$T_s = \frac{4}{\zeta\omega_n} = 4$

$s = -\zeta\omega_n \pm \omega_n\sqrt{1-\zeta^2}$

ME 431/862 Control Systems I
Final- December 2003

Time: 3 hours
Instructor: S. Habibi

Instructions: **1- <u>Answer ONLY 4 questions</u>**

2- Calculators are allowed
3- Students may bring up to 2 pages of letter-size notes
4- all questions carry equal marks

Q1: For a system with the following open-loop transfer function:

$$G(s) = \frac{1}{s(s+10)}$$

a) Draw the Bode gain and phase approximations
b) Graphically show the gain and phase margins on the Bode plots and obtain their value.
c) Assuming unity feedback, design a proportional controller that will have the maximum proportional gain without infringing on the stability requirements of 8db gain margin or 45 degree phase margin.
d) Add rate feedback to the system obtained from section c) and draw the block diagram of this system with the added rate feedback. Calculate the gain associated with the rate feedback for achieving critical damping.
e) What is the steady state error of your closed loop system obtained from (d) given a unit step input.
f) How is your design affected if the open transfer function is changed: to:

$$G(s) = \frac{100}{(s+10)(s+100)\left(\frac{s}{10000}+1\right)}$$. Explain why.

Q2: For a system with the following open-loop transfer function:

$$G(s) = \frac{1}{(s-1)(s+1)}$$

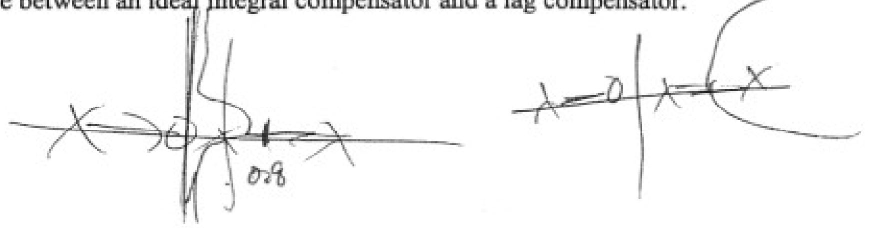
a) Design a PID controller by using the root locus design method. In this design:
   i. Assume unity feedback
   ii. Place at least one zero at –0.1
   iii. Achieve zero steady state error, a settling time of Ts=4 seconds, and a damping ratio of $\zeta = 0.707$.
b) Draw the block diagram of the system with its PID controller; in this diagram, clearly show the numerical values and structure of all transfer functions (that of the system and its PID compensator).
c) How is the system's performance affected when the following gains are changed:
   i. Proportional Gain
   ii. Integral Gain
   iii. Derivative Gain

Q3: a) Describe the process and the steps used in plotting a root locus diagram. Demonstrate each step of this process by applying it to the following open loop transfer function:

$$G(s) = \frac{K(s+1)}{s(s-2)(s+4)}$$

<u>(Your answer MUST contain a clear explanation of how the root locus is derived, including the process and the equations that are used. A root locus plot in its final form is NOT sufficient).</u>

b) For what values of K is the system stable in a closed loop unity feedback configuration.
c) What is the value of K that results in a marginally stable closed loop system
d) Explain the difference between an ideal integral compensator and a lag compensator.



Q4)

a) The response of a system to a unit step is given in Figure 4.1. Design a PID controller for this system by using the Ziegler Nichols method.

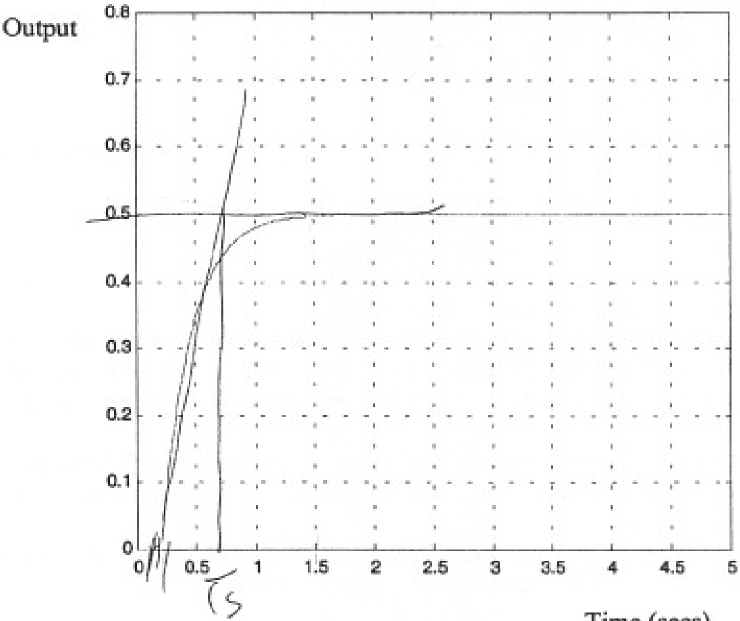


Fig: 4.1

b) Describe the Ziegler Nichols design process that can be applied to a system that exhibits a second order response characteristic.

c) A high order system with unity feedback and a proportional gain of 20 exhibits the oscillatory response of Figure 4.2 when subjected to a step input. Design a PID controller for this system by using the Ziegler Nichols methods.

d) Draw the block diagram of the system with its PID controller; in this diagram, clearly show the numerical values and the structure of the PID compensator.

