GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Semester-VI

Course Title: SMART AND WIRELESS INSTRUMENTATION

(Course Code: 4361707)

Diploma programme in which this course is offered	Semester in which offered
Instrumentation And Control Engineering	Sixth

1. RATIONALE

In today's data-centric landscape, smart and wireless instrumentation provides a wealth of diagnostic and other information, so plant personnel can get more from their instruments than simple 4–20 mA process variable measurements. It is desired that instrumentation diploma engineers will be able to install, troubleshoot and maintain smart and wireless instruments. This course has designed for diploma students through which they can learn basic to intermediate theory and practical concepts of smart and wireless instrumentation. The purpose of this course is to provide students with a comprehensive understanding of sensors used in industries, the concept of smart instrumentation, wireless sensor networks (WSN), power sources required for WSN, and energy management techniques in WSN. By studying these topics, students will be equipped with the necessary knowledge and skills to implement efficient and effective sensor systems in industrial settings.

2. COMPETENCY

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

- ✓ Implement efficient sensor systems in industrial settings by understanding the basics of sensors, smart instrumentation, wireless sensor networks, power sources, and energy management techniques.

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills should be taught to acquire different learning out comes in cognitive, psychomotor and affective domain for the achievement of the following CO's:

1) Illustrate the basics of sensors used in industries.
2) Explain the concept of smart instrumentation and wireless sensor networks.
3) Explore the power sources required for wireless sensor networks.
4) Apply the knowledge of smart instrumentation to implement a WSN for a required application.
5) Identify the issues in power efficient systems and implement energy management techniques in WSN.

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 Course Outcomes (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'.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Test characteristic of a thermistor as a thermal sensor.	I	2
2	Check the response of the capacitive type humidity sensor.	I	2
3	Test characteristic of a LDR as a Light sensor.	I	2
4	Measure and analyze carbon dioxide levels using CO2 sensing devices.	I	2
5	Measure and analyze light intensity and other relevant parameters using light sensors.	I	2
6	Explore the key milestones and advancements in the field of WSN.	II	2*
7	Draw a schematic representation of a WSN for a specific application.	II	2
8	Explore the process of project planning, sensor selection, network design and implementation.	II	2
9	Compare features and specifications of ISA-100, Wireless HART, and Zigbee	II	2*
10	List the selection criteria for the power sources used in WSN.	III	2
11	Perform/Explore simulations to determine the appropriate battery capacity and lifetime for a given WSN scenario.	III	4
12	Study the impact of IEEE 1451 standards on sensor networks.	IV	2*
13	Study power considerations for wireless instruments in terms of energy efficiency and battery life.	IV	2
14	Study about the steps for the development of WSN based power monitoring systems.	V	4
15	Study about the steps for the development of WSN based Physiological Parameters Monitoring System.	V	4

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	Conceptual clarity.	30
2	Experimental setup, Procedure and conduction by following safety practices.	40
3	Interpretation of Results and Ethical values.	30
Total		**100**

***** *Weightage of particular PrO may vary as per experiments.*

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	D.C. power supply, Multi-meter, Breadboard, patch cord.	1 to 5
2	Thermal sensor, Humidity sensor, Light sensor	1 to 5
3	CO2 sensor, Light Sensor	1 to 5
4	Simulator software to determine the appropriate battery capacity	11

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 course competency.

a. Work as a leader/a team member (while doing a micro-project).
b. Follow safety practices while using D.C. and AC supply and electrical equipment.
c. Work as a group member (while performing experiments and taking readings)
d. 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:

