VIT®

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF ELECTRONICS ENGINEERING

M. Tech Sensor System Technology

(M.Tech MSS)

Curriculum

(*2018-2019 admitted students*)

VISION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

Transforming life through excellence in education and research.

MISSION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

World class Education: Excellence in education, grounded in ethics and critical thinking, for improvement of life.
Cutting edge Research: An innovation ecosystem to extend knowledge and solve critical problems.
Impactful People: Happy, accountable, caring and effective workforce and students.
Rewarding Co-creations: Active collaboration with national & international, industries & universities for productivity and economic development.
Service to Society: Service to the region and world through knowledge and compassion.

VISION STATEMENT OF THE SCHOOL OF ELECTRONICS ENGINEERING

To be a leader by imparting in-depth knowledge in Electronics Engineering, nurturing engineers, technologists and researchers of highest competence, who would engage in sustainable development to cater the global needs of industry and society.

MISSION STATEMENT OF THE SCHOOL OF ELECTRONICS ENGINEERING

- Create and maintain an environment to excel in teaching, learning and applied research in the fields of electronics, communication engineering and allied disciplines which pioneer for sustainable growth.
- Equip our students with necessary knowledge and skills which enable them to be lifelong learners to solve practical problems and to improve the quality of human life.

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M. Tech Sensor System Technology

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

1. Graduates will be engineering practitioners and leaders, who would help solve industry's technological problems

2. Graduates will be engineering professionals, innovators or entrepreneurs engaged in technology development, technology deployment, or engineering system implementation in industry

3. Graduates will function in their profession with social awareness and responsibility

4. Graduates will interact with their peers in other disciplines in industry and society and contribute to the economic growth of the country

5. Graduates will be successful in pursuing higher studies in engineering or management

6. Graduates will pursue career paths in teaching or research

M. Tech Sensor System Technology

PROGRAMME OUTCOMES (POs)

PO_01: Having an ability to apply mathematics and science in engineering applications.

PO_03: Having an ability to design a component or a product applying all the relevant standards and with realistic constraints, including public health, safety, culture, society and environment

PO_04: Having an ability to design and conduct experiments, as well as to analyse and interpret data, and synthesis of information

PO_05: Having an ability to use techniques, skills, resources and modern engineering and IT tools necessary for engineering practice

PO_06: Having problem solving ability- to assess social issues (societal, health, safety, legal and cultural) and engineering problems

PO_07: Having adaptive thinking and adaptability in relation to environmental context and sustainable development

PO_08: Having a clear understanding of professional and ethical responsibility

PO_11: Having a good cognitive load management skills related to project management and finance

M. Tech Sensor System Technology

ADDITIONAL PROGRAMME OUTCOMES (APOs)

APO_02: Having Sense-Making Skills of creating unique insights in what is being seen or observed (Higher level thinking skills which cannot be codified)

APO_03: Having design thinking capability

APO_04: Having computational thinking (Ability to translate vast data in to abstract concepts and to understand database reasoning

APO_07: Having critical thinking and innovative skills

APO_08: Having a good digital footprint

M. Tech Sensor System Technology

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech. (Sensor System Technology) programme, graduates will be able to

- PSO1 Analyze advanced engineering problems in the fields of sensors, data acquisition and controls.
- PSO2 Apply advanced techniques and tools of sensing systems to solve multi-disciplinary challenges in industry and society.
- PSO3: To exhibit independent, and collaborative research with strategic planning, while demonstrating the professional and ethical responsibilities of the engineering profession.

M. Tech Sensor System Technology

CREDIT STRUCTURE

Category-wise Credit distribution

Category	Credits
University core (UC)	**27**
Programme core (PC)	**19**
Programme elective (PE)	**18**
University elective (UE)	**06**
Total credits	**70**

M. Tech Sensor System Technology

DETAILED CURRICULUM

University Core

S. No	Course Code	Course Title	L	T	P	J	C
1	MAT6001	Advanced Statistical Methods	2	0	2	0	3
2	ENG5001	Fundamentals of Communication Skills	0	0	2	0	2
3	ENG5001 and ENG5002 or GER5001	Technical English I and Technical English II (or) Deutsch fuer Anfaeger	{0 0 2	0 0 0	2 2 0	0 0} 0	2
4	STS5001 & STS5002	Soft Skills	0	0	0	0	2
5	SET5001	SET Project-I	0	0	0	0	2
6	SET5002	SET Project-II	0	0	0	0	2
7	ECE6099	Master's Thesis	0	0	0	0	16

Programme Core

S. No	Course Code	Course Title	L	T	P	J	C
1	ECE5001	Principles of Sensors	3	0	2	0	4
2	ECE5002	Data Acquisition and Hardware Interfaces	3	0	2	0	4
3	ECE5003	Control Systems	1	0	4	4	4
4	ECE6001	Wireless Sensor Networks and IoT	2	0	0	4	3
5	ECE6002	Microcontrollers and Embedded Sensors	2	0	2	4	4

Programme Electives

S.No	Course Code	Course Title	L	T	P	J	C
1	ECE5004	Software for Embedded Systems	2	0	2	0	3
2	ECE5006	Flexible and Wearable Sensors	3	0	0	0	3
3	ECE5007	Nanomaterials and Sensors	2	0	0	4	3
4	ECE5008	Micro and Nano Fluidics	2	0	0	4	3
5	ECE6003	Micro Systems & Hybrid Technology	2	0	2	0	3
6	ECE6004	RF and Microwave Sensors	3	0	0	0	3
7	ECE6005	Chemical Sensors	2	0	2	0	3
8	ECE6006	Automotive Sensors	2	0	2	0	3
9	ECE6007	Biomedical sensors	2	0	2	0	3
10	ECE6008	Biosensors	2	0	0	4	3
11	ECE6009	Environmental Sensors	2	0	0	4	3
12	ECE6029	Integrated Wave Optics	3	0	0	0	3
13	ECE6030	Signal Processing and Data Analytics	2	0	2	0	3
14	CSE5009	Soft Computing	3	0	0	0	3
15	MEE5050	Product Design, Management Techniques and Entrepreneurship	3	0	0	4	4

Course code	Course title	L	T	P	J	C
ECE5001	**PRINCIPLES OF SENSORS**	**3**	**0**	**2**	**0**	**4**
Pre-requisite	**Nil**	**Syllabus version**				
		v. 1.1				

Course Objectives:

1. To provide in depth knowledge in physical principles applied in sensing, measurement and a comprehensive understanding on how measurement systems are designed, calibrated, characterised, and analysed.
2. To introduce the students to sources and detectors of various Optical sensing mechanisms and provide in-depth understanding of the principle of measurement, and theory of instruments and sensors for measuring velocity and acceleration
3. To give a fundamental knowledge on the basic laws and phenomena on which operation of sensor transformation of energy is based.
4. To impart a reasonable level of competence in the design, construction, and execution of mechanical measurements strain, force, torque and pressure

Expected Course Outcome:

1. Use concepts in common methods for converting a physical parameter into an electrical quantity
2. Choose an appropriate sensor comparing different standards and guidelines to make sensitive measurements of physical parameters like pressure, flow, acceleration, etc
3. Design and develop sensors using optical methods with desired properties
4. Evaluate performance characteristics of different types of sensors
5. Locate different type of sensors used in real life applications and paraphrase their importance
6. Create analytical design and development solutions for sensors.

Student Learning Outcomes (SLO):	**1,5**

Module	Title	Hours
Module:1	**Sensor fundamentals and characteristics**	**4 hours**

Sensor Classification, Performance and Types, Error Analysis characteristics

Module	Title	Hours
Module:2	**Optical Sources and Detectors**	**6 hours**

Electronic and Optical properties of semiconductor as sensors, LED, Semiconductor lasers, Fiber optic sensors, Thermal detectors, Photo multipliers, photoconductive detectors, Photo diodes, Avalanche photodiodes, CCDs.

Module	Title	Hours
Module:3	**Intensity Polarization and Interferometric Sensors**	**6 hours**

Intensity sensor, Microbending concept, Interferometers, Mach Zehnder, Michelson, Fabry-Perot and Sagnac, Phase sensor: Phase detection, Polarization maintaining fibers.

Module	Title	Hours
Module:4	**Strain, Force, Torque and Pressure sensors**	**6 hours**

Strain gages, strain gage beam force sensor, piezoelectric force sensor, load cell, torque sensor, Piezo-resistive and capacitive pressure sensor, optoelectronic pressure sensors, vacuum sensors.

Module	Title	Hours
Module:5	**Position, Direction, Displacement and Level sensors**	**7 hours**

Potentiometric and capacitive sensors, Inductive and magnetic sensor, LVDT, RVDT, eddy current, transverse inductive, Hall effect, magneto resistive, magneto strictive sensors. Fiber optic liquid level sensing, Fabry Perot sensor, ultrasonic sensor, capacitive liquid level sensor.

Module:6	**Velocity and Acceleration sensors**	**6 hours**
Electromagnetic velocity sensor, Doppler with sound, light, Accelerometer characteristics, capacitive, piezo-resistive, piezoelectric accelerometer, thermal accelerometer, rotor, monolithic and optical gyroscopes.		
Module:7	**Flow, Temperature and Acoustic sensors**	**8 hours**
Flow sensors: pressure gradient technique, thermal transport, ultrasonic, electromagnetic and Laser anemometer. microflow sensor, coriolis mass flow and drag flow sensor. Temperature sensors- thermoresistive, thermoelectric, semiconductor and optical. Piezoelectric temperature sensor. Acoustic sensors- microphones-resistive, capacitive, piezoelectric, fiber optic, solid state -electrect microphone.		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1	Jacob Fraden, "Hand Book of Modern Sensors: physics, Designs and Applications", 2015, 3rd edition, Springer, New York.
2.	Jon. S. Wilson, "Sensor Technology Hand Book", 2011, 1st edition, Elsevier, Netherland.
Reference Books	
1.	Gerd Keiser,"Optical Fiber Communications", 2012, 4th edition, McGraw-Hill Science, Delhi.
2.	John G Webster, "Measurement, Instrumentation and sensor Handbook", 2014, 2nd edition, CRC Press, Florida.
3.	Eric Udd and W.B. Spillman, "Fiber optic sensors: An introduction for engineers and scientists", 2013, 2nd edition, Wiley, New Jersey.
4.	Bahaa E. A. Saleh and Malvin Carl Teich, "Fundamentals of photonics", 2012, 1st edition, John Wiley, New York.
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar	

List of Challenging Experiments (Indicative)		
1.	Strain, Force, pressure, and torque measurement i. Strain measurement with Bridge Circuit ii. Beam force sensor using Strain Gauge Bridge iii. Beam deflection sensing with Strain Gauge Bridge iv. Diaphragm pressure sensor using Strain Gauge Bridge v. Shear strain and angle of shift measurement of hollow shaft After completing the 1st set of characteristics. Design a weighing machine having a range of 0-5 Kg with a sensitivity of 5 mg. What modification he/she has to do to change the upper range to 100 Kg with a sensitivity of 100 mg.	8 hours
2.	Develop a displacement measurement system with the following sensors: i. Inductive transducer (LVDT) ii. Hall effect sensor	4 hours
3.	After studying the characteristics of temperature sensors listed below, develop a temperature measurement system for a particular application using	6 hours

	the suitable sensor. i. Thermocouple principles ii. Thermistor and linearization of NTC Thermistor iii. Resistance Temperature Detector iv. Semiconductor Temperature sensor v. Current output absolute temperature sensor	
4.	Develop a sensor system for force measurement using piezoelectric transducer	4 hours
5.	Measurement of shear strain and angle twist using strain gauge is not suitable for many applications. Based on other sensing experiments carried out suggest a non- contact method and try to complete its proof of concept.	8 hours
	Total Laboratory Hours	30 hours

Mode of assessment:			
Recommended by Board of Studies	21-08-2017		
Approved by Academic Council	No. 47	Date	5-10-2017

Course code	Course title	L	T	P	J	C
ECE5002	**DATA ACQUISITION AND HARDWARE INTERFACES**	**3**	**0**	**2**	**0**	**4**
Pre-requisite	**Nil**	**Syllabus version**				
		1.1				

Course Objectives:

1. To introduce the students with basics of computer interfacing and to provide comprehensive understanding of signal conditioning, signal conversion, data acquisition, signal processing, transmission and analysis.
2. To teach the students the applicability of various A/D and D/A boards.
3. To acquaint the students with various data acquisition methods and Interface Standards data loggers and PC buses.
4. To acquaint the students with Virtual instrumentation for testing, control, and designing of sensor systems using LabView.

Expected Course Outcome:

1. Understand the basics of various bus topology and computer interfacing
2. Comprehensively analyse signal conditioning, signal conversion, data acquisition, and signal processing.
3. Utilize A/D and D/A converter in various applications
4. Acquainted with various data acquisition methods and Interface Standards and PC buses.
5. Integrate and program various distributed and stand-alone Loggers.
6. Explore by experimenting Virtual instrumentation for testing, control, and designing of sensor systems using LabView.

Student Learning Outcomes (SLO): **1,5,14**

Module	Title	Hours
Module:1	**Fundamentals of Data Acquisition**	**4 hours**

Essentials of computer interfacing –configuration and structure –interface systems-interface bus.

