SCHEME : K

Name : _____

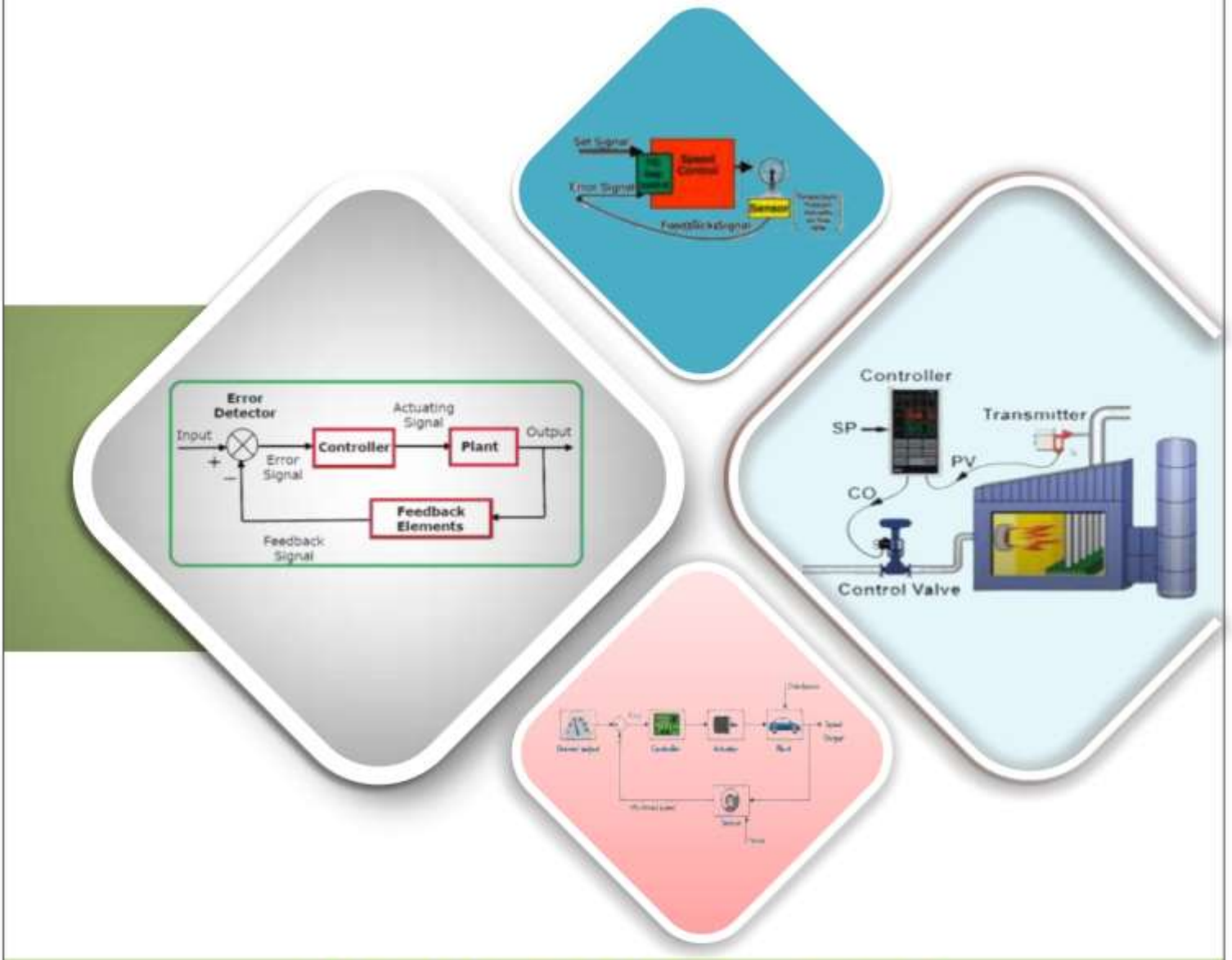
Roll No. : _____ Year : 20___ 20___

Exam Seat No. : _____

LABORATORY MANUAL FOR

CONTROL SYSTEM & COMPONENT

(313329)



ELECTRONICS ENGINEERING GROUP

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI

(Autonomous) (ISO 9001: 2015) (ISO/IEC 27001:2013)

VISION

To ensure that the Diploma level Technical Education constantly matches the latest requirements of Technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

MISSION

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the challenging technological & environmental challenges.

QUALITY POLICY

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation, evaluation and monitoring system along with adequate faculty development programmes.

CORE VALUES

MSBTE believes in the following

- Skill development in line with industry requirements
- Industry readiness and improved employability of Diploma holders
- Synergistic relationship with industry
- Collective and Cooperative development of all stake holders
- Technological interventions in societal development
- Access to uniform quality technical education

A Laboratory manual

for

Control System and Components

(313329)

K-Scheme

Semester – III

(AO/IC/IS)

Maharashtra State

Board of Technical Education, Mumbai

(Autonomous) (ISO 9001:2015) (ISO/IEC 27001:2013)

Maharashtra State Board of Technical Education, Mumbai
(Autonomous) (ISO 9001:2015) (ISO/IEC 27001:2013)
4th Floor, Government Polytechnic Building, 49,
Kherwadi, Bandra (East), Mumbai- 400051.
(Printed on July, 2024)

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION MUMBAI

Certificate

This is to certify that Mr./Ms.…….....

Roll. No.……. of Third Semester of Diploma in ……....

.....……..…….....

of Institute ……..……

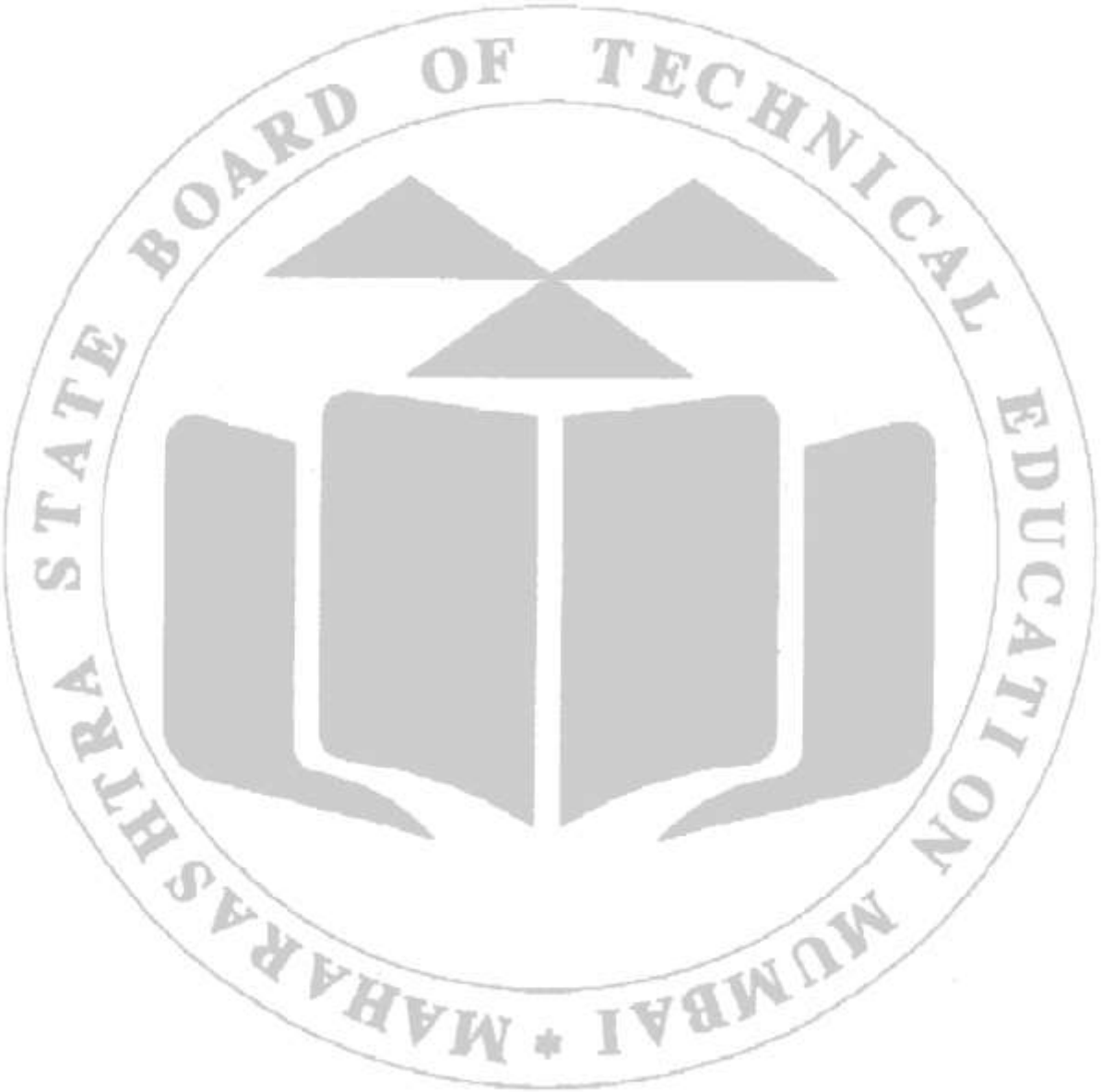
(Code: ……) has completed the term work satisfactorily in course **Control System and Components (313329)** for the academic year 20…….to 20……. as prescribed in the curriculum.

Place: …….. Enrollment No: ……

Date: …… Exam Seat No: ……

Subject Teacher **Head of department** **Principal**

Seal of Institute


MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
MUMBAI

Preface

The primary focus of any engineering laboratory/field work in the technical education system is to develop the much-needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'K' Scheme curricula for engineering diploma programmes with outcome-based education as the focus and accordingly, a relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher, instructor and student realize that every minute of the laboratory time needs to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome- based curriculum, every practical course has been designed to serve as a ***'vehicle'*** to develop this industry identified competency in every student. The practical skills are difficult to develop through "chalk and duster" activity in the classroom situation. Accordingly, the 'K' scheme laboratory manual development team designed the practical to focus on the outcomes, rather than the traditional age-old practice of conducting practical to 'verify the theory" (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the predetermined outcomes. It is expected. from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve as a key focal point for doing the practical. The students will then become aware about the skills they will achieve through the procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

The basic aim of the course Control System and Components (313329) is to facilitate the diploma students to acquire knowledge and skill sets to apply the principles of control system to initiate different control actions starting from simple home refrigeration systems to large industrial control systems.

