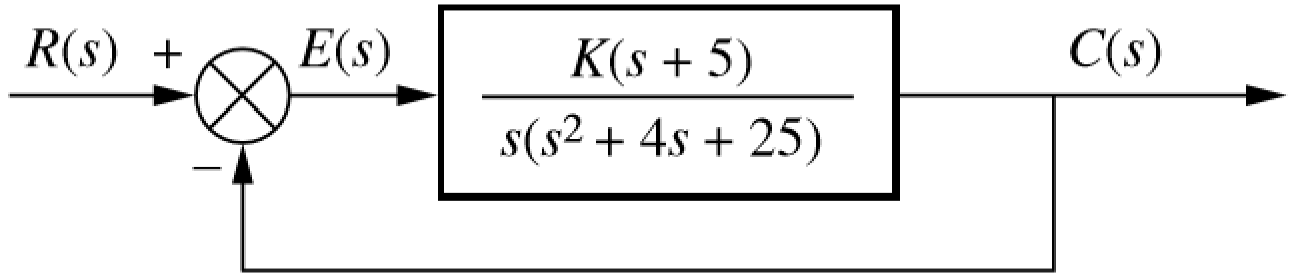


System 1



System 2

For the system



a. Plot the Bode magnitude and phase plots.

b. Assuming a second-order approximation, estimate the transient response of the system if $K = 40$.

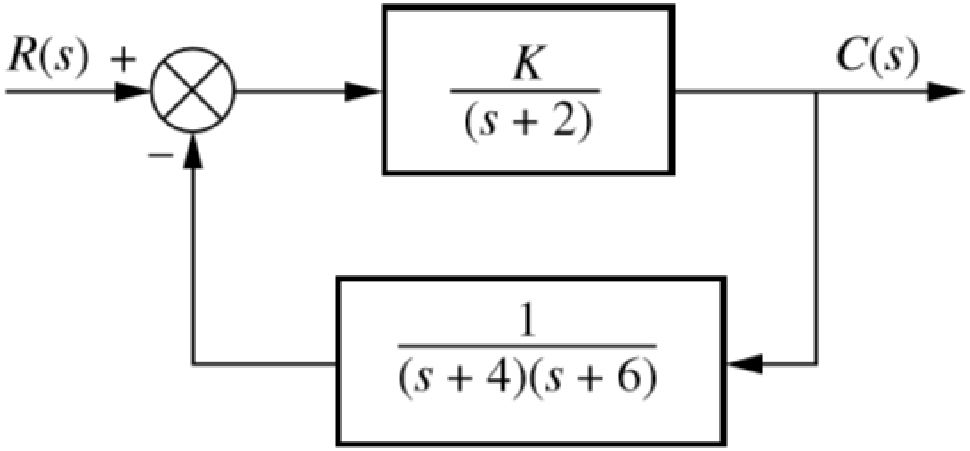
c. `Use MATLAB or any other program to check your assumptions by simulating the step response of the system.`