Module	Title	Hours
Module:2	**Design of Signal Conditioning Circuit**	**9 hours**

Signal amplifiers, analog filters, digital and pulse train conditioning, two-wire transmitter, and distributed I/O - high speed digital transmitter, noise reduction and isolation

Module	Title	Hours
Module:3	**A/D boards**	**7 hours**

Plug-in data acquisition boards- parameter setting- programmable gain array - memory buffer- bus interface. Sampling strategies for multi-channel analog inputs- speed Vs throughput.

Module	Title	Hours
Module:4	**D/A boards**	**7 hours**

D/A boards-parameter setting - memory buffer- timing circuitry-output amplifier buffer- bus interface, Digital I/O boards. Counter-timer I/O boards-waveform generation-measuring pulse width and frequency.

Module	Title	Hours
Module:5	**Interface Standards and PC buses**	**5 hours**

RS232, RS422, RS485, GPIB, USB, Firewire; Backplane buses - PCI, PCI-Express, PXI, PXI – Express, VME, VXI; Ethernet –TCP/IP protocols.

Module:6	**Distributed and Stand-alone Loggers**		**4 hours**
Programming and logging data using PCMCIA cards- stand-alone operation- direct and remote connection to host PC – power management circuitry- Host software- data loggers Vs internal systems			
Module:7	**Virtual Instrumentation**		**7 hours**
Virtual instrument and traditional instrument, Hardware and software for virtual instrumentation, Virtual instrumentation for test, control, and design, Graphical system design, Graphical and textual programming.			
Module:8	**Contemporary issues:**		**2 hours**
	Total Lecture hours:	**45 hours**	

Text Book(s)	
1	Ramon Pallas-Areny and John G Webster, Sensors and Signal Conditioning, 2012, 2nd ed., Wiley India Pvt. Ltd.
2.	John Park and Steve Mackay, Practical Data acquisition for Instrumentation and Control, 2011, 1st ed., Newness publishers, Oxford, UK.
Reference Books	
1.	Maurizio Di Paolo Emilio, Data Acquisition systems- from fundamentals to Applied Design, 2013, 1st ed., Springer, New York.
2.	Robert H King, Introduction to Data Acquisition with LabVIEW, 2012, 2nd ed., McGraw Hill, New York.
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar	

List of Challenging Experiments (Indicative)		
1.	Design of differential amplifier and instrumentation amplifier: Build a sensor bridge circuit using Multisim, having 1kΩ elements and sensitivity of 10mV/V with 5V excitation circuit. At full scale, sensors in the bridge exhibit 1% change in resistance value. Design the following amplifier circuits so that the full scale output of the amplifier is 5V. i) Single op amp differential amplifier. ii) Three op amp instrumentation amplifier. Simulate the above circuits to measure the voltage at its full scale.	4 hours
2.	Design of signal conditioning circuit for RTD: Design a RTD based temperature measurement circuit to convert 0°C to 80°C into 0 - 5V. Error should not exceed ±1℃. The given RTD has the following specifications: RRTD at 0°C is 100Ω, and temperature coefficients of resistance α is 0.004Ω/℃. Build the circuit in Multisim and simulate it.	4 hours
3.	Building temperature measurement system using NI Elvis: Design a thermocouple based temperature measurement circuit to convert 0°C to 50°C into 0- 5V. If the temperature exceeds 60°C then a LED alarm should glow. Build the circuit using NI ELVIS board. Test the performance	4 hours

	of the circuit.	
4.	Design of cold junction compensation while using a thermocouple: A K type thermocouple is to be used in the measurement system which must provide an output of 2V at 200˚C. A solid state temperature sensor system will be used to provide a reference temperature correction. Temperature sensor has three terminals: supply, output voltage and ground and the output varies as 8mV/˚C. Sensitivity of K-type thermocouple is 50µV/˚C at 200˚C. Build the circuit in multisim and simulate it.	4 hours
5.	Programming with LabVIEW: Signal acquisition and generation: Create a simple VI that simulates an analog signal and plots it on a waveform graph. The VI will give user control of the frequency and amplitude of this wave. Configure the following DAQ cards: i) NI ELVIS, ii) myDAQ and iii) cDAQ to generate the signal simulated by the simple VI. Also configure the DAQ cards to acquire the generated signal and display it on waveform graph.	5 hours
6.	Measuring strain, temperature, pressure (various physical parameters) using LabVIEW:	4 hours
7.	Design of LabVIEW system using Hall effect sensor: a) Using NI ELVIS tools study the properties of Hall-effect sensor. b) Build a simple gauss-meter and a position measurement system using a linear Hall-effect sensor. Plot the Hall voltage versus distance using the data measured. b) Using NI ELVIS tools study the properties of LDR. b) Build a simple LED light intensity controller, i.e switching on and off LED lights using LDR as a sensor. When there is light available the LED should be off but at night it should be on. c) LabVIEW interface for ultrasonic based distance measurement.	5 hours
	Total Laboratory Hours	30 hours

Mode of assessment: Continuous Assessment and FAT			
Recommended by Board of Studies	21-08-2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE5003	**CONTROL SYSTEMS**	**1**	**0**	**4**	**4**	**4**
Pre-requisite	**Nil**	**Syllabus version**				
		1.0				

Course Objectives:

1. Introduce the students to the techniques for solving complex control problems and expose them to the analysis of system response for standard test inputs and understanding its behavior.
2. Impart the design knowledge of compensators for adjusting the system performance using time domain analysis methods and to verify the system stability using time and frequency domain analysis methods.
3. Expose the students to develop the three term controllers (PID) based on the customer needs and the discrete control algorithms and the development of suitable digital controller for corrective action.
4. Expose the importance of PLC in automatic control action in the real time applications.

Expected Course Outcome:

1. Realize the need of control system and its recent developments. Able to model the system and simulate the model.
2. Analyze the behavior of the first and second order systems in time domain and frequency domain.
3. Analyze the system stability based on time domain, frequency domain and root locus techniques.
4. Design suitable compensators for the real world systems based on the customer requirements.
5. Indentify the need for incorporating the three term controller based on the customized requirement of the control action
6. Analyze the systems behavior in digital domain and develop digital control algorithm for the corrective action.
7. Competency in utilizing the PLCs in control actions for the real world problems.

Student Learning Outcomes (SLO):	**1, 5, 14**	
Module:1	**Introduction to Control System**	**1 hour**

Control system configuration – open loop, closed loop, analysis and design objectives; design process, LabVIEW and MATLAB/Simulink for control system design and simulation.

Module:2	**Time Domain Analysis and Design**	**2 hours**

First order, Second order control system response for step, ramp and impulse inputs. characteristic equation -Poles and Zeroes concept- stability and Routh criterion

Module:3	**Root Locus Techniques**	**2 hours**

Review of root locus construction – Lead/ Lag compensator design using root locus.

Module:4	**Frequency Response Techniques**	**2 hours**

Bode plots and stability- gain and phase margins- Lead/ Lag compensator design using Bode plots.

Module:5	**Three-Term Controllers**		**2 hours**
P, PI, PD, PID Controller- Basic control action - Effects of Derivative, Integral control actions- Design of P, PI, PID controllers – Tunable PID Controllers – Ziegler – Nichols Methods for Controller Tuning.			
Module:6	**Introduction to Digital Control System**		**2 hours**
Discrete Time systems, Sampling, time response of discrete data system, characteristics -Jury's stability test. Pulse transfer function, Digital PID controller			
Module:7	**Programmable Logic Controller**		**3 hours**
Evolution of PLC – Sequential and Programmable controllers – Architecture – Programming of PLC – Relay logic and Ladder logic – Functional blocks – Communication Networks for PLC.			
Module:8	**Contemporary issues:**		**2 hours**
	Total Lecture hours:	**15 hours**	

Text Book(s)		
1	Katsuhiko Ogata, "Modern Control Engineering", 2010, 5th ed., Prentice Hall, New Jersey USA.	
2.	M. Gopal "Modern Control System Theory", 2014, 2nd ed. New Age International, New Delhi, India.	
Reference Books		
1.	M. Gopal,"Digital control and state variable methods", 2012, 4th ed., Tata McGraw Hill, USA.	
2.	Webb & Reis, "Programmable Logic Controller - Principles and Applications", 2012, 5th ed., PHI, New Delhi, India.	
3.	I. J. Nagrath and M. Gopal, "Control Systems Engineering", 2017, 6th Ed., New Age International (p) Limited. New Delhi, India.	
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar		
List of Challenging Experiments (Indicative)		
1.	Create an application using LabVIEW control design and simulation module and the control and simulation loop in order to simulate the Mass-Spring system. The input force increases from 0 to 8N at t = 1s. The parameter values are M = 2 kg, K= 16 N/m, and B =4 N.s/m. Simulate the above response using MATLAB SIMULINK.	4 hours
2.	Create a SIMULINK model with a first order system (G(s), with gain, K = 1, and time constant, T = 0.1 sec. Input to the system is u(t) and the output is v(t). Simulate a square wave input with unit amplitude and frequency of 0.3 Hz. The sample time is 0.001 sec. For the closed loop unity feedback system, view the reference position xr(t), input u(t), and actual position, x(t), through a scope. x(t) is the output from the integrator that follows by the G(s). Experiment with different values of Kp and observe how the system response changes.	4 hours
3.	a) Using MATLAB, obtain the unit-ramp response of the closed-loop control system whose closed-loop transfer function is given as:	4 hours

	$\frac{C(s)}{R(s)} = \frac{(s+10)}{s^3+6s^2+9s+10}$ Also, obtain the response of this system when the input is given by: r(t) =$e^{-0.5t}$. b) Using MATLAB, obtain the unit-step response, unit-ramp response, and unit impulse response of the system defined as $\frac{C(s)}{R(s)} = \frac{10)}{s^2+2s+10}$. Where R(s) and C(s) are Laplace transform of the input r (t) and output c(t) respectively	
4.	a) The design of a turning control for a tracked vehicle, the open loop transfer function of power train and vehicle is $\frac{C(s)}{R(s)} = \frac{K}{s(s+5)(s+3)}$. The controller $Gc(s) = \frac{s+a}{s+1}$ is used for the closed loop unity feedback control. The parameters K and a affect the performance of the system including its stability. Determine under what conditions(i.e values of a and k) closed loop system is internally stable. In Matlab plot a Vs K (for K>0) that divides the regions of stability and instability and indicate which is the stable region. b) Given a plant described by the transfer function Gp(s) = $\frac{K}{s(s+5)(s+3)}$, a controller must be designed, such that the step response of the closed loop shows the following properties: Peak over shoot 16% and Rise time 0.6s.	4 hours
5.	Consider an open-loop system which has a transfer function of (s) $= \frac{(s+7)}{s(s+5)(s+15)(s+20)}$ Design a proportional controller using Root locus to give a closed loop unit step response of 5% overshoot with 1 sec rise time. Implement the design using Matlab.	4 hours
6.	a) A unity feedback system has the following transfer function G(s) $\frac{1}{s(s+4)(s+6)}$ Design a lead compensator using Root locus method where the settling time is reduced by a factor of 2 while maintaining the peak overshoot at 30% b) A unity feedback system has the following transfer function G(s) $\frac{1}{(s+1)(s+2)(s+10)}$ Using Root locus method, design a lag compensator to improve the steady state error by a factor of 10 if the system is operating with a damping ratio of 0.174	6 hours
7.	A unity feedback system has open loop transfer function G(s) $\frac{4}{s(s+4)}$. It is desired that dominant closed loop poles provide damping ratio=0.5 and have an un-damped natural frequency=4rad/sec. Velocity error constant is required to be greater than 4. a) Verify that only gain adjustment cannot meet these objectives. b) Design a lead compensator using SISO design tool to meet the objectives. c) Using GUI determine the peak overshoot and settling time of the lead-compensated system.	6 hours
	A unity feedback system has open loop transfer function G(s) $\frac{8.96}{0.00147s^2+0.01455s+1}$. Simulate its step response. Using a PD or PI controller, get the settling time to less than 0.5 sec (approx. 0.1 sec) while keeping the %OS lesser than 10%. Justify your design in the report.	4 hours
	a)A unity feedback system has open loop transfer function G(s) $\frac{4}{s(s+4)}$. Design a lead compensator using Bode Plot Method such that the velocity	4 hours

	error constant Kv = 20 sec^{-1}, Phase Margin PM = 50^o, Gain Margin GM > 10.	
	a) Interface the DC motor add on board with NI ELVIS. Build a VI to apply a step input (voltage) to the motor and record the response (angular velocity ω). Identify the transfer function of the motor $G(s) = \frac{K}{\tau s+1}$, where K is the steady state gain (rad/V-s) and τ is the time constant in s. Run the model simulation in parallel with the actual system to allow for model tuning and validation. b) Design a PI controller for the DC motor according to the desired specifications. Calculate the expected peak time *tp* and percent overshoot PO given the following design specifications: ξ = 0.75 and ω=16 rad/sec. Calculate the proportional and integral control gains *kp* and *ki*, respectively, according to the design specifications. Build a VI to implement the PI controller for the DC motor speed control. c) Build a VI to implement a PD controller for the DC motor position control. Design the proportional and derivative control gains Kp and KD to meet the following specifications: ξ = 0.6 and ω=25 rad/sec.	6 hours
	a) Interface the HVAC add-on board with NI ELVIS. Build a VI to apply on-off voltage to the open loop HVAC system and record the temperature response of the system. Identify the transfer function of the system using the response: $G(s) = \frac{Kv}{s}$ where Kv is the slope of the open loop system response. b) Design an on-off control or relay feedback to switch on the heater when the temperature is lower than the desired value (50°C), and to switched off the heater when the temperature is higher than the desired value. To avoid rapid switching introduce a hysteresis (0.25°C) in the relay switch. Build a VI to implement the on-off control. c) Build a VI to implement PI controller for the closed loop temperature control in HVAC system to meet the following specifications: ξ = 0.5 and ω=0.125 rad/sec.	6 hours
	Interface the Rotary pendulum add-on board with NI ELVIS. Build a VI to run the DC motor connected to the pendulum arm in open loop and measure the DC motor voltage and the corresponding pendulum arm and link angles to derive the state space model. Based on this model design a controller to balance the pendulum in its upright position using Linear Quadratic Regulator (LQR) optimization technique.	4 hours
	a) Interface the Vertical Take Off and Landing add-on board with NI ELVIS. Derive from first principles the equation of motion to obtain the transfer function representing the current to position. Build a VI to apply a current to the propeller actuator (DC fan) to lift the arm. Identify the current	4 hours

