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JNIT JAGANNATH GUPTA INSTITUTE OF ENGINEERING & TECHNOLOGY JAIPUR

I-Mid Term Examination Session 2017-2018

B.Tech .3rd. Year .6th. Semester

Branch: ECE | **Subject: Control System Engg**

Time: 10:00 am-11:30am | **Subject Code:6EC5A**

Date: 16/02/2018 | **Max. Marks: 20**

Attempt any four questions out of following five questions. All Que carry equal marks.

Q.1 What is control system? Write difference between open loop & Close loop Control system with Example and Diagram.

ANS

1.5 Control System

A control system comprises of control element (subsystem) and plant (system) which are connected together for the purpose of controlling the response of the system. So, control is an essential part of the system and helps in obtaining the specified value of output from the system. On the other hand control is that part of system which enables the system to obtain the desired response. Combining both of them (control and system) and connecting between input and output is called control system and study of control system in engineering field is termed as Control System Engineering. For example, heat produced by the furnace depends on the flow of fuel. In this system, subsystem called fuel valve and its actuators move by which heat outputs from the furnace can be controlled to regulate the room temperature. Figure 1.2 shows the simplest form of control system to produce an output or response for a given input or excitation.

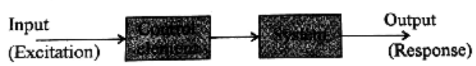

Figure 1.2 : Block diagram of a control system

For example, assume an automobile speed control system as shown in figure 1.3 is on a highway where the speed limit is 65 km/hr. The driver's control system acts as follows:

1. Actual speed is detected by the eye that observes the speedometer.
2. The brain assesses this speed in comparison with the desired speed.
3. If the brain judges the speed is too fast, it directs the foot to ease up on the accelerator and the speed is too slow then it direct the foot to make pressure on break.
4. Action is converged by the nerves in accordance to achive desired speed.

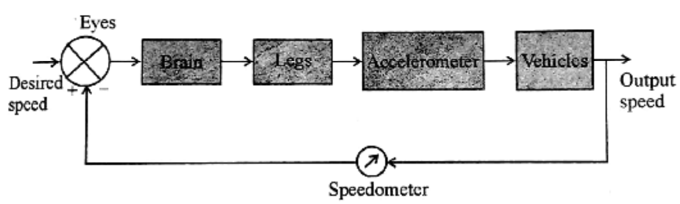

Figure 1.3 : Block diagram of automobile speed control system

.7 Differences Between Open Loop Control System and Closed–Loop Control System

able 1.1 : Difference Between Open Loop and Closed Loop Control Systems

S.No.	Open Loop Control Systems	Closed Loop Control Systems
1.	In open loop systems, the control action is independent of the output.	In closed loop systems, control action is dependent on the output.
2.	They are sensitive to external disturbances and internal variations in system parameters	They are very less sensitive to external disturbances and internal variations in system parameters.
3.	There is a need to use accurate as well as expensive components to obtain the accurate control of given plant.	We can even use less accurate as well as in–expensive components to obtain accurate control of given plant.
4.	It is used only where inputs to the system are known ahead of time.	It can be used when inputs are not known ahead of time.
5.	Number of components used in this system are less. So they are simple and cheap.	Number of components used in these system are more. So they are complex and costly.

Q.2 Explain Force-Voltage Analogy.

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Force-Voltage Analogy and Torque-Voltage Analogy:

Consider a series R–L–C circuit as shown in figure 2.9.

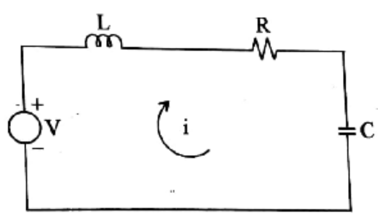


Figure 2.9 Series R–L–C circuit

Applying Kirchoff's voltage law.

$$V = Ri + L\frac{di}{dt} + \frac{1}{C}\int i dt$$

In terms of charge, equation becomes [i.e. $i = dq/dt$]

$$V = R\frac{dq}{dt} + L\frac{d^2q}{dt^2} + \frac{1}{C}q \quad \text{.....(2.3)}$$

Now, consider a mechanical system as shown in figure 2.7 and for that system equation of motion is given by equation (2.1) as under

$$F = M\frac{d^2x}{dt^2} + B\frac{dx}{dt} + Kx$$

If we compare a mechanical translational system with an electrical series circuit given by equation (2.3) we find similarity between them. They are therefore called analogous systems or we can say that behaviour of the mechanical system shown in figure 2.7 can be completely determined by simple R–L–C electrical circuit of figure 2.9 by making appropriate conversions of physical quantities as listed in the table.

