VIT®

Vellore Institute of Technology

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

SCHOOL OF ELECTRONICS ENGINEERING

M. Tech Internet of Things & Sensor Systems

(M.Tech MTS)

Curriculum

(*2019-2020 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.

M. Tech Internet of Things & Sensor Systems

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 Internet of Things & Sensor Systems

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 Internet of Things & Sensor Systems

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 Internet of Things & Sensor Systems

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech. (Internet of Things & Sensor Systems) programme, graduates will be able to

- PSO1: Competent, and innovative with a strong cognizance in the area of sensors, IoT, data science, controllers and signal processing through the application of acquired knowledge and skills

- PSO2: Apply advanced techniques and tools of sensing and computation 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 Internet of Things & Sensor Systems

CREDIT STRUCTURE

Category-wise Credit distribution

Category	Credits
University core (UC)	**27**
Programme core (PC)	**21**
Programme elective (PE)	**16**
University elective (UE)	**06**
Total credits	**70**

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M. Tech Internet of Things & Sensor Systems

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	ECE5060	Principles of Sensors and Signal Conditioning	2	0	2	0	3
2	ECE5061	IoT Fundamentals and Architecture	3	0	0	0	3
3	ECE5062	Data Acquisition	0	0	4	0	2
4	ECE5063	Control Systems	0	0	4	0	2
5	ECE5064	Programming and scripting languages	0	0	4	0	2
6	ECE5065	Microcontrollers for IoT Prototyping	2	0	2	0	3
7	ECE6001	Wireless Sensor Networks and IoT	2	0	0	4	3
8	ECE6030	Signal Processing and Data Analytics	2	0	2	0	3

M. Tech Internet of Things & Sensor Systems

Programme Electives

S.No	Course Code	Course Title	L	T	P	J	C
1	ECE5006	Flexible and Wearable Sensors	3	0	0	0	3
2	ECE5008	Micro and Nano Fluidics	2	0	0	4	3
3	ECE5066	Chemical and Environmental Sensor	2	0	2	0	3
4	ECE5067	Cloud and Fog Computing	2	0	2	0	3
5	ECE5068	IoT Security and Trust	2	0	0	4	3
6	ECE5069	IoT Applications and Web development	2	0	0	4	3
7	ECE6003	Micro Systems & Hybrid Technology	2	0	2	0	3
8	ECE6004	RF and Microwave Sensors	3	0	0	0	3
9	ECE6007	Biomedical sensors	2	0	2	0	3
10	ECE6087	Multi-disciplinary Product Development	3	0	0	4	4
11	ECE6088	Deep Learning — An Approach to Artificial Intelligence	3	0	0	0	3
12	ECE6089	Automotive Sensors & in-Vehicle Networking	2	0	2	0	3
13	ECE6090	Fibre optic Sensors and Photonics	3	0	0	0	3

Course Code	Course Title	L	T	P	J	C
ECE5060	PRINCIPLES OF SENSORS AND SIGNAL CONDITIONING	2	0	2	0	3
Pre-requisite	Nil	Syllabus version				
		1.0				

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 Outcomes:

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 types of sensors used in real life applications and paraphrase their importance
6. Create analytical design and development solutions for sensors.
7. Compete in the design, construction, and execution of systems for measuring physical quantities

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

Module	Title	Hours	
Module:1	Sensor fundamentals and characteristics	2 hours	
Sensor Classification, Performance and Types, Error Analysis characteristics			
Module:2	Optical Sources and Detectors	4 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:3	Intensity Polarization and Interferometric Sensors	4 hours	
Intensity sensor, Microbending concept, Interferometers, Mach Zehnder, Michelson, Fabry-Perot and Sagnac, Phase sensor: Phase detection, Polarization maintaining fibers.			
Module:4	Strain, Force, Torque and Pressure sensors	5 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. Design of signal conditioning circuits for strain gauges, piezo, capacitance and optoelectronics sensors			
Module:5	Position, Direction, Displacement and Level	4 hours	

	sensors		
Potentiometric and capacitive sensors, Inductive and magnetic sensor, LVDT, RVDT, eddy current, transverse inductive, Hall effect, magneto resistive, magnetostrictive sensors. Fiber optic liquid level sensing, Fabry Perot sensor, ultrasonic sensor, capacitive liquid level sensor. Signal condition circuits for reactive and self generating sensors.			
Module:6	**Velocity and Acceleration sensors**	**3 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**	**6 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:	**30 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.	GerdKeiser,"Optical Fiber Communications", 2017, 5th edition, McGraw-Hill Science, Delhi.
2.	John G Webster, "Measurement, Instrumentation and sensor Handbook", 2017, 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, Digital Assignments, Quiz, Online course, Paper publication, Projects, Hackathon/Makeathon and FAT.	

