GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-II

Course Title: Sensors and Transducers
(Course Code: 4322401)

Diploma programmer in which this course is offered	Semester in which offered
Power Electronics	Second

1. RATIONALE

With the advancement of technology measurement techniques have taken rapid strides with the introduction of different types of sensors and transducers. This course is intended to enable the student to understand the facts, concepts, principles and applications of the sensors and transducers and will be able to apply the same in almost all areas of electronics required to use and maintain different types of sensors and transducers used in the industry.

2. COMPETENCY

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

- **Select specific sensors and transducers in electronic circuits.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

1. **Classify sensors and transducers for various electronic applications.**
2. **Use Temperature & Optical Sensors and Transducers for specific application.**
3. **Use Electric, Magnetic & Mechanical Sensors and Transducers for specific application.**
4. **Use Acoustic, Chemical and Biological Sensors and Transducers for specific application.**
5. **Use of advance sensors for specific applications.**

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	-	2	4	30	70	25	25	150

(*): For this practical only course, 25 marks under the practical CA has two components i.e. the assessment of micro-project, which will be done out of 10 marks and the remaining 15 marks are for the assessment of practical. This is designed to facilitate attainment of COs holistically, as there is no theory ESE.

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

5. SUGGESTED PRACTICAL EXERCISES

*Following practical outcomes (PrOs) that are thesub-components 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'.*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1	Identify various characteristic parameters for selection of sensors.	1	2*
2	Test the performance of Resistance Temperature Detector.	2	2*
3	Test the performance of Thermistor.	2	2
4	Test the performance of Thermocouple.	2	2*
5	Test the performance of Thermopiles.	2	2
6	Use Photodiode and Photo Transistor for sensing application.	2	2
7	Use Pyroelectric sensor for specific application.	2	2
8	Use capacitive sensor for the position and displacement application.	3	2*
9	Use variable inductive sensor for the displacement application.	3	2*
10	Test the performance of Inductive proximity sensor.	3	2
11	Test the performance of Eddy current proximity sensor	3	2
12	Test the performance of LVDT.	3	2*
13	Use Hall effect sensor for specific application.	3	2
14	Test the performance of Strain gauge.	3	2
15	Test the performance of Load cell.	3	2*
16	Test the performance of Piezoresistive Pressure sensor.	4	2
17	Use Ultrasonic Magneto strictive sensor for specific application.	4	2
18	Use Piezoelectric Sensor for specific application.	4	2
19	Use Solid electrolyte sensors for specific application.	4	2
20	Use Capacitive moisture sensor for specific application.	4	4*
21	Use Resistive humidity sensor for specific application.	4	4
22	Use RFID Sensor for specific application.	5	2
23	Use PM2.5 and PM10 sensor for specific application.	5	4*
24	Use MOS sensor for specific application.	5	4
	Total		**28**

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

These major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to user in uniformity of practical's in all institutions across the state.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	**Temperature Transducer Trainer:** On Board 4 different Kind Temperatures Sensor (LM 35, RTD, Thermistor, Thermocouple -J type, On Board Buzzer For conditioning alarm, On board signal condition for each type of above temperature sensor, On board LCD (16X2) display for measuring o/p temperature, On board power Supply, Testing Socket On board selective toggle switch for selection to switch from one sensor to other, Banana Socket for each sensor input Individually Based on PIC microcontroller.	2, 3, 4, 5
2	**Sensor Lab:** On board display: 7" capacitive touchscreen Connectivity: USB, Ethernet & HDMI, Square wave generator: up to 40KHz, Low pass filter: up to 30KHz, High pass filter: After 40KHz Inverting amplifier: Variable gain 1-10 Non-inverting amplifier: Variable gain 2-10 Differential amplifier: Variable gain 1-10 Instrumentation amplifier: Variable gain 10-20 Frequency to Voltage: Input: 1-10KHz Converter range Output: 1-10Volt Voltage to Frequency: Input: 1-10Volt Converter range Output: 1-10KHz Current to Voltage: Input: 4-20mA Converter range Output: 0-5Volt Voltage to Current: Input: 0-5Volt Converter range Output: 4-20mA Analog/Digital converter: 4 channels (0-5V) Digital/Analog converter: 1 channel (0-3.3V) Input/output ports: 4-IP / 4-0P, Operating voltage range: 0 – 3.3V LM35: 10mV/ °C , Platinum RTD: 100 at 0°C (Temperature coefficient 0.385 /°C), K type thermocouple: -200°C to 1250°C J type thermocouple: - 200°C to +1200°C AD590: - 55°C to +150°C , NTC thermistor: 4.7kilo ohm BPX65 photo diode: 500nm – 1100nm L14G1 photo transistor: 500nm – 1100nm Photovoltaic Cell: 500mV – 580mV	2, 3,4,5, 6
3	**Optical Sensor Trainer:** IR transmitter: IR LED, Wavelength: 940nm IR Receiver: Phototransistor, Wavelength: 940nm, Sensing range: 0-10 mm. Magnetic Sensor: Operating input: 5V DC, Output: 5V DC, Range: 0-20mm. Inductive Proximity Sensor: Input: 12V DC, Sensor type: PNP, Output: 12V DC, Sensing range: 0-10 mm. Capacitive Proximity Sensor: Operating input: 12V DC, Sensor type: PNP, Output voltage: 12V DC, Sensing range: 0-10 mm.	6, 10, 11
4	**Pressure Transducer Trainer:** Measurement System: Transducer with electronic instrumentation. Transducer: Piezo type pressure transducer with shielded cable and connector. Transducer Range: 0 to 5 Kg/cm2. Amplifier: Solid state precision amplifier. Pressure Built-up Unit: It should consist a foot pump to develop pressure and a chamber with provision to connect the pressure pump and release valve to release the pressure built up in the chamber.	16

