Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. 1. A) Attempt any three of the following: (3x4=12 Marks)

i) Define the following:

a) Stability

b) Relative Stability

c) Gain Margin

d) Phase Margin

Ans:- (1 Mark Each)

a) **Stability:** A linear time invariant system is set to be stable if following conditions are satisfied.

1. When the system is excited by a bounded input the output is also bounded and controllable.
2. In the absence of input output must tend to zero irrespective of the initial conditions.

b) **Relative Stability**: The system is said to be relatively more stable on the basis of settling time if the settling time for a system is less than that of another system then the former system is said to be relatively more stable than the second one.

As the location of the poles move towards left half of S- plane, the settling time becomes smaller and system becomes more stable.

c) **Gain Margin**: Margin in the gain allowable by which gain can be increased till system reaches on the verge of instability.

d) **Phase Margin** : The amount of additional phase lag which can be introduced in the system till system reaches on the verge of instability

ii) Draw graphical representation of following test signals and give their Laplace representation:

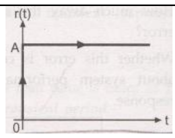
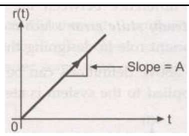
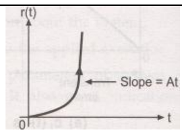
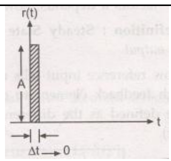
a) Step input

b) Impulse input

c) Ramp input

d) Parabolic input

Ans:-

Test Signal	Graphical representation	Laplace representation
Unit Step Input		**1/s**
Unit Ramp Input		**$1/s^2$**
Unit Parabolic Input		**$1/s^3$**
Unit Impulse		**1**

iii) Compare open loop and closed loop system with respect to

a) Stability

b) Accuracy

c) Feedback

d) Example

Ans: - **(1 mark each)**

System	Stability	Accuracy	Feedback	Example
Open loop	Generally stable	Less accurate	Absent	Electric switch, automatic washing machine, automatic toaster, traffic signal
Closed loop	Less stable than open loop	More accurate	Present	Human being , home heating system, missile launching system, voltage stabilizer, Manual speed control system etc.

iv) List any four advantages of robotics.

Ans: - **(1 mark each)**

Advantages of robotics:

1. Can work in hazardous and dangerous areas
2. Jobs which are monotonous like assembling, stamping, packaging etc. can be done by robots in industry.
3. Can be used in nuclear research, military applications, underwater applications etc. by replacing the human being.
4. To increase the productivity, robots are used in the manufacturing industry.

B) Attempt any one of the following: **(6x 1 = 6 marks)**

i) For a control system the open loop transfer function is

$$G(s) = \frac{20}{(s+1)(S^2+10s+6)}$$

Determine the steady state error of the system when transfer function of feedback path is

H(s) = 5 / (s+3) and the system input is r(t)=5

Ans:

Q1 [B]

(i) Given

$$G(s) = \frac{20}{(s+1)(s^2+10s+6)}$$

$$H(s) = \frac{5}{(s+3)}$$

$$r(t) = 5$$

$$e_{ss} = ?$$

$$e_{ss} = \lim_{s\to 0} \frac{s \cdot R(s)}{1+G(s)H(s)} \longrightarrow \text{1½ Marks}$$

$$r(t) = 5, \quad R(s) = \frac{5}{s} \longrightarrow \text{½ Marks}$$

$$\therefore e_{ss} = \lim_{s\to 0} \frac{s \cdot \frac{5}{s}}{1 + \frac{20}{(s+1)(s^2+10s+6)} \cdot \frac{5}{(s+3)}} \longrightarrow \text{1½ Marks}$$

$$= \lim_{s\to 0} \frac{5}{1 + \frac{100}{(s+1)(s+3)(s^2+10s+6)}}$$

$$= \frac{5}{1 + \frac{100}{(1)(3)(6)}}$$

$$= \frac{5}{1+5.56} = \frac{5}{6.56} = 0.7622$$

$$e_{ss} = 0.7622 \longrightarrow \text{½ Marks}$$

OR

$$K_p = \lim_{s\to 0} G(s)H(s) \longrightarrow \text{1 Mark}$$

$$= \lim_{s\to 0} \frac{20}{(s+1)(s^2+10s+6)} \cdot \frac{5}{(s+3)} \longrightarrow \text{1 Mark}$$

$$= \frac{100}{(1)(6)(3)}$$

$$K_p = 5.56 \longrightarrow \text{1 Mark}$$

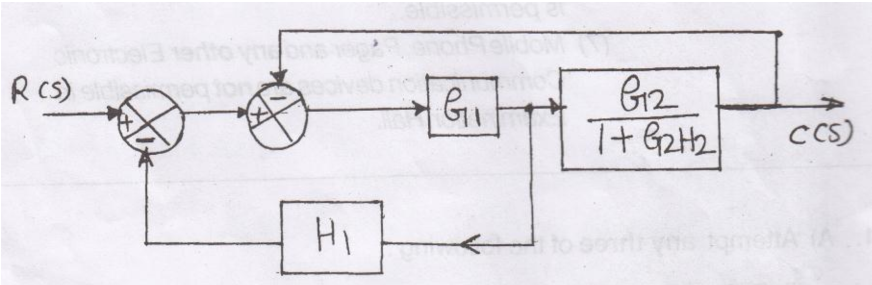
$$e_{ss} = \frac{A}{1+K_p} \longrightarrow \text{½ Marks}$$