Although best possible care has been taken to check for errors (if any) in this laboratory manual, perfection may elude us as this is the first edition of this manual. Any errors and suggestions for improvement are solicited and highly welcome.

Program Outcomes (POs)

PO1 Basic and Discipline specific knowledge: Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the broad-based Electronic Engineering group program problems.

PO2 Problem analysis: Identify and analyze well-defined Electronic Engineering group program problems using codified standard methods.

PO3 Design/ development of solutions: Design solutions for well-defined technical problems and assist with the design of Electronic Engineering group program systems components or processes to meet specified needs.

PO4 Engineering Tools, Experimentation and Testing: Apply modern Electronic Engineering group program tools and appropriate technique to conduct standard tests and measurements.

PO5 Engineering practices for society, sustainability and environment: Apply appropriate Electronic Engineering group program technology in context of society, sustainability, environment and ethical practices.

PO6 Project Management: Use Electronic Engineering group program management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.

PO7 Life-long learning: Ability to analyze individual needs and engage in updating in the context of Electronic Engineering group program technological changes.

List of relevant expected psychomotor domain skills

The following industry relevant skills of the identified competency "Use different types of controllers ensuring the stability of the given control system" are expected to be developed in student by undertaking the laboratory work as given in laboratory manual.

1. Apply fundamentals of control systems to derive the Transfer Function
2. Interpret the time response and stability of a given control system
3. Use relevant controller for controlling a given process system
4. Use relevant control system component for position control
5. Choose appropriate actuators for a given application
6. Proper handling of instruments.
7. Measure the physical quantities accurately.
8. Observe the phenomenon and list the observations in proper tabular form.
9. Adopt proper procedure while performing the experiment.

Practical-Course outcome matrix

COURSE LEVEL LEARNING OUTCOMES (COS)

CO1 Apply fundamentals of control systems to derive the Transfer Function
CO2 Interpret the time response and stability of a given control system
CO3 Use relevant controller for controlling a given process system
CO4 Use relevant control system component for position control
CO5 Choose appropriate actuators for a given application

Sr. No.	Title of the Practical	CO1	CO2	CO3	CO4	CO5
1	Open source software (Scilab) tools to derive transfer function of a given control system	✓	-	-	-	-
2	Open source software to determine the poles and zeros of a given transfer function	✓	-	-	-	-
3	Response of an R-C circuit (first order system) for unit step input	-	✓	-	-	-
4	Analysis of the step response of a first order system for various time constants using open-source software	-	✓	-	-	-
5	Analysis of unit step time response of a second order system for various damping factors using open-source software	-	✓	-	-	-
6	Determination of stability of a given control system by plotting poles and zeros in s-plane using open source software	-	✓	-	-	-
7	Steady state response of Type 0 control system for step input	-	✓	-	-	-
8	Analysis of steady state error for different inputs for Type 0 system using open-source software	-	✓	-	-	-
9	Analysis of steady state error for different inputs for Type 1 system using open-source software	-	✓	-	-	-
10	Demonstration of neutral zone of a given ON-OFF controller	-	-	✓	-	-
11	Proportional controller to control a given process parameter and demonstrate the proportional band	-	-	✓	-	-
12	Test the performance of PID controller for different values of P, I, D	-	-	✓	-	-
13	Test the performance of potentiometer as an error detector	-	-	-	✓	-
14	Test the performance of synchro as an error detector by practicing safety measures	-	-	-	✓	-
15	Angular position control using DC Servosystem	-	-	-	✓	-
16	Operation of pneumatic/ hydraulic single acting or double acting cylinder with the help of directional control valve	-	-	-	-	✓

Guidelines to Teachers

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain prior concepts to the students before starting of each experiment
3. Involve students in performance of each experiment.
4. Teacher should ensure that the respective skills and competencies are developed in. the students after the completion of the practical exercise.
5. Teachers should give opportunity to students for hands on experience after the demonstration.
6. Teacher is expected to share the skills and competencies to be developed in the students.
7. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected the students by the industry.
8. Finally give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions.
9. Teacher is expected to refer complete curriculum document and follow guidelines for implementation
10. At the beginning of the practical which is based on the simulation, teacher should make the students acquainted with any simulation software environment.

Instructions for Students

1. Listen carefully the lecture given by teacher about subject, curriculum, learning structure, skills to be developed.
2. Organize the work in the group and make record all programs.
3. Students shall develop maintenance skill as expected by industries.
4. Student shall attempt to develop related hand-on skills and gain confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. those included in scope of manual
6. Student shall refer technical magazines.
7. Student should develop habit to submit the practical on date and time.
8. Student should well prepare while submitting write-up of exercise.
9. Attach/paste separate papers wherever necessary.

Content Page

List of Practical's and Progressive Assessment Sheet

Sr. No	Title of the Practical	Page no.	Date of Performance	Date of Submission	Assessment Marks (25)	Dated sign of Teacher	Remark (If any)
1	Open-source software tools to derive transfer function of a given control system	1					
2	*Open-source software to determine the poles and zeros of a given transfer function	6					
3	*Response of an R-C circuit (first order system) for unit step input	11					
4	Analysis of the step response of first order system for various time constants using open-source software	17					
5	*Analysis of unit step time response of a second order system for various damping factors using open-source software	22					
6	Determination of stability of a given control system by plotting poles and zeros in s-plane using open-source software	27					
7	*Steady state response of Type 0 control system for step input	32					
8	Analysis of steady state error for different inputs for Type 0 system using open-source software	38					
9	Analysis of steady state error for different inputs for Type 1 system using open-source Software	43					
10	*Demonstration of neutral zone of a given ON-OFF controller	48					
11	*Proportional controller to control a given process parameter and demonstrate the proportional band	53					
12	Test the performance of PID controller for different values of P, I, D	58					
13	Test the performance of potentiometer as an error detector	64					
14	*Test the performance of synchro as an error detector by practicing safety measures	70					
15	Angular position control using DC Servosystem	76					
16	*Operation of pneumatic/ hydraulic single acting or double acting cylinder with the help of directional control valve	81					
	Total						

Note: Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

Practical No.1: Open-source software (Scilab) tools to derive transfer function of a given control system

I Practical Significance

To familiarize the students with the Open-source software Scilab)

II Industry/Employer Expected Outcome(s)

Develop, debug and run the code for the given problem

III Course Level Learning Outcome(s)

Apply fundamentals of control systems to derive the Transfer Function

IV Laboratory Learning Outcome(s)

1. Install open-source software (Scilab)
2. Use the appropriate software tools to derive the transfer function

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

A physical control system is considered as an idealized physical system or physical model by neglecting the nonlinearities. The physical model is converted to its mathematical model (which is the mathematical representation of the physical model). The mathematical model is depicted by differential equations by applying known equations or laws such as KVL, KCL. The differential equation is reshaped into Transfer functions using powerful mathematical tool such as Laplace Transform

Transfer Function: TF is defined as the ratio of Laplace transform of output to that of input under the zero initial condition.

VII Actual Circuit diagram used in laboratory with related equipment rating

NA

VIII Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC loaded with open-source software 'Scilab'	- -	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Use standard Electrical symbols.
4) Don't touch wire with wet hand.
5) Check the power supply before connection.

X Procedure

1. Open the open-source software Scilab in the computer
2. Write the code for the given problem
3. Execute the code
4. Verify the result

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Sample program:

Find out the Transfer function of the system from the given numerator and denominator:

Numerator = S+3

Denominator = (S+4) *(S+2)

TF= $\frac{s+3}{(s+4)*(s+2)}$

Scilab code	Comments
s=%s	(%s is the polynomial in the real cases by default, s = poly(0, "s"))
n= s+3	(n- numerator)
d=(s+4) *(s+2)	(d-denominator)
h=syslin("c",n/d)	(h-SISO TF, syslin-linear system, "c"-continuous system)

Problem statement for the students:

Find out the Transfer function of the system from the given numerator and denominator:
Numerator = S^2+9
Denominator = S^2+8S+7

TF=

Scilab code	Comments

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Write the name and specification of the software used to derive the transfer function the laboratory
2. Write the advantages and disadvantages of transfer function

[Space for Answers]

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XVIII References/Suggestions for further reading

1. https://archive.nptel.ac.in/courses/107/106/107106081/
2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.2: Open-source software to determine the poles and zeros of a given transfer function

I Practical Significance

To familiarize the students with the Open-source software (Scilab)

II Industry/Employer Expected Outcome(s)

Develop, debug and run the code for the given problem

III Course Level Learning Outcome(s)

Apply fundamentals of control systems to derive the Transfer Function

IV Laboratory Learning Outcome(s)

1. Determine the poles and zeros of a given transfer function
2. Use open loop software to determine the poles and zeros of a given transfer function

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

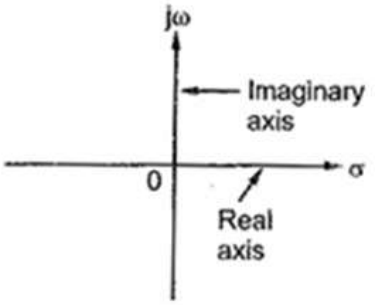
Transfer Function: TF is defined as the ratio of Laplace transform of output to that of input under the zero initial condition.

Poles: the value of S in the denominator of transfer function which makes the TF equal to infinity

Zero: the value of S in the numerator of transfer function which makes the TF equal to zero

S-plane: The graphical plane which is used to represent poles and zeros. X axis is the real axis and Y axis is the imaginary axis.

Poles are represented with × and zeros with **0** symbol in S-plane.



s-plane

Fig: 2:1

VII Actual Circuit diagram used in laboratory with related equipment rating

NA

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC loaded with open source software 'Scilab'	- -	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Check the power supply before connection.