Here the following analogies can be drawn :

1. Applied force F is analogous to applied voltage V.
2. Mass M is analogous to inductance L.
3. Coefficient of viscous friction B is analogous to resistance R.
4. Spring constant K is analogous to reciprocal of capacitance $\frac{1}{C}$.
5. Displacement x is analogous to electric charge q.

Similarly, if we compare a mechanical rotational system (figure 2.8) with an electrical series circuit (figure 2.9), we also find analogy between them. Both the analogies are given in table 2.2 below :

Table 2.2 Force voltage analogy and Torque voltage analogy

Mechanical System		Electrical System (Series R–L–C circuit)
Rotational motion	Translational Motion	
Torque T	Force F	Voltage V
Angular velocity ω	velocity	current i
Angular displacement q	Displacement x	charge q
Moment of inertia J	Mass M	Inductance L
Damping constant B_0	Viscous friction coefficient or damping constant B	Resistance R
Torsional constant k	Spring constant K	Capacitance 1/C

Q.3 writes the advantage and disadvantage of close loop control system .Drive an expression for close loop gain.

ANS

1.6.2 Closed Loop Control System

A closed loop control system is one in which control action some how depends on the output through a feedback path. A system with one or more feedback paths is called a closed–loop or feedback control system.

Closed–loop control systems are also called automatic control systems as these systems automatically correct for any variation in their outputs due to change in parameters, external conditions and disturbances etc. In a closed–loop control system, the output is continuously compared with the input through feedback path and difference of reference input signal and feedback signal forms an error signal through an error detector for supplying to the control element is shown in figure 1.5.

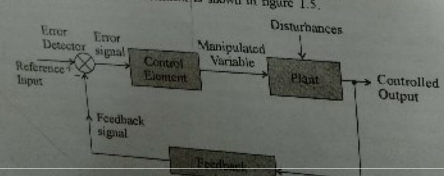


Figure 1.5 : Closed–loop control system

It is now important to note that fundamental difference between an open loop control system and closed–loop control system is that of feedback action. So, feedback is that property of closed–loop control system which allows the output to be compared with the input to the system so that the appropriate control action may be formed as a function of the output and input variable.

On the other hand, feedback is the output of the system which is appropriately and proportionately returned to modify the input in order to obtain desired output from the system. Feedback helps in achieving desired accuracy and reliability.

Feedback control systems should ideally satisfy the following requirements :

1. **Reliability**
2. **Accuracy**
3. **Linearity**
4. **Responsiveness**
5. **Isolated behaviour**
6. **Noise immunity**

A servomechanism is also a closed loop control system. In this case, controlled variable is essentially a mechanical quantity i.e. position, velocity or acceleration etc.

Feedback Path

This is the direction of flow of signal from output to input as shown in figure 4.4. Transfer function of a closed-loop system can be derived as follows : Block diagram of closed loop control system is shown in figure 4.5

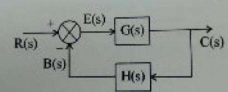


Figure 4.5 Block diagram representation of closed loop control system

where,

R(s) = Reference input

E(s) = Actuating signal or Error signal

G(s) = Forward path transfer function

C(s) = Output signal

H(s) = Feedback transfer function

B(s) = Feedback signal

From above figure 4.5

$$C(s) = G(s) \cdot E(s) \quad .....(4.1)$$

$$B(s) = H(s) \cdot C(s) \quad .....(4.2)$$

$$E(s) = R(s) - B(s) \quad .....(4.3)$$

Put the value of C(s) from equation (4.1) to equation (4.2)

$$B(s) = H(s) \cdot G(s)\ E(s) \quad .....(4.4)$$

This gives

$$\frac{B(s)}{E(s)} = G(s) \cdot H(s)$$

where, $\frac{B(s)}{E(s)}$ is open loop transfer function

Put the value of E(s) from equation (4.3) to equation (4.1)

$$C(s) = G(s)\ [R(s) - B(s)]$$

$$C(s) = R(s) \cdot G(s) - G(s) \cdot B(s) \quad .....(4.5)$$

Put the value of B(s) from equation (4.2) to equation (4.5)

$$C(s) = R(s)G(s) - G(s)H(s) \cdot C(s)$$

or $$C(s)\ [1 + G(s)H(s)] = R(s)G(s)$$

or $$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)}$$

$$\frac{C(s)}{R(s)} = M(s) = \text{Closed loop transfer function} = \frac{G(s)}{1+G(s)H(s)} \quad .....(4.6)$$

If the feedback is positive, then equation (4.6) becomes

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1-G(s)H(s)} \quad .....(4.7)$$