S. No.	Equipment Name with Broad Specifications	PrO. No.
5	**Ultrasonic Displacement Trainer:** Ultrasonic type Transducer, Resonant Frequency of the Transducer is to be 40 KHz. Excitation Source 40 KHz Frequency to be provided on board. Measurement Range From 25 cm to about 6 meters.	17
6	**Humidity Sensor Transducer Trainer:** Capacitive Humidity transducer for 90% non-condensed range 0 to 100%, RH humidity chamber.	19, 20
7	**LVDT Trainer:** Onboard LVDT displacement measurement jig with micrometer. Amplitude measurement for Excitation Generator. High repeatability and reliability. Measurement Range: 20 mm (±10 mm) Scope of Study: Study of Input and Output characteristics of LVDT. To determine linear range of operation of LVDT. To determine sensitivity of LVDT. To measure Phase difference between LVDT secondary.	12
8	**Load Cell Trainer:** Trainer kit is for study of strain measurement using load cell. A load cell of 10 kg range is to be provided. The load cell is excited with 12V dc. Unbalanced voltage of load cell Bridge is amplified with using instrumentation amplifier. There is provision for explaining the concept of tare weight. 32 Bit Microcontroller Card is used for sensing, processing and display. On LCD screen TARE weight and actual weight is to be displayed.	14, 15
9	**Inductive Displacement Trainer:** Linear Physical Displacement Measurement System: Micrometer screw type arrangement and Inductive Transducer with electronic instrumentation. Excitation Source: Sine wave.	9
10	**PM10 / PM2.5 Portable Particulate Monitor** The PM10 / PM2.5 Portable Particulate Monitor **for** measurement of PM10 and PM2.5 simultaneously, with the option of adding gaseous sensor heads to measure different pollutants like CO, CO2, NO2, VOC, O3, SO2, H2S.	23,24
11	**Optical Sensor Trainer** The base system should have following sensor/transducers for the displacement measurement: Inductive Proximity Sensor (IO Link Capable), Capacitive Proximity Sensor (IO Link Capable), Magnetic Proximity Sensor, Diffuse Photo Sensor, Retro-Reflective Photo Sensor, Through-Beam Photo Sensor (Barrier), Diffuse Fiber Optic Sensor, Through-Beam Fiber Optic Sensor, Ultrasonic Sensor (Digital/Analog), Laser Distance Sensor	6, 10, 11
12	**Hall effect transducer trainer**	**13**
13	**RFID Trainer**	22
14	**4½ Digit Multimeter** Function Range and Resolution Basic Accuracy DC volts, AC volts: 50.000 mV,500.00 mV, 5.0000 V, 50.000 V, 500.00 V, 1000.0 V. Accuracy: 0.025 %, 0.4 % (true-rms) DC current, AC current: 500.00 µA, 5000.0 µA, 50.000 mA, 400.00 mA, 5.0000 A, 10.000 A, Accuracy: 0.15 %, 0.7 % (true-rms) Temperature: -200.0 °C to 1350.0 °C (-328.0°F to 2462.0°F) Accuracy:1.0 % Resistance 50.000 Ω, 500.00 Ω, 5.0000 kΩ, 50.000 kΩ, 500.00 kΩ, 5.0000 MΩ, 50.00 MΩ, 500.0 MΩ, Accuracy: 0.05 % Capacitance 1.000 nF,10.00 nF 100.0 nF, 1.000 µF, 10.00 µF, 100.0 µF, 1000 µF, 10.00 mF, 100.0 mF, Accuracy: 1.0 % Frequency 99.999 Hz, 999.99 Hz, 9.9999 kHz, 99.999 kHz, 999.99 kHz. Accuracy: .005 %	2-14

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 instruments and tools.
c) Realize importance of sensors and transducers in electronic circuits.

