

BIOLOGICAL CONTROL SYSTEMS

SYSTEM CONCEPTS

TYPES OF SYSTEMS

Control systems are basically classified as –

- Open-loop control system
- Closed-loop control system

In open-loop system the control action is independent of output. In closed-loop system control action is somehow dependent on output. Each system has at least two things in common, a controller and an actuator (final control element). The input to the controller is called reference input. This signal represents the desired system output. Open-loop control system is used for very simple applications where inputs are known ahead of time and there is no disturbance. Here the output is sensitive to the changes in *disturbance* inputs. Disturbance inputs are undesirable inputs that tend to deflect the plant outputs from their desired values. They must be calibrated and adjusted at regular intervals to ensure proper operation. Closed-loop systems are also called feedback control systems. Feedback is the property of the closed-loop systems which permits the output to be compared with the input of the system so that appropriate control action may be formed as a function of inputs and outputs. Feedback systems has the following features:

- reduced effect of nonlinearities and distortion
- Increased accuracy
- Increased bandwidth
- Less sensitivity to variation of system parameters
- Tendency towards oscillations
- Reduced effects of external disturbances

The general block diagram of a control system is shown below.

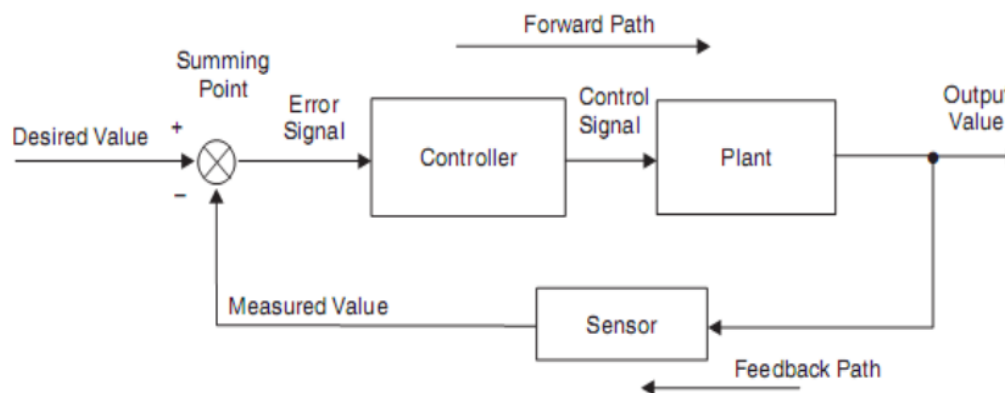


Figure: Closed-loop control system

BIOLOGICAL CONTROL SYSTEMS

Some Definitions

Reference input – It is the actual signal input to the control system.

Output (Controlled variable) – It is the actual response obtained from a control system.

Actuating error signal – It is the difference between the reference input and feedback signal.

Controller – It is a component required to generate control signal to drive the actuator.

Control signal – The signal obtained at the output of a controller is called control signal.

Actuator – It is a power device that produces input to the plant according to the control signal, so that output signal approaches the reference input signal.

Plant – The combination of object to be controlled and the actuator is called the plant.

Feedback Element – It is the element that provides a mean for feeding back the output quantity in order to compare it with the reference input.

Servomechanism – It is a feedback control system in which the output is mechanical position, velocity, or acceleration.

EXAMPLE OF CONTROL SYSTEMS

Toilet tank filling system:

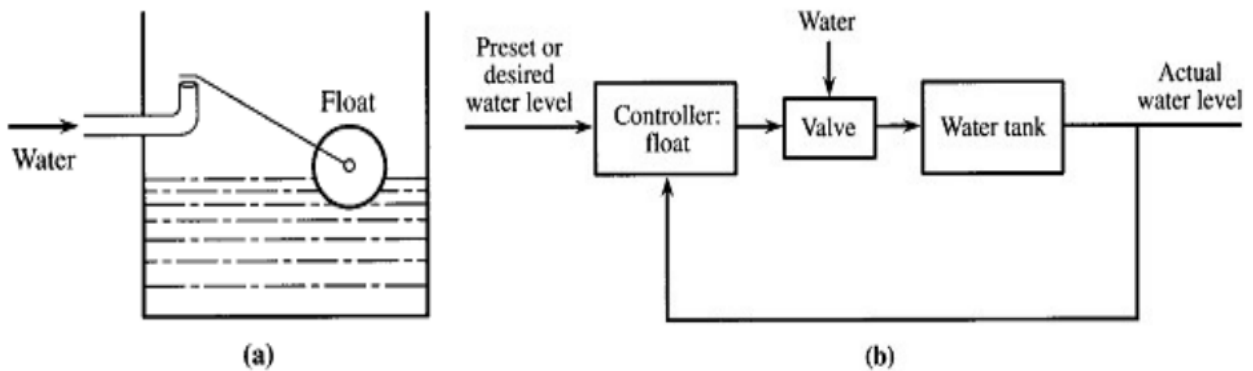


Figure: Toilet tank filling system

Position control system: [antenna]