MATLAB ML

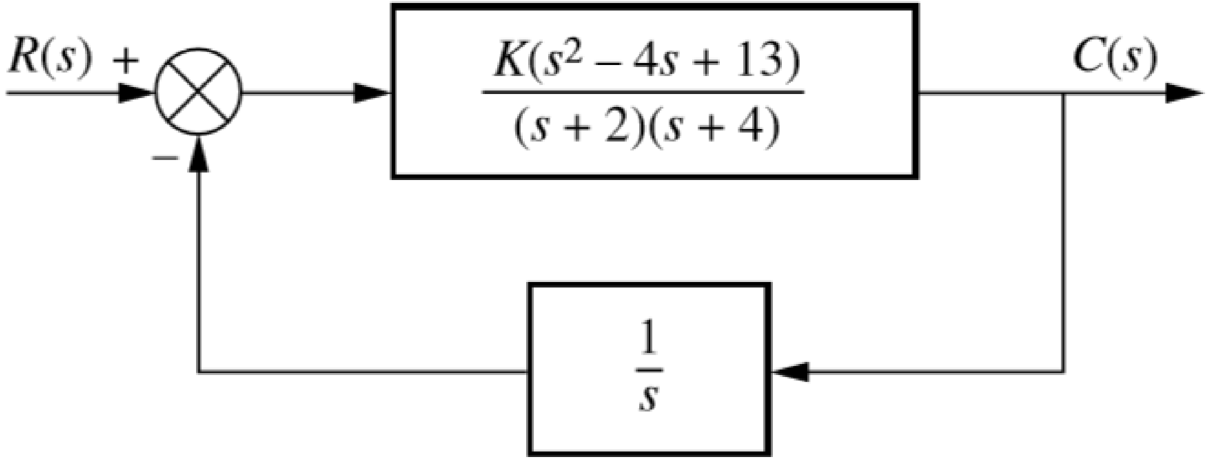
Nyquist Plots

- Useful in determining stability and how close to instability, without solving for the characteristic equations.
- Back in the day it was a big deal to solve the characteristic equation.
- GM and PM are easily viewed in Nyquist Plots

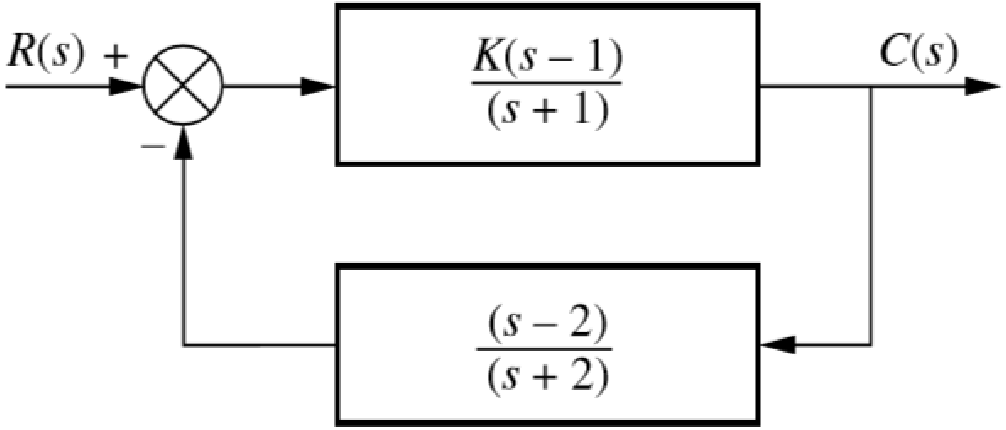
Using the Nyquist criterion, find the range of K for stability for each of the systems



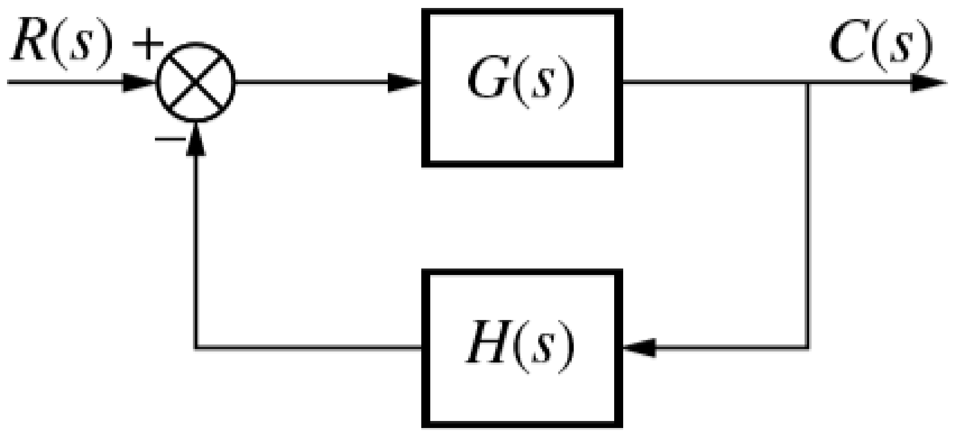
System 1



System 2



System 3



The linearized model of a particular network link working under TCP/IP and controlled using a random early detection (RED) algorithm can be described where $G(s) = M(s)P(s)$, $H = 1$, and

$$M(s) = \frac{0.005L}{s + 0.005}; \; P(s) = \frac{140625e^{-0.1s}}{(s + 2.67)(s + 10)}$$

let $L = 0.8$, but assume that the amount of delay is an unknown variable.

a. Plot the Nyquist diagram of the system for zero delay, and obtain the phase margin.

b. Find the maximum delay allowed for closed-loop stability.