$$= \frac{5}{1+5.56}$$

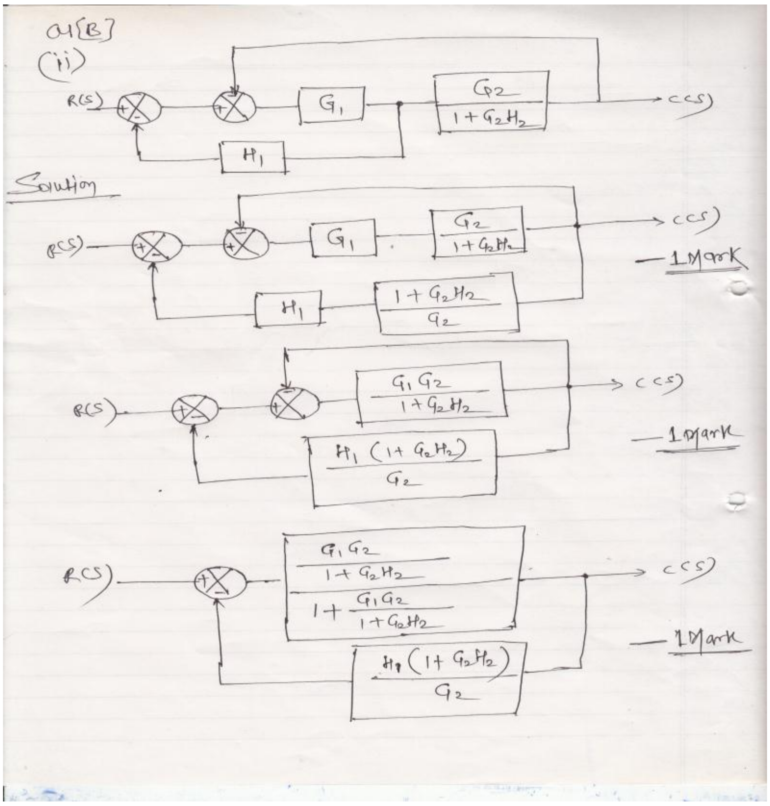
$$= \frac{5}{6.56}$$

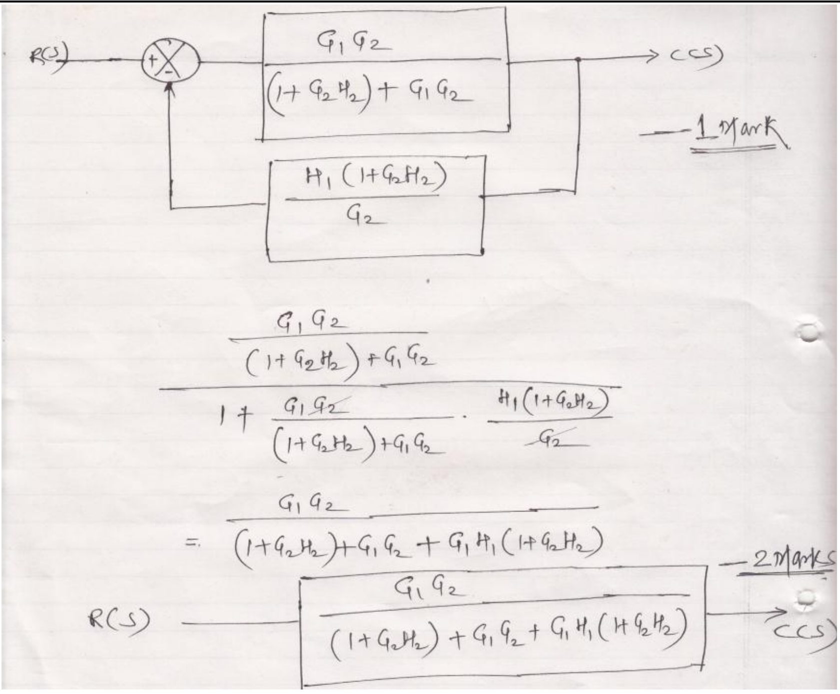
$$e_{ss} = 0.7622 \longrightarrow \text{½ Marks}$$

ii) Obtain single block equivalent by block diagram reduction for following figure.



Ans:





Q. 2. Attempt any two **(8*2=16)**

a) Determine the stability of

$S^4+4S^3+S^2+8S+1=0$

Ans:

Routh's array: **(6marks)**

S^4	1	1	1
S^3	4	8	0
S^2	-1	1	0
S	12	0	0
S^0	1	0	0

Conclusion: **(2mark)**

Routh's stability criteria states that the elements of 1^{st} column of Routh's array should not have any sign change for the system to be stable. The number of sign changes in the 1^{st} column indicates the number of Poles on RHS which makes the system unstable. Here, 2 sign changes in the 1^{st} column indicate 2 RHS poles. Therefore system is unstable.

b) i) Compare field controlled and armature controlled DC motor (any 4points, 1 mark each)

Field controlled DC motor	**Armature controlled DC motor**
Armature current is constant	Field current is constant
Control voltage is applied to field	Control voltage is applied to armature
Large time constant	small time constant
Suitable for small rated motor	Suitable for large rated motor
Open loop system	Closed loop system
Low power requirement	High power requirement
Poor efficiency	Better efficiency
costly	Economical, less costly

ii) Compare stepper motor and servo motor (any 4points, 1 mark each)

Stepper motor	**Servo motor (DC)**
Stepwise rotation	Continuous rotation
Steps controlled by no.of pulses	Rotation controlled by continuous supply of voltage
Stepping rate is governed by frequency of switching	Rotation is governed by supply voltage
Bidirectional rotation	Unidirectional rotation
Brushless	Has brushes
Less maintenance	Maintenance problem
No voltage supply to rotor, no control windings in rotor	Voltage supply to armature, armature has windings
Digital applications	Analog applications

c) Determine the stability of

$S^5+S^4+2S^3+2S^2+3S+15=0$

Ans: (Initial Rouths Array – 2 mark, Modified Rouths Array – 4 marks, Conclusion – 2 marks)

S^5	1	2	3	
S^4	1	2	15	
$\boxed{S^3}$	0	-12	0	special case
S^2	∞	--	--	Routh 'array failed
S				
S^0				

Substitute a small positive number ε in place of 0 occurred as a first element in a row. Complete the array with this number ε. Then examine the sign change by taking $\lim\limits_{\varepsilon \to 0}$.