a. 'Valuing Level' in 1st year.
b. 'Organization Level' in 2nd year.
c. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for the development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on the attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit I **Introduction to Smart Sensing and Instrumentation**	**1a.** Define Smart Instrumentation. **1b.** Draw block diagram of Smart Instrumentation **1c.** Classify various Industrial Sensors. **1d.** Explain working principle of various Industrial sensor.	**1.1** Introduction to Smart Instrumentation **1.1.1** Definition of Smart Instrumentation **1.1.2** Block Diagram of Smart Instrumentation **1.1.3** Industrial Sensors • Sensor Classification Measurand and Transduction Principle of the following: • Thermal sensors (Thermocouple, RTD, Thermistor) • Humidity sensors (Resistive Humidity Sensors, Capacitive Humidity Sensors, Thermal Conductivity Humidity Sensors) • Capacitive Sensors • Planar Inter digital Sensors • Planar Electromagnetic Sensors • Light Sensing Technology (Photometric sensors, Light Dependent resistors, Pyranometers) • Moisture Sensing Technology (Frequency Domain Reflectometry (FDR) Soil Moisture Sensor , Time Domain Reflectometry (TDR) Soil Moisture Sensor , Gypsum Blocks, Neutron Probes • Carbon Dioxide (CO2)sensing technology (Solid State Electrochemical (SSE) CO2 Sensors , Non-dispersive Infrared (NDIR) CO2 Sensors
Unit II **Wireless Sensor Network (WSN)**	**2a.** Discuss about the history of WSN. **2b**. Draw a schematic representation of WSN. **2c**. Explain about the frequency of wireless communication. **2d**. Discuss the steps for the development of WSN based project. **2e**. Describe about the Wireless sensor based on microcontroller and communication device (Zigbee Communication device) **2f.** Compare ISA-100, Wireless-HART and Zigbee.	**2.1** History of Wireless Sensor networks (WSN) **2.2** Schematic Representation of WSN **2.3** Frequency of Wireless communication **2.4** Development of Wireless Sensor Network based Project **2.5** Wireless sensor based on microcontroller and communication device (Zigbee Communication device) **2.6** Comparison of ISA-100, Wireless- HART and Zigbee.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit-III **Power sources-Energy Harvesting**	**3a**. List the power sources used for WSN. **3b**. List the types of batteries. **3c**. Explain the working of Solar and Lead acid batteries. **3d**. Explain RF Energy Harvesting. **3e**. Discuss about Energy harvesting from vibration. **3f**. Discuss about thermal energy harvesting. **3g**. List energy management techniques. **3h.** Explain various energy management techniques. **3i.** Discuss about the calculation for battery selection.	**3.1** Power Sources for WSN • Power from Main Supply • Battery (Selection of Batteries) **3.2** Solar and Lead acid batteries **3.3** RF Energy Harvesting **3.4** Energy Harvesting from vibration **3.5** Thermal Energy Harvesting **3.6** Energy Management Techniques **3.6.1** Routing Protocol **3.6.2** Introduction of Sleep Mode **3.6.3** MAC Protocol **3.7** Calculation for Battery Selection
Unit-IV **Wireless Instrumentation**	**4a**. List various wireless sensors and transducers. **4b**. Describe wireless accelerometer with block diagram. **4c**. Describe wireless web sensor. **4d**. Discuss the effect of IEEE 1451 standards on sensor networks **4e**.Draw the architecture of wireless instruments. **4f**. Explain the architecture of wireless instruments. **4g**. Explain Essential Components of Wireless Instruments. **4h.** Discuss Power Considerations of Wireless Instruments. **4i.** Discuss various Wireless network devices. (Bridges, Routers, Gateways, and Repeaters) **4j.** Explain Wireless data logger with diagram. **4k.** List out Energy Issues in Wireless Sensor Networks.	**4.1** Wireless Sensor Architecture and Network Design **4.1.1** Wireless Sensors and Transducers **4.1.2** Effect of IEEE 1451 Standards on Sensor Networks **4.2** Wireless Instrument Architecture and Network Design **4.2.1** Essential Components of Wireless Instruments **4.2.2** Power Considerations of Wireless Instruments **4.2.3** Wireless Bridges, Routers, Gateways, and Repeaters **4.2.4** Wireless data logger **4.3** Energy Issues in Wireless Sensor Networks **4.4** IEEE 802 Sensor and Instrument Networks

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
	4l. Discuss the need of IEEE 802 Sensor and Instrument Networks.	
Unit-V **Applications and Projects on WSN**	**5a**. Draw Block diagram of WSN based physiological parameters monitoring system. **5b**. List out sensors used in physiological parameters monitoring systems. **5c**. Explain communication between sensor module and microcontroller. **5d**. Write algorithms for each sensor used in a physiological parameters monitoring system. **5e**. Draw Block diagram of WSN Based Smart Power Monitoring System. **5f**. Explain method of measurement of voltage, current and power. **5h.** Explain Voltage and current sensing circuit integrated with ZigBee module.	**5.1** WSN Based Physiological Parameters Monitoring System **5.2** WSN Based Smart Power Monitoring System