From equation (4.1) put the value of C(s) in equation (4.6)

$$\frac{G(s)E(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)}$$

or $$\frac{E(s)}{R(s)} = \frac{1}{1+G(s)H(s)} \quad .....(4.8)$$

where, $\frac{E(s)}{R(s)}$ is called error ratio

For positive feedback,

$$\frac{E(s)}{R(s)} = \frac{1}{1-G(s)H(s)} \quad .....(4.9)$$

Put the value of C(s) from equations (4.1) to equation (4.2)

$$B(s) = H(s) \cdot G(s)E(s)$$

Put the value of E(s) that is E(s) = R(s) − B(s) in the above equation

$$B(s) = H(s) \cdot G(s)\ [R(s) - B(s)]$$

or $$\frac{B(s)}{R(s)} = \frac{G(s)H(s)}{1+G(s)H(s)} \quad .....(4.10)$$

where, $\frac{B(s)}{R(s)}$ is called primary feedback ratio

For positive feedback

$$\frac{B(s)}{R(s)} = \frac{G(s)H(s)}{1-G(s)H(s)} \quad .....(4.11)$$

Transfer function for unity feedback control system i.e. H(s) = 1 is shown in figure 4.6.

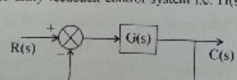
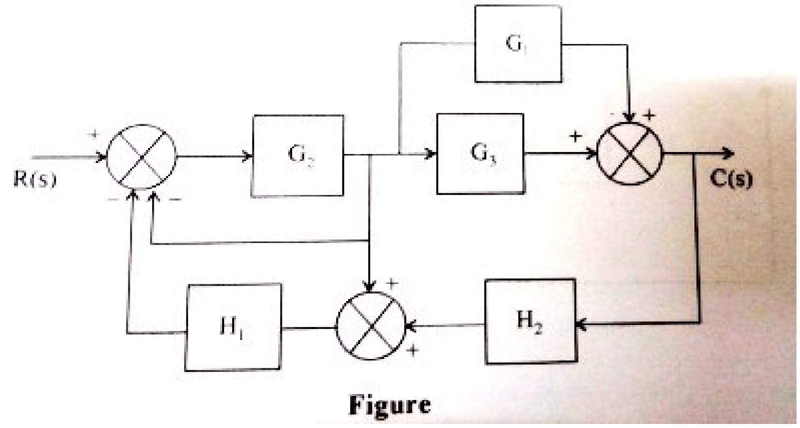


Figure 4.6 Unity feedback control system

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)}, \text{ For negative feedback} \quad .....(4.12)$$

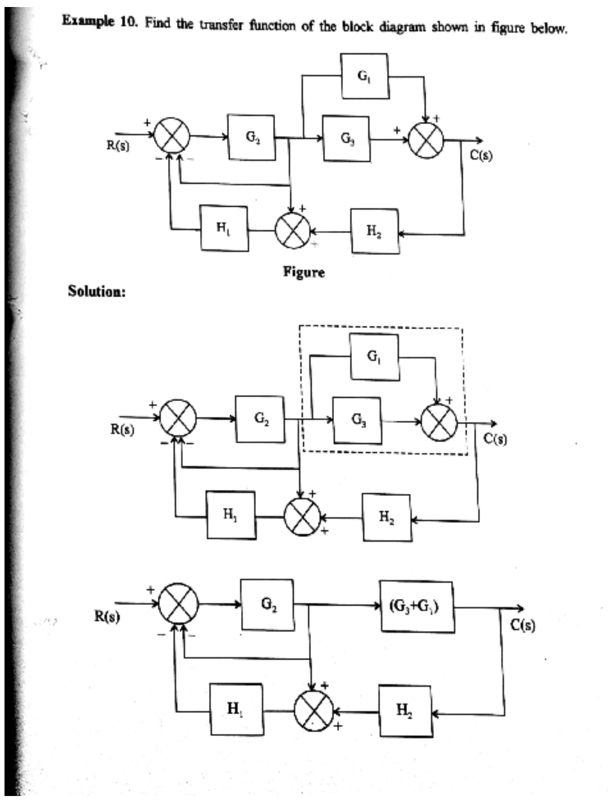
$$\frac{C(s)}{R(s)} = \frac{G(s)}{1-G(s)}, \text{ For positive feedback} \quad .....(4.13)$$

Q.4 Simplify the Block diagram given below and obtain the transfer function?