S^5	1	2	3
S^4	1	2	15
S^3	$\boxed{\varepsilon}$	-12	0
S^2	$\frac{2\varepsilon+12}{\varepsilon}$	15	0
S	$\frac{(-12(2\varepsilon+12))/\varepsilon - 15\varepsilon}{\frac{2\varepsilon+12}{\varepsilon}}$	0	0
S^0	15		

To examine sign change

$$\lim_{\varepsilon \to 0} \frac{2\varepsilon+12}{\varepsilon} = 2 + \lim_{\varepsilon \to 0} 12/\varepsilon = 2 + \infty = \infty \text{ (sign is positive)}$$

$$\lim_{\varepsilon \to 0} \frac{(-12(2\varepsilon+12))/\varepsilon - 15\varepsilon}{\frac{2\varepsilon+12}{\varepsilon}} = \lim_{\varepsilon \to 0} \frac{-24\varepsilon - 144 - 15\varepsilon^2}{2\varepsilon+12} = \frac{0-144-0}{0+12}$$

$=-12$ (sign is negative)

Final Rouths Array:

S^5	1	2	3
S^4	1	2	15
S^3	$\boxed{\varepsilon}$	-12	0
S^2	∞	15	0
S	-12	0	0
S^0	15		

There are two sign changes in the first column of Rouths Array which indicates two poles on RHS. Therefore system is unstable.

(Note: - Alternative method of Rouths Array by replacing S with 1/z in the original equation also can be done.)

Q. 3. Attempt any Four of the following. (4*4=16)

a) Define Transfer function. Write its features.

Ans:

Transfer Function is defined as the ratio of Laplace transform of Output to that of input under the zero initial condition. **1mark**

Features (any 3) 3marks

1. It gives mathematical models of all system components
2. As it uses Laplace transform, it converts time domain equations to simple algebraic equations.
3. It relates output to input
4. It describes input-output behavior of the system.
5. It helps in the stability analysis of the system
6. It helps in determining poles & zeros

b) Draw functional diagram of Robotic system. Give classification of robotics

Ans: (functional diagram 2 marks, classification 2 marks)

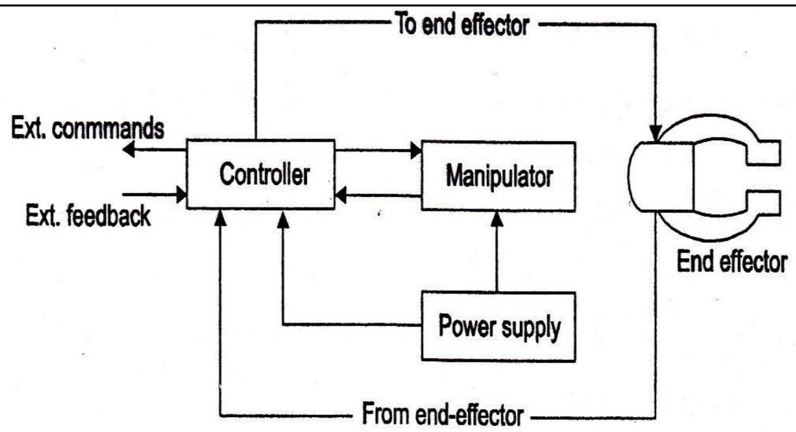
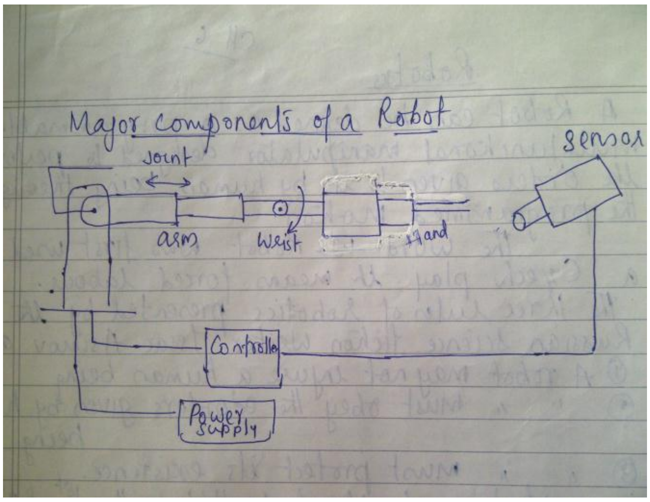


Fig.: Functional Diagram of Robotics

OR



Robotic systems are classified based on:

1) Power sources: electrical, pneumatic and hydraulic

2) Degree of freedom

3) Arm geometry or type of movement of manipulator (spherical, rectangular, and cylindrical)

4) Intelligence level: servo or non-servo

5) Types of motion

c) What is sequencing and modulating controllers?

Ans:

Modulating controllers: Here, set point is maintained throughout the operation of the plant. It is achieved by discontinuous and continuous control actions (on off, proportional, integral, derivative) which make adjustment to the plant to maintain set point.

(2marks)

Sequencing controllers: Here, controlling the process is done with a proper sequence. It ensures that an auxiliary device in a plant or process cannot be started unless all the permissive conditions for safe start have been established. Sequencing control is associated with start-up and shut-down of items of plant. The sequence should operate reliably in order to meet the system demands. Earlier, sequence control was achieved by electromagnetic relays. These are replaced by PLC later on. **(2marks)**

d) Distinguish between Integral and Derivative control action with following points:

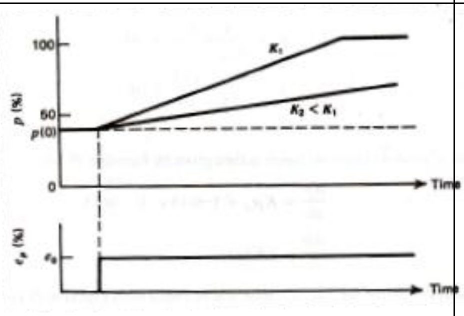
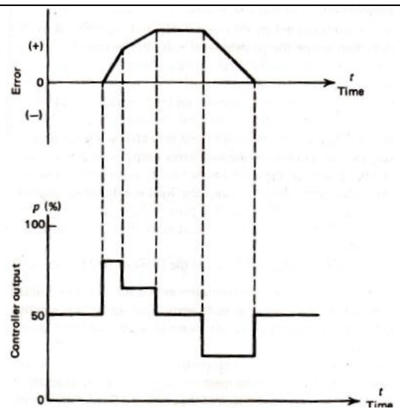
1) Nature of output