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to Smart Sensing and Instrumentation	10	8	4	2	14
II	Wireless Sensor Network (WSN)	8	7	7	0	14
III	Power sources- Energy Harvesting	8	5	7	2	14
IV	Wireless Instrumentation	10	7	7	0	14
V	Applications and Projects on WSN	6	3	4	7	14
Total		**42**	**30**	**29**	**11**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*
Note*: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may slightly vary from above table.*

10. 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 perform following activities in group (or individual) and prepare reports of about 5 pages for each activity. They should also collect/record physical evidence for their (student's) portfolio which may be useful for their placement interviews:

a) Present seminar on various topics from course content
b) Prepare a poster on WSN and its applications.
c) Mini project for industrial application.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/subtopics.
b) Guide student(s) in undertaking micro-projects.
c) Show animation/ video related to course content.
d) Co-relating the importance of content of this course with other practical application.
e) Industrial visit for practical exposure.
f) Quiz competition across intercollege branch students.
g) Organize workshop on WSN by expert from industry.
h) 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 in the beginning of the semester. In the first four semesters, the micro-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, 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 duration of the micro project should be about **12-14** ***(fourteen to sixteen) student engagement hours*** during the course. The students ought to submit 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:

a) Compare the accuracy and response time of various sensors for different ranges.
b) Design and create a schematic representation or block diagram of a wireless sensor network, illustrating the different components such as sensor nodes, gateway, and coordinator.
c) Develop a presentation or infographic showcasing the historical evolution of WSN and its impact on various industries.

d) Use simulation software to model and visualize the flow of data and communication within a WSN.

e) Conduct a comparative study on the features, capabilities, and applications of ISA-100, Wireless-HART, and Zigbee protocols in the context of WSN.

f) Compare the energy harvesting efficiency of RF energy harvesting and vibration energy harvesting techniques for WSN applications.

g) Evaluate the performance and characteristics of different battery types (e.g., lithium-ion, nickel-metal hydride) for WSN applications through experimentation.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Smart Sensors, Measurement and Instrumentation	Subhas Chandra Mukhopadhyay	Springer Heidelberg, New York, Dordrecht London, 2013.
2	Wireless Sensors and Instruments: Networks, Design and Applications	Halit Eren	CRC Press, Taylor and Francis Group, 2006.

14. SOFTWARE/LEARNING WEBSITES

- https://omnet-manual.com/wsn-simulation/
- https://www.isa.org/intech-home/2022/april-2022/features/smart-instrumentation-for-the-digital-present
- NS-2: http://www.isi.edu/nsnam/ns/
- OMNeT++: https://omnetpp.org/
- Castalia: https://castalia.forge.nicta.com.au/
- Contiki: https://www.contiki-ng.org/
- TOSSIM: https://github.com/tinyos/tinyos-main/tree/tinyos-2.x/support/sdk/c/sim
- JiST/SWANS: https://jist.ece.cornell.edu/
- COOJA (part of Contiki): https://www.contiki-os.org/start.html
- MiXiM: http://mixim.sourceforge.net/
- iLab Shared Architecture (ISA): https://www.ilabshare.org/
- Network Simulator 2 (NS-2) Virtual Labs: http://www.isi.edu/nsnam/ns/ns-lab.html

- LabVIEW Virtual Labs: https://www.ni.com/en-us/shop/labview/products/labview-virtual-labs.html
- CASTLE Lab: http://www.castlelab.princeton.edu/
- Sensor Network Virtual Labs (SenNetLab): http://www.sennetlab.eu/

15. PO-COMPETENCY-CO MAPPING:

Semester V	SMART AND WIRELESS INSTRUMENTATION **(Course Code : 4361707)**						
	POs						
Competency & Course Outcomes	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**
	Basic & Discipline specific knowledge	Problem Analysis	Design/ development of solution	Engineering Tools, Experimentation & Testing	Engineering practices for society, sustainability & environment	Project Management	Life-long learning
Competency	Implement efficient sensor systems in industrial settings by understanding the basics of sensors, smart instrumentation, wireless sensor networks, power sources, and energy management techniques.						
CO1	3	-	-	-	-	-	1
CO2	3	-	-	-	-	-	-
CO3	3	-	1	-	-	-	2
CO4	3	2	2	2	-	2	2
CO5	3	3	2	2	2	2	2

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low and '**-**' for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

Member – Board of Studies (GTU), Electrical and Allied branches

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