List of Experiments: (Indicative)	
1. Design of signal conditioning circuits for strain gauges- 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	4hours
3. After studying the characteristics of temperature sensors listed below, develop a	6hours

<table>
<tr><td colspan="4">temperature measurement system for a particular application using the suitable sensor.
i. Thermocouple principles
ii. Thermistor and linearization of NTC Thermistor
iii. Resistance Temperature Detector
iv. Semiconductor Temperature sensor OA79
v. Current output absolute temperature sensor</td><td></td></tr>
<tr><td colspan="4">4. Develop a sensor system for force measurement using piezoelectric transducer</td><td>4hours</td></tr>
<tr><td colspan="4">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.</td><td>8hours</td></tr>
<tr><td colspan="4">Total Laboratory hours</td><td>30hours</td></tr>
<tr><td colspan="5">Mode of Evaluation:Continuous Assessment and FAT</td></tr>
<tr><td>Recommended by Board of Studies</td><td colspan="4">26-06-2019</td></tr>
<tr><td>Approved by Academic Council</td><td>No. 55</td><td>Date</td><td colspan="2">13-06-2019</td></tr>
</table>

Course code	Course title	L	T	P	J	C
ECE5061	IoT Fundamentals and Architecture	3	0	0	0	3
Pre-requisite	Nil	Syllabus version				
		v. 1.00				

Course Objectives:

1. Introduce evolution of internet technology and need for IoT.
2. Discuss on IoT reference layer and various protocols and software.
3. Train the students to build IoT systems using sensors, single board computers and open source IoT platforms.
4. Make the students to apply IoT data for business solution in various domain in secured manner.

Expected Course Outcome:

1. Identify the IoT networking components with respect to OSI layer.
2. Build schematic for IoT solutions .
3. Design and develop IoT based sensor systems.
4. Select IoT protocols and software.
5. Evaluate the wireless technologies for IoT.
6. Appreciate the need for IoT Trust and variants of IoT.

Student Learning Outcomes (SLO):	5,6,14

Module:1	Evolution of IoT	7 hours

Review of computer communication concepts (OSI layers, components, packet communication, Networks, TCP-IP, subnetting,IPV4 addressing and challenges). IPV6 addressing. IoT architecture reference layer.

Module:2	Introduction to IoT components	6 hours

Characteristics IoT sensor nodes, Edge computer, cloud and peripheral cloud, single board computers, open source hardwares, Examples of IoT infrastructure

Module:3	IoT protocols and softwares	6 hours

MQTT, UDP, MQTT brokers, publish subscribe modes, HTTP, COAP,XMPP and gateway protocols,

Module:4	IoT point to point communication technologies	6 hours

IoTCommunicationPattern,IoTprotocolArchitecture, Selection of Wireless technologies (6LoWPAN, Zigbee, WIFI, BT, BLE,SIG,NFC, LORA,Lifi,Widi)

Module:5	Introduction to Cloud computation and Big data analytics	6hours

Evolution of Cloud Computation, Commercial clouds and their features, open source IoT platforms, cloud dashboards, Introduction to big data analytics and Hadoop.

Module:6	IoT security	6hours

Need for encryption, standard encryption protocol, light weight cryptography, Quadruple Trust Model for IoT-A – Threat Analysis and model for IoT-A, Cloud security

Module:7	IoT application and its Variants.	6 hours

Case studies: IoT for smart cities, health care, agriculture, smart meters.M2M, Web of things, Cellular IoT, Industrial IoT, Industry 4.0,IoT standards.			
Module:8	**Contemporary issues:**		**2hours**
	Total Lecture hours:	**45hours**	

Text Book(s)	
1.	Alessandro Bassi, Martin Bauer, Martin Fiedler, Thorsten Kramp, Rob van Kranenburg, Sebastian Lange, Stefan Meissner, "Enabling things to talk – Designing IoT solutions with the IoT Architecture Reference Model", Springer Open, 2016
2.	Jan Holler, Vlasios Tsiatsis, Catherine Mulligan, Stamatis Karnouskos, Stefan Avesand, David Boyle, "From Machine to Machine to Internet of Things", Elsevier Publications, 2014.
Reference Books	
1.	LuYan, Yan Zhang, Laurence T. Yang, Huansheng Ning, The Internet of Things: From RFID to the Next-Generation Pervasive Network, Aurbach publications, March,2008.
2.	Vijay Madisetti , Arshdeep Bahga, Adrian McEwen (Author), Hakim Cassimally "Internet of Things A Hands-on-Approach" Arshdeep Bahga & Vijay Madisetti, 2014.
3.	Asoke K Talukder and Roopa R Yavagal, "Mobile Computing," Tata McGraw Hill, 2010.
4	Barrie Sosinsky, "Cloud Computing Bible", Wiley-India, 2010
5	RonaldL. Krutz, Russell Dean Vines,Cloud Security: A Comprehensive Guide to Secure Cloud Computing,Wiley-India, 2010
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar	