2) Equation

3) Response of Error

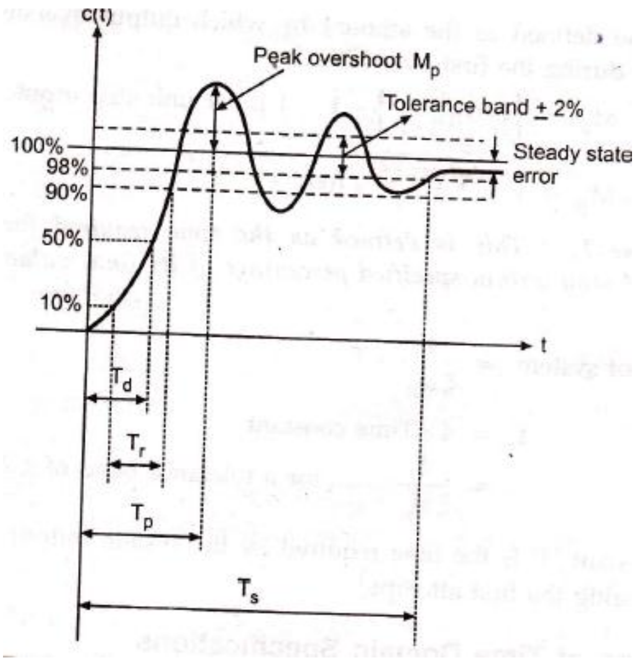
4) Application

Ans : - **(Each Point 1 Mark)**

Control Action	**Nature of output**	**Equation**	**Response of Error** (Note: Any other error response can be considered)	**Application**
Integral	Rate of change of controller output is proportional to error.	$p(t) = K_I \int_0^t e_p \, dt + p(0)$		Used in processes with small process lags & small capacitance such as flow & level control system
Derivative	Controller output is proportional to derivative of error.	$p(t) = K_D \frac{de_p}{dt}$		Used in processes with large process lags & inertia such as temperature control system

e) Draw labeled time response of second order control system for ζ< 1

Ans **(Neat Diagram 4 Marks)**



Q.4 A) Attempt any three of the following. **(4 x 3 = 12)**

a) Write any two advantages and disadvantages of frequency response analysis.

Ans:

Advantages: **(Any Two – 2 Marks)**

1. The absolute and relative stabilities of the closed loop system can be found out from the open loop frequency response characteristics by using the methods such as Nyquist stability criteria
2. The transfer function of complicated systems can be found out practically by frequency response test when it is difficult to find transfer function by writing differentiate equations.
3. Frequency response test are simple and can be done practically by the readily available laboratory equipment.
4. Without the knowledge of transfer function, the frequency response for stable open loop system can be obtained experimentally.
5. Due to the close relation between frequency response of a system and its step response, idea about step response can be obtained from the frequency response.

Dis advantages: **(Any Two – 2 Marks)**

1. Time consuming
2. Out dated methods compared to digital computation, simulation and modeling.
3. Methods can be applied mainly to linear systems.
4. Not recommended for systems with larger time constants.

b) What is the effect of ζ (zeta) in response of second order control system?

Ans: **(1 Mark for Each cases of ζ)**

Sr.No.	Range of ζ	Type of closed loop poles	Nature of response	System classification (Note: response diagram can also be considered)
1	$\zeta = 0$	Purely imaginary	Oscillations with constant frequency and amplitude	Undamped
2	$0 < \zeta < 1$	Complex conjugates with Negative real part	Damped oscillations	Underdamped
3	$\zeta = 1$	Real, Equal and Negative	Critical and pure exponential	Critically damped
4	$1 < \zeta < \infty$	Real, Unequal and Negative	Purely exponential slow an sluggish	Overdamped

c) Write standard equation for first order system and second order system. Give one practical example of each.

Ans: **(Equation -1 Mark Each, Any one example – 1 Mark Each)**

First order system equation: $$\frac{C(s)}{R(s)} = \frac{1}{1+\tau S} \text{ or } \frac{1}{1+RCS} \text{ or } \frac{LS}{R+LS}$$

Examples for First order system:

1) Mercury-in-glass thermometer
2) Search coil,
3) liquid, gas & thermal processes
4) Filters at output of a phase sensitive detector
5) Amplifiers in feedback systems
6) RL or RC circuit

Second order system equation: $$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{x^2+2\zeta\,\omega_n\,s+\omega_n^2}$$

Examples for Second order system:

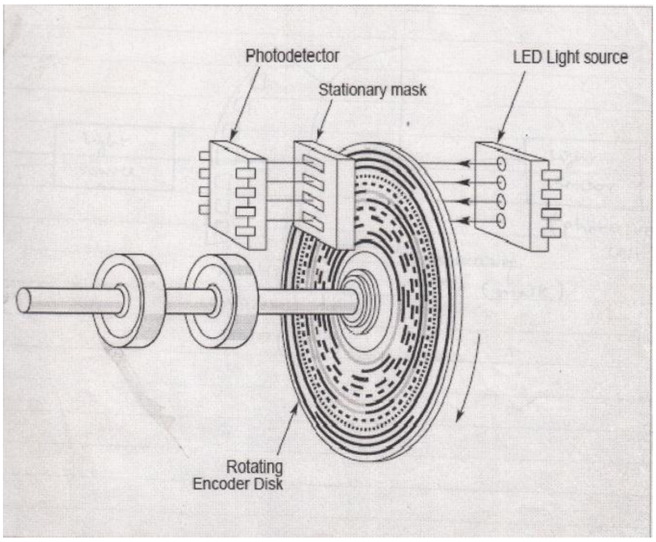
1. Electromechanical recorders
2. Spring balance
3. Moving coil indicators (P M M C)
4. Mass spring and damping system
5. Bourdon tube pressure gauge
6. RLC or LC circuit

d) What is rotary encoder? Explain its working.

Ans: **(Explanation 2 marks, Diagram -2 Marks)**

An encoder converts linear or rotary displacements into digital codes. It requires a sensing system of contacting or non-contacting type. In the rotary encoder the sensing system is optical. It converts rotary displacements into a digital output, thus measuring the angular displacements of the rotating body. It is a digital transducer.

Rotary encoder consists of a light source , a rotary disc, stationary mask and photo sensor. The rotary disc is connected to the rotating body whose angular displacement is to be measured. The light source and photo sensor are placed on the opposite sides of the rotary disc and stationary mask. Rotary disc has alternate opaque and transparent sectors similar to conducting and non-conducting areas. The mask is used to pass or block the light beam between light source and photo sensor. According to the speed of the rotating body the rotary disc rotates which passes or blocks the light to the light sensor. Thus the photo sensor detects the speed of rotation of the rotating body in the digital codes.