BIOLOGICAL CONTROL SYSTEMS

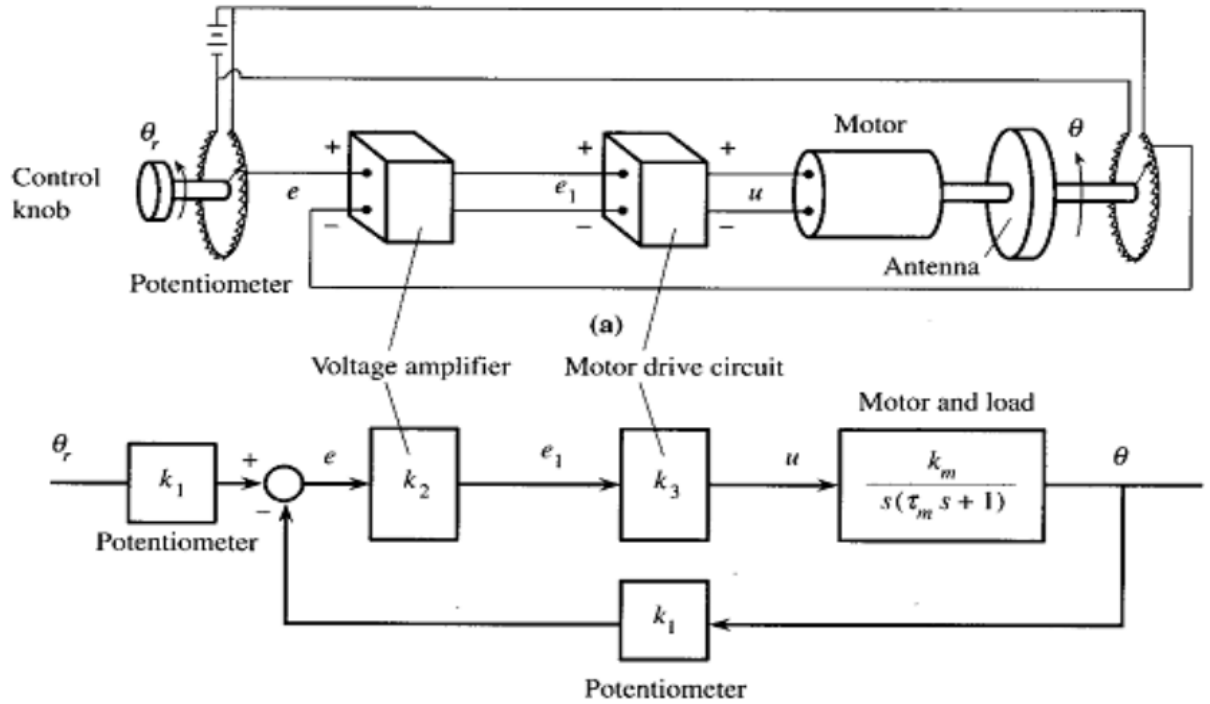


Figure: Position control system

Velocity control system: [audio/ video recorder]