Recommended by Board of Studies	26-04-2019		
Approved by Academic Council	No. 55	Date	13-06-2019

Course Code	Course Title	L	T	P	J	C
ECE5062	DATA ACQUISITION	0	0	4	0	2
Pre-requisite	NIL	Syllabus Version				
		1.0				

Course Objectives:

1. To explore the fundamentals of data acquisition using sensors, NI data acquisition hardware, and LabVIEW.
2. To teach the basics of hardware selection, including resolution and sample rate, and the foundation of sensor connectivity, including grounding and wiring configurations.
3. To provide knowledge on using the NI-DAQmx driver to measure, generate, and synchronize data acquisition tasks and analyze the data in MATLAB/ LabVIEW
4. To impart adequate knowledge on programming finite and continuous acquisitions, as well as best practices in hardware/software timing, triggering, and logging.
5. To give hands-on experience configuring and programming NI data acquisition hardware using NI-DAQmx and LabVIEW.

Course Outcomes:

1. Develop PC-based data acquisition and signal conditioning.
2. Understand how to control the analog input, analog output, counter/timer, and digital I/O subsystems of a DAQ device.
3. Perform different types of data acquisition and identify the correct sensor for their measurements. Develop integrated, high-performance data acquisition systems that produce accurate measurements
4. Acquire data from sensors, such as thermocouples and strain gages, using NI DAQ hardware and analyse the results in LabVIEW and MATLAB
5. Apply advanced understanding of LabVIEW and the NI-DAQmx API to create applications

Student Learning Outcomes (SLO):	**1,6**		
Task 1		**8 hours**	
LabVIEW Graphical Programming, NI DAQmx, Data acquisition Toolbox to read data into MATLAB and Simulink and write data into DAQ device.			
Task 2		**6 hours**	
Acquire and generate analog signals.			
Task 3		**6 hours**	
Acquire and generate non-clocked digital data.			
Task 4		**6 hours**	
Measure frequency, pulse width and count pulses using NI devices			
Task 5		**6 hours**	
Generate Pulse Width Modulated signal			
Task 6		**4 hours**	
Acquire and generate audio signals			

Task 7		**6 hours**	
Simultaneous and synchronized data acquisition			
Task 8		**4 hours**	
Simulink data acquisition			
Task 9		**6 hours**	
Arduino based multi-channel data acquisition			
Task 10		**8 hours**	
Remote data acquisition with NI WSN Gateway and nodes, CC3200 (WiFi)			
	Total Practical Hours	**60 hours**	
Text Book(s)			
1.	BehzadAhzani “Data Acquisition using LabVIEW” Packt Publishing, 2017		
2.	Data Acquisition Toolbox – User’s Guide, MathWorks, 2016		
Reference Book(s)			
1.	Lab VIEW: A Developer's Guide to Real World Integration edited by Ian Fair weather, Anne Brumfield, 2011, CRC Press.		
2.	DSP for Matlab and LabVIEW: Fundamentals of discrete signal processing, Morgan and Claypool Publishers, 2009		
3.	Maurizio Di Paolo Emilio, “Data Acquisition Systems- Fundamentals to Applied Design” , Springer, 2013.		
4.	“Data Acquisition Handbook”, Measurement and computing corporation, 2012		
Mode of Evaluation:Continuous Assessment and FAT			
Recommended by Board of Studies	26/04/2019		
Approved by Academic Council	55	Date: 13/06/2019	

Course Code	Course Title	L	T	P	J	C
ECE5063	SYSTEM DYNAMICS AND CONTROL	0	0	4	0	2
Prerequisite:	Nil					

Course Objectives:

- To impart knowledge on performance specification, limitations and structure of controllers
- To impart knowledge on design of controllers using root-locus and frequency domain techniques

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. Indentify the need for incorporating the three term controller based on the customized requirement of the control action
5. Analyze the systems behavior in digital domain and develop digital control algorithm for the corrective action.

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 Book(s)

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.

List of Experiments: (Through Inlab/Remotelab)

1.	Introduction to real time controller system operations	4 hours
2.	Speed regulation measurement of DC motor using armature control system	4 hours
3.	Speed regulation and torque measurement of AC Servomotor using armature control system	4 hours
4.	Modeling and performance analysis of stepper motor position control system	4 hours
5.	Performance analysis of BLDC motor control system and its parameter estimation	4 hours
6.	ON/OFF temperature control system using LabVIEW platform	4 hours