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	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
Unit – I Characteristics & Classification of Sensors and Transducers	1a. Explain role of sensors. 1b. Differentiate Sensors, Transducers and Actuators. 1c. Define various characteristics parameter of sensors. 1d. Classify Errors. 1e. Classify Sensors and Transducers. 1f. State the requirement, selection criteria, advantages and disadvantages for electrical transducer.	1.1 Role & Definition of Sensors, Transducers and Actuators. 1.2 Characteristics: Range, Span, Input and output full scale, Resolution, Dynamic range, Accuracy, Errors, Repeatability, Sensitivity, Hysteresis, Nonlinearity saturation, Frequency response, Response time, Bandwidth, Calibration, Excitation, and Reliability. 1.3 Classification of Sensors and Transducers. 1.4 Basic requirements, Selection criteria, Advantages and Disadvantages of Electrical Transducer.
Unit– II Temperature & Optical Sensors and Transducers	2.a Describe working of Resistance temperature detector, Silicon resistive sensor, Thermistor with their advantages and disadvantages. 2.b Describe working of Thermocouple, Semiconductor Thermocouple and Thermopiles with advantages and disadvantages. 2.c List thermocouple types and their properties.	2.1 Thermo resistive: Resistance temperature detector, Silicon resistive sensor, Thermistor. 2.2 Thermoelectric: Thermocouple, Semiconductor thermocouple, Thermopiles.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
	2.d Explain working Photodiodes, Photovoltaic diodes, photo transistor. 2.e Explain working Thermopile Passive IR, Pyroelectric sensor. 2.f List various Temperature & Optical Sensors and Transducers with their specific application and range.	2.3 Quantum-based optical sensors: Photodiodes, Photovoltaic diodes, Photo transistor. 2.4 Thermal-based optical sensors: Thermopile passive IR, Pyroelectric sensor.
Unit– III Electric, Magnetic & Mechanical Sensors and Transducers	3a. Describe working of Capacitive position, displacement and fluid level sensors. 3b. Describe working of Variable Inductive, Inductive proximity sensor, Eddy current proximity sensor, LVDT, Hall effect sensor with their advantages and disadvantages.	3.1 Capacitive: Capacitive position, Displacement, Fluid level sensors. 3.2 Magnetic: Variable Inductive, Inductive proximity sensor, Eddy current proximity sensor, LVDT, Hall effect sensor.
	3c. Explain working of Strain gauges, Semiconductor strain gauges and Load cell. 3d. Explain working of Capacitive and Magnetic accelerometers. 3e. Describe working of Piezoresistive and Magnetic pressure sensor. 3f. List various Electric, Magnetic & Mechanical Sensors and Transducers with their specific application and range.	3.3 Force sensors: Strain gauges, Semiconductor strain gauges and Load cell. 3.4 Accelerometers: Capacitive, Magnetic. 3.5 Pressure: Piezoresistive, Magnetic.
Unit– IV Acoustic, Chemical and Biological Sensors and Transducers	4a. Explain working of piezoelectric Sensor. 4b. Describe working of Ultrasonic Magneto strictive sensor.	4.1 The Piezoelectric sensor. 4.2 Ultrasonic Magneto strictive sensor.
	4c. Explain Solid electrolyte sensors and metal oxide semiconductor sensor. 4d. Explain Thermistor-based chemical sensors and Thermal conductivity sensor.	4.3 Electrochemical Sensors: Solid electrolyte sensors, The metal oxide semiconductor sensor. 4.4 Thermochemical sensors: Thermistor-based chemical sensors, Thermal conductivity sensor.
	4e. Describe working of Capacitive moisture, Resistive humidity and Thermal conduction moisture sensor. 4f. List various Acoustic, Chemical and Biological Sensors and Transducers with their specific application and range.	4.5 Humidity and moisture sensors: Capacitive moisture sensors, Resistive humidity sensor, Thermal conduction moisture sensors.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
Unit– V Advance Sensors	5a. Explain working of Pressure sensors, Mass air flow sensors, Inertial sensors, fluxgate magnetic sensors (MEMS). 5b. Describe working of RFID Sensor with their advantages and disadvantages.	5.1 MEMS sensors: Pressure sensors, Mass air flow sensors, Inertial sensors, MEMS fluxgate magnetic sensor. 5.2 RFID Sensor.
	5c. Explain working of PM2.5 and PM 10, MOS Sensors.	5.3 Pollution sensor: PM2.5, PM10, MOS.