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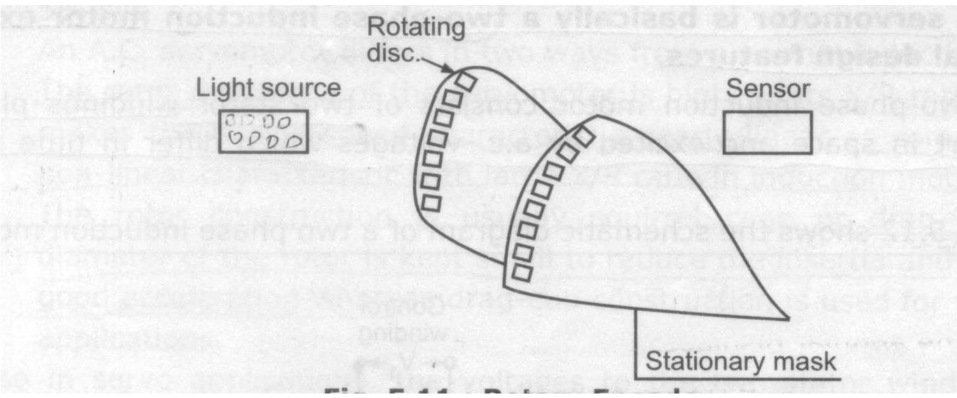
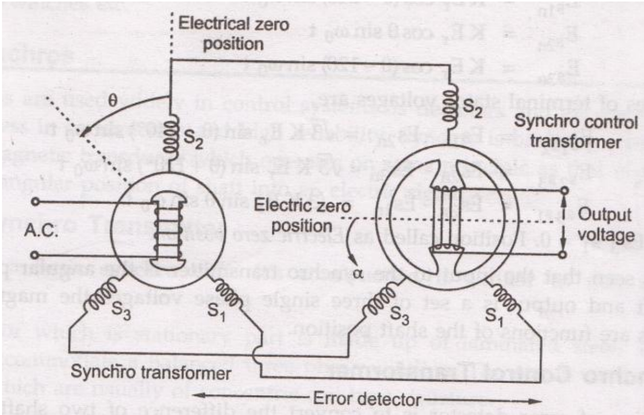


B) Attempt any one of the following. **(6 x 1 = 6)**

i) With neat diagram write operation of synchro as error detector.

Ans: **(Diagram 2 Marks, Explanation 4 Marks)**



Synchrotransmitter along with synchrocontrol transformer is used as synchro error detector. Here the output of synchro transmitter is applied to the stator windings of synchro control transformer. The control transformer is similar in construction to the synchro transmitter except the shape of rotor of control transformer which is cylindrical. Therefore air gap flux is uniformly distributed.

The voltage induced in the stator coils and the corresponding currents of the transmitter are given to the control transformer stator coils. Both the stator coils are connected to each other. Thus circulating currents of same phase but of different magnitude flow through the two sets of stator coils.

This establishes an identical flux pattern in the air gap of control transformer. Thus the flux pattern setup in the air gap of control transformer will have same orientation as that of transmitter rotor. Thus control transformer flux axis is in the same position as that of rotor. Therefore the voltage induced in the transformer rotor is proportional to the cosine of angle between the two rotors.

Output

$$e_0(t) = K\ V_r\ \sin\omega t + \cos\phi$$

$$V_r\ \sin\omega t$$

is the input voltage to the transmitter rotor.

Φ is the angular difference between the two rotors. When $\phi = 90^0$, both the rotors are perpendicular to each other and output $e_0(t)$ = 0 This position is known as electrical zero position and it is used as reference position.

ii) Illustrate PID (proportional integral derivative) control action with output equation, nature of output response, advantages and disadvantages.

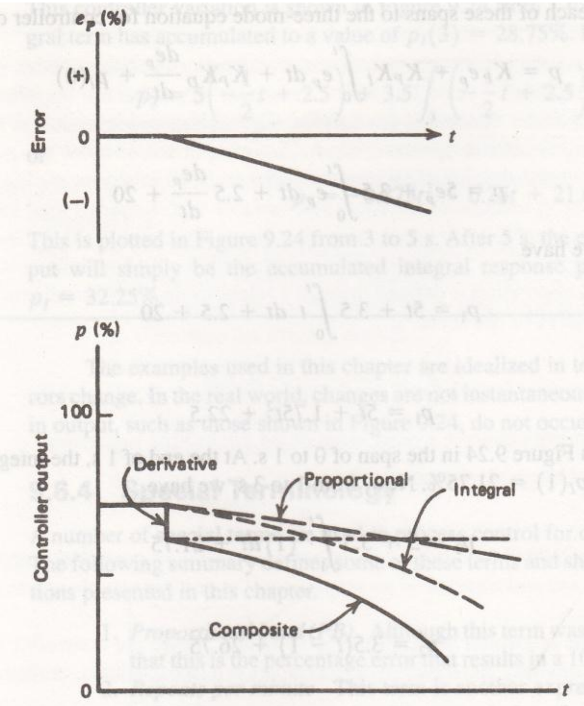
Ans:

Output equation: (1 ½ Marks)

$$p = K_p e_p + K_p + K_1 \int_0^t e_p \, dt + K_p + K_D \frac{de_p}{dt} + pt^0$$

Nature of output response: (1 ½ Marks)

(Note: Response with respect to any other error can be considered)



Advantages: (Any Two) (1 ½ Marks)

1. Most powerful mode of controller.
2. Eliminates offset.
3. Fast response.
4. Produces output depending upon magnitude duration, and rate of change of error.

Disadvantages: (Any Two) (1 ½ Marks)

1. Complex
2. Tuning of parameters (K_P, K_I, K_D) is difficult.

Q 5. Attempt any four of the following (4*4=16)

a) **State Routh's stability criterion**.

