GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2023 (COGC-2023)

Semester - IV

Course Title: Process Measurement

(Course Code : 4344103)

Diploma program in which this course is offered	Semester in which offered
AUTOMATION AND ROBOTICS	FOURTH

1. RATIONALE

In the industry environment, Automation and Robotics diploma graduates are expected to handle various sensors . The role of the process measurement is important for accurate and precise measurement of parameters such as temperature, level, pressure, flow, force and torque etc. is very essential for successful running of an automation industry. The sensors are also an integral part of robotics. Industrial sensors include the electronics required to detect, position, or identify an object or rotating axis in a Robotic controlled system. They utilize a variety of technologies, including inductive, magneto-resistive, capacitive, optical, pressure, and ultrasonic.

2. COMPETENCY ('Program Outcome' according to NBA Terminology)

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

● Use relevant measurement techniques for different applications related to Automation and Robotics.

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry-oriented COs associated with the above-mentioned competency:

- Select sensors or transducers for measuring flow and pressure in industrial process automation.
- Select sensors or transducers for measuring Temperature and level in industrial process automation.
- Use sensors or transducers for measuring force and torque in industrial process automation.
- Understand sensors for measuring various parameters like position, velocity, touch and slip in automation and robotics.
- Describe sensors or transducers for measuring various parameters like length, width, color, thickness in automation and robotics.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	4	30*	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

***Legends: L** - Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **CA** - Continuous Assessment; **ESE** - End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the subcomponents of the COs. Some of the PrOs marked '*' are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1	Measure a given unknown pressure using the U-tube Manometer.	1	02*
2	Perform Pressure Measurement using C-type Bourdon Tube Pressure Gauge	1	02*
3	Test and calibrate a given pressure gauge using a Dead Weight Tester.	1	02
4	Perform Pressure Measurement using LVDT type pressure Transducer.	1	02*
5	Perform Pressure Measurement using Strain Gauge type Pressure Transducer	1	02*
6	Perform Pressure Measurement using Capacitance type Pressure Transducer.	1	02*
7	Demonstrate the operation of the pressure switch.	1	02
8	Perform Flow Measurement using Orifice Plate.	1	02
9	Perform Flow Measurement using Venturi Tube.	1	02
10	Perform Flow Measurement using Rotameter.	1	02*
11	Perform Flow Measurement using ultrasonic Flow meter.	1	02
12	Perform temperature measurement using expansion thermometer	2	02
13	Verify the law of intermediate metal for the available type of thermocouple	2	02*
14	Convert output of thermocouple (mV) into temperature(˚C) using corresponding thermocouple calibration table	2	02*
15	Measure the temperature using RTD and Test	2	02*
16	Measure the temperature using Thermistors and Plot the characteristic curve	2	02*
17	Test the operation of temperature switch at given temp	2	02
18	Measurement of level in a tank using sight glass method	2	02
19	Measurement of level in a tank using capacitive transducer	2	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
20	Test Float type level switch	2	02*
21	Measure Speed using A.C. Tachometer.	4	02
22	Measure Speed using D. C. Tachometer.	4	02*
23	Measure Speed using strain gauge torsion meter	3	02
24	Measurement of force using strain gauge load cell	3	02*
25	Measurement of torque using proximity sensor	3	02*
26	Measurement of length using optical method (laser)	5	02*
27	Measure Speed using Stroboscope	5	02
28	Observe characteristic of Photodetector tactile sensor	4	02
29	Study Slip Detection Strategies for Automatic Grasping in Prosthetic Hands	4	02
30	Measure Position using synchro	4	02
	Total (any)		

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..*

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

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to usher in uniformity of practicals in all institutions across the state.

Sr. No	Equipment Name with Broad Specifications.	PrO. No.
1	Function generator (sine, square, triangle etc. with frequency range 10 Hz to 100 kHz	19
2	Measuring equipment's like CRO (preferably dual channel, 20Mhz)	19
3	Multimeter	All
4	DC power supply (-30 →0→+30 V with at least 1A current capacity)	All

5	Electrical tool kit.	All
6	U-tube Manometer	1
7	C-type Bourdon Tube Pressure Gauge	2
8	Dead Weight Tester.	3
9	Strain Gauge type Pressure Transducer	5
10	pressure switch.	7
11	Capacitance type Pressure Transducer.	6
12	Orifice Plate assembly.	8
13	Venturi Tube assembly.	9
14	Rotameter	10
15	Ultrasonic Flow meter	11
16	Expansion thermometer	12
17	LVDT	4
18	Circuit/Trainer board/ Demonstration modules of Thermocouples, RTDs, Thermistors	13-15
19	Temperature Switch	17
20	Sight Glass type Level Indicator	18
21	Float type	20
22	Capacitance type Level Transducer	19
23	A.C. Tachometer	21
24	D. C. Tachometer	22
25	Load Cell	24
26	strain gauge torsion meter	23
27	Proximity sensor	25
28	Stroboscope	27
29	Photodetector tactile sensor	28
30	Synchro	30