X Procedure

1. Open the open-source software Scilab in the computer
2. Write the code for the given problem
3. Execute the code
4. Verify the result
5. Observe the S-plane

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Sample program:

Find out the poles and zeros of the system from the given Transfer function:

TF= $\frac{s+4}{S^2+6S+9}$

Ans: Poles = -3, -3

Zero = -4

Scilab code	Comments
s=%s n= s+4 d= s^2+6*s+9 h=syslin("c",n/d) [z, p, k] = tf2zp(h) plzr(h)	(%s is the polynomial in the real cases by default, s = poly(0, "s")) (n- numerator) (d-denominator) (h-SISO TF, syslin-linear system, "c"-continuous system) (z,p,k- zero, pole, constant; tf2zp-TF to zeros and poles) (plot S plane with zero and pole)

Problem statement for the students:

Find out the poles and zeros of the system from the given Transfer function:

TF= $\frac{S^2+16}{S^2+7S+10}$

Answer:

Poles =

Zero =

Pole-zero plot on S-plane:

Scilab code	Comments

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Calculate the poles and zeros of the given Transfer Function

2. Write the significance of poles and zeros

[Space for Answers]

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XVIII References/Suggestions for further reading

1. https://archive.nptel.ac.in/courses/107/106/107106081/
2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.3: Response of an R-C circuit (first order system) for unit step input

I Practical Significance

To familiarize the students with the order of the system and standard input signals

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Interpret the time response and stability of a given control system

IV Laboratory Learning Outcome(s)

1. Plot the response of given R-C circuit (first order system)
2. Determine the time constant for given R-C circuit (first order system)

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

Order of the system: It is the highest power of S in the denominator of the TF.

Standard test input signals: 1) Step Input 2) Ramp Input 3) Parabolic Input 4) Impulse Input

Transfer Function of RC network: TF= $\frac{C(S)}{R(S)} = \frac{1}{RCS+1}$

The output equation for first order system response for unit step input: $c(t) = 1 - e^{-\frac{t}{RC}}$

VII Actual Circuit diagram used in laboratory with related equipment rating

Layout of Laboratory**:**

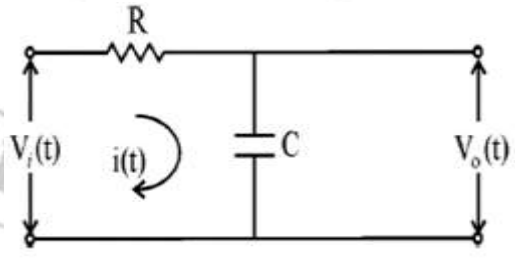

Fig: 3:1

Actual Circuit diagram:

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Resistor	100k	1
2	Capacitor	1000 microfarad	1
3	DC power supply	0-30V, 2 A	1
4	DMM		1
5	Stopwatch		1

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Check the power supply before connection.

X Procedure

1. Construct the RC circuit in bread board
2. Connect 5V power supply. This is the step input.
3. Connect DMM across the output of the circuit.
4. Apply 5V from power supply and start noting the output voltage from DMM for each 50 seconds till the readings become constant.
5. Plot the graph between output voltage vs. time
6. Calculate the time constant from the graph
7. Compare the practical and theoretical time constants.

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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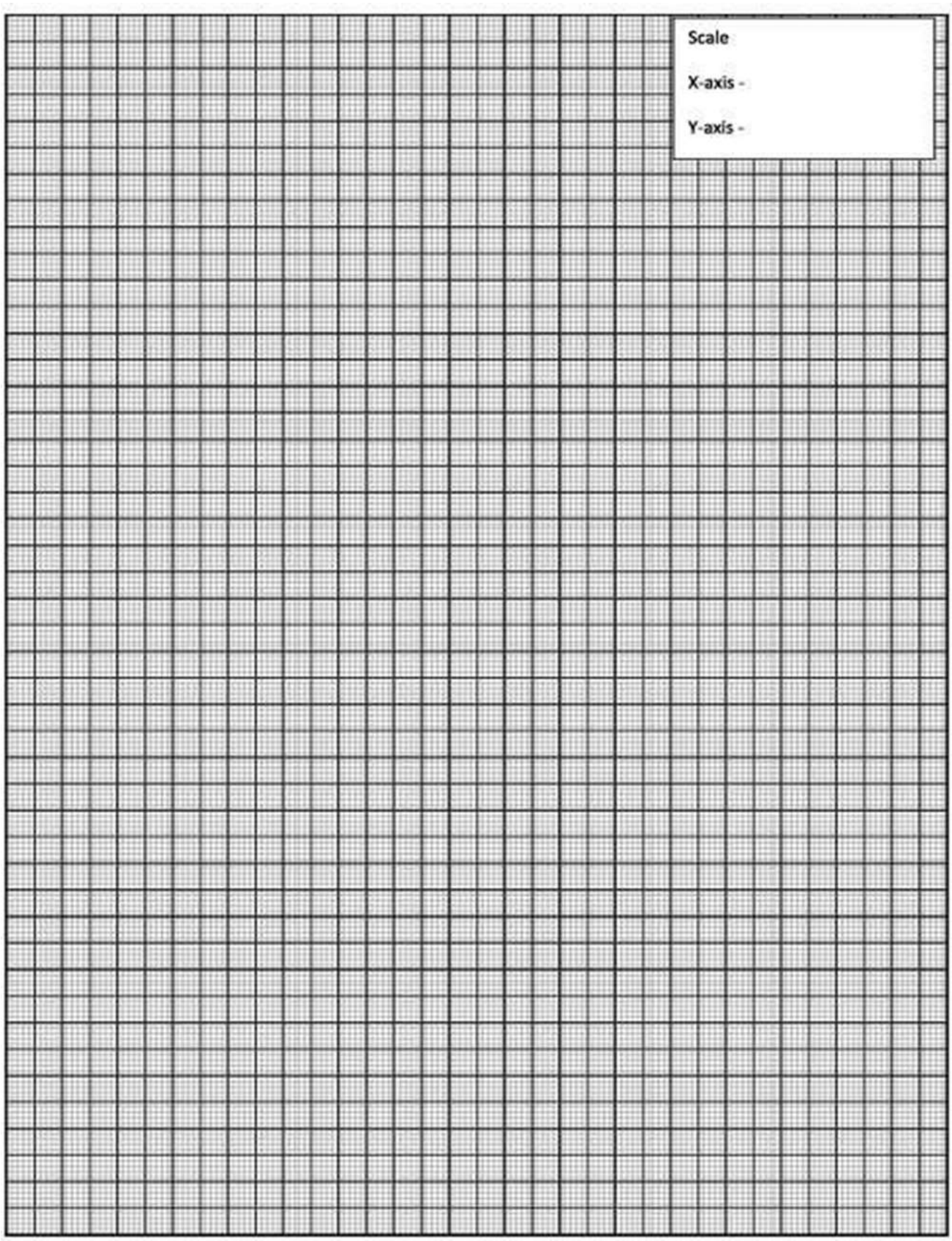
XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Observation column:

Time (sec)	Output voltage


Scale
X-axis -
Y-axis -

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Define time constant. Find out the time constant of the given system in the lab
2. Derive the output equation for first order system response for unit step input

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XVIII References/Suggestions for further reading

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2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.4: Analysis of the step response of a first order system for various time constants using open-source software

I Practical Significance

To familiarize the students with the concept of time constants

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Interpret the time response and stability of a given control system

IV Laboratory Learning Outcome(s)

1. Plot the response of a given first order system using open source software tools
2. Determine the time constant for given first order system

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

Time constant: It is the time taken by the system to reach 63.2% of the final value.

For an RC network with Transfer Function TF= $\frac{C(S)}{R(S)} = \frac{1}{RCS+1} = \frac{1}{\tau S+1}$, RC = τ is the time constant.

More the time constant, slower the system response.

VII Circuit diagram Layout of Laboratory

NA

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC loaded with open-source software 'Scilab'	- -	**1**

IX Precautions to be followed

1. Ensure proper earthing.
2. Check the power supply before connection.

X Procedure

1. Open the open-source software Scilab in the computer
2. Write the code for the given problem in 'scinote'
3. Execute the code
4. Observe the response graph

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Sample program:
Analyze the step response of a first order system for various time constants using open-source software

Consider the first order system transfer function = $\frac{1}{2S+1}$

Here, Time constant τ = 2

Scilab code	Comments
s=%s	(%s is the polynomial in the real cases by default, s = poly(0, "s"))
T=syslin ("c",1, 1+2*s)	(syslin-linear system, "c"-continuous system)
t=0:0.005:5	(it defines a time range)
y=csim ("step", t, T)	csim-continuous simulation, step-step input
plot (t, y)	Plot output vs. time

Problem statement for the students:

Analyze the step response of a first order system for various time constants using open-source software

1. Time constant = 5
2. Time constant = 10

Scilab code	Comments

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Give examples for practical first order systems
2. Write the significance of time constant

[Space for Answers]

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XVIII References/Suggestions for further reading

1. https://archive.nptel.ac.in/courses/107/106/107106081/
2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.5: Analysis of unit step time response of a second order system for various damping factor using open-source software

I Practical Significance

To familiarize the students with the concept of damping factor

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Interpret the time response and stability of a given control system

IV Laboratory Learning Outcome(s)

Record the behavior of a given control system for various damping factors using open-source software

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

The standard equation of Transfer Function for 2nd order system = $\frac{C(S)}{R(S)} = \frac{{w_n}^2}{S^2+2\zeta w_n S+{w_n}^2}$

w_n is the natural frequency.

ζ is the damping factor. Damping is defined as the opposition to oscillation. Depending on its value, there are four cases of response for the system.

VII Circuit diagram Layout of Laboratory

NA

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC loaded with open source software 'Scilab'	- -	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Check the power supply before connection.

X Procedure

1. Open the open source software Scilab in the computer
2. Write the code for the given problem in 'scinote'

3. Execute the code
4. Observe the response graph

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Sample program:

Analysis of unit step time response of a second order system for various damping factor using open-source software.

Consider the second order system transfer function = $\frac{16}{S^2+4\square+16}$

Here, compare it with standard equation of second order TF, $\frac{16}{S^2+4\square+16} = \frac{w_n{}^2}{S^2+2\zeta w_n S+w_n{}^2}$

$w_n{}^2 = 16$, $w_n = 4$, $2\zeta w_n = 4$, ζ=0.5 which is less than 1; Therefore, the system is underdamped.

Scilab code	Comments
s=%s	(%s is the polynomial in the real cases by default, s = poly(0, "s"))
T=syslin ("c",16, 16+4*s+s^2)	(syslin-linear system, "c"- continuous system, (16, 16+4*s+s^2) is the TF
t=0:0.005:5	(it defines a time range)
y=csim ("step", t, T)	csim-continuous simulation, step-step input
plot (t, y)	Plot output vs. time

Problem statement for the students:

Analysis of unit step time response of a second order system for various damping factor using open-source software for the following TF:

1. $\frac{9}{S^2+9}$
2. $\frac{9}{S^2+3S+9}$
3. $\frac{9}{S^2+6S+9}$
4. $\frac{9}{S^2+8S+9}$

Scilab code	Comments

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Give examples for practical second order systems
2. State the effect of ζ (zeta) in the output response of a control system

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XVIII References/Suggestions for further reading

1. https://archive.nptel.ac.in/courses/107/106/107106081/
2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.6: Determination of stability of a given control system by plotting poles and zeros in s plane using open source software

I Practical Significance

To familiarize the students with the concept of stability

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Interpret the time response and stability of a given control system

IV Laboratory Learning Outcome(s)

Determine the stability of a given control system from the pole locations using open-source software

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

Routh's stability criteria are used to analyze stability that enables to determine the number of closed loop poles which lie in right half of s-plane without factorizing the characteristic equation.