Ans: Characteristic equation: $a_n s^n + a_{n-1} s^{n-1} + \cdots + a_1 s + a_0 = 0$

Assume: $a_n > 0$ (otherwise make it so)
Necessary condition for stability is that all the coefficients (a_0, $a_1 \dots a_{n-1}$, a_n) are positive

Routh array elements

$$b_1 = \frac{a_{n-1}a_{n-2} - a_n a_{n-3}}{a_{n-1}} \qquad c_1 = \frac{b_1 a_{n-3} - a_{n-1} b_2}{b_1}$$

$$b_2 = \frac{a_{n-1}a_{n-4} - a_n a_{n-5}}{a_{n-1}} \qquad c_2 = \frac{b_1 a_{n-5} - a_{n-1} b_3}{b_1}$$

$$\vdots \qquad\qquad\qquad\qquad \vdots$$

Routh stability criterion: A necessary and sufficient condition for the feedback control system to be stable is for all the elements (b_1, c_1, …) in the first column of the Routh array to be positive (no sign change)
4marks

b) What is steady state response and steady state error in time domain analysis?

Ans: Steady-state response is simply the part of the total response that remains after the transient has died out.
If the steady-state response of the output does not agree with the desired reference exactly, the system is said to have a steady-state error. **2 mark**

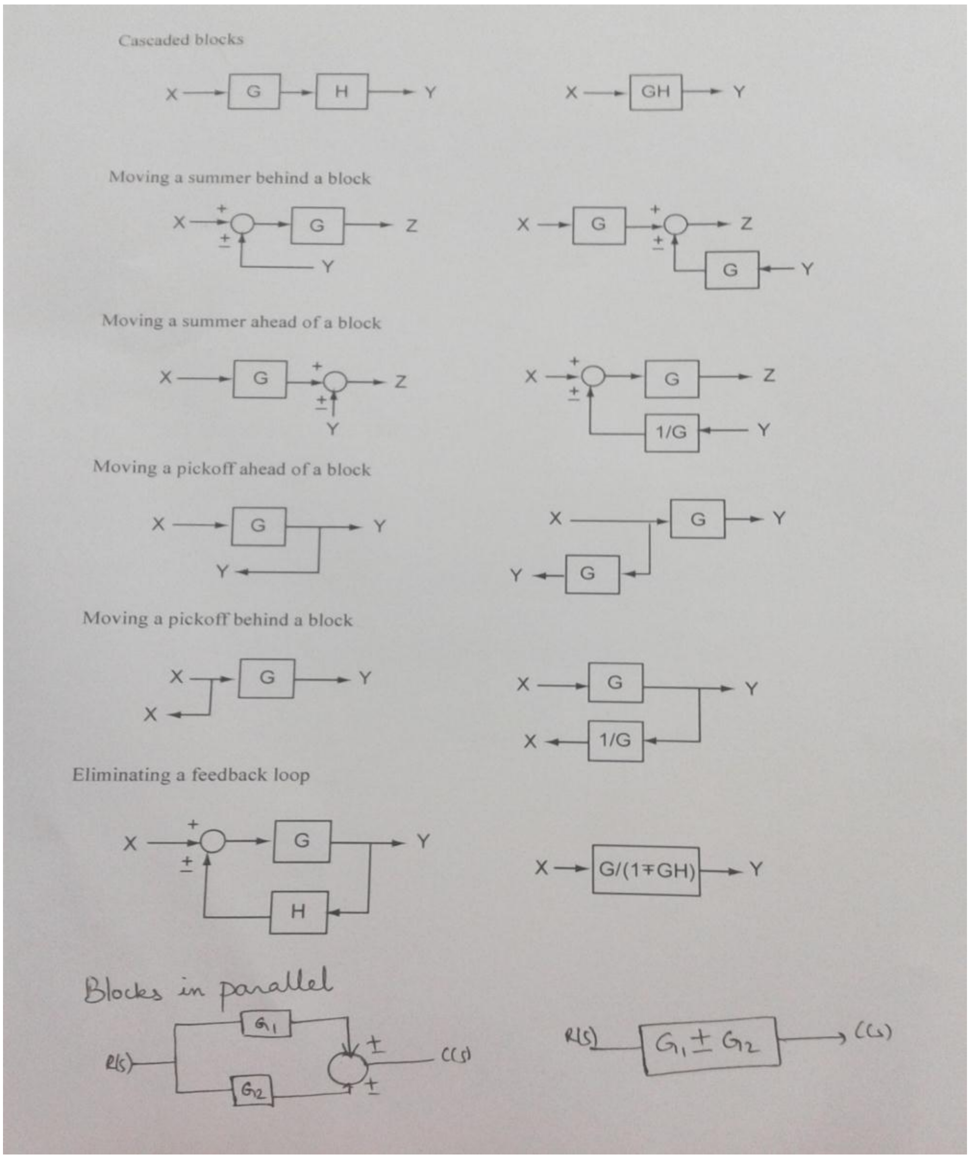
Steady-state error: The steady-state performance of a stable control system is generally judged by its steady-state error to step, ramp and parabolic inputs. For a unity feedback system,

$$E(s) = \frac{R(s)}{1+G(s)}, \Rightarrow e_{ss} = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{sR(s)}{1+G(s)}.$$

It is seen that steady-state error depends upon the input $R(s)$ and the forward transfer function $G(s)$. **2 mark**

c) **Explain any four block diagram reduction rules.**

Ans: **(Any 4 block diagram-4 marks)**



d) What is degree of freedom and end effector of a robotic system?

Ans: - DOF: **2M**

Degree of freedom is a term used to describe a robot's freedom of motion in 3 dimensional spaces specifically the ability to move forward and backward, up and down, left and right. For each DOF a joint is required.

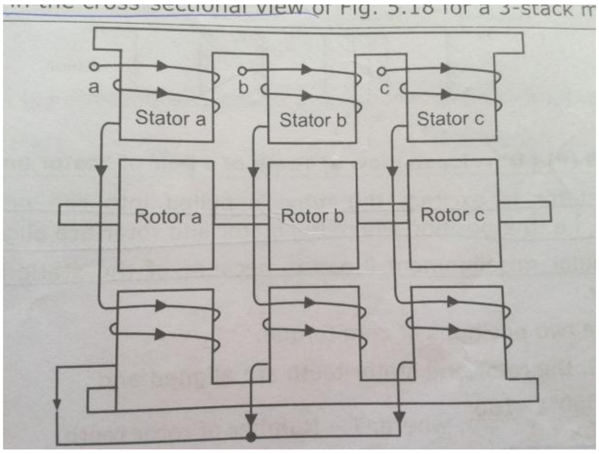
End effector: **2M**

End effector is the device at the end of a robotic arm designed to interact with the environment. End effector originates from robotic manipulators (robotic arm) It is the last link of the robot.

e) Explain construction of variable reluctance stepper motor with diagram.