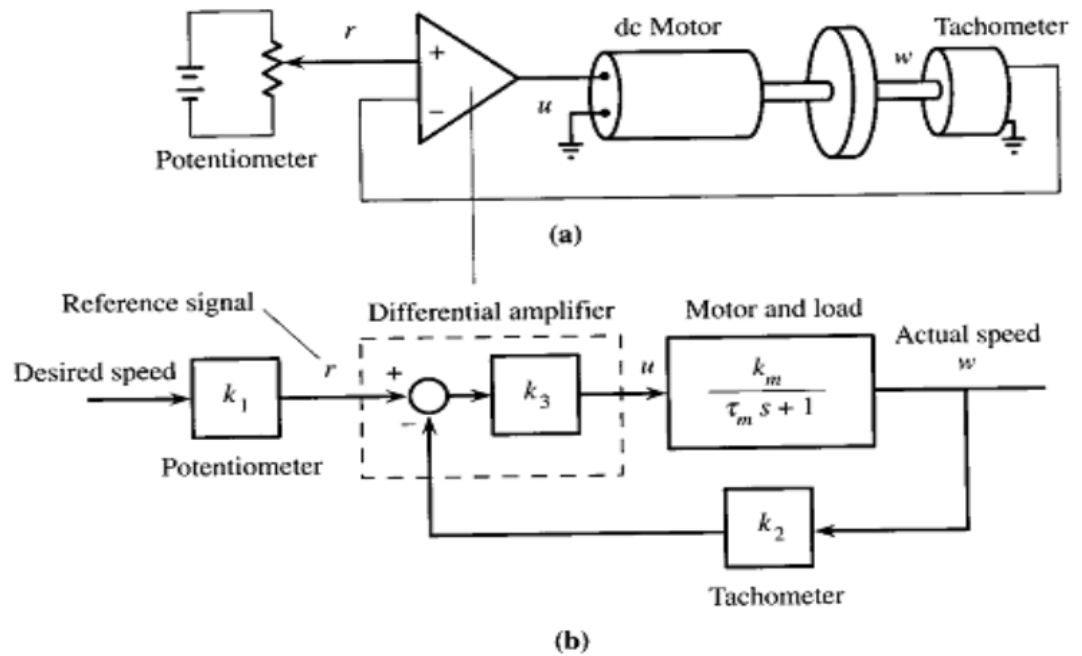


Figure: Velocity control system

BIOLOGICAL CONTROL SYSTEMS

Clothes Dryer:

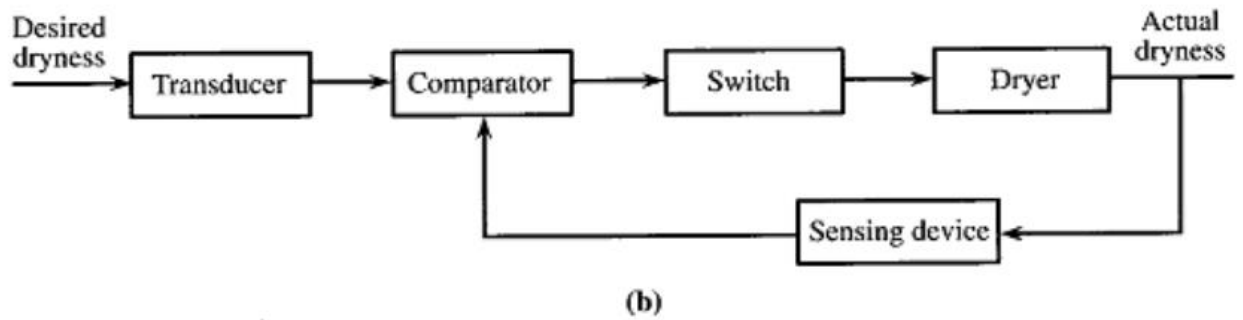


Figure: Automatic dryer

Temperature control system: [oven, refrigerator, house]