Here an array called Routh's array is made from the coefficients of characteristic equation

The necessary and sufficient condition for system to be stable is "All the terms in the first column of the Routh's array must have same sign". There should not be any sign change in the first column of Routh's array.

If there are any sign changes, it indicates that the system is unstable.

The number of sign changes is equal to the number of the poles in RHS of the S-plane

VII Circuit diagram Layout of Laboratory

NA

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC loaded with open source software 'Scilab'	**-** **-**	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Check the power supply before connection.

X Procedure

1. Open the open source software Scilab in the computer
2. Write the code for the given problem
3. Execute the code
4. Verify the result

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Sample program:

Analyze the stability of a given control system by Routh's array using open source software.

Consider the characteristic equation (1+ G(S)H(S))=$\boldsymbol{S^3 + 4S^2 + S + 16 = 0}$

Scilab code	**Comments**
s=%s	(%s is the polynomial in the real cases by default, s = poly(0, "s"))
p=s^3+4*s^2+s+16	p=characteristic equation
routh_t(p)	Routh's array

Result: Solution by Routh's array:

S^3	1	1
S^2	4	16
S	-3	0
S^0	16	0

Conclusion:

There are two sign changes in the first column. So, there are two RHS poles and therefore the system is unstable.

Problem statement for the students:

Analyze the stability of a given control system by Routh's array using open source software

Characteristic equation = 1+ G(S)H(S)=$\boldsymbol{S^3 + 3S^2 + 2S + 4 = 0}$

Scilab code	Comments

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Define stability. Show the location of poles for the stable, unstable and marginally stable system.
2. Find out the range of K for the system to be stable for unity feedback system with Open Loop Transfer Function = $\boldsymbol{G(S) = \frac{K}{S\,(S+2)(S+4)(S+5)}}$

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XVIII References/Suggestions for further reading

1. https://archive.nptel.ac.in/courses/107/106/107106081/
2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.7: Steady state response of Type 0 control system for step input

I Practical Significance

To familiarize the students with Steady state response of Type 0 control system for step input

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Interpret the time response and stability of a given control system

IV Laboratory Learning Outcome(s)

Plot the steady state response of a given Type 0 control system for unit step input

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

- Type of a system is the number of open loop poles at the origin of S-plane.
- Steady state error is the difference between the set point and the final steady state value.
- Steady state error $e_{ss} = \lim_{t\to\infty} e(t) = \lim_{s\to 0} SE(S)$ (By applying final value theorem of Laplace Transform)
- $e_{ss=} \lim_{s\to 0} S * E(S) = \lim_{S\to 0} S \frac{R(S)}{1\pm G(S)H(S)}$
- The ability of the system to reduce or eliminate the steady state error is represented by static error coefficients or constants. There are three Error coefficients which are Position error constant K_P, Velocity error constant K_V , Acceleration error constant K_A

Equation of static error constants and steady state errors for unit step input:

I/P	Error constant	Steady state error
Unit Step	$K_P = \lim_{S\to 0} G(S)H(S)$	$e_{SS} = \frac{1}{1+K_P}$

Relationship between the inputs, static error constants and steady state errors for Type 0 system:

Input	Steady state error e_{ss}	Type 0	
		Static error constant	e_{ss}
Step	$\frac{1}{1+K_P}$	$K_P = constant$	$\frac{1}{1+K_P}$

VII Actual Circuit diagram used in a laboratory with related equipment rating

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Standard test signal generator kit: - outputs- Step: Variable DC Voltage: -12V to +12V; Frequency- approx. 50Hz to 5KHz; Power Requirements- DC regulated from 230V single phase AC	-	**1**
2	Type 0 system trainer kit: - Input Type- provision to connect external inputs (step); Frequency of operation- approx. 50Hz to 5KHz (may vary for different inputs; Power Requirements- DC regulated from 230V single phase AC	-	**1**
3	Timer	-	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Check the power supply before connection.

X Procedure

1. Connect test signal generator to the input terminal of Type 0 kit
2. Connect DMM to the test signal generator to measure input voltage
3. Connect another DMM to the output of Type 0 kit to measure output voltage

For Step signal:

1. Choose ‘step’ mode in test signal generator for Step input signal.
2. Adjust the input voltage and measure the corresponding output voltage for Step signal.
3. Repeat the procedure for different values of input voltages.
4. Plot the graph

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
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2			
3			

XII Actual Procedure

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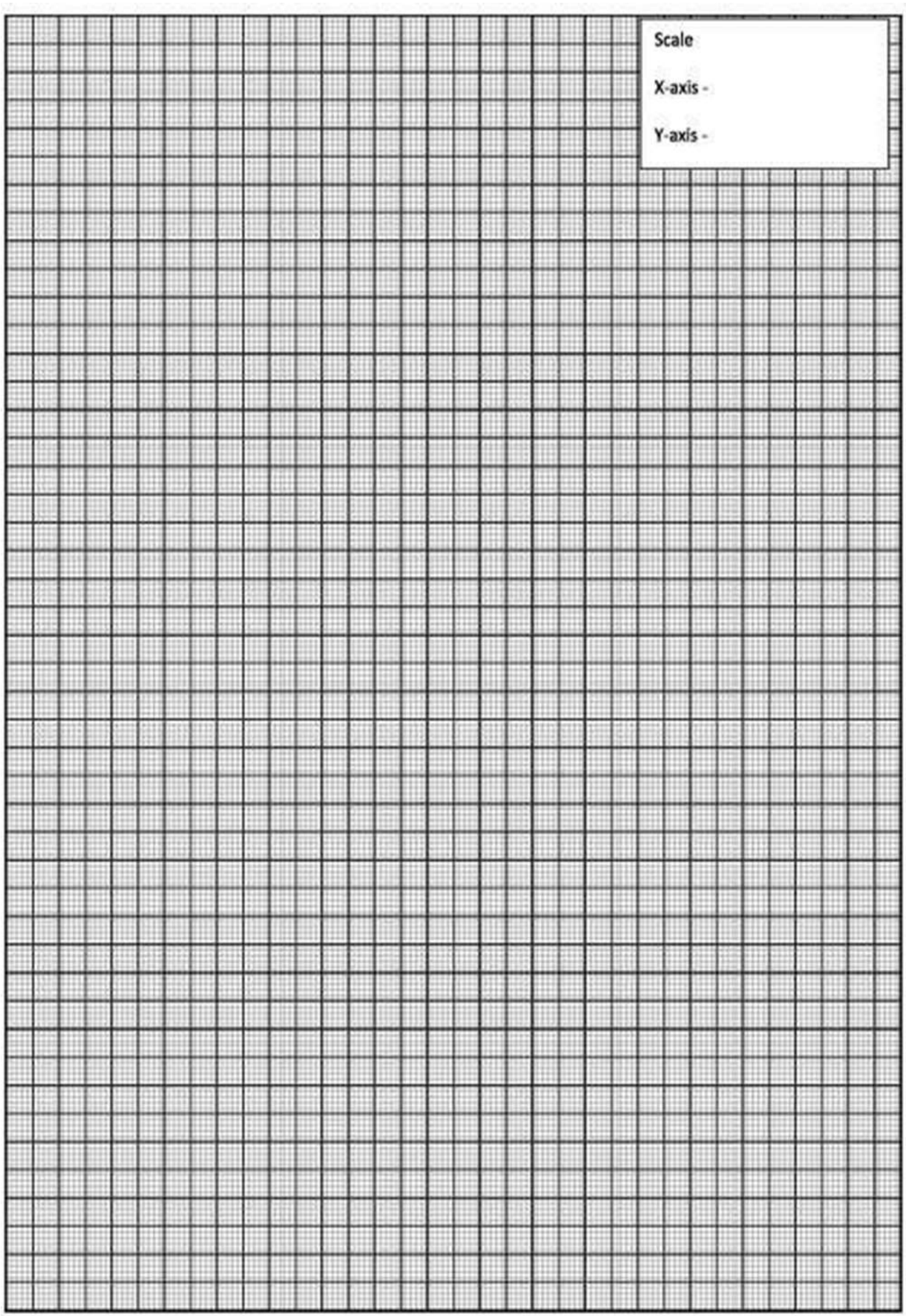
XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Input Voltage (V)	Output Voltage (V)
0.4	
0.6	
0.8	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Y-axis -

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Define steady state error. State its equation.
2. Plot the steady state response of a given Type 0 control system for unit step input

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XVIII References/Suggestions for further reading

1. https://archive.nptel.ac.in/courses/107/106/107106081/
2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.8: Analysis of steady state error for different inputs for Type 0 system using open-source software

I Practical Significance

To familiarize the students with the concept of steady state error

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Interpret the time response and stability of a given control system

IV Laboratory Learning Outcome(s)

Analyze steady state error for different inputs for Type 0 system using open-source software

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

- Type of a system is the number of open loop poles at the origin of S-plane.
- Steady state error is the difference between the set point and the final steady state value.
- The ability of the system to reduce or eliminate the steady state error is represented by static error coefficients or constants. There are three Error coefficients which are Position error constant $\boldsymbol{K_P}$, Velocity error constant $\boldsymbol{K_V}$, Acceleration error constant $\boldsymbol{K_A}$

Equation of error constants and steady state errors:

I/P	Error constant	Steady state error
Unit Step	$\boldsymbol{K_P} = \lim_{S\to 0} \boldsymbol{G(S)H(S)}$	$\boldsymbol{e_{SS}} = \frac{1}{1+K_P}$
Unit Ramp	$\boldsymbol{K_V} = \lim_{S\to 0} \boldsymbol{S\,G(S)H(S)}$	$\boldsymbol{e_{SS}}$
Unit Parabolic	$\boldsymbol{K_A} = \lim_{S\to 0} \boldsymbol{S^2\,G(S)H(S)}$	$\boldsymbol{e_{SS}}$

Relationship between the inputs, static error constants and steady state errors for Type 0 system:

Input	Steady state error e_{ss}	Type 0	
		Static error constant	e_{ss}
Step	$\frac{1}{1+K_P}$	$K_P = constant$	$\frac{1}{1+K_P}$
Ramp	$\frac{1}{K_V}$	$K_V = 0$	∞
Parabolic	$\frac{1}{K_A}$	$K_A = 0$	∞

VII Circuit diagram Layout of Laboratory

NA

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC loaded with open source software 'Scilab'	- -	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Check the power supply before connection.

