Scheme of Evaluation

III/IV B.Tech (Regular/Supplementary) DEGREE EXAMINATION

October, 2018 **Electronics and Communication Engineering**

Fifth Semester **Linear Control Systems**

Time: Three Hours **Maximum :** 60 Marks

Answer Question No.1 compulsorily. (1X12 = 12 Marks)

Answer ONE question from each unit. (4X12=48 Marks)

1. Answer all questions (1X12=12 Marks)

a) State the effect of feedback on sensitivity, stability.
Stability reduces, sensitivity improves

b) Define Non-linear control system.
Doesn't satisfies homogeneous and additive property

c) Mention any two advantages of negative feedback.
Gives gain of the system, simple algebraic expressions, no differential terms present.

d) Define rise time.
The time required for a pulse to rise from 10 per cent to 90 per cent of its steady value.

e) What is the effect of adding pole at origin on steady state error?
e_{ss} reduced

f) What is the necessary condition for stability?
All the coefficients of the polynomial must have the same sign.

g) The open loop transfer function of a unity feedback control system is 10/(s+5). The gain margin of the system will be _______ .
∞

h) How does adding a zero in the forward path of a second order system effects the rise time?
Decreases

i) The pole factor 1/(1+jwT) has a slope of _______.
-20 dB/decade

j) Define state space.
The state space of a dynamical system is the set of all possible states of the system.

k) Define controllability.
A system is said to be completely controllable, if there exists a control law (a signal, say u(t)) which could drive the state (all the state variables) from an initial value to a final value, within a finite interval of time.

l) What is breakaway point?
A breakaway point is the point on a real axis segment of the root locus between two real poles where the two real closed-loop poles meet and diverge to become complex conjugates.

UNIT I

2. a) **What do you mean by closed loop system ? Give an example of closed-loop system. Discuss the advantages of closed loop system.** **6M**

The quantity of the output being measured is called the "feedback signal", and the type of control system which uses feedback signals to both control and adjust itself is called a Close-loop System.

A Closed-loop Control System, also known as a feedback control system is a control system which uses the concept of an open loop system as its forward path but has one or more feedback loops (hence its name) or paths between its output and its input. The reference to "feedback", simply means that some portion of the output is returned "back" to the input to form part of the systems excitation.

Closed-loop systems are designed to automatically achieve and maintain the desired output condition by comparing it with the actual condition. It does this by generating an error signal which is the difference between the output and the reference input. In other words, a "closed-loop system" is a fully automatic control system in which its control action being dependent on the output in some way.

So for example, consider our electric clothes dryer from the previous Open-loop tutorial. Suppose we used a sensor or transducer (input device) to continually monitor the temperature or dryness of the clothes and feed a signal relating to the dryness back to the controller as shown below.
Then we can define the main characteristics of Closed-loop Control as being:

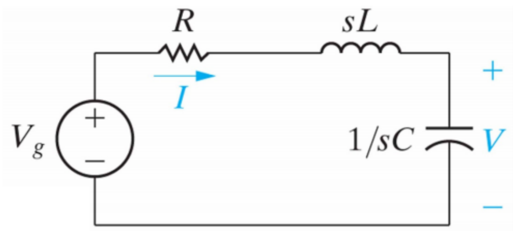
To reduce errors by automatically adjusting the systems input.
To improve stability of an unstable system.
To increase or reduce the systems sensitivity.
To enhance robustness against external disturbances to the process.
To produce a reliable and repeatable performance.

b) **The transfer function of a system is given by $G(S) = \frac{4s+1}{s^2+2s+3}$. Find the differential equation of the system having input x and output y.** **6M**

$$\frac{d^2y}{ds^2} + 2\frac{dy}{ds} + 3y(s) = 4\frac{dx}{ds} + x(s)$$

(OR)

3. a) **Find the transfer function of a series RLC circuit by taking the output across the capacitor** **7M**



$$H(s) = \frac{V}{V_g} = \frac{(sC)^{-1}}{R + sL + (sC)^{-1}} = \frac{1}{s^2LC + sRC + 1}$$

b) **Illustrate the effect of feedback on disturbance.** **5M**

There are certain factors that affect control operation in close-loop system, some of which are disturbances as shown in (figure 1), in this system, the control unit counts error in input (set point) and variables (out-put , sensor noise and disturbance) to decrease error since that will affect active operation as time passes on the controller repeats measurement of results unit the error reaches zero level ,that is most often being result out form disturbance, the following three cases discuss the idea of Disturbance on Closed-Loop Control System.