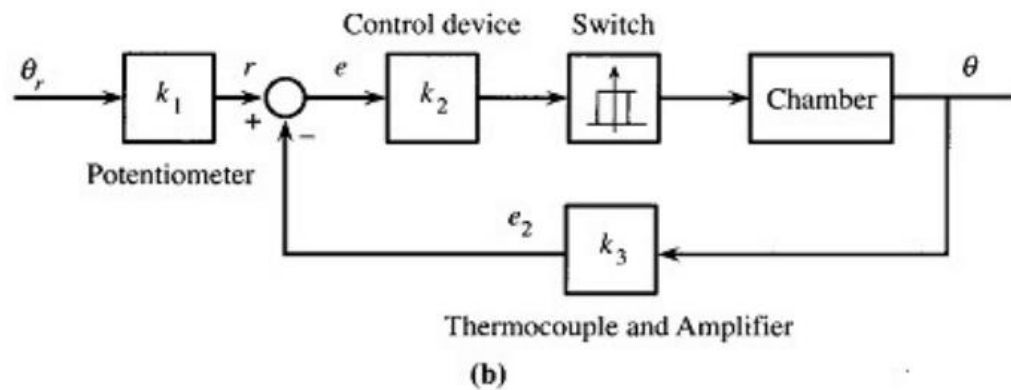
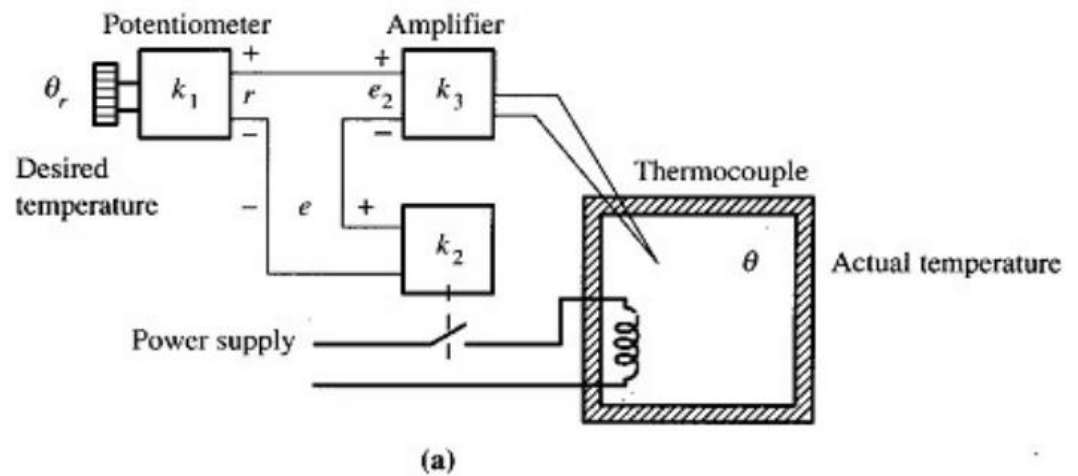
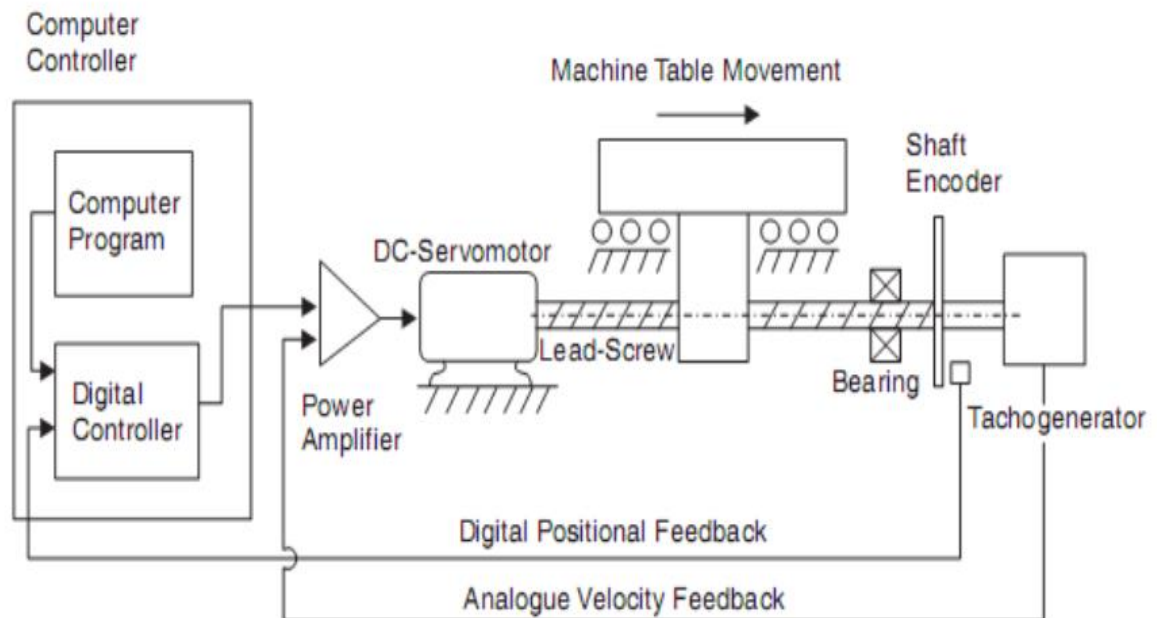


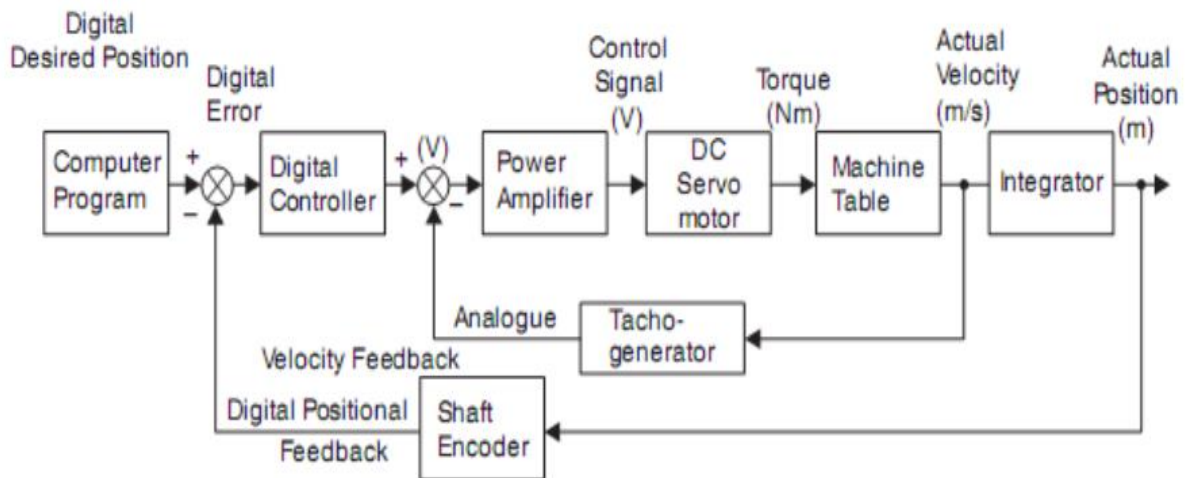
Figure: Temperature control system

BIOLOGICAL CONTROL SYSTEMS

Computer numerically controlled (CNC) machine tool:



(a)



(b)

Figure: CNC machine tool control system

BIOLOGICAL CONTROL SYSTEMS

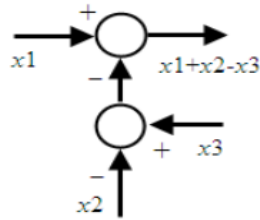
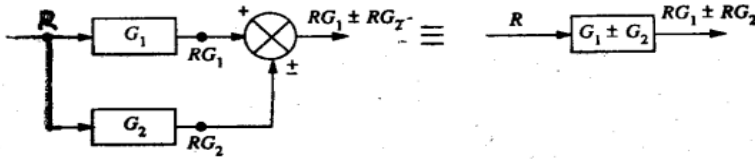
BLOCK DIAGRAM ALGEBRA

A complex system is represented by the interconnection of the blocks for individual elements. Evaluation of complex system requires simplification of block diagrams by block diagram rearrangement. Some of the important rules are given in figure below.

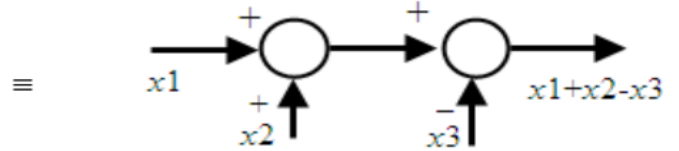
<i>Rule</i>	<i>Original diagram</i>	<i>Equivalent diagram</i>
1. Combining blocks in cascade		
2. Moving a summing point after a block		
3. Moving a summing point ahead of a block		
4. Moving a take off point after a block		
5. Moving a take off point ahead of a block		
6. Eliminating a feedback loop		

7. Combining Blocks in Parallel

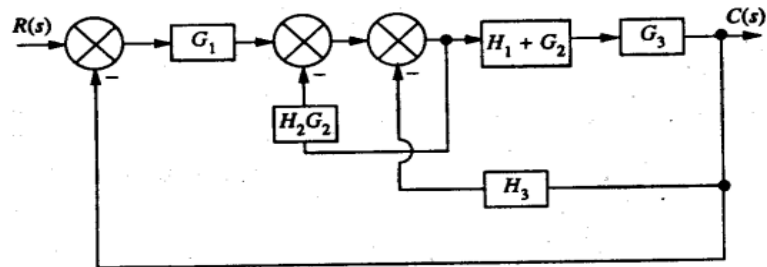
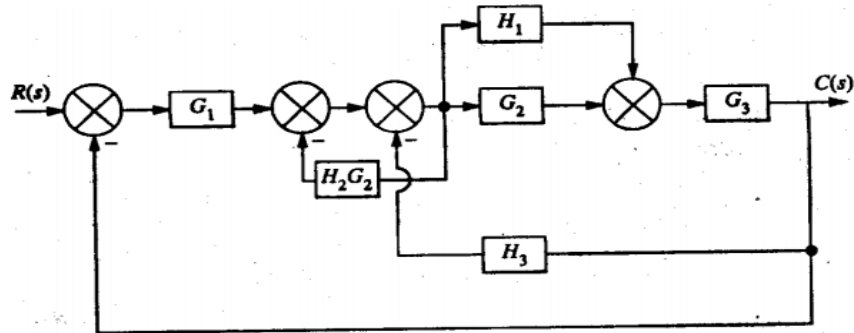
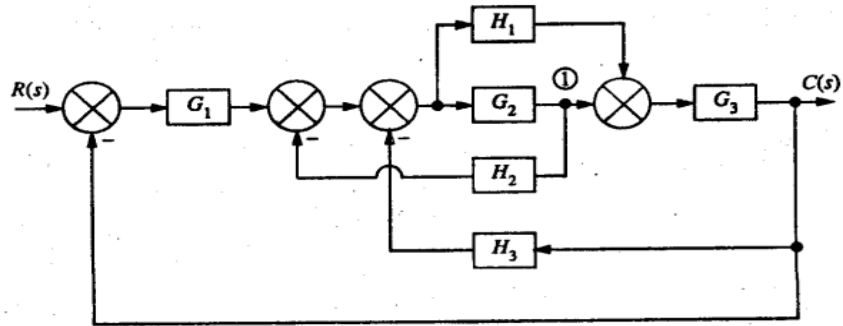
BIOLOGICAL CONTROL SYSTEMS