X Procedure

1. Open the open-source software Scilab in the computer
2. Write the code for the given problem
3. Execute the code
4. Verify the result

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Sample program:

Analyze steady state error for different inputs for Type 0 system with open loop Transfer Function G(S)H(S)=$\frac{16}{(s+4)}$ using open-source software.

$$K_P = \lim_{S\to 0} G(S)H(S) = 4 \qquad e_{SS} = \frac{1}{1+K_P} = 0.2$$

$$K_V = \lim_{S\to 0} S * G(S)H(S) = 0 \qquad e_{SS} = \frac{1}{K_V} = \infty$$

$$K_A = \lim_{S\to 0} S^2 * G(S)H(S) = 0 \qquad e_{SS} = \frac{1}{K_A} = \infty$$

Scilab code	**Comments**
s=%s	(%s is the polynomial in the real cases by default, s = poly(0, "s"))
GsHs=16/(s+4)	(GsHs=G(S)H(S) in the equation of steady state error ess)
kp=horner(GsHs,0)	Horner (GsHs,0) indicates $\lim_{S\to 0} G(S)H(S)$
ess=1/(1+kp)	ess indicates steady state error
kv=horner(s*GsHs,0)	horner(s*GsHs,0) indicates $\lim_{S\to 0} S\,G(S)H(S)$
ess=1/kv	
ka=horner(s^2*GsHs,0)	horner(s^2*GsHs,0) indicates $\lim_{S\to 0} S^2\,G(S)H(S)$
ess=1/ka	

Problem statement for the students:

Analyze steady state error for different inputs for Type 0 system with open loopTransfer Function G(S)H(S)=$\frac{100}{(s+2)(s+10)}$ using open-source software.

Scilab code	**Comments**

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Define Type of the system. State the general expression for Type 0 system.
2. State the relation between Type 0 system and steady state error constants.

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XVIII References/Suggestions for further reading

1. https://archive.nptel.ac.in/courses/107/106/107106081/
2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.9: Analysis of steady state error for different inputs for Type 1 system using open-source software

I Practical Significance

To familiarize the students with the concept of steady state error

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Interpret the time response and stability of a given control system

IV Laboratory Learning Outcome(s)

Analyze steady state error for different inputs for Type 1 system using open-source software

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

- Type of a system is the number of open loop poles at the origin of S-plane.
- Steady state error is the difference between the set point and the final steady state value.
- The ability of the system to reduce or eliminate the steady state error is represented by static error coefficients or constants. There are three Error coefficients which are position error constant $\boldsymbol{K_P}$, Velocity error constant $\boldsymbol{K_V}$, Acceleration error constant $\boldsymbol{K_A}$

Equation of error constants and steady state errors:

I/P	Error constant	Steady state error
Unit Step	$\boldsymbol{K_P = \lim_{S\to 0} G(S)H(S)}$	$\boldsymbol{e_{SS} = \frac{1}{1+K_P}}$
Unit Ramp	$\boldsymbol{K_V = \lim_{S\to 0} S\, G(S)H(S)}$	$\boldsymbol{e_{SS}}$
Unit Parabolic	$\boldsymbol{K_A = \lim_{S\to 0} S^2\, G(S)H(S)}$	$\boldsymbol{e_{SS}}$

Relationship between the inputs, static error constants and steady state errors for Type 1 system:

Input	Steady state error e_{ss}	Type 1	
		Static error constant	e_{ss}
Step	$\frac{1}{1+K_P}$	$K_P = \infty$	0
Ramp	$\frac{1}{K_V}$	K_V = constant	constant
Parabolic	$\frac{1}{K_A}$	$K_A = 0$	∞

VII Circuit diagram Layout of Laboratory

NA

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Desktop PC loaded with open source software 'Scilab'	-	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Check the power supply before connection.

X Procedure

1. Open the open source software Scilab in the computer
2. Write the code for the given problem
3. Execute the code
4. Verify the result

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Sample program:

Analyze steady state error for different inputs for Type 1 system with open loop Transfer Function G(S)H(S)=$\frac{8}{S\,(S+2)}$ using open-source software.

$$K_P = \lim_{S\to 0} G(S)H(S) = \infty \qquad e_{SS} = \frac{1}{1+K_P} = 0$$

$$K_V = \lim_{S\to 0} S * G(S)H(S) = 4 \qquad e_{SS} = \frac{1}{K_V} = 0.25$$

$$K_A = \lim_{S\to 0} S^2 * G(S)H(S) = 0 \qquad e_{SS} = \frac{1}{K_A} = \infty$$

Scilab code	**Comments**
s=%s GsHs=8/s*(s+2) kp=horner(GsHs,0) ess=1/(1+kp) kv=horner(s*GsHs,0) ess=1/kv ka=horner(s^2*GsHs,0) ess=1/ka	(%s is the polynomial in the real cases by default, s = poly(0, "s")) (GsHs=G(S)H(S) in the equation of steady state error ess) horner(GsHs,0) indicates $\lim_{S\to 0} G(S)H(S)$ ess indicates steady state error horner(s*GsHs,0) indicates $\lim_{S\to 0} S\,G(S)H(S)$ horner(s^2*GsHs,0) indicates $\lim_{S\to 0} S^2\,G(S)H(S)$

Problem statement for the students:

Analyze steady state error for different inputs for Type 1 system with open loop Transfer Function G(S)H(S)=$\frac{50}{s\,(s+2)(s+4)}$ using open-source software.

Scilab code	**Comments**

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. State the general expression for Type1 system.
2. State the relation between Type 1 system and steady state error constants.

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XVIII References/Suggestions for further reading

1. https://archive.nptel.ac.in/courses/107/106/107106081/
2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.10: Demonstration of neutral zone of a given ON-OFF controller

I Practical Significance

To familiarize the students with the neutral zone of a given ON-OFF controller.

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Use relevant controller for controlling a given process system

IV Laboratory Learning Outcome(s)

Demonstrate the neutral zone of a given ON-OFF controller

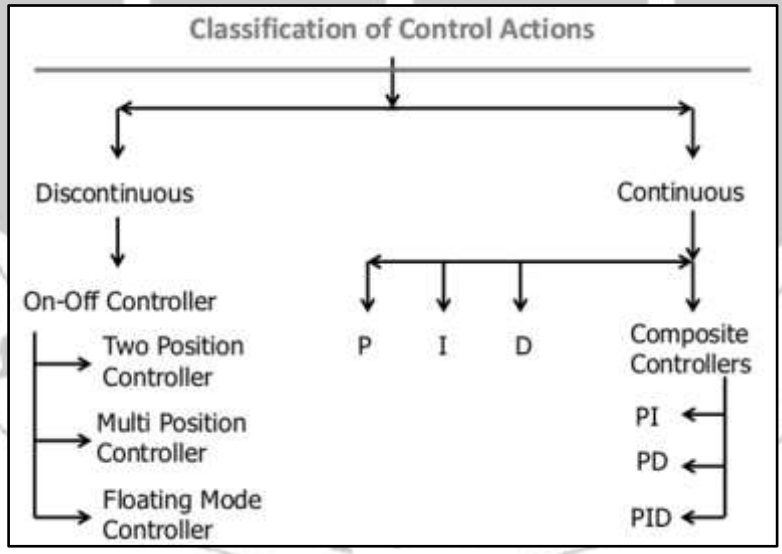
V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

The controller determines the action required to drive the controlled variable to the set point value. The controller output is the commanding signal given to the final control element (FCE) to reduce the error.



On- Off Controller:

It has only two fixed positions such as on (1) and off (0). The output signal P remains either 0% or 100% depending upon whether the error is negative or positive.

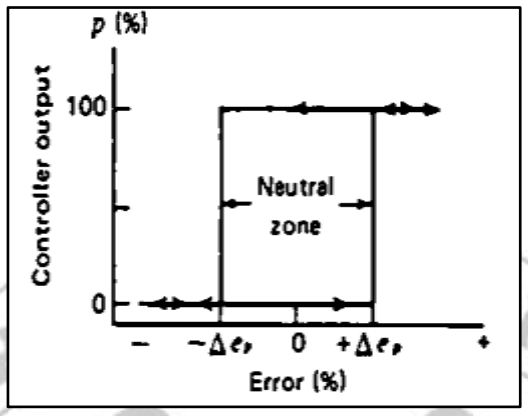
Equation of On-Off controller:

P = 100% (on) for positive error

P = 0% (off) for negative error.

Neutral Zone (NZ) or Differential Gap:

It is defined as the range of errors in On-Off controller in which the controller output remains constant. It is designed to avoid frequent chattering of the controller. It is shown below:



VII Actual Circuit diagram used in laboratory with related equipment rating-

Layout of Laboratory:

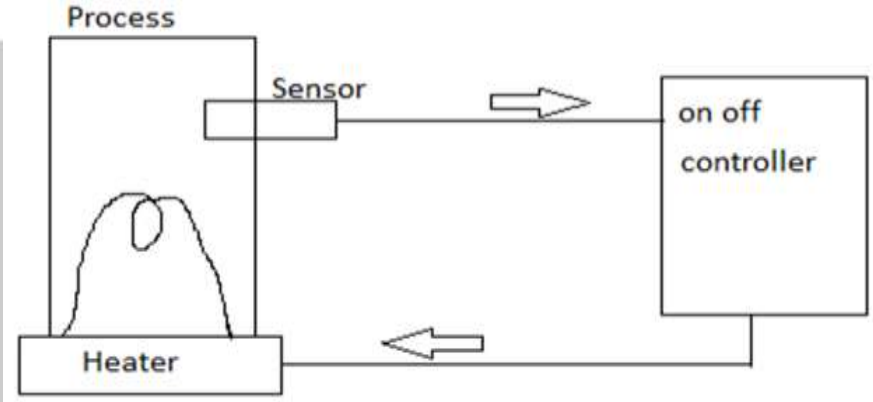


Fig: 10:1

Actual Circuit diagram:

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	On-off controller: - Controlled variable- Temperature or Flow or Pressure or Level; Signal Conditioning- OPAMP based signal conditioning with 1-5% accuracy; Control- Relay based; Power requirement- 230V single phase AC	-	**1**
2	Thermometer	–	**1**
3	Heating medium	–	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Use standard Electrical symbols.
4) Don't touch the wire with your wet hand.
5) Check the power supply before connection.