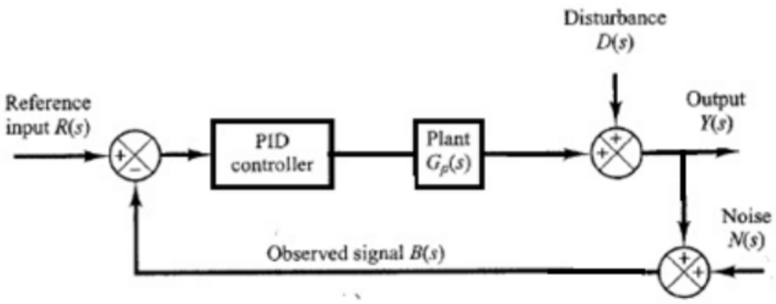


Fig. 1. Block Diagram of close loop system

Case 1: If disturbances value and sensor noise signal (feedback signal) being disabled to zero point and the PID controller is Gp(s) , error process variables and transfer function are given by input and output only. These changes in input cause the controller unit to perform a new successive controlling effect that in turn drive variables processes upwards or down according to physical characteristics processing in Figure

Case 2 If sensor noise signal (feedback signal) and input are completely disabled or at least constant, the main closed-loop diagram can be counted and rearranged in order to explain the way disturbances affect in process variable "the original control loop diagram can be rearranged mathematically to show how disturbances affect the process variable. Disturbances pass through a modified process that is mathematically equivalent to the original process being driven by a feedback signal passing through the controller.

Case 3: Close loop system using feedback technique by adding the output signal to the input signal this error is having a better output response .One of the disadvantage of the open loop system its effects and sensitivity to disturbance using close loop feedback system is helpful on solving the disturbance so to compensate it by measuring the output

UNIT II

4. a) Find (i) w_d (ii) T_s for 2% (iii)M_p for a system having transfer function $\frac{C(S)}{R(S)} = \frac{500}{s(s+15)}$ **6M**

$$\omega_d = \omega_n\sqrt{1-\zeta^2}\ ,\quad \%M_p = e^{-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}} \times 100\ ,\quad t_s = \frac{4}{\zeta\omega_n}$$

$$\omega_d = 21.07 \text{rad/sec},\ \%M_p = 12.7\%,\ t_s = 0.53 \text{sec}$$

b) **Determine the step, ramp, parabolic error constants of the following feedback control system.** $G(S) = \frac{120}{s(s^2+10s+120)}$ **6M**

$$K_p = \lim_{s\to 0} G(s)\ ,\ K_v = \lim_{s\to 0} sG(s)\ K_a = \lim_{s\to 0} s^2G(s)$$

$$K_p = \infty, K_v = 1, K_a = \infty$$

(OR)

5. a) **Describe the concept of stability, absolute stability, and conditional stability.** **6M**

Stability: A system is said to be stable, if its output is under control. Otherwise, it is said to be unstable. A stable system produces a bounded output for a given bounded input.
Absolutely Stable System: If the system is stable for all the range of system component values, then it is known as the absolutely stable system. Similarly, the closed loop control system is absolutely stable if all the poles of the closed loop transfer function present in the left half of the 's' plane.
Conditional stability: A system with variable gain is conditionally stable if it is BIBO stable for certain values of gain, but not BIBO stable for other values of gain. Continuous-Time. A system or signal that is defined at all points.

b) **Investigate the stability of the system with characteristic equation**
$s^5 + 2s^4 + 24s^3 + 48s^2 - 25s - 50 = 0$. Also find the roots of the equation. **6M**
Roots ±1, ±j5, and -2, unstable.

UNIT III

6. a) **Find the frequency domain specifications of a system having $H(S) = \frac{81}{s^2+7s+81}$** **6M**

$$\text{Resonant peak, } M_r = \frac{1}{2\zeta\sqrt{1-\zeta^2}}$$

$$\text{The resonant frequency, } \omega_r = \omega_n\sqrt{1-2\zeta^2}$$

$$\text{Bandwidth, } \omega_b = \omega_n u_b = \omega_n\left[1-2\zeta^2+\sqrt{2-4\zeta^2+4\zeta^4}\right]^{\frac{1}{2}}$$

$$\text{The phase margin, } \gamma = 180 + \angle G(j\omega)|_{\omega=\omega_{gc}}$$

The gain margin of second order system is infinite.

$$M_r = 1.395, \omega_r = 7.58\,rad/sec, \omega_b = 12.52\,rad/sec, PM = 74^0, GM = \infty$$

b) **Draw the polar plot for the system with $G(S)H(S) = \frac{15}{s(s+1)(s+2)}$. Calculate its gain margin in dB and comment on its stability**. **6M**

Magnitude equation (1M)
Phase angle equation (1M)
Values of magnitude and phase angle (2M)
Polar plot (2M)

GM= -7.96dB, System is unstable.

(OR)

7. a) **For the system $(S)H(S) = \frac{10K(s+0.6)}{s^2(s+2)(s+10)}$, draw the Nyquist plot and using Nyquist stability criterion determine stability with K=1, K=10 and K=100.** **6M**

Nyquist plot sections:4
Nyquist plot for each section 4M
Stability analysis 2M

K=1, stable, K=10, stable, K=100, unstable

b) **A unity feedback control system has $(S) = \frac{40}{s(s+2)(s+5)}$. Draw the Bode plot, Find Gain Margin and Phase Margin.** **6M**

Magnitude equation (1M)
Phase angle equation (1M)
Values of magnitude and phase angle (2M)
Bode plot (2M)

GM=6.76 dB, PM= 4 deg.