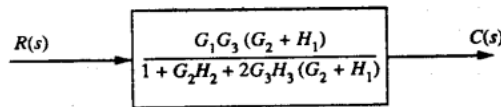
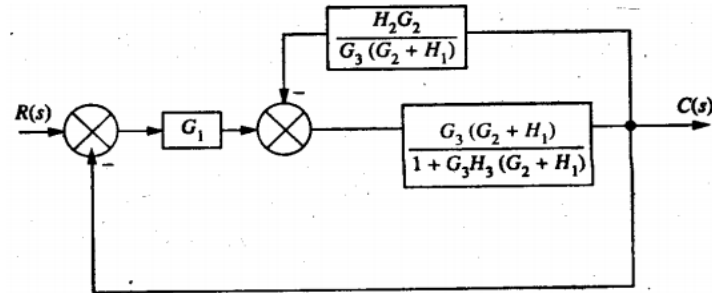
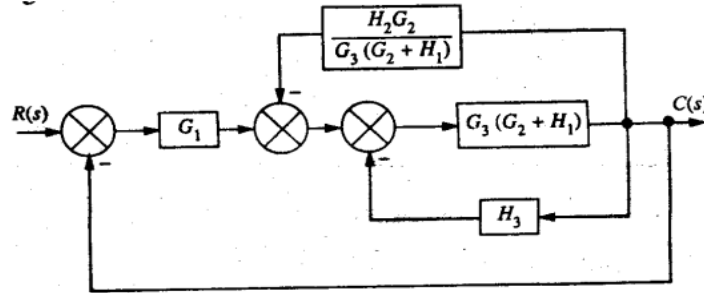
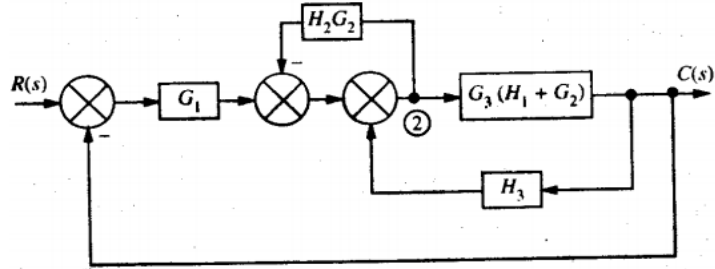
8. Moving summing point :



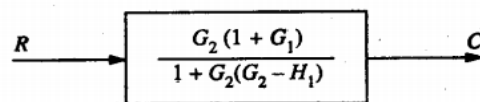
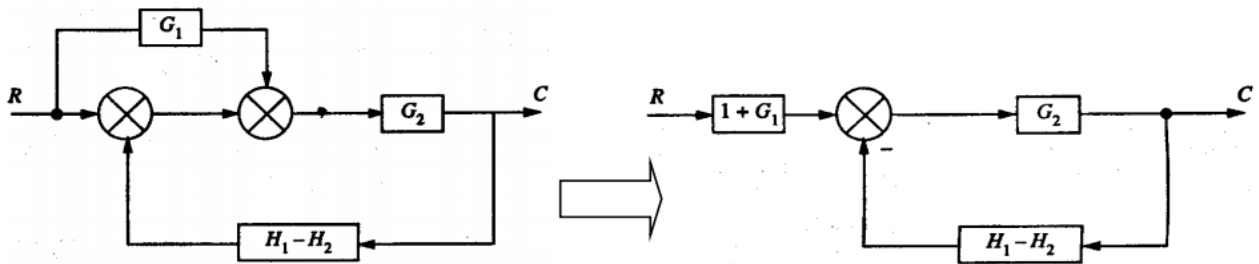
Example: Simplify the block diagram shown in Figure below.



BIOLOGICAL CONTROL SYSTEMS



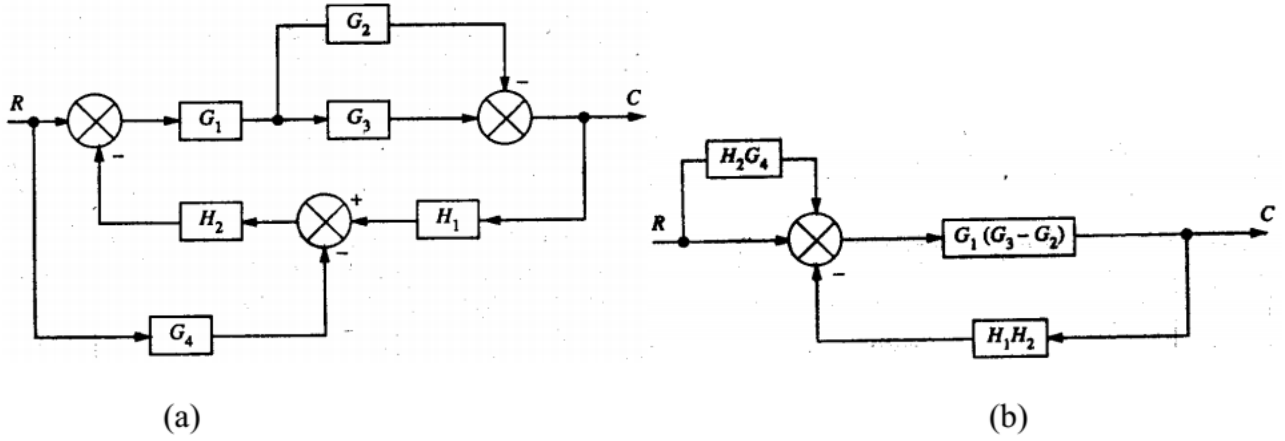
Example: Obtain the transfer function C/R of the block diagram shown in Figure below.