Design problems

You will be given either,

- ✓Percentage overshoot and rise time/peak time/settling time
- ✓Or
- ✓PM and GM

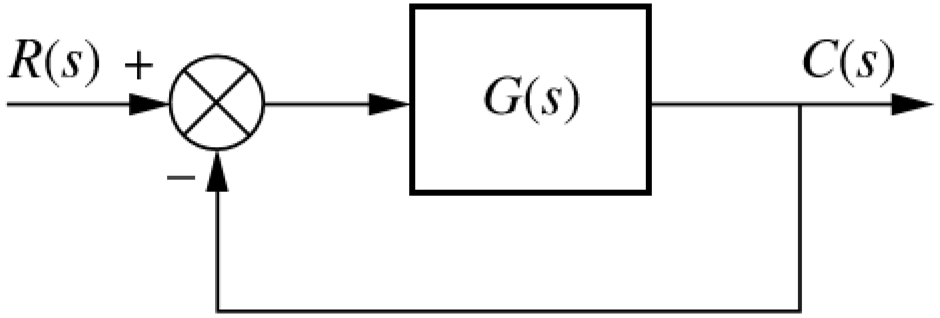
And you may also be given Kp/Kv/Ka to be met.

You have to choose the best technique to solve unless otherwise specified.

The unity feedback system of with

$$G(s) = \frac{K}{s(s+7)}$$

is operating with 15% overshoot. Using frequency response techniques, design a compensator to yield $K_v = 50$ with the phase-margin frequency and phase margin remaining approximately the same as in the uncompensated system.



Design a compensator for the unity feedback system of with

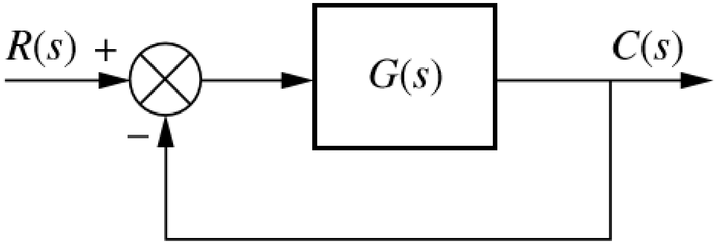
$$G(s) = \frac{K}{s(s+3)(s+15)(s+20)}$$

to yield a $K_v = 4$ and a phase margin of 40°.

Use frequency response methods to design a lag-lead compensator for a unity feedback system where

$$G(s) = \frac{K(s+7)}{s(s+5)(s+15)}$$

and the following specifications are to be met: percent overshoot = 15%, settling time = 0.1 second, and $K_v = 1000$.



Control of HIV/AIDS. the linearized model for an HIV/AIDS patient treated with RTIs was shown to be

$$P(s) = \frac{Y(s)}{U_1(s)} = \frac{-520s - 10.3844}{s^3 + 2.6817s^2 + 0.11s + 0.0126}$$

$$= \frac{-520(s + 0.02)}{(s + 2.2644)(s^2 + 0.04s + 0.0048)}$$

It is assumed here that the patient will be treated and monitored using the closed-loop configuration shown in Figure Since the plant has a negative dc gain, assume for simplicity that $G(s) = G_c(s)\,P(s)$ and $G_c(0) < 0$. Assume also that the specifications for the design are (1) zero steady-state error for step inputs, (2) overdamped time-domain response, and (3) settling time $T_s \approx 100$ days

a. The overdamped specification requires a $\Phi_M \approx 90°$. Find the corresponding bandwidth required to satisfy the settling time requirement.

b. The zero steady-state error specification implies that the open-loop transfer function must be augmented to Type 1. The –0.02 zero of the plant adds too much phase lead at low frequencies, and the complex conjugate poles, if left uncompensated within the loop, result in undesired oscillations in the time domain. Thus, as an initial approach to compensation for this system we can try

$$G_c(s) = \frac{-K(s^2 + 0.04s + 0.0048)}{s(s + 0.02)}$$

For $K = 1$, make a Bode plot of the resulting system. Obtain the value of K necessary to achieve the design demands. Check for closed-loop stability.

c. Simulate the unit step response of the system using MATLAB. Adjust K to achieve the desired response.