GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering

Level: Diploma

Branch: Automation and Robotics

Subject Code : DI04041021

Subject Name : Process Measurement

w. e. f. Academic Year:	2025-26
Semester:	4th
Category of the Course:	PCC

Prerequisite:	Students should have basic knowledge of electrical and electronic fundamentals, engineering physics, and mathematics. They must understand basic concepts such as current, voltage, resistance, force, pressure, temperature, and motion to learn the process measurement techniques covered in this course.
Rationale:	In modern Automation and Robotics industries, accurate measurement of process parameters such as temperature, pressure, level, flow, speed, force, torque, vibration, and humidity is essential for effective monitoring, control, safety, and automation of processes. This course develops the skills required to select, construct, operate, and apply industrial sensors and transmitters used in automated systems, robotic applications, pneumatic and hydraulic circuits, and Industry 4.0 environments. The knowledge gained through this course enables students to interface sensors with PLCs, controllers, and robotic systems, and prepares them to diagnose, maintain, and troubleshoot measurement-related issues in industrial automation setups.

COURSE OUTCOME:

After Completion of the Course, Student will able to:

No	Course Outcomes	RBT Level
1	Apply basic temperature measurement methods using contact and non-contact instruments.	U A
2	Identify and compare pressure measurement methods and sensors.	R U A
3	Use and explain different level measurement methods and level transmitters.	U A
4	Apply suitable flow measurement devices for different industrial needs.	U A
5	Select and use instruments for measuring speed, force, torque, vibration, and humidity.	R U A

**Revised Bloom's Taxonomy (RBT)*

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TEACHING AND EXAMINATION SCHEME:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE(E)	PA(M)	PA(I)	ESE(V)	
3	0	2	4	70	30	20	30	150

COURSE CONTENT:

Unit	Topics and Sub-topics	No. Of Hrs.	% Weightage
Unit-I Temperature Measurement Techniques	**1.1 Introduction to Temperature Measurement** 1.1.1 Temperature units and scales: Celsius (°C), Fahrenheit (°F), Kelvin (K) 1.1.2 Industrial temperature ranges **1.2 Thermocouples** 1.2.1 Seebeck effect (Thermoelectric principle) 1.2.2 Thermoelectric laws (Law of intermediate metals & temperatures) 1.2.3 Modern thermocouple types (J, K, R, S, T, N) 1.2.4 Cold junction compensation (CJC methods) 1.2.5 Thermocouple temperature calculation (mV-Temperature conversion using ITS-90 tables) **1.3 Resistance Temperature Detectors (RTD)** 1.3.1 Industrial RTD construction (Pt100, Class A/B) 1.3.2 Lead wire compensation – need & principle 1.3.3 Measuring circuits (2-wire, 3-wire, 4-wire) **1.4 Thermistors** 1.4.1 NTC thermistor 1.4.2 PTC thermistor 1.4.3 Resistance-Temperature (R-T) characteristics **1.5 Integrated Circuit (IC) Temperature Sensors** 1.5.1 Working principle	10	20 %

	1.5.2 Common IC sensors (LM35, AD590, TMP36, digital sensors) **1.6 Non-contact Type Thermometry** 1.6.1 Construction and Working Principles of: • Radiation thermometer • Optical pyrometer • Infrared thermometer • Fiber optic thermometer **1.7 Temperature Switches and Digital Thermostats** 1.7.1 Operating principle 1.7.2 Types: Bimetal, Solid-state, Digital		
Unit-II Pressure Measurement Techniques	**2.1 Introduction to Pressure Measurement** 2.1.1 Types of pressure: Absolute, Gauge, Differential 2.1.2 Pressure unit conversion (Bar, Pa, psi) **2.2 Mechanical Pressure Instruments** 2.2.1 Bourdon tube pressure gauge • Basic construction (C-type, Helical, Spiral) • Working principle 2.2.2 Diaphragm pressure gauge • Construction, working and Applications 2.2.3 Capsule diaphragm gauge • Construction, working and Applications **2.3 Electrical / Electronic Pressure Sensors** 2.3.1 Strain-gauge pressure sensor 2.3.2 Piezoresistive pressure sensor 2.3.3 Piezoelectric pressure sensor 2.3.4 Capacitive pressure sensor • Construction, Working principle and Applications for all above sensors (2.3.1 to 2.3.4). **2.4 Pressure Transmitters** 2.4.1 Differential pressure (DP) transmitter • Construction and working principle 2.4.2 Smart pressure transmitter • Construction and working principle	8	20 %
Unit-III	**3.1 Introduction to Level Measurement**	9	20 %