<table>
<tr><td></td><td colspan="3">required to bring the VTOL to a horizontal position. Build a VI to apply step current to the propeller and record the oscillating response of VTOL and measure the natural frequency.

b) Design a PID controller for VTOL to meet the required specifications: peak time 1.25s and peak overshoot of 20%. Implement the controller using LabVIEW.</td><td></td></tr>
<tr><td colspan="4" align="right">Total Laboratory Hours</td><td>30 hours</td></tr>
<tr><td colspan="5">Mode of assessment: Continuous Assessment and FAT</td></tr>
<tr><td colspan="2">Recommended by Board of Studies</td><td colspan="3">21-08-2017</td></tr>
<tr><td colspan="2">Approved by Academic Council</td><td>No. 47</td><td>Date</td><td>05-10-2017</td></tr>
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Course code	Course title	L	T	P	J	C
ECE6001	**WIRELESS SENSOR NETWORKS AND IoT**	**2**	**0**	**0**	**4**	**3**
Prerequisite:	**ECE5001 Principles of Sensors**	**Syllabus version**				
		1.0				

Course Objectives:

1. To identify and expose the students to the central elements in the design of communication protocols for the WSNs.
2. To disseminate the design knowledge in analyzing the specific requirements for applications in WSNs regarding energy supply, memory, processing, and transmission capacity
3. To get the perception of mobile ad hoc networks, design, implementation issues, and solutions based on different algorithms and protocols for power management, sensor data routing and query processing.
4. To associate, hardware platforms and software frameworks used to realize dynamic Wireless sensor network

Expected Course Outcome:

1. Assess the applicability and limitations of communication protocols for a real time WSN application.
2. Confirms the behavior of mobile ad hoc networks (MANETs) and correlates the infrastructure-based networks
3. Proactive in understating the routing protocols function and their implications on data transmission delay and bandwidth
4. Able to establish networks with an attempt to reduce issue of broadcast and flooding techniques.
5. Contribute appropriate algorithms to improve existing or to develop new wireless sensor network applications.
6. Familiarize the protocol, design requirements, suitable algorithms, and the state-of-the-art cloud platform to meet the industrial requirement.
7. On a profound level to implement hardware & software for wireless sensor networks in day to day life

Student Learning Outcomes (SLO): **5, 7**

Module	Title	Hours
Module:1	**Network for embedded systems**	**4 hours**

RS232, RS485, SPI, I2C, CAN, LIN, FLEXRAY.

Module	Title	Hours
Module:2	**Embedded wireless communication**	**4 hours**

Bluetooth, Zigbee, Wifi, UWB

Module	Title	Hours
Module:3	**Wireless sensor network (WSN)**	**4 hours**

Characteristic and challenges, WSN vs Adhoc Networks, Sensor node architecture, Physical layer and transceiver design considerations in WSNs, Energy usage profile, Choice of modulation scheme, Dynamic modulation scaling, Antenna considerations.

Module	Title	Hours
Module:4	**WSN (Medium access control)**	**5 hours**

Fundamentals of MAC protocols - Low duty cycle protocols and wakeup concepts, Contention Based protocols, Schedule-based protocols - SMAC – BMAC, Traffic-adaptive medium access

protocol (TRAMA), The IEEE 802.15.4 MAC protocol.			
Module:5	**Sensor Network Architecture**	**5 hours**	
Data Dissemination, Flooding and Gossiping-Data gathering Sensor Network Scenarios, Optimization Goals and Figures of Merit, Design Principles for WSNs- Gateway Concepts, Need for gateway, WSN and Internet Communication, WSN Tunneling			
Module:6	**IP based WSN**	**4 hours**	
Circuit switching, packet switching, concept of IPV4, IPV6, 6LOWPAN and IP, IP based WSN, 6LOWPAN based WSN, IOT			
Module:7	**Tiny OS**	**2 hours**	
Tiny OS for WSN and IOT, M2M communication, Alljoyn network			
Module:8	**Contemporary issues:**	**2 hours**	
	Total Lecture hours:	**30 hours**	

Text Book(s)	
1	Holger Karl, Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks" 2011, 1st ed., John Wiley & Sons, New Jersey.
2.	Jun Zheng, Abbas Jamalipour, "Wireless Sensor Networks: A Networking Perspective", 2014, 1st ed., Wiley-IEEE Press, USA.
Reference Books	
1.	Waltenegus W. Dargie, Christian Poellabauer, "Fundamentals of Wireless Sensor Networks: Theory and Practice", 2014, 1st ed., John Wiley & Sons, New Jersey.
2.	Ian F. Akyildiz, Mehmet Can Vuran, "Wireless Sensor Networks", 2011, 1st ed., John Wiley & Sons, New Jersey.
3.	Zach Shelby, Carsten Bormann, "6LoWPAN: The Wireless Embedded Internet", 2009, 1st ed., John Wiley & Sons, New Jersey.
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar	

List of Challenging Experiments (Indicative)		
1.	1. Smart door locks offer sophisticated "access control" features to any home or business. Proximity sensors like Bluetooth and NFC can enable a door to unlock whenever an authorized user's smartphone approaches. Users can also remotely lock and unlock the door, or share access with any number of others, using mobile apps. Keeping the above design parameters implement a Smart locks for apartment's security using IoT principle.	
2.	2. The refrigerator is the most frequently used domiciliary/kitchen electrical appliance all over the world for food storage. Implement a Smart refrigeration module designed to convert any existing normal refrigerator into a smart and low-cost machine using sensors. Smart refrigerator compares the status of the food for e.g. weight, quantity etc. The smart refrigerator must also able be remotely controlled and notifies the user about scarce products via wifi module (internet) on user's mobile android application. Add functionality which includes the ice ready indication,	

	power saving, smell detection, overweighting etc.	
3.	3. Water has become a scarce resource and is crucial to the production of food. Therefore, design and implement a wireless sensor network to manage and conserve this vital resource. Part of the system includes the design and development of three sensor nodes to monitor soil moisture. An interface to display and store the status of the water content and also to be uploaded to a web server.	
4.	4. Design and provide necessary modules and service, such as command dissemination, feedback module, data logging and collection module, network programming module and time synchronization service between different sensor nodes.	
5.	5. WSN has a variety of services based on sensor network architecture. Common issues such as network bandwidth reduction, collision occurrence and performance deterioration due to the broadcasting of message in large-scale networks have become main challenges. To overcome these issues implement routing algorithm based on data-centric routing and address-based routing schemes, by which the query messages are delivered to the target area by using address-based routing scheme, then, the broadcast scheme.	
	Total Laboratory Hours	30 hours

Mode of assessment: Continuous Assessment and FAT			
Recommended by Board of Studies	21-08-2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course code	Course title	L	T	P	J	C
ECE6002	**MICROCONTROLLERS AND EMBEDDED SENSORS**	**2**	**0**	**2**	**4**	**4**
Pre-requisite	**Nil**	**Syllabus version**				
		1.0				

Course Objectives:

1. Introduce low power microcontrollers and to develop the skill set of programming low power sensing applications.
2. Impart the knowledge of various peripheral related to sensing and communication using wired or wireless means.
3. Upgrade the students by introducing them Advanced ARM Cortex microcontrollers
4. Develop the skill set of students capture various kinds of sensor and present the output in J2ME applications

Expected Course Outcome:

1. Design and develop embedded programs for low power microcontrollers for sensor applications.
2. Develop ARM basic and advanced programs.
3. Interface and deploy analog sensors
4. Interface digital sensors
5. Interface Bio medical sensors and develop logging systems
6. Develop communication system with sensor units
7. Present the data to real world using displays and actuators

Student Learning Outcomes (SLO): 5,6

Module:1	**Texas MSP430**	**6 hours**

Architecture of the MSP430, Memory, Addressing modes, Reflections on the CPU instruction set. Clock system, Exceptions: Interrupts and resets. Functions and subroutines, Mixing C and assembly language, Interrupts, Interrupt service routines, Issues associated with interrupts, Low-power modes of operation.

Module:2	**ARM Cortex MX microcontroller**	**6 hours**

ARM Cortex M4: Assembly language basics, Thumb-2 Technology, ARM Instruction set, Cortex M4 architecture, advantages, peripherals, instruction set, floating point operations, Advanced Cortex MX Microcontroller, core, architecture, on-chip wi-fi.

Module:3	**Analog sensors interfacing**	**4 hours**

Analog sensor for Temperature, pressure, moisture, accelerometers, inclinometers, gyroscopes, flex, color, light, Principle of data acquisition, programming ADC and sensor interface.

Module:4	**Digital Sensors interfacing**	**4 hours**

Digital sensor for Temperature, pressure, moisture, accelerometers, inclinometers, gyroscopes, flex, color, light, Programming Timers, frequency counters, PWM generation, demodulation

Module:5	**Multi channel signal acquisition and logging**	**4 hours**

Multichannel ADC, sample rate generation, data logging, interfacing SD card, multi channel data logging: bio medical signal acquisition, real time, clock, reading writing GPS & GSM

controller			
Module:6	**Communication modules**		**2 hours**
Peripheral programming SPI, I2C, UART, Zigbee controller.			
Module:7	**Output devices**		**2 hours**
GPIO, LCD display, graphical display, relays.			
Module:8	**Contemporary issues:**		**2 hours**
	Total Lecture hours:	**30 hours**	
Text Book(s)			
1.	John H. Davies, "MSP430 Microcontroller Basics", 2011, 2nd ed., Newnes publishing, New York.		
2.	Jacob Fraden, "Hand Book of Modern Sensors: physics, Designs and Applications", 2014, 4th ed., Springer, New York.		
Reference Books			
1.	Sergey Y. Yurish,"Digital Sensors and Sensor Systems: Practical Design", 2011, 1st ed., IFSA publishing, New York.		
2	Jonathan W Valvano, "Introduction to ARM Cortex –M3 Microcontrollers", 2012, 5th ed., Create Space publishing, New York.		
3	Muhammad Ali Mazidi, Shujen Chen, Sarmad Naimi, Sepehr Naimi, "TI ARM Peripherals Programming and Interfacing: Using C Language", 2015, 2nd ed., Mazidi and Naimi publishing, New York.		
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar			
List of Challenging Experiments (Indicative)			
1.	Analog Sensor interface with microcontroller • Sub Task 1: Port programming of MSP430 microcontrollers • Sub Task 2: Analog to Digital Conversion using MSP430 microcontroller • Sub Task 3: LCD display of characters and numbers.	4 hours	
2.	Digital Sensor interface with MSP430 microcontroller • Sub Task 1: Timer programming of MSP430 microcontroller • Sub Task 2: PWM generation demodulation • Sub Task 3: Frequency counting	4 hours	
3.	Low powerWireless transmission using Zigbee • Sub Task 1 : Interfacing Zigbee controller with MSP 430 microcontroller using SPI/UART. • Sub Task 2: Programming sleep and wake up mode of MSP 430.	4 hours	
4.	Offline Data loggers • Sub Task 1: Sampling and recording medical signals (ARM). • Sub Task 2: IP configuration of sensor node. • Sub Task 3: configuration of remote IP for sending and receiving	4 hours	

	data to and from sensor node.	
5.	Analog Sensor interface with microcontroller • Sub Task 1: Port programming of MSP430 microcontrollers • Sub Task 2: Analog to Digital Conversion using MSP430 microcontroller • Sub Task 3: LCD display of characters and numbers.	4 hours
	Total Laboratory Hours	30 hours

Mode of assessment: Continuous Assessment and FAT			
Recommended by Board of Studies	21-08-2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
CSE5009	**SOFT COMPUTING**	**3**	**0**	**0**	**0**	**3**
Prerequisite:	**Nil**	**Syllabus version**				
		1.0				

Course Objectives:

1. To introduce the fundamental theory and concepts of computational intelligence methods and provide a comprehensive foundation to artificial neural networks, neuro-modeling, and their applications to pattern recognition.
2. To explore the learning paradigms of supervised and unsupervised neural networks.
3. To provide a comprehensive knowledge on fuzzy logic inference, and its applications in solving engineering problems
4. To expose the students to the concepts of biologically inspired methodologies such as genetics, evolutionary computing paradigm (genetic algorithm) and its application to optimization problems.