7. 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 fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using electrical appliances.
c) Practice environmentally friendly methods and processes. (Environment related)

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

Only the major Underpinning Theory is formulated as higher level UOs of Revised Bloom's taxonomy in order development of the COs and competency is not missed out by the students and teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Major Learning Outcomes ('Course Outcomes' in Cognitive Domain according to NBA terminology)		Topics and Sub-topics	
Unit-I Pressure and Flow measurement techniques in automation	1a	Give different units and standards of pressure	1.1	1.1.1 Principles of pressure management 1.1.2 units of pressure measurements: PSI, PSIG, Bar, mm Hg, 1.1.3 standards of pressure measurements: Gauge, absolute, differential, sealed
	1b	Give the standard range of industrial pressure : low, medium, high		
	1c	Define : gauge pressure, absolute pressure, differential pressure, sealed pressure		
	1d	Classify pressure measurement methods	1.2	Pressure measurement methods: 1.2.1 direct measurement 1.2.2 indirect measurement
	1e	Explain direct pressure measurement with example (pressure gauge/ indicator type)		
	1f	Explain indirect pressure measurement with example (DP transmitter / strain gauge)		
	1g	Classify pressure sensors and transducers	1.3	Pressure transducers and elements – mechanical 1.3.1 bourdon tube 1.3.2 bellows, capsule 1.3.3 Manometer 1.3.4 Deadweight piston gauge
	1h	Explain the working principle, construction and working of various mechanical pressure transducer		
	1i	Explain the working principle, construction and working of various electrical pressure transducers	1.4	Electric pressure transducer 1.4.1. Capacitive 1.4.2 strain gauge 1.4.3 LVDT
	1j	Explain the construction and working of pressure switch	1.5	Pressure switches: 1.5.1 Pressure switch
	1k	List various factors for installation considerations for pressure transducers.	1.5	Installation consideration

Unit	Major Learning Outcomes ('Course Outcomes' in Cognitive Domain according to NBA terminology)		Topics and Sub-topics	
	1l	Explain the working and construction of the I to P convertor.	1.6	Pressure transducers inside the control loop with PLC. 1.6.1 I to P convertor 1.6.2 P to I convertor
	1m	Explain the working and construction of the P to I convertor.		
	1n	Explain calibration of pressure gauge using Dead weight tester	1.8	Calibration of pressure sensors and transducers Dead weight tester
	1o	Define different types of Flow and reynold number(Turbulent and Laminar flow)	1.9	Types of flow, reynold number
	1p	Explain the construction and working of the rotameter.	1.10	Flow transducers-mechanical: 1.9.1 variable head type: orifice, venturi 1.9.2 variable area type: Rotameter 1.9.3 Positive displacement type: nutating disc
	1q	Explain the working and construction of orifice and venturi meter.		
	1r	Explain the construction and working of nutating disc type flowmeters.		
	1k	Explain the construction and working of electromagnetic flowmeter Explain the construction and working of turbine flowmeter	1.11	Flow transducers-electromechanical: 1.11.1 Electromagnetic flowmeter 1.11.2 Turbine flowmeter
	1l	List various factors for installation considerations for flow transducers.	1.12	Installation of flow transducers
	1m	Explain the interfacing of DP transmitter with PLC	1.13	Flow transducers inside the control loop with PLC.
	1n	Explain wet calibration method	1.15	Calibration of flow sensors and transducers:
Unit-II Temperature and Level measurement techniques in automation	2a	Describe construction and working of solid and liquid expansion thermometer	2.1	Expansion thermometer
	2b	Describe Seebeck effect, Peltier effect and Thomson effect	2.1.1	Solid expansion thermometer
	2c	State and explain thermoelectric laws.	2.1.2	Liquid expansion thermometer
	2d	Explain cold junction compensation method used in thermocouple	2.2	Thermocouples