X Procedure

1. Place the thermometer in the heating medium which is the process where temperature is the process parameter.
2. Connect the controller kit to the heating medium.
3. Switch on the set up.
4. Adjust the required set point in the controller.
5. Note the temperature when the indicator bulb in the process turns on and off.

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Observation column:

Set point	Temperature on	Temperature off

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Draw the response of the ON-OFF controller for a given process variable.
2. Give two advantages and disadvantages of ON-Off controllers.

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XVIII References/Suggestions for further reading

1. https://www.ni.com/en/shop/labview/pid-theory-explained.html #:~:text=The%20basic%20idea%20behind%20a,components%20to%20compute%20the%20output.
2. Process Control Instrumentation Technology by Johnson C. D.

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.11: Proportional controller to control a given process parameter and demonstrate the proportional band

I Practical Significance

To familiarize the students with the Proportional controller to control a given process parameter and demonstrate the proportional band

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Use relevant controller for controlling a given process system

IV Laboratory Learning Outcome(s)

1. Plot the response of the given Proportional controller
2. Demonstrate the Proportional band

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

The controller determines the action required to drive the controlled variable to the set point value. The controller output is the commanding signal given to the final control element (FCE) to reduce the error.

Proportional controller:

In proportional controller, the controller output is directly proportional to the error. It gives the information about the present error

Equation of P controller:

$$\boldsymbol{Pout = KpEp + Po}$$

Pout= Controller output
Kp= proportional constant
Ep = Error percentage
Po= Controller output when error is zero

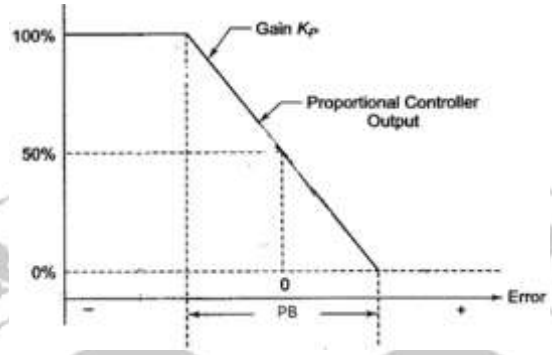
Proportional Band PB:

PB is the range of error for which the proportional controller output changes from 0 % to 100%.

Offset:

It is the permanent residual error / steady state error in proportional controller which is inherent in nature. It is the major disadvantage of the P controller.

Characteristics:



VII Actual Circuit diagram used in laboratory with related equipment rating

Layout of Laboratory:

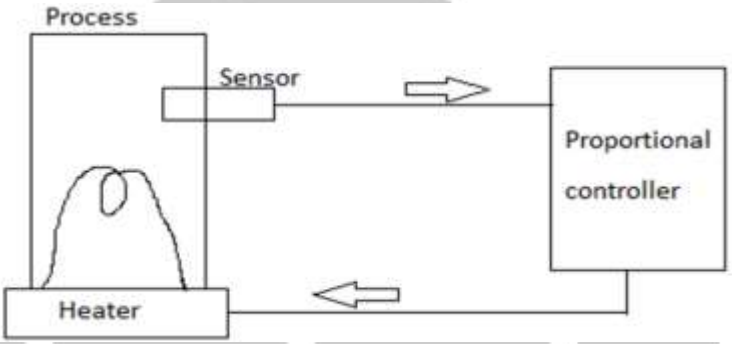


Fig: 11:1

Actual Circuit diagram:

VIII Resources Required:

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Proportional and PID controller: - Controlled Variable- Temperature or flow or pressure or level; Input Value- Linear 0-20mA and or 4-20mA, 0-5V and or 1-5V; Output Value- appropriate range to study PID controller response; Display Type- 4.5-digit 7 segment or 16x2 LCD	–	**1**
2	RTD	–	**1**
3	Heating medium	–	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Don't touch wire with a wet hand.
4) Check the power supply before connection.

X Procedure

1. Place the RTD in the heating medium which is the process where temperature is the process parameter.
2. Connect the controller kit to the heating medium.
3. Connect RTD output to the Proportional controller.
4. Switch on the set up.
5. Adjust the required set point and proportional constant Kp in the controller.
6. Note the temperature of the process variable with respect to time.

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Observation column:

	Time (min)	Process variable (degree Celsius)
Set point= ----- ^{0} C Kp = -----	0	
	2	
	4	
	6	

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Define offset.
2. Write the advantages and disadvantages of proportional controller.

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XVIII References/Suggestions for further reading

1. https://www.ni.com/en/shop/labview/pid-theory-explained.html#:~:text=The%20basic%20idea%20behind%20a,components%20to%20compute%20the%20output.
2. Process Control Instrumentation Technology by Johnson C. D.

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.12: Test the performance of PID controller for different values of P, I, D

I Practical Significance

To familiarize the students to test the performance of PID controller for different values of P, I, D.

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Use relevant controller for controlling a given process system

IV Laboratory Learning Outcome(s)

1. Test the performance of PID controller
2. Plot the time response of the PID controller for different values of P, I, D

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

The controller determines the action required to drive the controlled variable to the set point value. The controller output is the commanding signal given to the final control element (FCE) to reduce the error.

PID controller:

- In proportional controller, the controller output is directly proportional to the error.
- In Integral controller, the rate of change of controller output is proportional to the error it and eliminates offset of the P controller by providing the reset of the zero-error output after the load change.
- In Derivative the controller, output is directly proportional to the rate of change of error signal. Therefore, it is also called rate controller.
- The Derivative controller output will be zero if i) error is zero ii) if error is constant.
- PID controller is the combination of Proportional, Integral and Derivative controllers.

Equation of PID controller:

$$\boldsymbol{Pout = Kp\,Ep + Kp\,K1\int_0^t Kp\,Ep\,dt + K_PK_D\frac{dEp}{dt} + P(0)}$$

Pout= Controller output

Kp= proportional constant

Ep = Error percentage

Po= Controller output when error is zero

Characteristics:

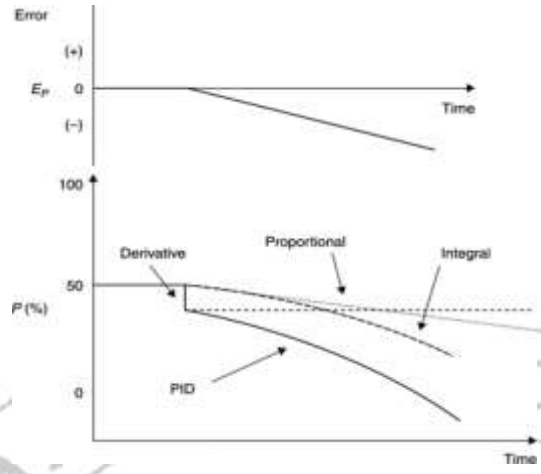

Fig: 12:1

VII Actual Circuit diagram used in a laboratory with related equipment rating

Layout of Laboratory:

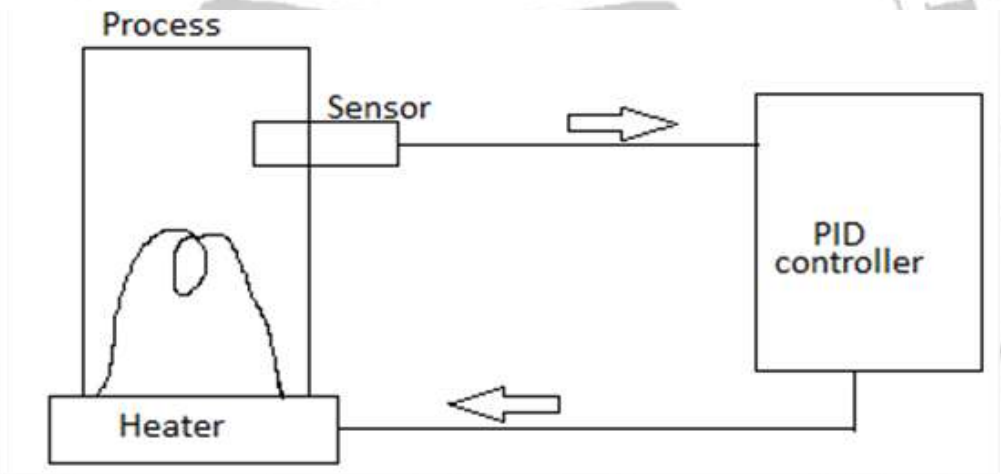

Fig: 12:2

Actual Circuit diagram:

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	PID controller: - Controlled Variable- Temperature or flow or pressure or level; Input Value- Linear 0-20mA and or 4-20mA, 0-5V and or 1-5V; Output Value- appropriate range to study PID controller response; Display Type- 4.5-digit 7 segment or 16x2 LCD; Set up- Appropriate setup for control of controlled variable; Power requirement- 230V single phase AC	–	**1**
2	RTD	–	**1**
3	Heating medium	–	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Use standard Electrical symbols.
4) Don't touch wire with a wet hand.
5) Check the power supply before connection.

X Procedure

1. Place the RTD in the heating medium which is the process where temperature is the process parameter.
2. Connect the controller kit to the heating medium.
3. Connect RTD output to the PID controller.
4. Switch on the set up.
5. Adjust the required set point and proportional constant, integral constant and derivative constant in the controller.
6. Note the temperature of the process variable with respect to time.

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Observation column:

	Time (min)	Process variable (degree Celsius)
$Set\ point =$ $K_P =$ $K_I =$ $K_D =$	0	
	2	
	4	
	6	

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Draw the characteristics of a PID controller.
2. Write the advantages and disadvantages of PID controller.

[Space for Answers]

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XVIII References/Suggestions for further reading

1. Process Control Instrumentation Technology by Johnson C. D.
2. https://www.ni.com/en/shop/labview/pid-theory-explained.html#:~:text=The%20basic%20idea%20behind%20a,components%20to%20compute%20the%20output.

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.13: Test the performance of potentiometer as an error detector

I Practical Significance

To familiarize the students to test the performance of potentiometer as an error detector

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Use relevant control system component for position control

IV Laboratory Learning Outcome(s)

Plot the response of the potentiometer as an error detector

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

Feedback control systems operate from the error signal which is generated by a comparison of the reference and the output. Error detectors perform the crucial task of comparing the reference and output signals. In a purely electrical system where the reference and output are voltages, the error detector is a simple comparator. A position control system with both input and output variables as mechanical positions (linear or angular) consists of two potentiometers- reference and output, which function as an error detector.