Expected Course Outcome:

1. Understand the differences between networks for supervised and unsupervised learning.
2. Conceptualize and parameterize various problems to be solved through basic soft computing techniques
3. Develop and train neural networks for classification, storage, regression and clustering.
4. Comprehend the fuzzy logic and the concept of fuzziness involved in various systems and fuzzy set theory.
5. Understand the concepts of fuzzy sets, knowledge representation using fuzzy rules, approximate reasoning, fuzzy inference systems, and fuzzy logic
6. Describe the flow of a genetic algorithm and identify its elements and design genetic algorithms for single and multiple objective optimization

Student Learning Outcomes (SLO): **1,5**

Module:1	**Artificial Neural Networks**	**5 hours**

Soft computing vs. hard computing, types and applications of soft computing techniques. Artificial neural networks and their biological motivation – Terminology – Models of neuron –Topology – characteristics of artificial neural networks – types of activation functions-,learning methods – error correction learning – Hebbian learning, Linear separability and XOR problem

Module:2	**Supervised Learning Networks**	**6 hours**

Discrete and continuous Perceptron, adaline, multilayer Perceptron, Back Propagation algorithm, limitations and improvements

Module:3	**Associative Memory Networks**	**6 hours**

Autoassociation, heteroassociation, recall and cross talk-Linear auto associator – Bi-directional associative memory – Hopfield neural network

Module:4	**Unsupervised Learning Networks**	**6 hours**

Neural Nets based on competition-Max net – Mexican Hat – Hamming net - Kohonen Self organizing Feature Map – Counter propagation – Learning Vector Quantization Adaptive Resonance Theory

Module:5	**Fuzzy Sets and Fuzzy Relations**	**5 hours**
Introduction –classical sets and fuzzy sets –classical relations and fuzzy relations –membership functions –fuzzy to crisp conversion, Fuzzy numbers, vectors, and extension principle		
Module:6	**Fuzzy Logic System**	**6 hours**
Fuzzy Logic, Fuzzy knowledge and rule based system, fuzzy decision making –fuzzy logic modeling and control.		
Module:7	**Genetic Algorithm**	**8 hours**
Basic concepts, encoding, fitness function, reproduction, Genetic modeling: Inheritance operator, cross over, inversion & deletion, mutation operator, Bitwise operator, Generational Cycle, Convergence of GA, Applications & advances in GA, Differences & similarities between GA & other traditional method		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	S, Rajasekaran and G.A. Vijayalakshmi Pai, "Neural Networks, Fuzzy Logic & Genetic Algorithms, Synthesis & applications", 2017, 2nd ed., PHI Publication, New Delhi, India.
2	Lauren Fausett, "Fundamentals of Neural Networks-Architectures, algorithms and applications", 2010, 1st ed., Pearson Education Inc.,USA.

Reference Books

1.	Bishop, C. ,M., Pattern Recognition and Machine Learning, Springer, 2011
2	S.N. Sivanandam and S.N. Deepa, "Principles of Soft Computing", 2011, 2nd ed., Wiley Publications, United kingdom.
3	Rich E and Knight K, "Artificial Intelligence", 2011, 2nd ed., TMH, New Delhi,

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar

Recommended by Board of Studies	28.01.2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE5004	SOFTWARE FOR EMBEDDED SYSTEMS	2	0	2	0	3
Pre-requisite	Nil	Syllabus version				
		1.1				

Course Objectives:

1. To introduce and train the students in various software useful for embedded systems
2. To impart basic understanding of embedded C programming for 8 bit micro controller and to apply function pointers and data structures
3. To introduce and train the students in fundamental python programming
4. To develop the skill set of students in J2ME applications
5. To make the students to appreciate Embedded OS and interprocess communication
6. To introduce Contiki OS for sensor devices

Expected Course Outcome:

1. Program microcontroller for port interface, timer and interrupt using embededd C programming.
2. Design data structures and linked list for sensor applications
3. Understand the software development tools like compiler libraries make file macros assemblers.
4. Program python for fundamental functionalities, graphics and signal processing. To understand RTOS and inter-process communication
5. Introduction to Contiki tiny OS for sensor applications

Student Learning Outcomes (SLO):	1,5

Module:1	Embedded Programming	4 hours

C and Assembly, Programming Style, Declarations and Expressions, Arrays, Qualifiers and Reading Numbers, Decision and Control Statements, Programming Process, More Control Statements, Variable Scope and Functions, C Pre-processor, Advanced Types, Simple Pointers, Debugging and Optimization, In-line Assembly

Module:2	C Programming Tool chain in Linux	4 hours

C preprocessor, Stages of Compilation, Introduction to GCC, Debugging with GDB, The Make utility, GNU Configure and Build System, GNU Binary utilities, Profiling, using gprof, Memory Leak Detection with valgrind - Introduction to GNU C Library

Module:3	Adding Structure to ‘C’ Code	6 hours

Object oriented programming with C, Header files for Project and Port, Examples. Meeting Real time constraints, Creating hardware delays, Need for timeout mechanism, Creating loop timeouts, Creating hardware timeouts. Creating embedded operating system, Basis of a simple embedded OS, Introduction to sEOS, Using Timer 0 and Timer 1, Portability issue.

Module:4	Time-Driven Multi-State Architecture and Hardware	6 hours

Multi-State systems and function sequences: Implementing multi-state (Timed) system. Using the Serial Interface: RS232, The Basic RS-232 Protocol, Asynchronous data transmission and baud rates, Flow control, Software architecture, Using on-chip UART for RS-232 communication - Memory requirements, the serial menu architecture, Examples. Case study: Intruder alarm system.

Module:5	Embedded Java	2 hours

Introduction to Embedded Java and J2ME, Smart Card basics, Java card technology overview, Java card objects, Java card applets, working with APDUs, Web Technology for Embedded Systems.			
Module:6	**Contiki OS**		**2 hours**
Mote types, Broadcast, unicast, mesh, shell, cooja simulator.			
Module:7	**Scripting Python**		**4 hours**
Data structures, control flow, functions, input , output, scipy, array and matrix manipulations, plotting, filtering, transforms			
Module:8	**Contemporary issues:**		**2 hours**
	Total Lecture hours:	**30 hours**	

Text Book(s)	
1.	Mark Lutz, "Programming Python", 2010, 4th Edition, O'Reilly Media, Inc, USA.
2.	Michael J Pont, "Embedded C", 2011, 1st Edition, Dorling Kindersley (India).
Reference Books	
1.	Neil Mathew, Richard stones, "Beginning Linux Programming" 2012, 4th Edition, Wrox – Wiley Publishing.
2	Christopher Hallinan. "Embedded Linux Primer: A Practical Real-World Approach", 2011, 2nd Edition, Pearson Education, India.
3	Stephen Kochan, "Programming in C", 2015, 4th Edition, Sams Publishing.
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar	

List of Challenging Experiments (Indicative)		
1.	Develop an embedded software to interface a sensor giving analog output with the microcontroller unit and transmit the sensor value to a personal computer using serial port.	6 hours
2.	Port Raspbian in the raspberry Pi board and test the Linux functionalities.(gcc, shell program, file system the Delay generation using Timer	6 hours
3.	Design and develop a python program to interface the Raspberry pi board with a sensor giving analog output. Programming Interrupts	6 hours
4.	Design and implement basic exercises to deploy the inter process communication in a OS.	6 hours
5.	Design and develop a software based system to uplink the sensor value in cloud	6 hours
	Total Laboratory Hours	30 hours
Mode of assessment: Continuous Assessment and FAT		

Recommended by Board of Studies	21-08-2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE5006	**FLEXIBLE AND WEARABLE SENSORS**	**3**	**0**	**0**	**0**	**3**
Prerequisite:	**ECE5001-Principles of Sensors**	**Syllabus version**				
		1.1				

Course Objectives:

1. To provide the overview of flexible electronics technology and the issues with materials processing for thin film electronics.
2. To expose the students for the materials selection and patterning methods for thin film electronics development.
3. To describe the process involved in transferring the flexible electronics from foils to textiles and also the challenges, opportunities and the future of wearable devices.
4. To expose the students to the design, challenges of wearable sensors employed for sensing the physical and biological parameters and the process involved in the conversion of conducting and semiconducting fibers to smart textiles.

Expected Course Outcome:

1. Realize the technology developments in the flexible electronics technology.
2. Ability to identify the suitable materials and its processing for the development of thin film electronics
3. Ability to design the pattern and develop with suitable patterning methods.
4. Realize the process involved in the transformation of electronics from foils to textiles
5. Acquire the design knowledge for developing wearable sensors for physical and chemical parameters
6. Gain the competency in transferring the conducting and semiconducting fibers to smart textiles

Student Learning Outcomes (SLO):	**1,5**

Module:1	**Overview of flexible electronics technology**	**5 hours**

History of flexible electronics - Materials for flexible electronics: degrees of flexiblility, substrates, backplane electronics, front plane technologies, encapsulation - Fabrication technology for flexible electronics - Fabrication on sheets by batch processing, fabrication on web by Roll-to-Roll processing - Additive printing.

Module:2	**Amorphous and nano-crystalline silicon materials and Thin film transistors**	**7 hours**

Fundamental issues for low temperature processing - low temperature amorphous and nano-crystalline silicon - characteristics of low temperature dielectric thin film deposition - low temperature silicon nitride and silicon oxide characteristics - Device structures and materials processing - Device performance - Contacts for the device - Device stability.

Module:3	**Materials and Novel patterning methods for flexible electronics**	**7 hours**

Materials considerations for flexible electronics: Overview, Inorganics semiconductors and dielectrics, organic semiconductors and dielectrics, conductors - Print processing options for device fabrication: Overview, control of feature sizes of jet printed liquids, jet printing for etch mask patterning, methods for minimizing feature size, printing active materials.

Module:4	**Flexible electronics from foils to textiles**	**6 hours**

Introduction -Thin film transistors: Materials and Technologies - Review of semiconductors employed in flexible electronics - Thin film transistors based on IGZO - Plastic electronics for

smart textiles - Improvements and limitations.		
Module:5	**Wearable haptics**	**6 hours**
World of wearables - Attributes of wearables - Textiles and clothing: The meta wearable - Challenges and opportunities - Future of wearables - Need for wearable haptic devices - Categories of wearable haptic and tactile display.		
Module:6	**Wearable Bio, Chemical and Inertial sensors**	**6 hours**
Introduction-Systems design - Challenges in chemical and biochemical sensing - Application areas -Wearable inertial sensors - obtained parameters from inertial sensors - Applications for wearable motion sensors - Practical considerations for wearable inertial sensor - Application in clinical practice and future scope		
Module:7	**Knitted electronic textiles**	**6 hours**
From fibers to textile sensors - Interlaced network -Textile sensors for physiological state monitoring - Biomechanical sensing - Noninvasive sweat monitoring by textile sensors and other applications. FBG sensor in Intelligent Clothing and Biomechanics.		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Michael J. McGrath, Cliodhna Ni Scanaill, Dawn Nafus, "Sensor Technologies: Healthcare, Wellness and Environmental Applications", 201, 1st Edition , Apress Media LLC, New York.
2.	William S. Wong, Alberto Salleo, Flexible Electronics: Materials and Applications, 2011, 1st Edition, Springer, New York.

Reference Books

1.	Edward Sazonov, Michael R. Newman, "Wearable Sensors: Fundamentals, Implementation and Applications", 2014, 1st Edition, Academic Press, Cambridge.
2	Kate Hartman, "Make: Wearable Electronics: Design, prototype, and wear your own interactive garments", 2014, 1st Edition, Marker Media, Netherlands.
3	Guozhen Shen, Zhiyong Fan, "Flexible Electronics: From Materials to Devices", 2015, 1st Edition, World Scientific Publishing Co, Singapore.
4	Yugang Sun, John A. Rogers, "Semiconductor Nanomaterials for Flexible Technologies: From Photovoltaics and Electronics to Sensors and Energy Storage (Micro and Nano Technologies)", 2011, 1st Edition, William Andrew, New York.

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar

Recommended by Board of Studies	21-08-2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE5007	**NANOMATERIALS AND SENSORS**	**3**	**0**	**0**	**0**	**3**
Prerequisite:	**Nil**	**Syllabus version**				
		1.0				

Course Objectives:

1. To provide an insight of nanomaterials and its synthesis and to expose the students to the different methods being used for nanomaterials characterization.
2. To educate the students about the process involved in the fabrication of sensors using metallic nanoparticles and nanowires and the need for using special materials like CNTs for sensor development.
3. To impart the knowledge of developing sensors using different nano structures of metal oxides and make the students to understand the developments in the nanopolymers and its role in sensors.
4. To provide an insight of quantum dots and its potential application in sensor development.

