CAIRO UNIVERSITY
ELECTRONICS & COMMUNICATIONS DEP.
CONTROL ENGINEERING

FACULTY OF ENGINEERING
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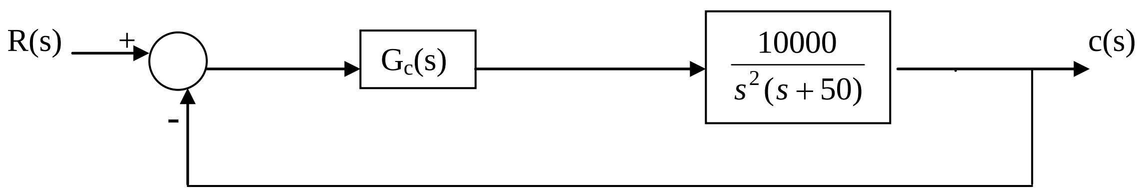
SHEET 4

PID Controller

[1] The block diagram of a type 2 system with a cascade controller $G_c(s)$ is shown in figure. The objective is to design a controller $G_c(s)$ so that:

- Maximum overshoot < 10%
- Settling time <1

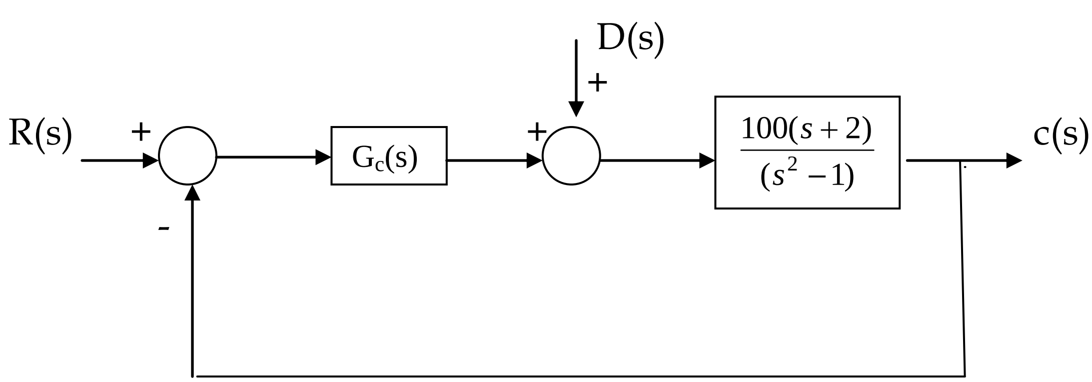
Design the controller that satisfies the performance specifications given above.



[2] The block diagram of a guided missile attitude control system is shown in figure r(t) is the reference input and d(t) represents the disturbance. The objective of this problem is to study the effect of the controller $G_c(s)$.

a. Let $G_c(s)=1$. Find the steady state error when r(t)is a unit step function.
b. Let $G_c(s)= (s+5)/s$. find the steady state error when r(t) is a unit step.
c. Set r(t)=0, $G_c(s)= (s+5)/s$. Find the steady state error when d(t) is a unit step.

What is the effect of the proportional controller in part a and proportional plus integral controller in part b on the steady state response of the system?

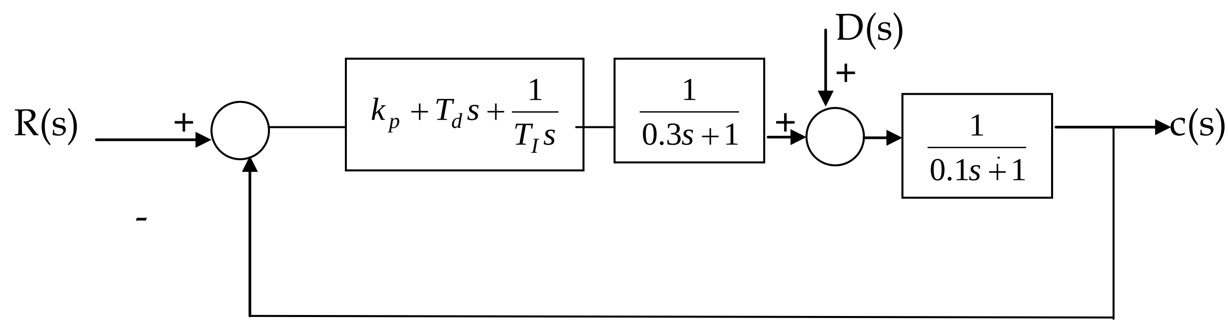


[3] (Final 2000) Consider a unity feedback controller system whose feedforward transfer function is:

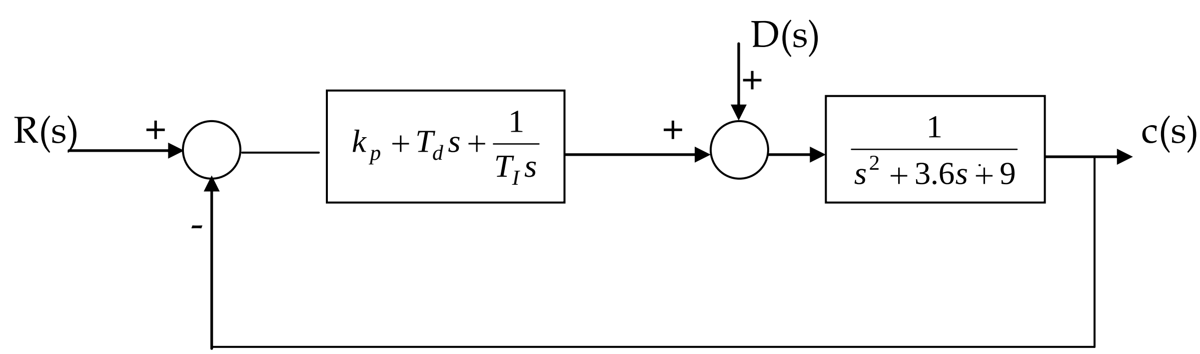
$$G(s) = \frac{2}{s(s+2)(s+8)}$$

a. Find the static error coefficients and the error series for unit ramp input.
b. Design a compensator so that the closed loop dominant poles are located at $s = -1 \pm j2\sqrt{3}$

[4](Final 98) A control system with a type 0 process and PID controller is shown in figure . Design the parameters of the PID controller so that the following specifications are satisfied:
a. Settling time ≤ 0.2
b. Max. Overshoot ≤ 5 percent.
c. Steady state error due to unit step disturbance =zero.



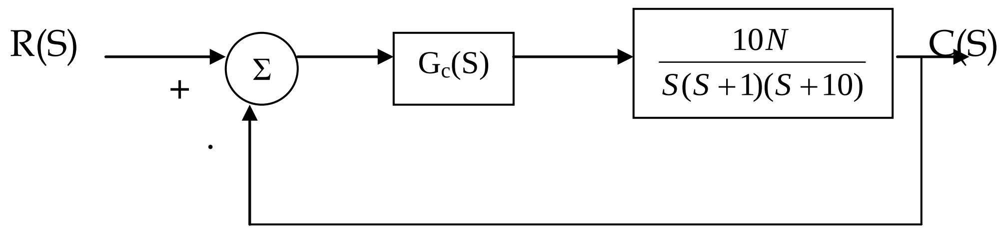
[5] The system shown in figure is a PID control of a second order plant G(s). It is assumed that the reference input r(t) is normally held constant and the response characteristics to disturbance are of a very important consideration in this system. The specifications require that the response to the unit step disturbance is such that the setting time is 2 sec. and the system has a reasonable damping. Design PID controller that achieves the above specifications. Then obtain the improvement in the steady state error to the unit step disturbance input.



[6](Final2001)Figure (2) shows the block diagram of the liquid level control system. The liquid level is represented by c(t), and N denotes the number of inlets. It is desired that N=20.
Design a controller $G_c(S)$ such that:

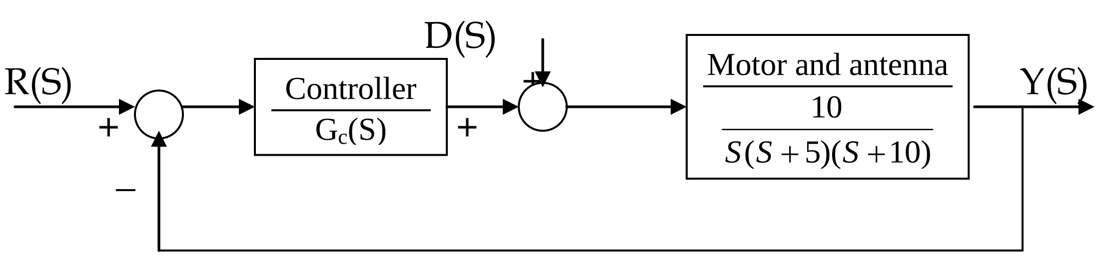
- The overshoot is zero.
- The tank is filled to the reference level within 2.5 sec.

What is the effect of the controller on the steady state response? And why?



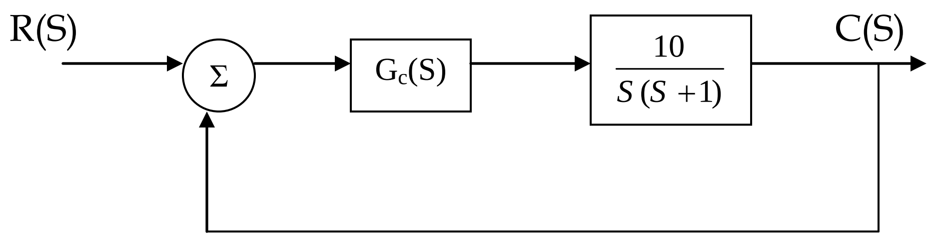
[7](Final 2003)A large antenna is used to receive satellite signals and must accurately track the satellite as it moves across the sky. The control system uses an armature controlled motor and a controller to be selected as shown in Figure. The system specifications require an overshoot to a step input less than or equal 10% with a settling time less than or equal 2 seconds.