VII Actual Circuit diagram used in laboratory with related equipment rating

Layout of Laboratory:

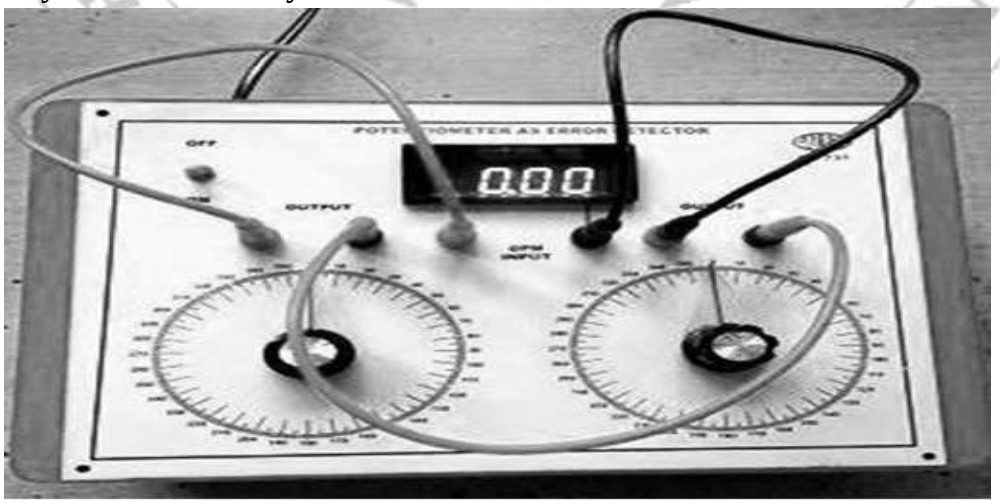

Fig: 13:1

Actual Circuit diagram:

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Potentiometer as an error detector: - Potentiometer- 270 to 360 degree rotation with 1 degree resolution; on kit 3½ digit DVM; Test points- Sockets at Different Places; Power Supply- Inbuilt regulated power supply from 220 V, 50 Hz AC supply	-	1
2	Digital multimeter	0-600V-0-10A, 0-10MΩ	1

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Use standard Electrical symbols.
4) Don't touch wire with a wet hand.
5) Check the power supply before connection.

X Procedure

1) Connect set up as shown in figure.
2) Keep the input potentiometer at 0 degree position.
3) Observe position of output potentiometer.
4) Change the input potentiometer with angle of 30^0 .
5) Measure error voltage of each change in degree in voltmeter.
6) Observe the voltage and angular position of the output potentiometer.
7) Tabulate the observation in the table.
8) Plot the graph of error Vs output voltage.

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Observation column:

Sr.No	Input angle	Error value in Volt	Output voltage at Initial position	Final voltage

XIV Result(s)

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XV Interpretation of results

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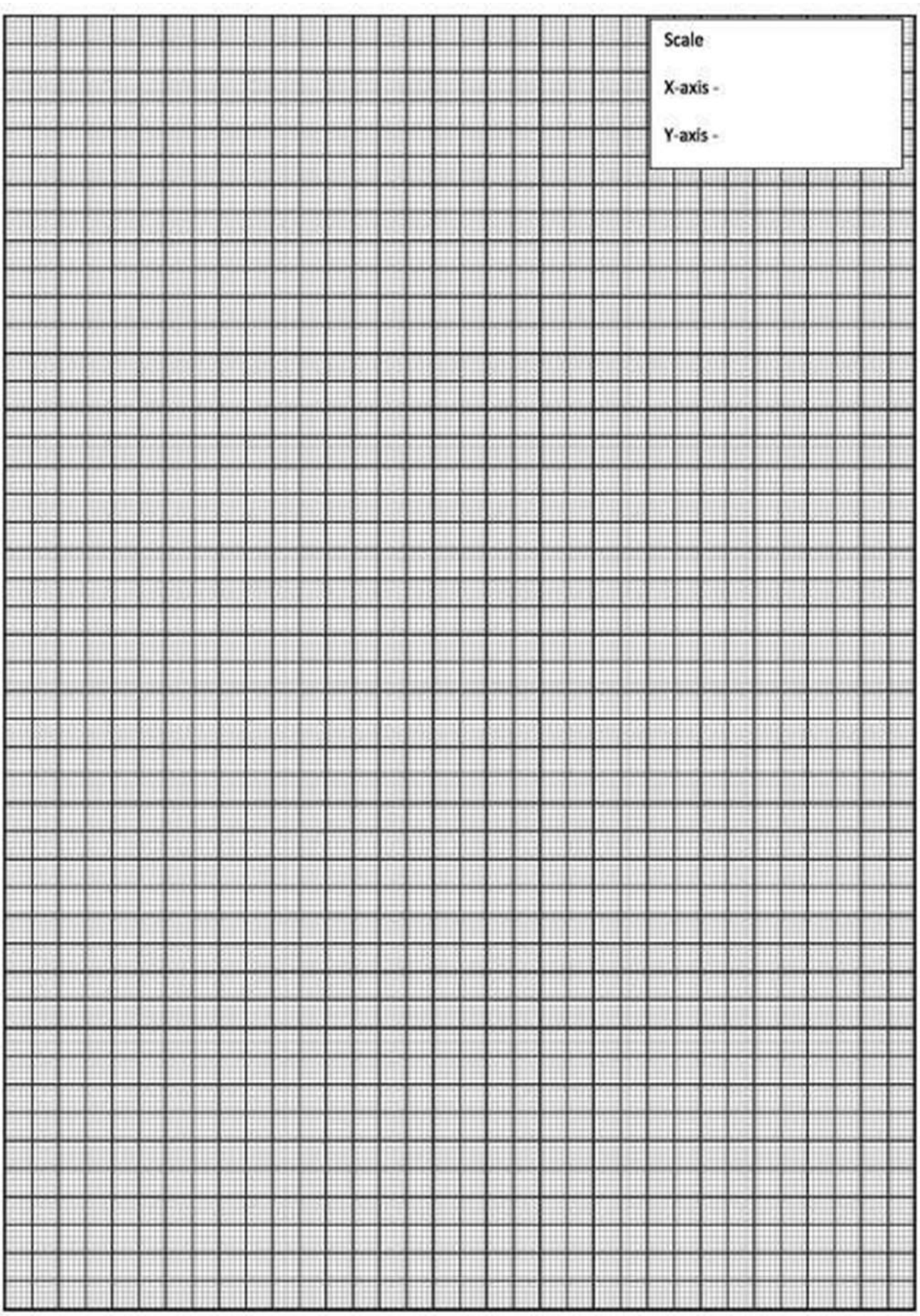
Scale
X-axis -
Y-axis -

XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. State the testing method of linearity of potentiometer.
2. State initial calibration process of potentiometer.
3. State voltage of input potentiometer of different angle.

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XVIII References/Suggestions for further reading

1. Control System Engineering by Nagrath I.J, M. Gopal
2. www.electrical4u.com/control-engineering

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.14: Test the performance of synchro as an error detector by practicing safety measures

I Practical Significance

To familiarize the students to test the performance of synchro as an error detector by practicing safety measures

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Use relevant control system component for position control

IV Laboratory Learning Outcome(s)

1. Plot the response of the synchro as an error detector
2. Take safety measures in operating the synchro error detector

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

Synchro as error detector:

- Synchro transmitter along with synchro control transformer is used as error detector in AC servo system.
- The voltage induced in the transformer rotor will be proportional to the cosine of angle between the two rotors.
- The output equation is given by:
  $e(t) = kV_r sin\omega t cos\Phi$ where ϕ is the angular difference between both rotors.
- When ϕ=90 both rotors are perpendicular to each other and the output voltage is zero. This position is called electrical zero and is used as reference position.
- The error voltage is proportional to the angular difference between the shaft positions of the transmitter and control transformer.

VII Circuit diagram Layout of Laboratory

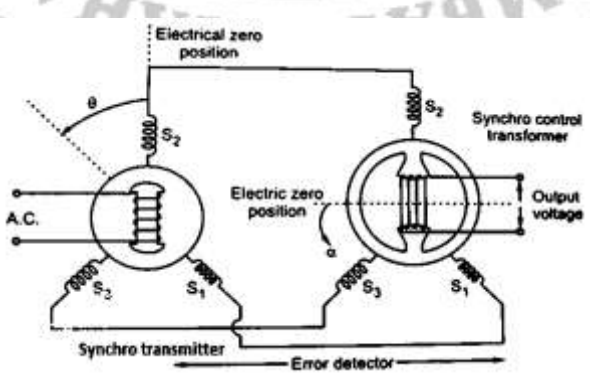

Fig: 14:1

Actual Circuit diagram:

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Synchro Transmitter Receiver Kit: - Synchro transmitter-receiver pair with calibrated dials (0-200V AC); Receiver use as control transformer; Built-in balanced demodulator circuit; Panel meter for ac/dc voltages; Locking system for receiver rotor; Power requirement- 230V single phase 50 Hz	–	**1**
2	Synchro control transformer	–	**1**
3	DMM	–	**1**
4	Power supply for synchro	–	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Use standard Electrical symbols.
4) Don't touch wire with wet hand.
5) Check the power supply before connection.