Expected Course Outcome:

1. Will acquire an insight of nanomaterials and its synthesis.
2. Able to visualize the different methods being used for nanomaterials characterization.
3. Understand the process involved in the fabrication of sensors using metallic nanoparticles and nanowires.
4. Able to develop sensors using different nano structures of metal oxides for making it more specific.
5. Will acquire an insight of the developments in the nanopolymers and its role in sensors.
6. Gain the competency of understanding the quantum dots and its potential application in sensor development.(FAT)

Student Learning Outcomes (SLO):	**1,5**

Module:1	**Introduction to nanotechnology**	**6 hours**

Definition of nanotechnology - main features of nano-materials - types of nanostructures (0D, 1D, and 2D structures) – synthesis of nano-materials and nano-composites - chemical/physical/electrical/optical properties of nano-materials and composites.

Module:2	**Characterization of nanomaterials**	**6 hours**

Methods for characterizing the nano-materials: Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) and spectroscopy - spectrometry based surface analysis techniques.

Module:3	**Metal nanoparticle and Nanowire based Sensors**	**7 hours**

Definition of nanoparticle - features of nanoparticles - production of nanoparticles by physical approach and chemical approaches- Definition of nanowires - features of nanowires - fabrication of individual nanowire by top-down approaches and bottom -up approaches - fabrication of nanowire arrays (fluidic channel, blown bubble film, contact printing, spray coating, etc.).

Module:4	**Carbon Nanotubes-based Sensors**	**6 hours**

Definition of carbon nanotube- features of carbon nanotubes - synthesis of carbon nanotubes - fabrication and working principles of sensors based on individual carbon nanotube - fabrication and working principles of sensors based on random array of carbon nanotubes.

Module:5	**Sensors Based on Nanostructures of Metal Oxide**	**6 hours**
Synthesis of metal oxide structures by dry and wet methods - Types of metal oxide gas sensors (0D, 1D, and 2D) - defect chemistry of the metal oxide sensors -sensing mechanism of metal - oxide gas sensors - Porous metal - Oxide structures for improved sensing applications.		
Module:6	**Sensors Based on Nanostructures of Polymers**	**6 hours**
Working principle of sensors based on polymeric nanostructures - sensing mechanism and applications of nanomaterial - Nano polymer based chemiresistors and field effect transistors of semi/conductive polymers.		
Module:7	**Sensors based on Quantum dots**	**6 hours**
Definition of quantum dot - fabrication techniques of quantum dots - Macroscopic and microscopic photoluminescence measurements - applications of quantum dots as multimodal contrast agents in bioimaging - Application of quantum dots as biosensors.		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Dieter Vollath, “Nanomaterials: An Introduction to Synthesis, Properties and Applications”, 2014, 2nd Edition, Wiley, New Jersey.
2.	Guozhong Cao, “Nanostructures & Nanomaterials: Synthesis, Properties & Applications”,2011, 2nd Edition, Imperial College Press, London.
Reference Books	
1.	Martin Pumera, “Nanomaterials for Electrochemical Sensing and Biosensing”, 2014, 1st Edition, Pan Stanford.
2	Michael A. Carpenter, Sanjay Mathur, Andrei Kolmakov, Metal Oxide Nanomaterials for Chemical Sensors, 2013, 1st Edition, Springer, New York.
3	Wonbong Choi, Jo-won Lee, “Graphene: Synthesis and Applications (Nanomaterials and their Applications)”, 2011, 1st Edition, CRC Press, Florida.

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar			
Mode of assessment: Continuous Assessment and FAT			
Recommended by Board of Studies	21-08-2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE5008	**MICRO AND NANO FLUIDICS**	**2**	**0**	**0**	**4**	**3**
Prerequisite:	**Nil**	**Syllabus version**				
		1.0				

Course Objectives:

1. Introduce and discuss the fundamental physics of micro and nano scale fluids and their hydrodynamics.
2. Comprehend techniques of miniaturization, methods and tools to create microfluidic architectures and discuss various existing microfluidic devices.
3. Discuss and identify the usage of microfluidics in various lab-on-chip and bioreactor applications
4. Investigate and compare microfabrication techniques to design vasculature and 3D micro-channels.

Expected Course Outcome:

1. Identify and understand the fundamental physics of micro and nano scale fluids and their hydrodynamics. Comprehend the basics of miniaturization, methods and tools to create microfluidic architectures.
2. Recognise and interpret the working principle of various existing microfluidic devices.
3. Describe various microfluidic lab-on-chip applications.
4. Acquaint with various bioreactor based microchips
5. Investigate and compare various microfabrication techniques to design vasculature and 3D micro channels with existing techniques.
6. Incorporate simulation and microfluidic device fabrication knowledge for developing various microfluidic devices.

Student Learning Outcomes (SLO):	**1,5**

Module:1	**Fundamentals for Microscale and Nanoscale Flow**	**5 hours**

Fluids and nonfluids, properties of fluids, classification of fluids, Newtonian and Non Newtonian fluids, pressure driven flow, reynolds number , Electrokinetic phenomena, Electric double layer, debye length, coupling species transport and fluid mechanics, Micro channel Resistance, Shear stress, capillary flow, flow through porous media, Diffusion, surface tension, contact angle and Wetting.

Module:2	**Hydrodynamics**	**4 hours**

Introduction to surface, surface charge, surface energy, Thermodynamics of surfaces, Fluids in Electrical fields, The Navier Strokes equation, Boundary and Initial conditions problems,

Module:3	**Fabrication methods and techniques**	**4 hours**

Patterning, Photolithography, Micromachining, Micromolding, Soft lithography, PDMS properties, Fabrication of microfludics channels.

Module:4	**Microfluidic Devices**	**3 hours**

Droplet Microfluids, Active Flow control, Microvalves, Electrically actuated microvalves, Micromixers, Combinational Mixers, Elastomeric Micromixers

Module:5	**Microfluidics Lab on Chip**	**3 hours**

Microfluidic for Flow cytometry, cell sorting, cell trapping, Cell culture in microenvironment.			
Module:6	**Bioreactors on Microchips**	**4 hours**	
Enzyme assay and inhibition, Chemical synthesis in microreactors, Sequential reaction and Parallel reaction in micro reactors, chemical separation, liquid chromatography			
Module:7	**3D Vascular Network for Engineered tissues**	**5 hours**	
Fabrication, Microfabrication of vasculature, Materials for 3D Microfluidic vasculature, Laser Micro-machined 3D channels, Introduction to Comsol Multiphysics, Mathematical Modeling of Microchannels in Microfludics Model builder.			
Module:8	**Contemporary issues:**	**2 hours**	
	Total Lecture hours:	**30 hours**	

Text Book(s)	
1.	Clement Kleinstreuer, "Microfluidics and Nanofluidics: Theory and Selected Applications",2013, 1st ed., John Wiley & Sons, New Jersey.
2.	Shaurya Prakash, JunghoonYeom, "Nanofluidics and Microfluidics: Systems and Applications",2014, 1st ed., William Andrew; Norwich, New York.
Reference Books	
1.	Albert Folch, "Introduction to BioMEMS", 2012, 1st ed., CRC Press, United Kingdom.
2	Patrick Tabeling, "Introduction to Microfluidics", 2011, Reprint ed., Oxford University Press, Great Britain.
3	Xiujun James Li, Yu Zhou , "Microfluidic Devices for Biomedical Applications", 2013, 1st ed., Wood head Publishing, Cambridge.
4	Terrence Conlisk. A, "Essentials of Micro- and Nanofluidics: With Applications to the Biological and Chemical Sciences", 2012, 1st ed., Cambridge University Press, New York.

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar			
Mode of assessment: Continuous Assessment and FAT			
Recommended by Board of Studies	21-08-2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE6003	**MICROSYSTEMS AND HYBRID TECHNOLOGY**	**2**	**0**	**2**	**0**	**3**
Prerequisite	**ECE5001 Principles of Sensors**	**Syllabus version**				
		1.1				

Course Objectives:

1. To introduce the fundamental concepts of MEMS based sensors and actuators.
2. To acquaint the students with various materials and material properties for Microsystem designing.
3. To provide comprehensive understanding of various micromachining techniques and expose the students to design, simulation and analysis software.
4. Enhancing the basics of thick film and hybrid technologies for sensor development.

Expected Course Outcome:

1. Identify and understand the fundamental concepts and background of MEMS and Microsystems
2. Familiar with the basics of various sensors and actuators.
3. The students were acquainted with various materials for Microsystem designing.
4. Determine and compare the scaling effects in miniaturizing devices.
5. Recognize and interpret various micromachining techniques and design, analysis and applications of various MEMS devices micromachining tools and techniques
6. Acquainted with thick film and hybrid technologies for sensor development.
7. Incorporate simulation and micro-fabrication knowledge for developing various MEMS devices.

Student Learning Outcomes (SLO):	**1,5**

Module:1	**Introduction to MEMS and Microsystems**	**3 hours**

MEMS and Microsystems, Miniaturization, Benefits of Microsystems, Typical MEMS and Microsystems products, Evolution of Micro fabrication and Applications.

Module:2	**Introduction to Sensors and Actuators**	**3 hours**

Various domains and classification of transducers: electrostatic, piezoelectric, thermal. Sensing principles: electrostatic, resistive, chemical etc. SAW devices. Micro actuators, Design of Micro accelerometers, Engineering Science for Microsystem design and fabrication.

Module:3	**Materials for Microsystems**	**4 hours**

Silicon, Silicon compounds, Silicon Piezo resistors, Gallium Arsenide, Quartz, Piezoelectric materials, Polymers, Shape Memory Alloys, ferroelectric and rheological materials.

Module:4	**Scaling Effects in Microsystems**	**4 hours**

Introduction to Scaling, Scaling laws, Scaling in Geometry, Scaling in Rigid body dynamics, Scaling in Electromagnetic, Electrostatic, magnetic, optical and Thermal domains. Scaling in Fluid mechanics.

Module:5	**Micromachining Technologies**	**4 hours**

Overview of silicon processes techniques, Photolithography, Ion Implantation, Diffusion, Chemical Vapor Deposition, Physical vapor Deposition, Epitaxy, Etching, Bulk micromachining, Surface Micromachining, LIGA and other techniques.

Module:6	**MEMS and micro systems applications**	**4 hours**

Details of application in actual systems, introduction to RF- MEMS, MOEMS, future of smart

structures and MEMS leading to NEMS. Packaging, test and calibration of MEMS.			
Module:7	**Hybrid Technology**		**2 hours**
Thick-film and hybrid technology in sensor production. Basic materials, components, manufacturing Screen manufacturing, Screen printing, Parameters, Comparison: thick- vs. thin-film technology Structure dimensions, Assembly and packaging Surface mount technology (SMT) Active and passive devices (SMD), Connection technologies, Packaging.			
Module:8	**Contemporary issues:**		**2 hours**
	Total Lecture hours:	**30 hours**	

Text Book(s)		
1.	G.K.Ananthasuresh, K J Vinoy, S Gopalakrishnan, KN Bhatt, V K Aatre," Micro and smart systems", 2012, 1st ed., Wiley, New York.	
2.	Tai-Ran Hsu, "MEMS & Microsystem, Design and Manufacture", 2017, 1st ed., McGraw Hill India, New Delhi.	
Reference Books		
1.	Mahalick NP, "MEMS", 2017, 1st ed., Tata McGraw Hill, New Delhi	
2	Wolfgang Menz, Jürgen Mohr, Oliver Paul, "Microsystem Technology", 2011, 2nd ed., Wiley, New York.	
3	Banks H.T. Smith R.C. and Wang Y.Smart, 'Material Structures – Modeling, Estimation and Control', 2011, 1st ed., John Wiley & Sons, NewYork.	
4	Massood Tabib – Arar, 'Microactuators – Electrical, Magnetic Thermal, Optical, Mechanical, Chemical and Smart structures', 2014, 1st ed., Kluwer Academic publishers, New York .	
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar		
List of Challenging Experiments (Indicative)		
1.	Design and Simulation of MEMS Capacitance based Accelerometer: In this topic, you need to design a capacitive accelerometer that has a full-scale Measurement range of ± 10 g. The accelerometer may be designed using a closed loop or an open-loop. You need to have reasonable over range protection in your device. Specification: Measurement range: ± 10g Output capacitance: at least tens of fF level Device simulation results (must take into account parasitic capacitance of your design): (a) Static analyses: Gap vs. acceleration Capacitance (or differential capacitance) vs. acceleration (identify sensitivity [F/g]) (b) Dynamic analyses: Your device's response on vibration.	15 hours
2.	Piezoresistive barometric pressure sensor: In this topic, you need to design a piezoresistive pressure sensor that has the	15 hours

	measurement range of 0 - 1.1 bar. You need to have a reasonable over range protection in your device. Specification: Measurement range: 0 -1.1 bar. Device simulation results: (i) Strain in the piezoresistor vs. pressure (ii) Resistance vs. pressure (iii) Voltage output vs. pressure for Wheatstone bridge circuit output. Circuit integration issues: Temperature compensation circuit design	
	Total Laboratory Hours	30 hours

Mode of assessment: Continuous Assessment and FAT			
Recommended by Board of Studies	28.01.2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE6004	**RF AND MICROWAVE SENSORS**	**3**	**0**	**0**	**0**	**3**
Prerequisite:	**ECE5001-Principles of Sensors**	**Syllabus version**				
		1.0				

Course Objectives:

1. To introduce the students with different RF and Microwave sensors,
2. To familiarize antenna design with a good understanding of their parameters and applications.
3. To introduce comprehensive knowledge of wearable antenna.
4. To explore and understand basics of RFID technology.