Ans: - **(Diagram -2M, Explanation-2M,)**

A variable reluctance stepper motor consists of only one or several stacks of stators and rotors. Stators have a common frame whereas rotors have a common shaft



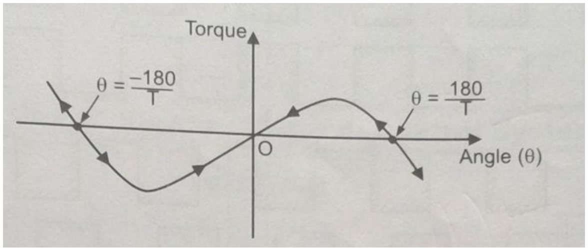


Fig: Static Torque- Angle Characteristic

i. Teeth aligned position Θ =0, is a stable position ie. Slight disturbance from this position in either direction brings the rotor back to it.

ii. Tooth slot aligned position Θ= 180/T is unstable ie. Slight disturbance from this position in either direction makes the rotor move away from it.

iii. The teeth on all the rotors are perfectly aligned but the stator teeths differ by an angular displacement of $\alpha = 360/(nT)$
Where n=number of stacks , T no of rotor teeth

Or

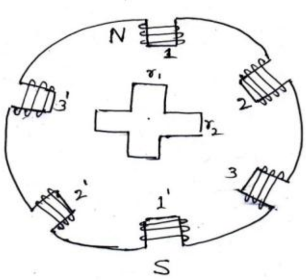


Fig (a)

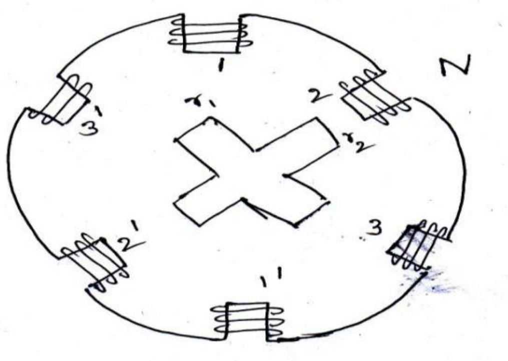


fig (b) 3 stator phases (6poles) and 4 rotor poles

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Variable reluctance type of stepper motor

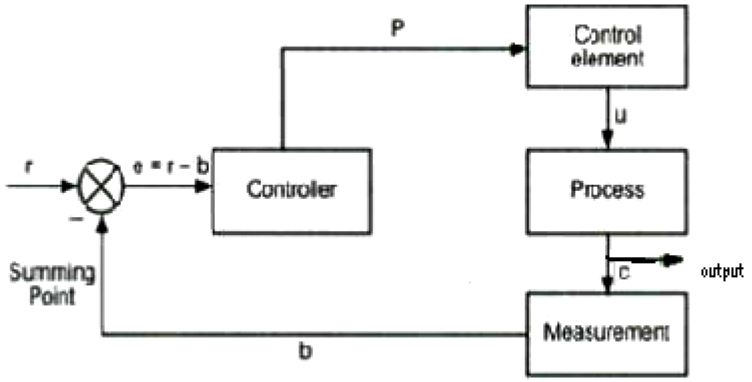
Here rotor is made of magnetic material with a certain number of teeth. The rotor is derives by a phased arrangement of stator coils with different no of poles so that the rotor can never be in perfect alignment with stator. As the no of stator & rotor poles can be increased, the step angle can be reduced here. Therefore it is used applications where small step angles are needed such as micro positioning tables. Consider a VRSM with 3 stator phases (6 poles) and 4 rotor poles. Here, consider no.1 stator pole as excited, making it North & '1' as South. Rotor pole r1, r2 are South poles. In fig (a) r1 is aligned with no.1 stator pole. In fig 2, no.2 stator poles are excited. Rotor pole r2 is nearest to the position of alignment rotor moved to align r2 with no.2 stator pole. It causes a rotation of rotor by 30^0 anticlockwise.

Relationship to find step angler in VRSM = 360/(no of rotor teeth * no of stator phases).

Therefore here, 360/(4*3) = 30^o

f) Draw block diagram of process control system. Give classification of control action.

Ans: (Diagram 1 mark, explanation 1 mark , classification of control action 2 marks)



Explanation:

Process consists of several regulated operations.

Measuring element: measures or sense the actual value of the controlled variable and converts it into proportional feedback variable.

Error detector compares the feedback variable with the set point.

Controller generates the correct signal which is then applied to the final control element

Final control element adjusts the manipulated variable with the set point.

Classification of control action:

a) Continuous mode of control actions: - Proportional control mode, Integral control mode & Derivative control mode.

b) Composite mode of control actions: - Proportional Integral control (PI) ,Proportional Derivative control (PD) & Three mode controller (PID) or proportional Integral Derivative control.

c) Discontinuous mode of control action:- ON-OFF control action

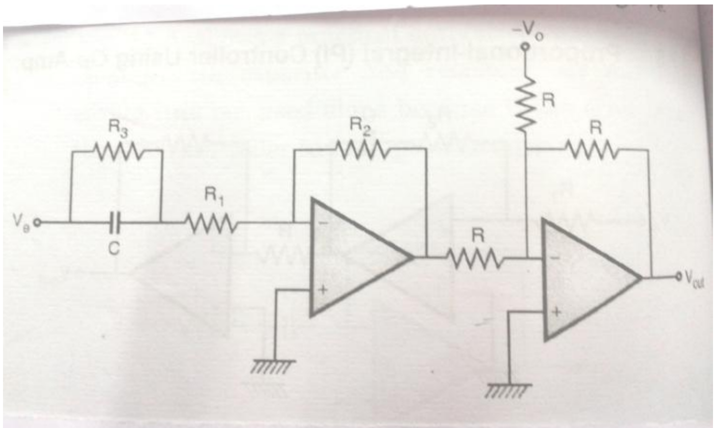
Q 6. Attempt any four of the following: (4*4=16)

a) Why derivative control mode is never used alone? Draw circuit to implement PD (Proportional Derivative) control action.