[Ans]

BIOLOGICAL CONTROL SYSTEMS

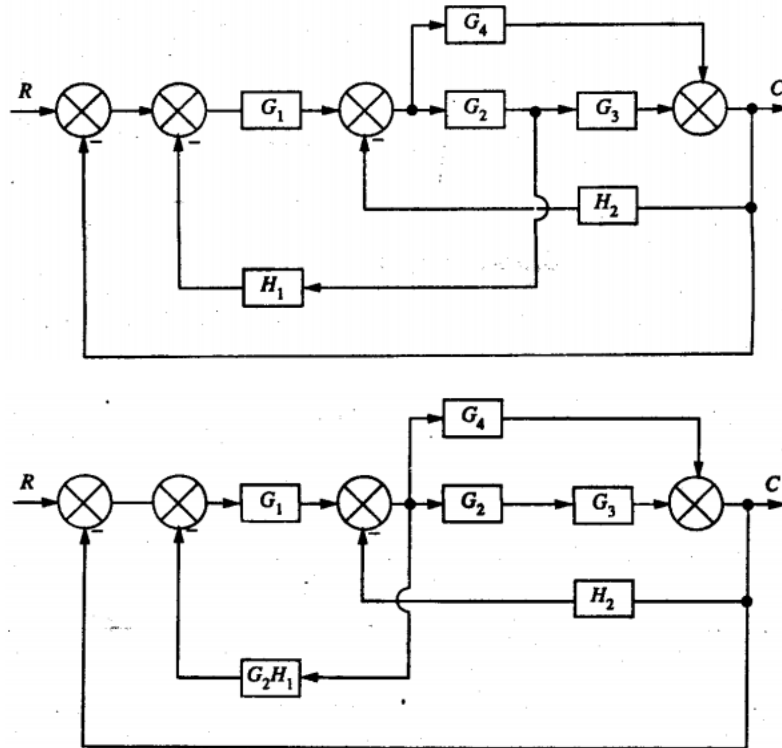
Example: Derive the transfer function of the system shown below.



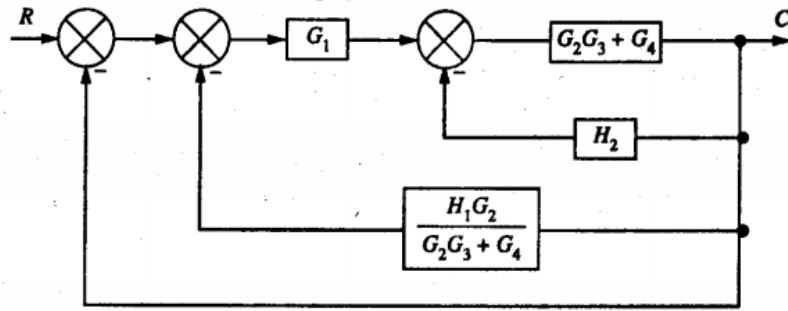
$$R \rightarrow \boxed{\frac{G_1 (G_3 - G_2) (1 + H_2 G_4)}{1 + G_1 H_1 H_2 (G_3 - G_2)}} \rightarrow C$$

[Answer]

Example: Derive the transfer function of the system shown below.

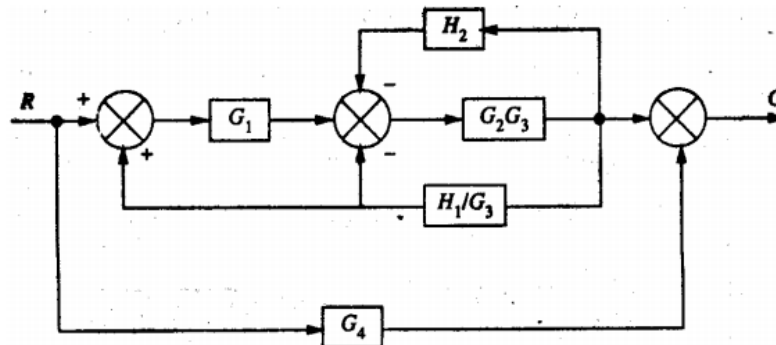
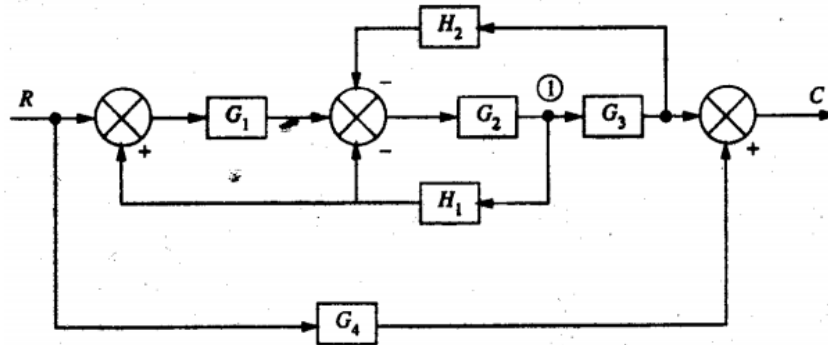