Expected Course Outcome:

1. Select a proper antenna design to be used in the RF spectral region
2. Model specific radiation pattern and evaluate them in different domains
3. Correlate the principle behind different radar systems and determine various applications based on the radar systems.
4. Apply the basic knowledge in the measurement of RF radiation.
5. Gain knowledge about the RFID technology.

Student Learning Outcomes (SLO): **1,6,17**

Module:1	**RF Sensors**	**6 hours**

Microwave Antenna-Introduction, types of Antenna, fundamental parameters of antennas, radiation mechanism, Fresnel and Fraunhofer regions. Antenna for communication and Antenna for sensing, radiometer and radar

Module:2	**Antenna for personal area communication.**	**5 hours**

Concepts of Printed Antennas, Broadband Microstrip Patch Antennas, Antennas for Wearable Devices, Design Requirements, Modeling and Characterization of Wearable Antennas, WBAN Radio Channel Characterization and Effect of Wearable Antennas, Domains of Operation, Sources on the Human Body, Compact Wearable Antenna for different applications.

Module:3	**Radar**	**5 hours**

Introduction to RADAR, RADAR range equation, MTI and pulse Doppler RADAR, Tracking RADAR, SAR pulse RADAR, CW RADAR

Module:4	**Applications of Radar**	**6 hours**

Automotive, remote sensing, agriculture, medicine, detection of buried objects, NDT, defense factors affecting the performance of RADAR, RADAR transmitters, Receivers,

Module:5	**Radiometers**	**6 hours**

Radiative transfer theory, SMMR, Types of radiometers - and Bolometers, Applications in automotive, agriculture, medicine, weather forecasting

Module:6	**Microwave power Sensors**	**6 hours**

Diode Sensors: Diode detector principles, dynamic range average power sensors, signal waveform effects on the measurement uncertainty of diode sensors. Thermocouple Sensors: Principles of Thermocouple sensor, power meters for thermocouple sensors.

Module:7	**RFID Sensors**		**8 hours**
Introduction, Components of RFID systems, hardware and software components, RFID standards, RFID applications.			
Module:8	**Contemporary issues:**		**2 hours**
	Total Lecture hours:	**45 hours**	
Text Book(s)			
1.	Finkenzeuer Klaus, “RFID Handbook”, 2011, 3rd edition, John Wiley and Sons, New Jersey.		
2.	Constantine A. Balanis, “Antenna Theory Analysis and Design”, 2016, 4th edition, John Wiley and Sons, New Jersey.		
Reference Books			
1.	B. Hoffman - Wellenhof, H.Lichtenegger and J.Collins, "GPS: Theory and Practice ", 5th edition, Springer, New York, 2012.		
2	Lillesand & Kiefer, “Remote Sensing and Image Interpretation”, 2011, 6th edition, John Wiley and Sons, New Jersey.		
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	28.01.2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE6005	**CHEMICAL SENSORS**	**2**	**0**	**2**	**0**	**3**
Prerequisite:	**ECE5001-Principles of Sensors**	**Syllabus version**				
		1.1				

Course Objectives:

1. To extend engineering principles to electrochemical sensor development with a clear understating of oxidation and reduction of an electrolytic cell.
2. To propound the conception of ion selective and enzyme stabilized electrodes for the detection of chemical and biomolecules.
3. To be expedient in applying specific interaction methods in the recognition of ion selective gases using metal oxide based sensors.
4. Ability to analyze the modes of vibration and develop the suitable mass and thermal sensitive sensors.

Expected Course Outcome:

1. Realize the need for half-cell and to analyze potential developed in any electrochemical cell. Apply the same for ion selective measurement
2. Be familiar with a wide range of chemical sensing methods and material characteristics to be applied in biosensors .
3. Ability to design gas sensors for commercial and industrial applications.
4. Gain knowledge of nanomaterials for biological and medical applications
5. Able to discuss, develop and apply mass/thermal sensors design for social and environmental problems
6. Capable of critically analyzing Biosensing and transduction problems in the thrust areas and apply the knowledge

Student Learning Outcomes (SLO):	**1,5,14**

Module	Title	Hours
Module:1	**Electrochemistry**	**4 hours**

Thermodynamics, , Enthalpy, Entropy, Gibbs free Energy, Law of Mass Action, simple Galvanic Cells, Electrode – Electrolyte Interface, Fluid Electrolytes, Dissociation of Salt, Solubility Product, Ion Product, pH Value, Ionic Conductivity, Ionic Mobility, Phase Diagrams.

Module	Title	Hours
Module:2	**Transduction Principles**	**4 hours**

Transduction Elements- Electrochemical Transducers-Introduction Potentiometry and Ion-Selective Electrodes: The Nernst Equation Voltametry and amperometry, conductivity, FET, Modified Electrodes, Thin-Film Electrodes and Screen-Printed electrodes, photometric sensors

Module	Title	Hours
Module:3	**Chemical Sensing Elements**	**4 hours**

Ionic recognition, molecular recognition-chemical recognition agent, spectroscopic recognition, biological recognition agents. Immobilization of biological components, performance factors of Urea Biosensors, Amino Acid Biosensors, Glucose Biosensors and Uric Acid, factors affecting the performance of sensors.

Module	Title	Hours
Module:4	**Potentiometric and Amperometric Sensors**	**4 hours**

Potentiometric- Ion selective electrodes- pH linked, Ammonia linked, CO2 linked, Silver sulfide linked, Iodine selective, amperometric -bio sensors and gas sensors,

Module:5	**Conductometric Sensors**	**4 hours**
Conductometric-chemirsistor-biosensor based chemiresistor-semiconducting oxide sensor, CHEMFETs, ISFETs, FET based Biosensors.		
Module:6	**Mass and Thermal Sensors**	**4 hours**
Piezoelectric effect- gas sensor applications, Biosensor applications- Quartz crystal microbalance, surface acoustic waves, plate mode oscillators, resonant cantilevers, enzymatic mass sensor, Glucose thermistor, catalytic gas sensor, pellistors, enzyme thermistor		
Module:7	**Photometric Chemical Sensors**	**4 hours**
Visible absorption spectroscopy- pH, CO_2, ammonia, examples in biosensors, fluorescent reagents, fluorophore and chromophores based fiberoptic biosensors:-enzyme based non-mediated fiberoptic biosensors – chromophores and flurophore detection, bioluminescence and chemi-luminescence based fiber-optic sensors.		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**30 hours**

Text Book(s)

1.	Janata, Jiri,"Principles of Chemical sensors", 2014, 2nd edition, Springer, New York.

Reference Books

1.	Brian R Eggins, "Chemical Sensors and Biosensors", (Part of AnTS Series), 2010, 1st edition, John Wiley Sons Ltd, New York.
2	Peter Grundler, "Chemical Sensors: Introduction for Scientists and Engineers", 2011, 1st edition, Springer, New York.
3	R.G.Jackson, "Novel Sensors and Sensing", 2012, 1st edition, Philadelphia Institute of Physics.

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar

List of Challenging Experiments (Indicative)

1.	Develop a suitable electrochemical cell which can distinguish normal and contaminated water samples. Cyclic voltammetry technique can be used as the detection method. Develop the electronic circuitry and display to indicate the type of water.	6 hours
2	Interdigitated Electrodes (IDT) are required for effective chemical sensing application. Using copper as the electrode material, develop IDT finger type electrodes using suitable deposition method.	6 hours
3	After analysing the advantages and drawbacks of various methods used for depositing the oxide materials on planar rigid substrates, deposit zirconium oxide on the IDT electrodes fabricated on alumina substrate using the suitable deposition method.	6 hours
4	Among the various types of conductometric sensors, identify a suitable sensor which can measure the humidity and develop asensor system which can measure the relative humidity in the range of 40 to 60 percent.	6 hours
5.	Develop a potentiostat circuit for a chemoresistive sensor which can be used	6 hours

	for gas sensing application. The nominal resistance of the sensor will be 100 to 130 ohms and the expected change in resistance will +/-5%. Develop the electronic circuit which can convert the change in resistance in to a voltage signal/current signal.			
			Total Laboratory Hours	30 hours
Mode of assessment: Continuous Assessment and FAT				
Recommended by Board of Studies	28.01.2017			
Approved by Academic Council	No. 47	Date	05-10-2010	

Course code	Course title	L	T	P	J	C
ECE6006	**AUTOMOTIVE SENSORS**	**2**	**0**	**2**	**0**	**3**
Prerequisite:	**ECE5001-Principles of Sensors**	**Syllabus version**				
		1.1				

Course Objectives:

1. Acquaint with the basic automotive parts and the need for sensor integration in different automotive systems
2. Discuss the basics of various Power train sensors and associated systems for proper vehicle dynamics and stability in automotive systems.
3. Comprehend various sensors for vehicle body management and discuss various sensors and technologies for passenger convenience, safety and security systems.
4. Acquaint various communication standards and protocols followed within the automotive systems.

Expected Course Outcome:

1. Identify and understand the basic automotive parts and the requirement of sensors and their integration in different automotive systems
2. Discus and identify the basics of various Power train sensors
3. Comprehend and analyse various systems like ABS, ESP, TCS, etc for understanding vehicle dynamics and stability.
4. Comprehend the various sensors for vehicle body management, convenience & security systems.
5. Identify various technologies developed for passenger convenience, Air Bag deployment and Seat Belt Tensioner System, etc with the students
6. Recognize various communication standards and protocols followed within the automotive systems.

Student Learning Outcomes (SLO):	**1,5,14**

Module	Title	Hours
Module:1	**Introduction to Automotive Engineering, Automotive Management systems**	**4 hours**

Power-train, Combustion Engines, Transmission, Differential Gear, Braking Systems,
Introduction to Modern Automotive Systems and need for electronics in Automobiles, Application areas of electronics in the automobiles, Possibilities and challenges in the automotive industry, Enabling technologies and Industry trends.

Module	Title	Hours
Module:2	**Power train Sensors**	**4 hours**

λ sensors, exhaust temperature sensor, NOx sensor, PM sensor, fuel quality sensor, level sensor, torque sensor, speed sensor, mass flow sensor, manifold pressure sensor.

Module	Title	Hours
Module:3	**Sensors for Chassis management**	**4 hours**

Wheel speed sensors/direction sensors, steering position sensor (multi turn), acceleration sensor (inertia measurement), brake pneumatic pressure sensor, ABS sensor, electronic stability sensor.

Module	Title	Hours
Module:4	**Sensors for vehicle body management, Sensors for automotive vehicle convenience and security systems**	**6 hours**

Gas sensors (CO_2), Temperature/humidity sensor, air bag sensor, key less entering sensor, radar sensors. Tire pressure monitoring systems, Two wheeler and Four wheeler security systems,

parking guide systems, anti-lock braking system, future safety technologies, Vehicle diagnostics and health monitoring, Safety and Reliability, Traction Control, Vehicle dynamics control, Accelerators and tilt sensors for sensing skidding and anti-collision, Anti-collision techniques using ultrasonic Doppler sensors.			
Module:5	**Air Bag and Seat Belt Pre tensioner Systems**		**3 hours**
Principal Sensor Functions, Distributed Front Air Bag sensing systems, Single-Point Sensing systems, Side-Impact Sensing, and Future Occupant Protection systems.			
Module:6	**Passenger Convenience Systems**		**3 hours**
Electromechanical Seat, Seat Belt Height, Steering Wheel, and Mirror Adjustments, Central Locking Systems, Tire Pressure Control Systems, Electromechanical Window Drives.			
Module:7	**Modern Trends and Technical Solutions**		**4 hours**
Enabling Connectivity by Networking:-In vehicle communication standards (CAN & LIN), Telematic solutions, Portable or embedded connectivity- Endorsing Dependability in Drive-by-wire systems:- Terminology and concepts , Why by-wire, FLEXRAY, Requirements on cost and dependability, Drive-by-wire case studies- prototype development-future of In vehicle communication.			
Module:8	**Contemporary issues:**		**2 hours**
	Total Lecture hours:	**30 hours**	