Ans: Derivative control action responds to the rate at which the error is changing. Derivative action is not used alone because it provides no output when error is constant.

2 marks

Diagram of PD control action: 2 marks



b) **What are linear time varying and time invarying systems? Give example of each**.

Ans:

A linear time variant or varying system is defined as a control system in which parameters of the system are varying with time that means as time passes parameters varies. **1 mark**

Example: differential equation with variable coefficients, for example, as the automobile vehicle covers a distance ie. As time passes petrol level goes on decreasing in the tank due to consumption of fuel. **1 mark**

A linear time in-variant or varying system is defined as a control system in which parameters of the system does not vary with time. **1 mark**

Example: control systems described by linear differential equation with constant coefficients. The parameters of these systems are unaffected by time **1 mark**

c) **What are static error coefficients? Explain**

Ans:

For a unity feedback system,

$$E(s) = \frac{R(s)}{1+G(s)}, \Rightarrow e_{ss} = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{sR(s)}{1+G(s)}.$$ **1 mark**

It is seen that steady-state error E(s) depends upon the input $R(s)$ and the forward transfer function $G(s)$.

The steady-state errors for different inputs are derived as follows:

1. For unit-step input: $r(t) = u(t), R(s) = \frac{1}{s}$

$$e_{ss} = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{1}{1+G(s)} = \frac{1}{1+G(0)} = \frac{1}{1+k_p};$$ k_p is called position error constant.

1 mark

2. For unit-ramp input: $r(t) = tu(t), R(s) = \frac{1}{s^2}$

$$e_{ss} = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{1}{s\left[1+G(s)\right]} = \lim_{s\to 0} \frac{1}{sG(s)} = \frac{1}{k_v};$$ k_v is called velocity error constant.

1 mark

3. For unit-parabolic input: $r(t) = t^2/2, R(s) = \frac{1}{s^3}$

$$e_{ss} = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{1}{s^2\left[1+G(s)\right]} = \lim_{s\to 0} \frac{1}{s^2G(s)} = \frac{1}{k_a};$$ k_a is called acceleration error constant.

1 mark

d) **Compare AC servomotor with DC servomotor.**

Ans: **(any 4 points – 4 marks)**

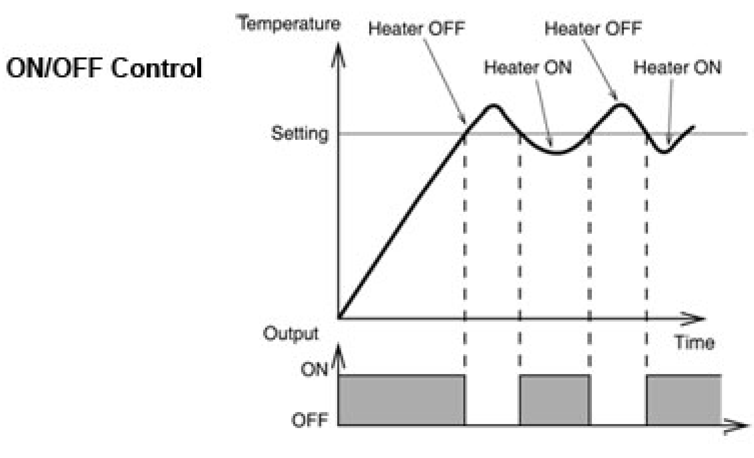
Sr no.	**AC servo motor**	**DC servomotor**
1	Low power o/p	High power o/p
2	Maintenance is less	More maintenance
3	Brushes / commutators absent	Brushes / problem commutators present
4	Stable and smooth operation	Noise
5	Less problem of stability	More problem of stability

6	No RF noise because of absence of brushes	Brushes produce of RF noise.
7	Non – linear characteristics	Linear characteristics
8	No voltage supply to rotor, Rotor current is supplied inductively by rotating magnetic field of stator.	Voltage is given through power supply to rotor.
9	Applications:- low power(computer peripherals, recorders etc.)	Applications:- high power (machine tools, robotics)

e) Explain ON-OFF controller. Give example.

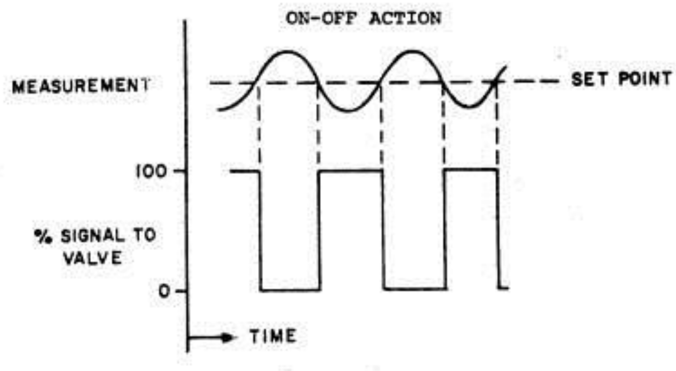
Ans:-
ON-OFF controller is the most elementary controller mode which has only two fixed position, ie. ON and OFF position. It is the simplest and cheapest mode of action, hence commonly used in industrial and domestic controls. **1 mark**
In this mode, when the error signal e(t) is greater than the set point r(t) i.e reference point, the output u(t) of the controller is zero(OFF) and when the error signal is less than the set point the output maximum(ON).
Mathematical expression:
$u(t)= 0\%$ (OFF) for $e(t) > 0$
$u(t)=100\%$ (ON) for $e(t) < 0$ **1 mark**

Example - 2 mark
An on-off controller is the simplest form of temperature control device. The output from the device is either on or off. An on-off controller will switch the output only when the temperature crosses the setpoint. For heating control, the output is on when the temperature is below the setpoint, and off above setpoint. Since the temperature crosses the setpoint to change the output state, the process temperature will be cycling continually, going from below setpoint to above, and back below.



or

FIGURE 5


ON-OFF ACTION
MEASUREMENT
SET POINT
100
% SIGNAL TO VALVE
0
TIME