Unit	Major Learning Outcomes ('Course Outcomes' in Cognitive Domain according to NBA terminology)		Topics and Sub-topics	
	2e	State positive and negative extension wires used in following type of thermocouples: B, E, J, K, R, S, and T	2.2.1	Thermocouple effect
	2f	Describe the output of thermocouple (mV) converted to corresponding temperature value using thermocouple calibration table.	2.2.2	Thermocouple Laws
	2g	Describe construction of industrial RTD	2.2.3	Cold junction compensation
	2h	State need of lead wire compensation in RTD	2.2.4	Thermocouple wires and extension wires
	2i	Describe measuring circuit of RTD. (2 wire, 3-wire, 4-wire)	2.2.5	Thermocouple temperature calculation
	2j	Describe temperature measuring circuit of thermistor.	2.3	Resistance Temperature Detector (RTD
	2k	Explain Integrated Circuit (IC) based temperature sensors	2.3.1	2-Wire RTD
	2l	Explain working and construction of level measurement methods (2.7 and 2.8)	2.3.2	3-Wire RTD
	2m	Explain working and construction of various Temperature and level switches .(2.9 and 2.10)	2.3.3	4-Wire RTD
			2.4	Thermistor
			2.5	Integrated Circuit (IC) based Temperature sensors
			2.6	Infrared thermometer
			2.7	Level measurement Direct methods
			2.7.1	Sight glass/Gauge glass
			2.8	Level measurement indirect methods
			2.8.1	Air purge system
			2.8.2	Capacitance level detector
			2.8.3	Radiation (Radiometric) level detector
			2.8.4	Ultrasonic level detector.
			2.8.5	Radar (Non-contact & Guided wave radar) level detector.
			2.9	Temperature switch
			2.10	Level switch

Unit	Major Learning Outcomes ('Course Outcomes' in Cognitive Domain according to NBA terminology)		Topics and Sub-topics	
Unit – III Torque and Force measurement techniques	3a	Define Torque and Force	3.1	Torque Measurement
	3b	State importance of torque measurement in robotics	3.1.1	Strain gauge torsion meter
	3c	Explain working and construction of listed torque transducers.	3.1.2	Proximity sensor based torque measurement
	3d	Explain working and construction of listed Force transducers.	3.1.3	Optical torque measurement method
			3.2	Force measurement
			3.2.1	Elastic Force meter
			3.2.2	Strain gauge load cell
			3.2.3	Force sensing by motor current monitoring
			3.2.3	Piezoelectric load cell
Unit IV Miscellaneous measurement Part-1	4a	State the difficulty arises to measure position using potentiometer.	4.1	Position measurement
	4b	Explain working and construction of listed Position transducers.	4.1.1	Synchro
	4c	Explain construction and working of D.C.Tachometer.	4.1.2	Resolver
	4d	Explain construction and working of Accelerometer.	4.1.3	opto interrupters
			4.2	Velocity and acceleration measurement
			4.2.1	D.C. Tachometer
			4.2.2	Accelerometers
			4.3	Touch and slip sensor
	4e	Explain in brief the listed touch and slip sensor.		
			4.3.1	Photodetector tactile sensor
			4.3.2	Conductive elastomer sensor
			4.3.3	Lift and try techniques for slip detection
			4.3.4	Interrupter type slip sensor
			4.3.5	Slip sensing "Fingers"
Unit – V Miscellaneous measurement Part-2	5a	Describe construction and working of measurement techniques in detail .(5.1 to 5.6)	5.1	Thickness measurement
	5b	Describe construction and working of laser based length measurement.	5.1.1.	Inductive pickup
	5c	Describe construction and working of camera based width measurement.	5.1.2	Capacitive pickup

Unit	Major Learning Outcomes ('Course Outcomes' in Cognitive Domain according to NBA terminology)		Topics and Sub-topics	
	5d	Describe construction and working of basic color sensor	5.1.3	Radiation type
	5e	Describe construction and working of magnetic reed switch.	5.2	Laser based length measurement
	5f	Describe construction and working of stroboscopes.	5.3	Camera based width measurement
			5.4	Basic color sensor
			5.5	Magnetic Reed switch
			5.6	Stroboscope for speed measurement

***Note**: The UOs need to be formulated at the 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Pressure and Flow measurement techniques in automation	12	4	12	5	21
II	Temperature and Level measurement techniques in automation	12	4	12	5	21
III	Torque and Force measurement techniques	5	0	4	4	8
IV	Miscellaneous measurement Part-1	7	2	6	2	10
V	Miscellaneous measurement Part-2	6	2	6	2	10
	Total	**42**	12	40	18	**70**

Legends: R = Remember; U = Understand; A = Apply and above levels (Bloom's revised taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

10. SUGGESTED LIST OF STUDENT ACTIVITIES

i. 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. Industrial visit for students. (Chemical industries, petroleum industries, production industries.) So that students can have exposure to the real industrial realm.
B. Department should arrange a workshop/seminar where students can have interaction with industry personnel.