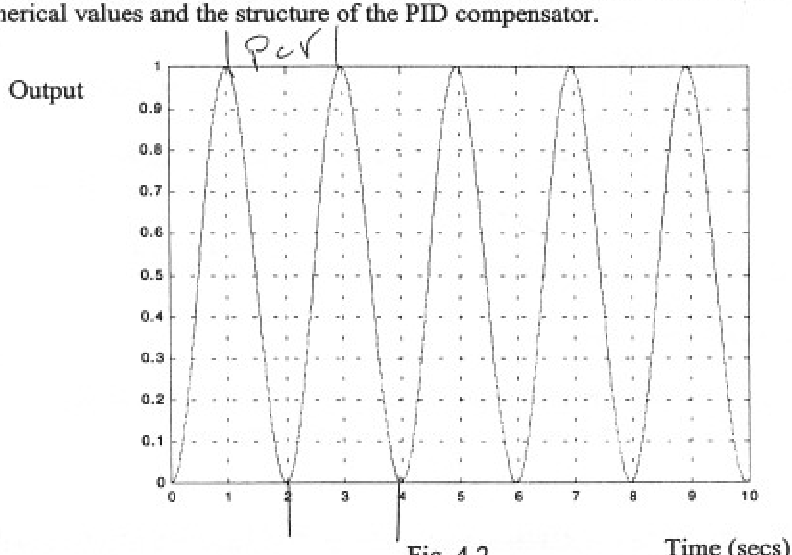


Fig. 4.2

e) The response of a second order system to a step input is given in Figure 4.3. Obtain the transfer function of this system from its time response.

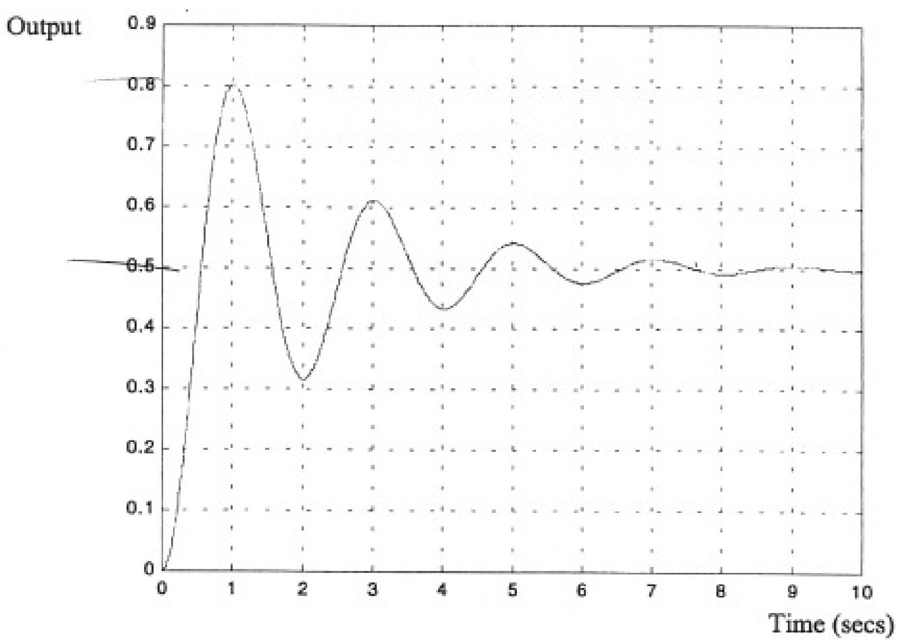


Fig. 4.2

f) Using the transfer function from e) and the Ziegler Nichols method, design a PID controller

Q5: a) Draw the block diagram of a system with unity feedback given the following open loop transfer function:

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

b) Derive clearly the equations relating the gain and phase of G(s) to a sinusoidal input signal with excitation frequency ω.

c) Calculate the gain of the transfer function when its phase angles are 0, -90 and -180 degrees respectively. Your answer should clearly indicate how this calculation is performed by using the equations derived in b).

d) Draw the Nyquist Diagram and the Nyquist Path of the system in a). Apply the Nyquist criterion for its stability analysis.

e) Show how the gain and phase margins can be obtained from the Nyquist Diagram.