Text Book(s)		
1.	Automotive Electrics, Automotive Electronics: Systems & Components, 2014, 5th Edition, BOSCH.	
2	John Turner, Automotive Sensors, 2010, 1st Edition, Momentum Press, New York.	
Reference Books		
1.	Automotive Sensors Handbook, 8th Edition, 2011, BOSCH.	
2	Jiri Marek, Hans-Peter Trah, Yasutoshi Suzuki, Iwao Yokomori, Sensors for Automotive Technology, 2010, 4th Edition, Wiley, New York.	
3	Ernest O. Doebelin, “Measurement Systems – Application and Design”, 2017, 6th Edition, McGraw-Hill, New Delhi.	
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar		
List of Challenging Experiments (Indicative)		
1.	Tire Pressure Monitoring Systems uses a wireless radio frequency signal to communicate the tire pressure from sensors inside the wheel to a receiver centrally located in the vehicle. The sensors are powered by batteries that eventually wear out, so the amplitude of the transmitted signal is minimized in order to conserve power. Unfortunately, this has resulted in unreliable communication and it is not uncommon to lose communication with the sensors resulting in a false low-pressure indication. Develop a better way of sending RF signals from the wheels to the vehicle to conserve power and improve communication.	6 hours
2	After studying the characteristics of various types of thermal sensors,	6 hours

	develop a suitable system which can measure the automotive engine temperature in a non-contact method with an accuracy of +/-0.5ºC.	
3	Anti-collision system is preferred for all the automotive systems to improve the passenger safety. Using the Doppler effect as the detection principle, develop an anti-collision system using ultrasonic transceivers.	6 hours
4	In certain situations, airbag triggering in the automotive systems must be prevented when deployment would be injurious to one of the vehicle's occupants (for instance, if a child is sitting in the seat next to the driver, or a child's safety seat is fitted). Develop an intelligent occupant classification system which can classify based on distance between hip bones, occupied surface, profile structure and dynamic response.	6 hours
5.	Develop an intelligent inertial navigation system using motion sensors (accelerometers), rotation sensors (gyroscopes), and magnetic sensors (magnetometers), to continuously calculate the position, orientation, and velocity (direction and speed of movement) of an automotive system.	6 hours
	Total Laboratory Hours	30 hours

Mode of assessment: Continuous Assessment and FAT			
Recommended by Board of Studies	28.01.2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE6007	**BIOMEDICAL SENSORS**	**2**	**0**	**2**	**0**	**3**
Prerequisite:	**ECE5001-Principles of Sensors**	**Syllabus version**				
		1.1				

Course Objectives:

1. Introduce the students to different types of electrodes used in bio potential recording
2. To facilitate the students in recognizing electrode configuration and issues related with the electrode relative motions.
3. To expose the students to perceive the need for bio amplifiers and their characteristics needed to be design for various bandwidth and frequency response.
4. Review the cardiac, respiratory and muscular physiological systems. Study the designs of several instruments used to acquire signals from living systems.
5. To proclaim the conception in detection of chemical and biomolecules.
6. Students will be expedient in applying specific radiology methods in diagnostics and analysis.
7. The students also understand the theory behind the sound and tissue interaction, and able to apply in therapeutic application.

Expected Course Outcome:

1. Realize the need for reusable electrodes and understands the method of implementation.
2. Will be familiar with electrode placements for various biopotential recording as per the voltage range.
3. Capable of understanding the design principles of bio-amplifiers and drawback related with noises.
4. Gain knowledge for implementing different types of physiological parameter measurement using appropriate sensors.
5. Able to discuss, develop and apply site specific chemical sensors design and imaging techniques for typical issues
    a. To disseminate the design knowledge in analyzing in-vivo ailments

Student Learning Outcomes (SLO):	**1,5,14**

Module:1	**Biopotential Electrodes**	**3 hours**

Origin of bio potential and its propagation. Electrode-electrolyte interface, electrode–skin interface, half-cell potential, impedance, polarization effects of electrode – nonpolarizable electrodes. Types of electrodes - surface, needle and micro electrodes and their equivalent circuits. Recording problems - measurement with two electrodes.

Module:2	**EEG, EMG & ECG**	**3 hours**

Bio signal characteristics – frequency and amplitude ranges. ECG – Einthoven's triangle, standard 12 lead system. EEG – 10-20 electrode system, unipolar, bipolar and average mode. EMG– unipolar and bipolar mode. EEG- procedure, signal artefacts, signal analysis, evoked potential, EMG- procedure and signal analysis, Nerve conduction study

Module:3	**Bio Amplifiers**	**3 hours**

Need for bio-amplifier - single ended bio-amplifier, differential bio-amplifier – right leg driven ECG amplifier. Band pass filtering, isolation amplifiers – transformer and optical isolation -

isolated DC amplifier and AC carrier amplifier. Chopper amplifier. Power line interference			
Module:4	**Physical Sensors in Biomedicine**	**8 hours**	
Temperature measurement: core temperature,-surface temperature- invasive. Blood flow measurement: skin blood- hot film anemometer- Doppler sonography- electromagnetic sensor - blood pressure measurement: noninvasive- hemodynamic invasive. Spirometry- sensors for pressure pulses and movement- ocular pressure sensor- acoustic sensors in hearing aid, in blood flow measurement, sensors for bio-magnetism, tactile sensors for artificial limbs, sensors in ophthalmoscopy, artificial retina.			
Module:5	**Sensors for Chemical Quantities in Biomedicine**	**3 hours**	
Blood gas and pH sensor, electrochemical sensor, transcutaneous, optical fiber sensor, mass spectrometer, optical oximetry, pulseoximetry, earoximetry.			
Module:6	**Detectors in Radiology**	**4 hours**	
X ray imaging with sensors, detectors in nuclear radiology, magnetic field sensors for imaging, magnetic resonance imaging.			
Module:7	**Sound in Medicine**	**4 hours**	
Interaction of Ultrasound with matter; Cavitations, Reflection, Transmission- Scanning systems – Artefacts- Ultrasound- Doppler-Double Doppler shift-Clinical Applications			
Module:8	**Contemporary issues:**	**2 hours**	
	Total Lecture hours:	**30 hours**	
Text Book(s)			
1.	J. G. Webster, J. G. Webster ,"Medical Instrumentation; Application and Design", John Wiley & Sons, Inc., New York, 4th Edition, 2015		
Reference Books			
1.	Khandpur R.S, "Handbook of Biomedical Instrumentation", Tata McGraw-Hill, New Delhi, 3rd edition ,2014.		
2	John Enderle, Joseph Bronzino, "Introduction to Biomedical Engineering", Academic Press, 3rd Edition, 2011.		
3	Myer Kutz, "Biomedical Engineering and Design Handbook, Volume 1: Volume I: Biomedical Engineering Fundamentals", McGraw Hill Publisher, USA, 2nd Edition 2009.		
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar			
List of Challenging Experiments (Indicative)			
1.	Pulse oximetry can be a useful aid in decision-making, everyone's oxygen saturation fluctuates, due to changing activities and health condition. Design a circuit to determine oxygen range, and record each measurement in the activity log. A SpO2 of greater than 95% is generally considered to be normal. If SpO2 of 92% or less (at sea level) indicate the condition using an alarm. Use two led source and two detectors to measure the saturation of oxygen in the test subject.	6 hours	

2	The overall aim, of this experiment, is to build and test an ECG amplifier and study its noise interference problem. The signals should be displayed, stored and processed. Modify the instrumentation amplifier to implement DC offset cancellation and driven-right leg circuit to reduce common-mode voltage due to interference and safeguard the patient from high voltage. Also, include a low-pass filter that limits the bandwidth of the amplifier.	6 hours
3	Impedance plethysmography is a method of determining changing tissue volumes in the body, based on the measurement of electric impedance at the body surface. Determine the change in the conductivity due to the flow volume which in turn changes the distribution of the introduced current in the volume conductor. Measure and analyze the conductivity using a DAQ system.	6 hours
4	Strain gauge plethysmography were used prospectively to study the hemodynamic changes. Design a strain gauges based plethysmograph in which the strain gauges should be designed so that the active portion of the gauge is the same as the circumference of the limb or digit being measured. This allows the plethysmograph to relate resistance change to volume change. The size for limb strain gauges should be 1-3 cm less that the circumference of the limb so they will stretch slightly. Digits strain gauge should be 0.5 cm less than the circumference of the digit. Analyze the volume change using a DAQ system.	6 hours
5.	Design a method to analysis liquid flow velocity using a non-contact measurement technique(Laser/Ultrasonic sensor). Record the dynamic flow velocity using LabView	6 hours
	Total Laboratory Hours	30 hours

Mode of assessment: Continuous Assessment and FAT			
Recommended by Board of Studies	28.01.2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE6008	BIO SENSORS	2	0	0	4	3
Prerequisite:	ECE5001-Principles of Sensors	Syllabus version				
		1.0				

Course Objectives:

1. To introduce the students to recently developed and advanced techniques for immobilization of biomolecules.
2. To perform a measurement technique, estimate the uncertainty due to non-specific binding, and express methods to minimize the issues.
3. To proclaim the conception of ion selective and enzyme stabilized glass electrodes for the detection of chemical and biomolecules.
4. Students will be expedient in applying specific interaction methods in the labeled and non-labeled molecular recognition.

Expected Course Outcome:

1. Will be familiar with electrode placements for various biopotential recording as per the voltage range.
2. Capable of understanding the design principles of bio-amplifiers and drawback related with noises.
3. Gain knowledge for implementing different types of physiological parameter measurement using appropriate sensors.
4. Able to discuss, develop and apply site specific chemical sensors design and imaging techniques for typical issues
5. To disseminate the design knowledge in analyzing in-vivo ailments

Student Learning Outcomes (SLO):	1,5,6

Module:1	Introduction to sensor and transducers	2 hours

Enzyme electrodes, Immobilization methods, entrapments of biomolecules, sensing element design considerations

Module:2	Characteristics of Biosensors	4 hours

Electrochemical, optical, potentiometric, piezoelectric, voltametric, galvanometric CHEMFETs, ISFETs, FET based Biosensors

Module:3	Amperometric Biosensor	4 hours

Amperometric enzyme electrodes: substrate and enzyme activity, Detection mode and transduction method, mediated and modified electrodes, commercially available biosensor.

Module:4	Potentiometric Biosensor	4 hours

pH glass and ion selective electrodes, solid state and redox electrodes, gas electrodes, commercially available biosensors

Module:5	Optical Biosensor	4 hours

Fiber optic biosensor, Fluorophore and chromophore based biosensor, Bioluminescence and chemiluminescence based biosensors

Module:6	**Immunosensors**				**4 hours**
Non labled and labled immunosensors, Microbial Biosensors: electrochemical, photomicrobial, Microbial thermistor. Application of microbial biosensors in glucose, ammonia, acetic acid, alcohol, BOD, methane sensing					
Module:7	**Hybrid Biosensor, In Vivo Biosensor and Commercial Biosensor**				**6 hours**
Hybrid biosensor, O_2, CO_2, blood gas, pH sensing, environmental monitoring, Glucose, hCG, Glutamate, cancer detection, and pollutant and environmental Biosensor					
Module:8	**Contemporary issues:**				**2 hours**
	Total Lecture hours:	**30 hours**			
Text Book(s)					
1.	Brian R Eggins, Chemical sensors and Biosensors, 2010, 1st edition, John Wiley sons Ltd, New York.				
Reference Books					
1.	Loic J Blum and Coulet, "Biosensor: Principle and applications", 2010, 2nd edition, CRC Press, Florida.				
2	Janata, Jiri,"Principles of Chemical sensors", 2014, 2nd edition, Springer, New York.				
3	Florinel-Gabriel Banica "Chemical Sensors and Biosensors: Fundamentals and Applications" 2012, 1st edition, Wiley-Blackwell, New Jersey.				
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar					
Recommended by Board of Studies	28.01.2017				
Approved by Academic Council	No. 47	Date	05-10-2017		

Course code	Course title	L	T	P	J	C
ECE6009	**ENVIRONMENTAL SENSORS**	**2**	**0**	**0**	**4**	**3**
Prerequisite:	**ECE5001-Principles of Sensors**	**Syllabus version**				
		1.0				

Course Objectives:

1. To improve the understanding of the students about the sources of pollution in air, water and soil and the impact of these sources on the environment and health and to develop the skills required to combat the pollution in three environmental compartments air, water and soil
2. To provide an understanding of water quality parameters, their properties and the measurement techniques and impart knowledge on the various chemical pollutants in water, their properties and the measuring techniques.
3. To provide an overview on basic environmental engineering in the field of water and waste water treatment.
4. To provide students with a scientific and technical background in sources of air pollutants, their properties and measurement techniques and improve the skills of students in designing sensors for exhaust gas treatment.

Expected Course Outcome:

1. Gain understanding of the basic concepts of radiation, air pollution and its effects on human and ecosystem health
2. List the main sources of pollutants in water, air and soil and their effects on human health, welfare and the environment
3. Critically analyse the environmental sensors, and suggest improvements to their design and functionality.
4. Discuss several types of water pollution, air pollution problems and the chemistry and physics affecting them.
5. Evaluate process design criteria for different water treatment technologies
6. Develop and create analytical designing of novel prototype models for various environmental parameter sensing systems.

Student Learning Outcomes (SLO):	**1,5**

Module:1	**Basics of Radiation and its Measurement.**	**4 hours**

Introduction- Human Toxicology Ecotoxicology, Water and air pollution sources, Basics of Radiation: decay, nucleus, nuclear reaction, statistics and interaction with matter, Radiation Protection: sources, doses, contamination, protection, shields, Sensors: gas counters, ion chamber, proportional and GM-counter, Scintillators, Semiconductors, Spectral methods of analysis: absorption spectroscopy, Beer’s law.

Module:2	**Measurement techniques for water quality**	**4 hours**

Quality of water: Standards of raw & treated water, sources of water & their natural quality, effects of water quality. Water quality parameters: Thermal conductivity, detectors, Opacity monitors, pH analysers & their application, conductivity analyzers & their application.