C. Videos/Animation for different devices should be shown. Download videos of different industries from various YouTube channels like how it's made, how stuff works and show in class and discuss instrumentation used in that industry.
D. Model making.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

i. Take small instrumentation components to the class when teaching
ii. Massive open online courses (MOOCs) may be used to teach various topics/sub topics.
iii. Internet based home assignments
iv. Mini project
v. About 20% of the topics/sub-topics which are relatively simpler or descriptive in nature is to be given to the students for self-learning, but to be assessed during different assessment methods.
vi. Guide students on how to address issues on environment and sustainability

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her at the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be individually undertaken to build up the skill and confidence in every student to become problem solver so that he/she contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should not exceed three.

The micro-project could be industry application based, internet-based, workshop- based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact an integration of PrOs, UOs and ADOs. Each student will have to maintain a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than 16 (sixteen) student engagement hours during the course. The student ought to submit a micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

13. SUGGESTED LEARNING RESOURCES

Sr. No	Title of Books	Author	Publication
1	Process Measurement and Analysis	Liptak, B. G.	I.S.A
2	Industrial Instrumentation	Eckman, D. P.	Wiley Eastern Limited, New Delhi
3	Industrial Instrumentation	Singh, S.K.	Tata Mc Graw Hill, New Delhi
4	Mechanical Measurements	Kumar, D. S.	Metropolitan Book Company, New Delhi
5	Process Instrumentation and Control	Kulkarni, A.P.	Nirali Prakashan, Pune

6	Mechanical and Industrial measurements	Jain, R.K.	Khanna publication, New Delhi
7	Industrial Instrumentation	Krishnaswamy, K. and S. Vijayachitra,	New Age International Publication, New Delhi
8	Mechanical Measurements and Instrumentation & control	A K Sawhney	DHANPAT RAI & Co
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
12	Robotic Engineering an integrated approach	Richard.D.Klafter,Thomas A.Chmeelewski,Michael Negin	PHI
13	Robotics Control ,Sensing, vision and intelligence	K.S.Fu,R.C.Gonzalez,C.S.G .Lee	Mc Graw Hill International edition

14. **List of Software/Learning Websites**

i. www.nptel.com
ii. https://instrumentationtools.com
iii. https://www.vlab.co.in/participating-institute-coe-pune
iv. https://vlab.amrita.edu/?sub=1&brch=282&sim=1511&cnt=1
v. https://www.iqsdirectory.com/articles/pressure-switch.html
vi. https://appmeas.co.uk/resources/pressure-measurement-notes/what-are-the-different-types-of-pressure-measurement/
vii. https://vlab.amrita.edu/?sub=62&brch=271&sim=1606&cnt=3359
viii. http://vlabs.iitkgp.ernet.in/rcs/index.html#
ix. https://arxiv.org/pdf/2303.00935.pdf
x. https://www.ri.cmu.edu/pub_files/pub3/hall_david_j_1984_1/hall_david_j_1984_1.pdf

15. **PO-COMPETENCY-CO MAPPING**

Semester IV	**Process Measurement (Course Code: 4344103)**						
	POs						
Competency & Course Outcomes	**PO 1 Basic & Discipline specific knowledge**	**PO 2 Problem Analysis**	**PO 3 Design/ develop-ment of solutions**	**PO 4 Engineering Tools, Experimen-tation & Testing**	**PO 5 Engineering practices for society, sustainability & environment**	**PO 6 Project Manage-ment**	**PO 7 Life-long learning**
Competency							
CO1: Select sensors or transducers for measuring flow and pressure in industrial process automation	3	2	-	2		2	2

CO2: Select sensors or transducers for measuring Temperature and level in industrial process automation.	3	2	-	2	1	2	2
CO3: Use sensors or transducers for measuring force and torque in industrial process automation.	3	-	-	2	-	-	1
CO4: Understand sensors for measuring various parameters like position, velocity, touch and slip in automation and robotics	3		2	2	-	2	2
CO5: Describe sensors or transducers for measuring various parameters like length, width, color, thickness in automation and robotics.	3	-	1	2			1

Legend: '**3'** for high, '**2**' for medium, **'1'** for low or **'-'** for the relevant correlation of each competency, CO, with PO/ PSO

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

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