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

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	**Characteristics & Classification of Sensors and Transducers**	06	8	4	0	12
II	**Temperature & Optical Sensors and Transducers**	09	4	8	4	16
III	**Electric, Magnetic & Mechanical Sensors and Transducers**	11	6	12	4	22
IV	**Acoustic, Chemical and Biological Sensors and Transducers**	10	4	6	2	12
V	**Advance Sensors**	06	4	4	0	8

***Legends:** R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions assess the attainment of theUOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may varyslightly 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 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) Prepare specification of sensors and transducers.
b) Give seminar on reading a datasheet of sensors and transducers.
c) Undertake a market survey of different sensors and transducers.
d) Prepare Hazard Analysis report for various materials e-waste of sensors and transducers.
e) Prepare application chart for various sensors and transducers.

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/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4***means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) 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 using different assessment methods.
e) With respect to ***section No.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Use video/animation films to demonstrate various sensors and transducers.
g) Guide students for reading data sheets.

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-project is 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 s/he 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 dated work diary consisting of individual contribution 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 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) Prepare a demonstration board consist of different sensors and transducers.
b) Demonstrate Interfacing of various sensors and transducers with Arduino.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication with place, year and ISBN
1	Sensors, Actuators, and Their Interfaces A multidisciplinary introduction 2nd Edition	Nathan Ida	The Institution of Engineering and Technology, UK ISBN 978-1-78561-835-2 (hard) ISBN 978-1-78561-836-9 (Pdf)
2	Electrical and Electronic Measurements and Instrumentation, 4/e	Er. R K Rajput	S. Chand Publishing, India ISBN: 9789385676017
3	Handbook of Modern Sensors Physics, Designs, and Applications	Jacob Fraden	Springer International Publishing ISBN 978-3-319-19302-1 ISBN 978-3-319-19303-8 (Pdf)
4	Transducers and Instrumentation 2nd Edition,	DVS Murthy	PHI Learning P. Ltd ISBN-13 978-8120335691
5	Electrical and Electronics Measurement and Instrumentation	A.K. Shawney	Dhanpat Rai Publishing Co Pvt Ltd ISBN: 9788177001006

14. SOFTWARE/LEARNING WEBSITES

a) https://www.electronics-tutorials.ws/io/io_1.html
b) https://www.electronicshub.org/sensors-and-transducers-introduction/
c) https://instrumentationtools.com/sensors-and-transducers-classification/
d) https://www.electricaltechnology.org/2018/11/types-sensors-applications.html
e) https://www.electrical4u.com/temperature-transducers/
f) https://www.youtube.com/watch?v=DAwXk77DXUM&list=PLUtfVcb-iqn_Dq6RnkCaOaLjPDu3cmxpo
g) https://sciencing.com/uses-photocells-5494652.html
h) https://www.akm.com/us/en/products/hall-sensor/tutorial/magnetic-sensor/
i) https://iopscience.iop.org/article/10.1088/2631-8695/ac0838
j) https://www.bksv.com/en/transducers/acoustic
k) https://www.mdpi.com/1424-8220/21/4/1109/htm
l) https://www.elprocus.com/mems-sensor-working-and-its-applications/
m) https://sl-coep.vlabs.ac.in/

15. PO-COMPETENCY-CO MAPPING

Semester II	Electrical & Electronic Workshop (Course Code: 4322401) POs and PSOs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimentation &Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency	**Select specific sensors and transducers in electronic circuits.**						
Course Outcomes							
CO 1) Classify sensors and transducers for various electronic applications.	2	1	0	0	**1**	1	1
CO 2) Use Temperature & Optical Sensors and Transducers for specific application.	2	1	2	2	1	1	3
CO 3) Use Electric, Magnetic & Mechanical Sensors and Transducers for specific application.	2	1	2	2	1	1	3
CO 4) Use Acoustic, Chemical and Biological Sensors and Transducers for specific application.	2	1	2	2	1	1	3
CO 5) Use of advance sensors for specific applications.	1	1	1	2	3	1	3

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

GTU Resource Persons

S. No.	Name and Designation	Institute	Contact No.	Email
1.	Mr. Sunil A. Patel, Lecturer in Power Electronics	Dr. S. & S. S. Ghandhy College of Engineering & Technology, Surat	+91-9898073753	Patel_sunil5@gtu.edu.in