Module:3	**Measurement techniques for chemical pollutants**	**4 hours**

Introduction-Measurement techniques for chemical pollutants - chloride - sulphides - nitrates and

nitrites - phosphates - fluoride - phenolic compounds. Water treatment: Requirement of water treatment facilities, process design, Sensors for soil and ground water pollution.			
Module:4	**Waste water treatment**	**4 hours**	
Automatic waste water sampling, optimum waste water sampling locations, and waste water measurement techniques, Instrumentation set up for waste water treatment plant, Latest methods of waste water treatment plants.			
Module:5	**Air pollution & Its sources**	**4 hours**	
Air pollution: its effect on environment, its classification, meteorological factors responsible for pollution, method of sampling and measurement, air pollution from thermal power plant, their characteristics and control.			
Module:6	**Measurement techniques for air quality**	**4 hours**	
Measurement techniques for particulate matter in air. Specific gaseous pollutants analysis and control- Measurement of oxides of sulphur, oxides of nitrogen unburnt hydrocarbons, carbon-monoxide, dust mist and fog.			
Module:7	**Sensors in exhaust gas treatment**	**4 hours**	
Engine combustion process, Catalytic exhaust after treatment, Emission limits, Exhaust sensors and Engine control, Emission test cycles, On-board diagnose (OBD): Diagnose Strategies, Exhaust sensors for OBD, Control Sensors: Hydro-Carbon Sensors, NOx-Sensors, Temperature Sensors, Oxygen Sensors.			
Module:8	**Contemporary issues:**	**2 hours**	
	Total Lecture hours:	**30 hours**	

Text Book(s)	
1.	Karl B. Schnelle, Jr., Charles A. Brown, “Air Pollution Control technology Handbook”, 2015, 2nd Edition, CRC Press, New York.
2	Nathanson Jerry, “Basic Environmental Technology: Water Supply, Waste Management, and Pollution Control”, 2014, 6th Edition, Prentice Hall India, New Delhi.
Reference Books	
1.	James K. Lein, "Environmental Sensing: Analytical Techniques for Earth Observation", 2012, 1st Edition, Springer, New York.
2	M. Campbell, "Sensor Systems for Environmental Monitoring: Volume Two: Environmental Monitoring", 2011, 1st Edition, Springer, New York.

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	28.01.2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE6029	**INTEGRATED WAVE OPTICS**	**3**	**0**	**0**	**0**	**3**
Prerequisite:	**ECE5001-Principles of Sensors**	**Syllabus version**				
		1.0				

Course Objectives:

1. To introduce the theory and technology of integrated optics to improve their understanding in rapidly growing field.
2. To predict the nonlinear index in optical devices and phenomena induced due the intensity based effects.
3. To estimate the symmetry, charge distribution, optical parameters of various nonlinear crystals, and its application in optical switching
4. To analyses and decide the process flow conditions and steps involved for different polymers with appropriate optical characteristic for polymer waveguides..

Expected Course Outcome:

1. Attainment of basic idea in integrated optical waveguides and optical devices employed in all optical networks.
2. Will be conversance in nonlinearities introduced by high power and competent enough to mitigate the drawbacks.
3. Entrust the characteristics of a suitable materials for the integrated device in a given application.
4. Identify and apply the knowledge in designing all optical networks devices more effectively in optical communication.
5. Comprehend the fabrication process involved in designing substrate based optical devices with various doping materials
6. Will be aware of different polymers and their chemical, optical characteristics to formulate miniaturized optical devices.

Student Learning Outcomes (SLO):	**1,6**

Module	Title	Hours
Module:1	**Theory of Optical Waveguides**	**5 hours**

Wave theory of optical waveguides, formation of guided modes, Slab waveguide, Rectangular waveguide, Radiation fields from waveguide, Effective index method, Marcatili's method, Beam propagation method.

Module	Title	Hours
Module:2	**Theory of Coupled modes**	**6 hours**

Coupled mode theory, co-directional coupler, coupling coefficient, Loss in optical waveguides, couplers using planar waveguides, Two mode coupler-symmetrical, asymmetrical types, fiber-slab coupler, multimode coupler, grating assisted mode coupler.

Module	Title	Hours
Module:3	**Nonlinearity in waveguides**	**7 hours**

Nonlinear optics, Intensity induced refractive index, Optical susceptibility, Optical Kerr effect, Simulated Raman effect, Simulated Brillouin, EDFA, Second Harmonic generation, Four wave mixing.

Module	Title	Hours
Module:4	**Optical Modulators**	**6 hours**

Phase modulator, intensity modulator, Electro-optic effects, single waveguide modulator, dual channel waveguide modulator, Acousto-optic modulator, Raman-Nath modulator, Bragg type

modulator, Switching characteristics of Modulators.			
Module:5	**Materials properties for Modulators**		**6 hours**
LiNbO3 - Stoichiometry, Mechanical, Electrical & Pyroelectrical, Thermal and Optical properties, Ta_2O_5 , Si_3N_4 waveguides, $LiNbO_3$ Modulator - Mach-zender type modulator.			
Module:6	**Fabrication of SOI waveguide**		**6 hours**
Silicon on Insulator waveguides, Silicon photonics, SOI waveguide fabrication, Thallium, Indium doped SOI waveguide and applications.			
Module:7	**Polymer based waveguide**		**7 hours**
Polymer based waveguide, materials, properties, fabrication process of polymer based waveguide, Polymer based optical components - Passive, Active polymer devices, Ring Resonator, structure, theory, Filter using Ring Resonator.			
Module:8	**Contemporary issues:**		**2 hours**
	Total Lecture hours:	**30 hours**	

Text Book(s)	
1.	Katsunari Okamoto, "Fundamentals of Optical Waveguides", 2010, 2nd Edition, Academic Press, USA.
Reference Books	
1.	Xingcun Colin Tong, "Advanced Materials for Integrated Optical Waveguides", 2014, 1st Edition Springer Nature, Switzerland.
2	Le Nguyen Binh, "Guided Wave Photonics: Fundamentals and Applications with MATLAB", 2016, 1st Edition, CRC Press, New York.
3	Robert Hunsperger, "Integrated Optics: Theory and Technology," 2010, 6th edition, Springer Verlag, New York.
4	Dominik G. Rabus, "Integrated Ring Resonators: The Compendium", 2010, 1st Edition, Springer Verlag, Berlin.

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	28.01.2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
ECE6030	**SIGNAL PROCESSING AND DATA ANALYTICS**	**2**	**0**	**2**	**0**	**3**
Prerequisite:	**ECE5002-Data Acquisition and Hardware Interfaces**	**Syllabus version**				
		1.1				

Course Objectives:

1. To introduce the concepts of *discrete* time *signal processing* and the characterization of *random signals*.
2. To present the basic theory of modeling the signals and the methods of estimating the unknowns using prediction filters
3. To provide a comprehensive understanding on applying FFT, DCT, and wavelet techniques for extracting the signal features.
4. To provide an overview of analysing big data using intelligent techniques and an in-depth introduction to two main areas of *Machine Learning*: supervised and unsupervised.

Expected Course Outcome:

1. Apply FFT, DCT wavelet techniques for extracting the features from the big data
2. Develop algorithms that can be used to analyses the real-world univariate and multivariate time series data.
3. Design an approach to leverage data using the steps in the machine learning process
4. Understand and apply both supervised and unsupervised classification methods to detect and characterize patterns in real-world data.
5. Estimate the signal parameters and identify the model using ARMA models and prediction filters.
6. Understand the methods of visualization and analysis of big data.

Student Learning Outcomes (SLO):	**7,14**

Module:1	**Discrete Random Signal Processing**	**4 hours**

Random Processes, Ensemble Average, Gaussian Process, Multi variate Gausssian Process, Stationary process, Autocorrelation, Auto Covariance, Ergodicity, White noise, Power Spectrum, Filtering of Random Process

Module:2	**Signal Modeling**	**4 hours**

ARMA, AR, MA Models. Wiener filter, Linear prediction, Kalman Filter.

Module:3	**Feature extraction**	**4 hours**

FFT, Power spectrum, DCT, filter banks, Wavelet, Wavelet Packets, Cepstrum

Module:4	**Time series analysis**	**4 hours**

Basic analysis, Univariate time series analysis, Multivariate time series analysis, non stationary time series.

Module:5	**Reduction of dimensionality**	**4 hours**

Bayesian decision, Linear discrimination, Principal Component analysis, SVD, Independent Component Analysis.

Module:6	**Machine learning**	**4 hours**

Supervised learning, generative algorithms, Support Vector machines, Unsupervised learning, K means clustering, Neural network (SOM, ART), Expectation maximization.

Module:7	**Big Data Analytics**		**4 hours**
Introduction Big data analytics, visualization and data exploration, basic and intermediate analysis, linear and logistic regression, decision tree.			
Module:8	**Contemporary issues:**		**2 hours**
	Total Lecture hours:	**30 hours**	

Text Book(s)		
1.	J. G. Proakis, DG. Manolakis and D. Sharma, “Digital signal processing principles, algorithms and applications”, 2012, 4th ed., Person education, USA	
2	Sophocles J. Orfanidis, “Inroduction to signal Processing” 2010, 2nd ed., Prentice Hall, New Delhi India.	
Reference Books		
1.	Oppenhiem V. A.V and Schaffer R. W, “Discrete- time signal Processing”, 2014, 3rd ed., Prentice Hall,. New Delhi, India	
2	Thomas A. Runkler, "Data Analytics: Models and Algorithms for Intelligent Data Analysis", 2016, 2nd ed., Springer Verlag, UK	
3	Kevin P. Murphy, "Machine Learning: A Probabilistic Perspective" 2012, 1st ed., MIT Press, USA	
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar		
List of Challenging Experiments (Indicative)		
1.	Design and implementation of Wiener filter and Kalman filter.	6 hours
2	Design and implementation of filter banks and wavelets for random process (speech, audio).	6 hours
3	Design and implementation of Principal Component Analysis (PCA) and Single Value Decomposition (SVD).	6 hours
4	Design an expert system for simple application (speech recognition, speaker recognition, face recognition).	6 hours
5.	Consider a real time data available in college campus and develop a data analytic system to determine the average, trend and prediction	6 hours
	Total Laboratory Hours	30 hours
Mode of assessment: Continuous Assessment and FAT		

Recommended by Board of Studies	28.01.2017		
Approved by Academic Council	No. 47	Date	05-10-2017

Course code	Course title	L	T	P	J	C
MEE5050	Product Design, Management Techniques and Entrepreneurship	**3**	**0**	**0**	**4**	**4**
Prerequisite:	**Nil**	**Syllabus version**				
		1.0				

Course Objectives:

Introduced to new product design concepts
Exposed to the concept of economic feasibility before the product design
Study the management of skills required for setting up small business

Expected Course Outcome:

1. Design the new product with concept development process
2. Analyze the manufacturing cost of new product
3. Study the economic feasibility of product development projects
4. Apply the management techniques for small businesses
5. Develop the skills and characteristics for successful entrepreneur
6. Evaluate the project of new businesses

Student Learning Outcomes (SLO):	**12, 17, 19**

Module	Title	Hours
Module:1	**Product Design**	**7 hours**
Concept generation - Product Architecture - Industrial Design Process - Management of Industrial design Process and Assessing the quality of Industrial Design - Establishing the product specification.		
Module:2	**Product Development**	**8 hours**
Criteria for selection of product – Product development process - Design for Manufacture - Estimate the manufacturing cost - Reduce the support cost – Prototyping		
Module:3	**Product Economic Feasibility**	**6 hours**
Elements of Economic analysis		
Module:4	**Management Techniques**	**7 hours**
Technology Management – Scientific Management- Development of Management -Principles of Management - Functions of management – planning - organization		
Module:5	**Entrepreneurial Competence**	**7 hours**
Management by objective - SWOT analysis - Enterprise Resource planning and supply chain		
Module:6	**Entrepreneurship as a career**	**3 hours**
Personality Characteristics of a successful Entrepreneur- Knowledge and skill required for an Entrepreneur.		
Module:7	**Management of Small Business**	**5 hours**
Pre feasibility study Ownership-budgeting - project profile preparation - Feasibility Report preparation- Evaluation Criteria		
Module:8	**Contemporary issues:**	**2 hours**

 # Mode: Flipped Class Room , [Lecture to be video taped], Use of physical and computer models to lecture, and Min of 2 lecture.
Project : Student need to prepare a report on the product design and product economic feasibility and market potentiality.

	Total Lecture hours:	**45 hours**	

Text Book(s)

1.	Karal, T.Ulrich, Steven.D.Eppinger,–Product Design and Development‖, McGraw- Hill, 2008.

Reference Books

1.	H.Koontz and Cyril O Donnell, –Essentials of management‖, McGraw Hill, 2010.
2	Robert.D.Hisrich, Michael P Peters, –Entrepreneurship‖ McGraw Hill, 2009
3	Stephen R.Rosenthal, –Effective Product Design and Development: How to cut lead time and increase customer satisfaction‖, McGraw-Hill Professional

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar

Recommended by Board of Studies	28.01.2017		
Approved by Academic Council	No. 47	Date	05-10-2017