Level Measurement Techniques	3.1.1 Definition of level measurement 3.1.2 Units used for level measurement **3.2 Direct Level Measurement Methods** 3.2.1 Sight Glass / Gauge Glass • Working principle • Industrial usage 3.2.2 Magnetic Level Indicator • Working principle • Industrial usage **3.3 Indirect Level Measurement Methods** 3.3.1 Construction, working and applications of: • Hydrostatic Pressure Method (Pressure Gauge Type) • Capacitance Level Detector • Ultrasonic Level Detector • Radar Level Detector (Non-contact radar & Guided wave radar) • Laser Level Sensor **3.4 Level Switches** 3.3.1 Working principle and applications of: • Conductivity Level Switch • Tuning fork level switch • Capacitive Level Switch **3.5 Level Transmitters** 3.5.1 Electronic level transmitters (Ultrasonic, Capacitive, Radar) • Construction and working principle		
Unit IV Flow Measurement Techniques	**4.1 Introduction to Flow Measurement** 4.1.1 Need for flow measurement in Industry 4.1.2 Types of flow (Laminar/Turbulent) **4.2 Differential Pressure Flowmeters** 4.2.1 Principle, construction, working and applications of: • Orifice Plate • Venturi Tube **4.3 Variable Area Flowmeter** 4.3.1 Rotameter • Principle, construction, working and applications	8	20 %

	4.4 Modern Flowmeters 4.4.1 Principle, construction, working and applications of: • Turbine Flow Meter • Electromagnetic Flow Meter • Ultrasonic Flow Meter (Doppler & Transit Time) • Thermal Mass Flow Meter		
Unit – V Measurement of Speed, Force, Torque, Vibration and Humidity	**5.1 Speed Measurement** 5.1.1 Construction, working principle and applications of: • Contact Tachometer (Mechanical / Digital) • Non-contact Tachometer (Laser / Optical) • Proximity Sensors for RPM (Inductive / Optical) • Hall-effect Speed Sensor **5.2 Force and Torque Measurement** 5.2.1 Construction, working principle and applications of: • Load Cells • Strain-gauge Force Sensors • Torque Transducers (Rotary / Inline) **5.3 Vibration Measurement** 5.3.1 Construction, working principle and applications of: • Seismic Vibration Sensor • Piezoelectric Accelerometer • Vibration Analyzer (FFT, RMS) **5.4 Humidity / Moisture Measurement** 5.4.1 Construction, working principle and applications of: • Resistive Humidity Sensor • Capacitive Humidity Sensor • Digital Humidity Sensors (DHT, SHT Series)	10	20 %
	Total	**45 Hrs**	**100%**

SUGGESTED PRACTICAL EXERCISES:

The following practical outcomes (PrOs) that are the sub-components of the COs. *Some of the* ***PrOs*** *marked* ***'*'*** *are compulsory, as they are crucial for that particular CO. These PrOs need to be attained at least at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.*