Figure

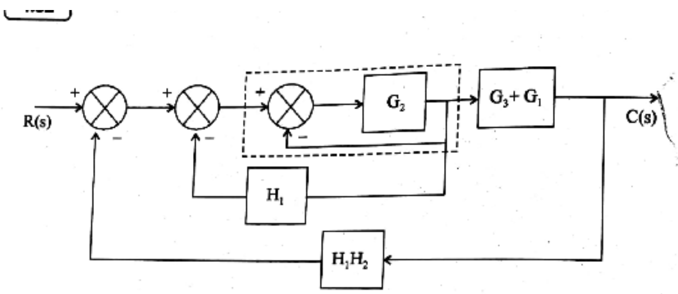
ANS

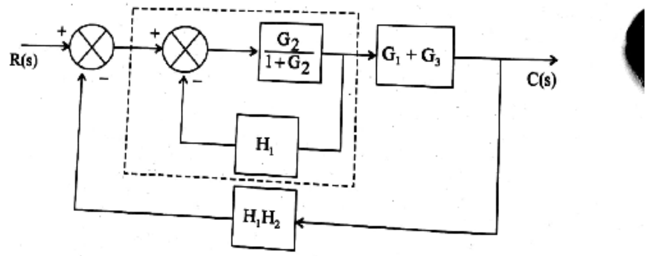


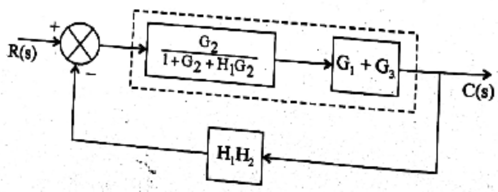
Example 10. Find the transfer function of the block diagram shown in figure below.

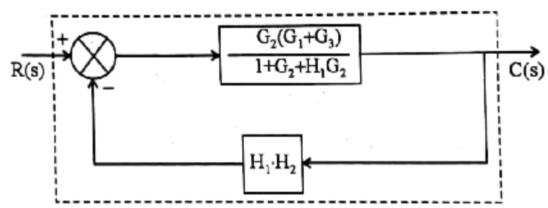
Figure

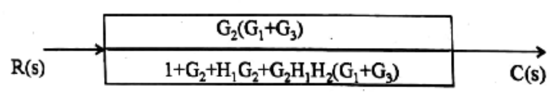
Solution:





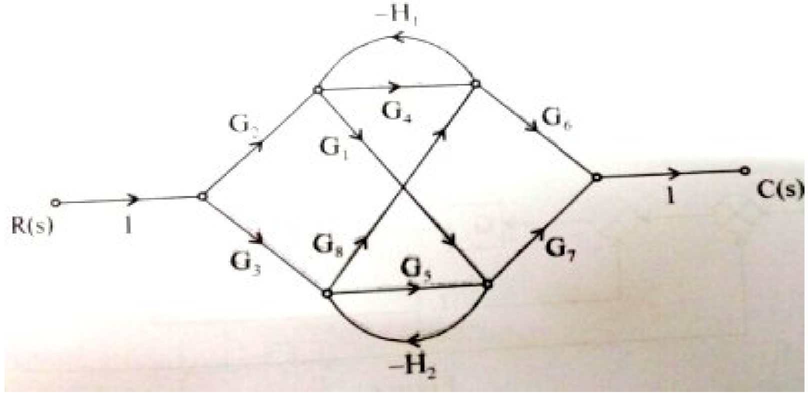






$$\frac{C(s)}{R(s)} = \frac{G_2(G_1+G_3)}{1+G_2+H_1G_2(1+H_2\,G_1+H_2G_3)}$$ **Ans.**

Q.5 The signal flow graph of a system is shown in figure .find the transfer function?



ANS

$$F_2 = G_3G_5G_7$$
$$F_3 = G_2G_1G_7$$
$$F_4 = G_3G_8G_6$$
$$F_5 = G_2G_1(-H_2)G_8G_6 = -\ G_1G_2G_6G_8H_2$$
$$F_6 = G_3G_8(-H_1)G_1G_7 = -\ G_1G_3G_7G_8H_1$$

Individual loops

$$L_{11} = G_4(-H_1) = -\ G_4H_1$$
$$L_{12} = G_5(-H_2) = -\ G_5H_2$$
$$L_{13} = (-H_1)G_1(-H_2)G_8 = H_1H_2G_1G_8$$

Two non–touching loops

$$NT_1 = (-G_4H_1)(-G_5H_2) = G_4G_5H_1H_2$$

Forward path F_1 does not touch L_{12} loop and forward path F_2 does not touch L_{11} loop. But all other paths touch both the loops. Therefore,

$$\Delta_1 = 1 + G_5H_2, \quad \Delta_2 = 1 + G_4H_1$$
$$\Delta_3 = \Delta_4 = \Delta_6 = 1$$
$$\Delta = 1 + G_4H_1 + G_5H_2 - H_1H_2G_1G_8 + G_4G_5H_1H_2$$

$$\text{T.F.} = \frac{G_2G_4G_6(1+G_5H_2)+G_3G_5G_7(1+G_4H_1)+G_2G_1G_7}{1+G_4H_1+G_5H_2-H_1H_2G_1G_8+G_4G_5H_1H_2}$$

$$+\frac{G_3G_8G_6-G_1G_2G_6G_8H_2-G_1G_3G_7G_8H_1}{1+G_4H_1+G_5H_2-H_1H_2G_1G_8+G_4G_5H_1H_2} \quad \textbf{Ans.}$$