- Design a controller $G_c(S)$ to achieve the required specifications and plot the resulting response.
- Determine the effect of the disturbance [D(S)=Q/S] on the steady state output.



[8](Final 2004)Consider the control system shown in the fifure.Design a compansator such that the following specifications are satisfied:

The steady state error to unit ramp input is eliminated.
One of the dominant closed loop poles is located at : $s = -2 + j\sqrt{6}$



[9](Final 2003) Consider a unity feedback control system with the forward transfer function:

$$G(S) = \frac{1}{(S+1)(S^2+2S+3)}$$

PID controller of the form: $G_c(S) = K_p(1 + T_d S + \frac{1}{T_I S})$ is used to achieve a reasonable transient response. Apply the second method of Ziegler-Nichols tuning rules t determine the values of the parameters K_p, T_d and T_I.

[10](Final 2004) Consider a unity feedback control system with the forward transfer function:

$$G(S) = \frac{1}{S(S+1)(S+3)}$$

PID controller of the form: $G_c(S) = K_p + K_d S + \frac{K_i}{S}$ is used to achieve a reasonable transient response. Apply the second method of Ziegler-Nichols tuning rules t determine the values of the parameters of the controller.

Summary:

1. ***P controller:***

$$\boxed{G_c(S) = K_p}$$

Specifications:

- Improve $e_{s.s}$ to a certain value.
- Decrease the damping in the system(the system is more oscillatory)
- As $K_p \uparrow\uparrow$, $e_{ss} \downarrow\downarrow$, $\zeta \downarrow\downarrow$.

2. ***PI controller:***

$$\boxed{G_c(S) = K_p(1+\frac{1}{T_i S}) \text{ or } (K_p + \frac{K_i}{S})}$$

Specifications:

- Used to achieve *steady state specifications*.
- Eliminate the steady state error.
- Increase the settling time of the system.

3. ***PD controller:***

$$\boxed{G_c(S) = K_p(1+T_d S) \text{ or } (K_p + K_d S)}$$

Specifications:

- Used to achieve *transient response specifications* or *a desired location of the dominant poles*.
- Improve the transient response ($M_p \downarrow\downarrow, t_s \downarrow\downarrow$).
- Adds damping to the system ($\zeta \uparrow\uparrow$) and thus permits the use of larger value of the gain K, which will decrease e_{ss}.

4. ***PID controller:***

$$\boxed{G_c(S) = K_p(1+T_d S + \frac{1}{T_i S}) \text{ or } (K_p + K_d S + \frac{K_i}{S})}$$

Specifications:

- Used to achieve *transient response specifications* and *steady state specifications*
- Improve the transient response ($M_p \downarrow\downarrow, t_s \downarrow\downarrow$) and eliminate the steady state error.

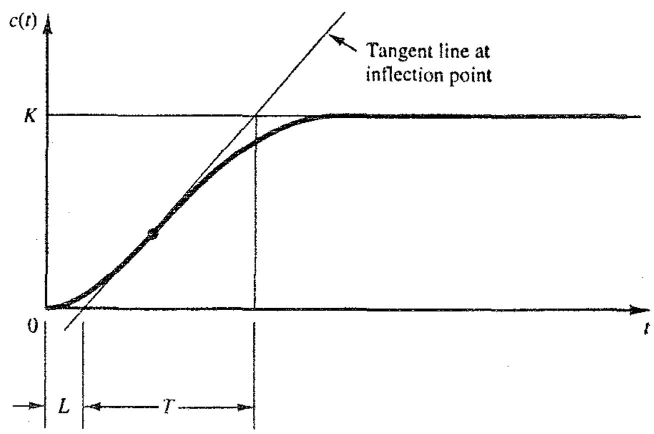
5. *Tuning Rules For PID Controller:*

- ***Ziegler – Nichols Rule:***

a) *Method 1:*

1) Obtain experimentally the response of the plant to a unit step input.
2) Such a unit response curve may look like an S-shaped curve as shown in the figure, if not, this method does not apply.
3) Determine the values of both K, T and L (from graph).
4) The equation of the PID is: $G_c(S) = 1.2\frac{T}{L}(1 + \frac{1}{2LS} + 0.5LS)$.

$$\frac{C(S)}{R(S)} = \frac{Ke^{-LS}}{1+TS}$$



b) *Method 2:*

1) Set $T_i = \infty, T_d = 0$.(use only the proportional mode)
2) Increase K_p from 0 to K_{cr} where the output exhibits sustained oscillations (if the output does not oscillate for whatever value K_p, then this method does not apply).
3) Determine both values of K_{cr} and P_{cr} where P_{cr} is the corresponding period of oscillation (see the figure).

- *NOTE:* we use routh criteria to get both K_{cr} and P_{cr} .

4) The equation of the PID is: $G_c(S) = 0.6K_{cr}(1 + \frac{1}{0.5P_{cr}S} + 0.125P_{cr}S)$.