X Procedure

1. Connect Synchro transmitter to synchro control transformer by shorting both the secondaries S_1- S_1, S_2-S_2, S_3-S_3
2. Apply AC supply voltage to the rotor of Synchro transmitter.
3. Connect DMM across the rotor of synchro control transformer to measure the output voltage.
4. Set the position of rotor of Synchro transmitter at 0^0 and keep the position of rotor of synchro control transformer constant at 90^0.
5. Vary the position of rotor of Synchro transmitter in steps of 45^0

6. Note the output voltage.
7. Plot the graph between output voltage and position of rotor of Synchro transmitter

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Observation column:

Position of rotor of Synchro transmitter (degree)	Position of rotor of Synchro control transformer (degree)	O/p voltage (V)
0	90	
45		
90		
135		
180		
225		
270		

XIV Result(s)

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XV Interpretation of results

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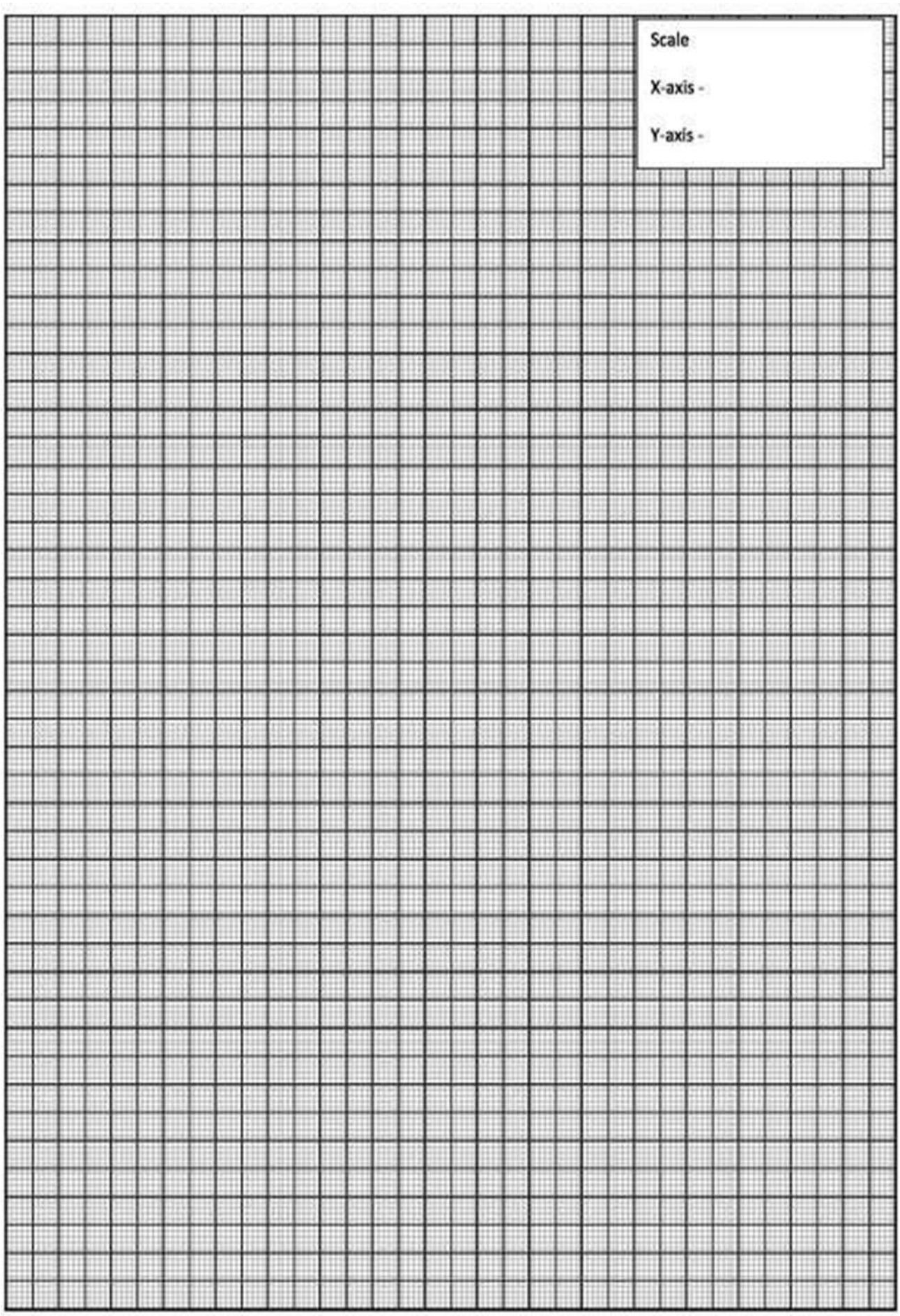
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Y-axis -

XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Explain Synchro as error detector.
2. Define servo system.

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XVIII References/Suggestions for further reading

1. https://www.electricalengineeringinfo.com/2017/06/transfer-function-construction-working-synchro-error-detector-transmitter.html
2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.15: Angular position control using DC Servo system

I Practical Significance

To familiarize the students to perform Angular position control using DC Servo system

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Use relevant control system component for position control

IV Laboratory Learning Outcome(s)

Perform experiment to control the angular position using DC Servo system

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

Servo system:

Servo system is defined as an automatic feedback control system working on error signals giving the output as mechanical position, velocity or acceleration. The types of Servo system are DC Servo system and AC Servo system.

DC position control system:

DC position control system consists of DC components such as 2 potentiometers in parallel as error detector, DC servo amplifier and DC servo motor which is connected to the load. The load is connected to the wiper of one potentiometer as feedback. The other potentiometer wiper is kept constant at the reference position. The differential output of the 2 potentiometers is the error voltage which is given to the servo amplifier. The amplifier output which is the error voltage is given to the motor. Thus, the speed of the motor is adjusted according to the error voltage and feedback signal.

VII Actual Circuit diagram used in laboratory with related equipment rating

Layout of Laboratory

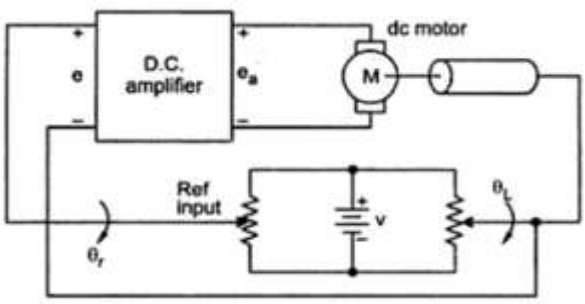

Fig: 15:1

Actual Circuit diagram:

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	D.C. Position control system: - DC Motor- Geared PM motor 12V/1A (50/60 RPM); Tacho Feedback- Positive/Negative tacho-generator feedback with polarity reverse switch; Tacho Constant- Calibrated tacho constant 0.2 to 1 in steps; Motor Unit- The motor unit housed in a separate cabinet with transparent cover; Interconnection with the main unit- appropriate connector; Built in capture/ display card- optional; Power Requirement: Inbuilt regulated power supply from 220 V, 50 Hz AC supply.	–	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Use standard Electrical symbols.
4) Don't touch wire with wet hand.
5) Check the power supply before connection.

X Procedure

1. Connect the input power supply to DC position control system kit.
2. Set the position of input potentiometer at 0^0 and note the corresponding position of output potentiometer.
3. Vary the position of input in steps of 30^0 and note the corresponding position of output potentiometer.

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

Observation column:

Input Pot (degree)	O/p Pot (degree)
0	
30	
60	
90	
120	

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Explain angular position control using DC Servomotor.

2. Draw the characteristic of DC Servomotor.

[Space for Answers]

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XVIII References/Suggestions for further reading

1. https://www.electrical4u.com/dc-servo-motors-theory-and-working-principle/
2. Control System Engineering by Nagrath I.J, M. Gopal

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.16: *Operation of pneumatic/ hydraulic single acting or double acting cylinder with the help of directional control valve

I Practical Significance

To familiarize the students about the operation of pneumatic/ hydraulic single acting or double acting cylinder with the help of directional control valve

II Industry/Employer Expected Outcome(s)

Use different types of controllers ensuring the stability of the given control system

III Course Level Learning Outcome(s)

Choose appropriate actuators for a given application

IV Laboratory Learning Outcome(s)

Operate single acting or double acting cylinder using directional control valve

V Relevant Affective Domain related outcome(s)

Follow ethical practices

Handle tools and equipment carefully.

VI Relevant Theoretical Background

Directional control valves are the valves which control the direction of fluid flow in pneumatic and hydraulic systems. They perform 3 functions: stop fluid flow, allow fluid flow and change the direction of fluid flow.

Common types of directional control valves are 2/2, 3/2, 5/2, etc. The first number represents the number of ports; the second number represents the number of positions. [Number of ports] / [number of positions]

In a single acting cylinder, the fluid pressure is applied to just one side of the piston. The piston can move in only one direction for a task such as lifting an object.

In a double acting cylinder, the fluid pressure is applied on both sides of the piston. Therefore, it works in both directions, and it can move loads in both directions.

VII Actual Circuit diagram used in laboratory with related equipment rating

Layout of Laboratory

Operation of Single acting cylinder with the help of directional control valve:

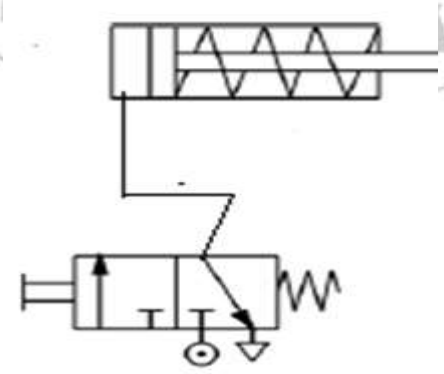

Fig: 16:1

Operation of double acting cylinder with the help of directional control valve:

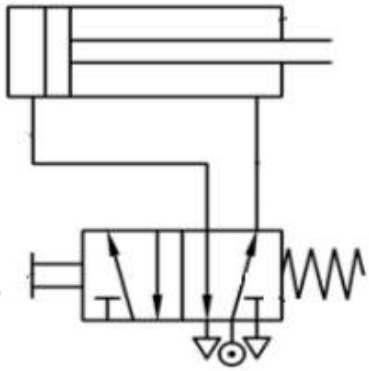

Fig: 16:2

Actual Circuit diagram:

VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Electro pneumatic trainer kit	Air Compressor- 0 to 8/10 bar pressure, 150-180 psi capacity, auto cutoff; Single/ Double acting cylinder- 20mm to 30mm bore, 25 to 75 stroke, pressure 0.5 to 8/10 bar; Directional control valve-3/2 for single acting and 5/2 for double acting, 0-8/10 bar, lever or solenoid operated	**1**

IX Precautions to be followed

1) Verify power ratings.
2) Ensure proper earthing.
3) Don't touch wire with wet hand.
4) Check the power supply before connection.

X Procedure

1. Clean the trainer unit to ensure a clean working environment.
2. Know the specifications of all components
3. Connect all selected components as per circuit diagram
4. Start and run the compressor to store sufficient pressure.
5. Observe the operation.

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XII Actual Procedure

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XIII Observations and Calculations (use blank sheet provided if space not sufficient)

NA

XIV Result(s)

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XV Interpretation of results

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XVI Conclusion and recommendation

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XVII Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Draw and label 3/2 and 5/2 DCV.
2. Draw and label single acting and double acting cylinder

[Space for Answers]

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XVIII References/Suggestions for further reading

1. https://forumautomation.com/t/types-of-directional-control-v
2. Hydraulics and Pneumatics by Andrew A. Parr

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	Working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	