UNIT IV

8. a) **Sketch the root locus for the system having $G(S) = \frac{K}{(s+1)}$ and $H(S) = \frac{(s+1)}{s^2+4s+5}$ where G(S) is the forward path transfer function and H(S) the feed back transfer function.** **8M**

Step1: Locate the poles and zeros (1M)
Step2:Root locus on real axis (1M)
Step3:Angle of asymptotes and centroid (1M)
Step4: Breakaway and breakin points (1M)
Step5: Angle of departure for complex pole (1M)
Step6:Poin of intersection with imaginary axis (1M)
Root locus plot (2M)

b) **Illustrate the effect of addition of pole on root locus with an example.** **4M**

The general effect of addition of a pole is a tendency to shift the locus towards right side of S-plane and this lowers the stability

Ex: G(s)=K/S(S+2) and K/S(S+1)(S+2)

(OR)

9. a) **State and prove the properties of state transition matrix** **6M**

$\Phi(t,\tau)$ is called the *state transition matrix*

Properties

1) $\Phi(t,t) = I$,

2) $\Phi^{-1}(t,\tau) = \Phi(\tau,t)$,

3) $\Phi(t_1,t_2) = \Phi(t_1,t_0)\Phi(t_0,t_2)$.

4) $\frac{d}{dt}\Phi(t,\tau) = A\Phi(t,\tau), \qquad \Phi(\tau,\tau) = I.$

Proof:

1) $\Phi(t,t) = P(t)P^{-1}(t) = I$,

2) $\Phi^{-1}(t,\tau) = \left[P(t)P^{-1}(\tau)\right]^{-1} = P(\tau)P^{-1}(t) = \Phi(\tau,t)$,

3) $\Phi(t_1,t_2) = P(t_1)P^{-1}(t_2)P(t_2)P^{-1}(t_3) = P(t_1)P^{-1}(t_3) = \Phi(t_1,t_3)$.

4) $\frac{d}{dt}\Phi(t,\tau) = \frac{d}{dt}P(t)P(\tau)^{-1} = \dot{P}(t)P(\tau) = A(t)P(t)P(\tau) = A(t)\Phi(t,\tau)$.

b) Find the output response of the following system **6M**

$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & 1\\ -3 & -4\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}0\\ 1\end{bmatrix}[u]$

And output $y = [1 \quad 0]x$, where u(t) is the unit step input and $x_1(0)$ and $x_2(0)=0$.

$$X(t) = e^{At}X(0) + \int_0^t e^{A(t-\tau)} B\, U(\tau)\, d\tau$$

$$L^{-1}[sI - A]^{-1} = \phi(t) = e^{At}$$

$$e^{At} = \begin{bmatrix}\frac{3}{2}e^{-t} - \frac{1}{2}e^{-3t} & \frac{1}{2}e^{-t} + \frac{1}{2}e^{-3t}\\ \frac{-3}{2}e^{-t} + \frac{3}{2}e^{-3t} & \frac{-1}{-2}e^{-t} + \frac{3}{2}e^{-3t}\end{bmatrix}$$

Scheme of Evaluation

1.			12X1=12M.
	a) Stability reduces, sensitivity improves		
	b) Doesn’t satisfies homogeneous and additive property		
	c) Gives gain of the system, simple algebraic expressions, no differential terms present		
	d) Rise time definition		
	e) e_{ss} reduced		
	f) All the coefficients of the polynomial must have the same sign		
	g) ∞		
	h) Decreases		
	i) -20 dB/decade		
	j) Definition of state space		
	k) Condition for controllability		
	l) The point at which two poles meets and goes away from that point.		
2.	a) Definition of closed loop system	------	2M
	Example	------	2M
	Advantages	------	2M
	b) Differential equations for the given transfer function	------	6M
3.	a) Series RLC circuit	------	2M
	Equation of loop	------	2M
	Transfer function	------	3M
	b) Block diagram	------	2M
	Expression for showing effect of disturbance signal	------	3M
4.	a) formulas	------	3M
	Answers	------	3M
	b) Formulas	------	3M
	Answers	------	3M
5.	a) concept of stability	------	2M
	conditional stability	------	2M
	absolute stability	------	2M
	b) Forming Routh’s table	------	3M
	Roots ± 1, $\pm j5$, and -2.	------	3M
6.	a) M_r=1.395, w_r=7.515 rad/sec, BW=12.46 rad/sec	------	6M
	b) Polar plot	------	3M
	-7.96	------	2M
	unstable	------	1M
7.	a) K=1, stable, K=10, stable, K=100, unstable	------	6M
	b) Drawing Bode plot	------	4M
	6.76 dB, 4 deg.	------	2M
8.	a) Formulas of rules to construct root locus	------	4M
	Drawing the root locus	------	4M
	b) Drawing root locus before and after adding a pole	------	4M
9.	a) Properties	------	3M
	Proof for properties	------	3M
	b) Response of the state model	------	6M