BIOLOGICAL CONTROL SYSTEMS



$$\frac{C}{R} = \frac{G_1 [G_2 G_3 + G_4]}{1 + H_2 [G_2 G_3 + G_4] + G_1 G_2 H_1 + G_1 [G_2 G_3 + G_4]}$$

Example: Find the transfer function of the following system.

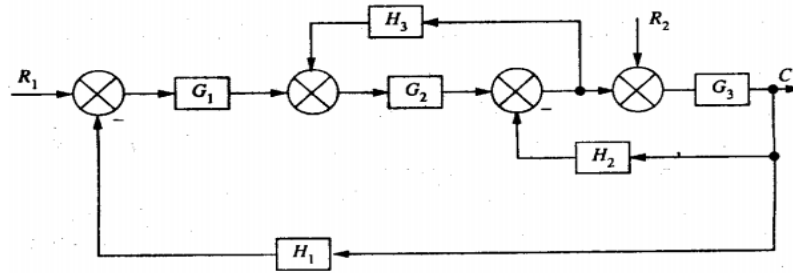


$$\frac{C}{R} = G_4 + \frac{G_1 G_2 G_3}{1 + H_2 G_2 G_3 + G_2 H_1 - H_1 G_1 G_2}$$

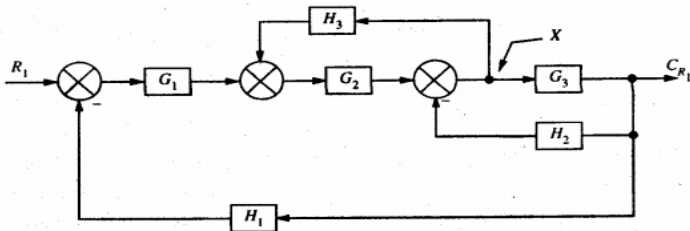
{Answer}

Example: Find the output of the system shown below.

BIOLOGICAL CONTROL SYSTEMS

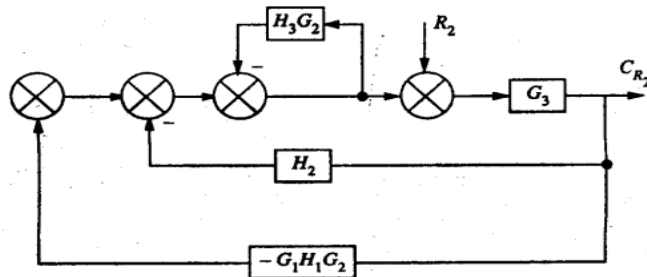
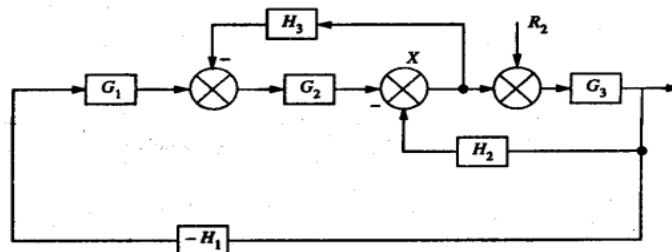


For Input R_1 :



$$C_{R_1} = \left[\frac{G_1 G_2 G_3}{1 + G_3 H_2 + H_3 G_2 + G_1 G_2 G_3 H_1} \right] R_1 \dots\dots\dots (1)$$

For input R_2 :



$$C_{R_2} = \left[\frac{G_3 [1 + G_2 H_3]}{1 + G_2 H_3 + G_3 [G_1 G_2 H_1 + H_2]} \right] R_2 \dots\dots\dots (2)$$

BIOLOGICAL CONTROL SYSTEMS

$$C = C_{R_1} + C_{R_2}$$
$$C = \left[\frac{G_1 G_2 G_3}{1 + G_3 H_2 + G_2 H_3 + G_1 G_2 G_3 H_1} \right] R_1 + \left[\frac{G_3 [1 + G_2 H_3]}{1 + G_2 H_3 + G_3 [G_1 G_2 H_1 + H_2]} \right] R_2 \quad \{\text{Answer}\}$$