Sr. No.	Practical Outcomes (PrOs)	Approx. Hrs. Required
1	Measure temperature using thermocouples and verify mV–°C conversion.	04
2	Measure temperature using RTD (Pt100) and determine R–T characteristics.	04
3	Measure temperature using thermistors (NTC/PTC).	04
4	Measure temperature using non-contact infrared and optical thermometers.	04
5	Measure pressure using Bourdon tube, diaphragm, and capsule gauges.	04
6	Measure pressure using strain-gauge, piezoresistive, and capacitive sensors.	04
7	Use differential pressure (DP) transmitter for pressure/level measurement.	04
8	Use smart pressure transmitter (4–20 mA / HART).	04
9	Measure liquid level using sight glass and magnetic level indicator.	04
10	Measure liquid level using ultrasonic / capacitive / radar level transmitters.	04
11	Test operation of float, conductivity, capacitive, and vibrating-fork level switches.	04
12	Measure flow rate using orifice plate and Venturi meter.	04
13	Measure flow rate using rotameter.	04
14	Measure flow using turbine, electromagnetic, ultrasonic, and thermal mass flowmeters.	04
15	Measure speed using contact tachometer.	04
16	Measure speed using non-contact tachometer.	04
17	Measure RPM using proximity sensors (inductive/optical) and Hall-effect sensors.	04
18	Measure force using load cell.	04
19	Measure torque using torque transducer.	04

Sr. No.	Practical Outcomes (PrOs)	Approx. Hrs. Required
20	Measure vibration using seismic sensor and piezoelectric accelerometer.	04
21	Analyze vibration using vibration analyzer (FFT/RMS).	04
22	Measure humidity using resistive, capacitive, and digital humidity sensors.	04

Note

i. *More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*

ii. *The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Prepare experimental setup	30
2	Operate the equipment setup or circuit	10
3	Follow safe practices measures	20
4	Record observations correctly	20
5	Interpret the result and conclude	20
Total		**100**

MAJOR EQUIPMENT/ INSTRUMENTS AND SOFTWARE REQUIRED:

These major equipment/instruments and Software required to develop PrOs are given below with broad specifications to facilitate procurement of them by the administrators/management of the institutes. This will ensure conduction of practical in all institutions across the state in proper way so that the desired skills are developed in students.

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Thermocouple, RTD, and Thermistor trainer kits	1, 2, 3
2	Infrared thermometer & Optical pyrometer	4

3	Digital temperature indicator	1, 2, 3, 4
4	Bourdon tube, Diaphragm & Capsule gauges	5
5	Strain-gauge, Piezoresistive & Capacitive pressure sensors	6
6	Differential Pressure (DP) transmitter	7
7	Smart pressure transmitter (4–20 mA / HART)	8
8	Sight glass & Magnetic level indicator	9
9	Ultrasonic / Capacitive / Radar level transmitters	10
10	Float, Conductivity, Capacitive & Vibrating fork level switches	11
11	Orifice plate & Venturi meter setup	12
12	Rotameter	13
13	Turbine, Electromagnetic & Ultrasonic flowmeters	14
14	Thermal mass flowmeter	14
15	Contact & Non-contact tachometer	15, 16
16	Inductive/Optical proximity sensors, Hall-effect sensor	17
17	Load cell, Strain-gauge sensor, Torque transducer	18, 19
18	Seismic vibration sensor, Piezo accelerometer, Vibration analyzer	20, 21
19	Resistive, Capacitive & Digital humidity sensors	22
20	Multimeter	ALL
21	DC power supply	ALL
22	Signal conditioning modules	6,7,14,17, 18,19

AFFECTIVE DOMAIN OUTCOMES:

The following sample Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfil the development of this competency.

a) Work as a leader/a team member for assigned student activity.

b) Follow safety practices and procedure in Lab.
c) Realize the importance of engineering for societal development.
d) Develop gradually the engineering mindset in day-to-day observation

SUGGESTED STUDENT ACTIVITIES:

Other than the classroom and laboratory learning, following are the suggested student-related co-curricular activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Collect datasheets of commonly used temperature, pressure, level, and flow sensors and prepare a comparison chart of their specifications.
b) Prepare a technical poster or mini-report on modern industrial sensors used in automation and robotics (e.g., ultrasonic, radar, IR sensors, torque sensors).
c) Visit a nearby industry, workshop, or automation lab and document the process measurement instruments used (temperature, pressure, level, flow, vibration).
d) Assemble and test a simple measurement setup using Arduino/PLC (optional):
   - Temperature measurement
   - Level detection
   - Speed measurement using Hall sensor.
e) Prepare a small video demonstration showing the working of a selected instrument (e.g., DP transmitter, IR thermometer, flowmeter).

SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any):

Following Sample strategies teacher can use to accelerate the attainment of the various outcomes in this course:

a) Demonstrate actual industrial sensors and transmitters during teaching.
b) Use trainer kits, cut-models, and real lab instruments for explanation.
c) Encourage hands-on calibration and testing of sensors in the lab.
d) Use videos or animations to explain modern sensors (ultrasonic, radar, laser).
e) Conduct small troubleshooting tasks to build problem-solving skills.
f) Show basic sensor interfacing using Arduino/PLC where possible.
g) Promote group activities, discussions, and short presentations.

SUGGESTED MICRO-PROJECTS:

a) Temperature monitoring system using thermocouple/RTD.
b) Pressure measurement setup using strain-gauge sensor.
c) Level detection module using ultrasonic or capacitive sensor.
d) Flow measurement model using rotameter or turbine sensor.
e) Motor RPM measurement using Hall-effect or optical sensor.
f) Vibration monitoring using piezoelectric sensor.
g) Humidity monitoring using digital humidity sensors.
h) Calibration report of any one process sensor.

SUGGESTED LEARNING RESOURCES:

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Process Measurement and Analysis	B. G. Liptak	I.S.A
2	Industrial Instrumentation	D. P. Eckman	Wiley Eastern Limited, New Delhi
3	Industrial Instrumentation	S.K. Singh	Tata Mc Graw Hill, New Delhi
4	Mechanical Measurements	D. S. Kumar	Metropolitan Book Company, New Delhi
5	Process Instrumentation and Control	A.P. Kulkarni	Nirali Prakashan, Pune
6	Mechanical and Industrial measurements	R.K. Jain	Khanna publication, New Delhi
7	Industrial Instrumentation	Krishnaswamy, K. and S. Vijayachitra,	New Age International Publishers, New Delhi, Latest Edition, ISBN: 978-8122438120
8	Process Instrumentation and Control	A.K. Sawhney	Dhanpat Rai Publications, New Delhi, Latest Edition, ISBN: 978-9383182181
9	Applied Instrumentation in Process Industries Vol-3a	William G Adrews	Gulf Publication Company
10	Lessons In Industrial Instrumentation (Version 3.01)	Tony R. Kuphaldt	Samurai Media Limited
11	Measurement Systems Application and Design	E O Doeblin D N Manik	Tata Mc Graw Hill

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
12	Introduction to Mechatronics and Measurement Systems	David G. Alciatore, Michael B. Histand	McGraw Hill Education, Latest Edition, ISBN: 978-9339221539
13	Industrial Measurement Systems	B. C. Nakra & K. K. Chaudhry	Tata McGraw Hill, New Delhi, Latest Edition, ISBN: 978-0074519586

SUGGESTED LEARNING WEBSITES:

1. https://www.nptel.com
2. https://instrumentationtools.com
3. https://www.vlab.co.in/participating-institute-coe-pune
4. https://vlab.amrita.edu/?sub=1&brch=282&sim=1511&cnt=1
5. http://www.ni.com
6. https://www.engineeringtoolbox.com
7. https://www.omega.com/en-us/resources
8. https://www.emerson.com
9. https://www.keyence.com
10. https://www.yokogawa.com/library/resources/white-papers
11. https://ocw.mit.edu/
12. https://www.ptc.com/en/learning

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