7	Step response analysis of second order system using Matlab	4 hours
8	Frequency response analysis of LEAD/LAG compensating network	6 hours
9	Temperature control of a plant using PID controller with LabVIEW platform/MSP430	6 hours
10	Modelling and implementation of level control system using PLC	6 hours
11	Modelling and implementation of a. Speed regulation of servo motor using Fuzzy logic controller with Matlab/MSP430 b. Water level controller using Fuzzy logic controller c. Comparison of plant performance with PID vs Fuzzy logic controller	6 hours
12	(a) Vertical take-off and landing system- Modelling, Current Control & Flight Control (b) Inverted pendulum control system: Modelling Balance Control design & Up control c. HVAC system (Quanser NI Elvis): On-off Control, PI Control d. DC motor speed control (Quanser NI Evis) : Modelling, Speed Control & Position Control.	8 hours
	Total Laboratory Hours	**60 hours**

Mode of Evaluation: Continuous Assessment LabCAT and LabFAT			
Recommended by Board of Studies			
Approved by Academic Council	No. 55	Date	13-06-2019

Course Code	Course Title	L	T	P	J	C
ECE5064	**Programming and scripting languages**	**0**	**0**	**4**	**0**	**2**
Prerequisite:	**Nil**	**Syllabus Version**				
		1.0				

Course Objectives:

1. To expose the students to the fundamentals of embedded Programming.
2. To Introduce the GNU C, C++ Programming Tool Chain in Linux.
3. To study the basic programming of Python and R .

Expected Outcomes:

The students will be able to

1. Solve problems using C
2. Appreciate and apply C++
3. Perform tasks using linux scripts.
4. Understanding the basic concepts of process and IPC mechanisms
5. Program R for simple data oriented applications

Task1	**Embedded Programming**	**12 hours**

C programming, Declarations and Expressions, Arrays, Pointers, Constructs, Data structures and Linked list, Embedded C (Keil).

Task:2	**C++ Programming.**	**12 hours**

Programs for class, objects, member functions, access modifiers, OOPS encapsulation, inheritance polymorphism functions, constructors, and destructors Stream class to perform File input-output

Task 3	**Python Programming**	**12 hours**

Basic operations, String manipulation, Dictionary, Signal plotting and processing, Graphics

Task 4	**Linux**	**6 hours**

Shell programming, Regular expression, Process creation, Inter process communication

Task 5	**R programming**	**2 hours**

Data types, Data plotting ,analysis and regression, Machine intelligence

Text Book(s)

1.	David Russell, "Introduction to Embedded systems Using ANSI C and the Arduino development Environment", 2010, 1rd edition, Morgan & Claypool Publishers.
2.	Brandon Rhodes, John Goerzen, "Foundations of Python Network Programming", 2014, 3rd ed. edition Apress Publisher
3.	Garrett Grolemund, "Hands-On Programming with R: Write Your Own Functions and Simulations", 2014, Shroff/O'Reilly Publisher
4.	Richard Petersen, "Linux: The Complete Reference", 2017, Sixth Edition, McGraw Hill Education

Mode of Evaluation:Continuous Assessment and FAT			
Recommended by Board of Studies		26/04/2019	
Approved by Academic Council	No. 55	Date	13/06/2019

Course Code	Course Title	L	T	P	J	C
ECE5065	**MICROCONTROLLERS FOR IOT PROTOTYPING**	**2**	**0**	**2**	**0**	**3**
Prerequisite:	**Nil**	**Syllabus Version**				
		1.0				

Course Objectives: The course is aimed to

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 to build IoT systems and sensor interfacing.

Course Outcomes (CO): At the end of the course the student should be able to

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 and digital sensors
4. Develop communication system with sensor units
5. Design develop IoT systems using Wi-Fi CC3200.
6. Program the single board computers to read sensor data and posting in cloud.

Student Learning Outcomes (SLO):	**5,6,14**

Module:1	**MSP430 microcontrollers**	**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	**Display and Communication modules**	**4 hours**

GPIO, LCD display, graphical display, relays, Peripheral programming SPI, I2C, UART, Zigbee controller.

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

Sensors interfacing techniques- Port Programming, ADC, SPI thermometer, I2C thermometer, PWM generation and demodulation, DTH11, single wire thermometer, Frequency counters.

Module:5	**Microcontrollers for IoT**	**2 hours**

<table>
<tr><td colspan="3">ESP8266,NodeMCU,TI-CC3200,Access point and station point mode, HTTP, MQTT, transmission and receiving, Intel-Gallileo boards.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Module:6</td><td>Single board computers</td><td>4 hours</td></tr>
<tr><td colspan="3">Raspberry pi board, porting Raspbian, sensor interface examples, Python programming for cloud access, sensor systems using Arduino boards</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Module:7</td><td>Cloud interfacing</td><td>2 hours</td></tr>
<tr><td colspan="3">Interfacing and data logging with cloud: Thing speak, Things board, Blync platform.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Module:8</td><td>Contemporary Issues</td><td>2 hours</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td></td><td>Total Lecture:</td><td>30 hours</td></tr>
</table>

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 Book(s)	
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, SarmadNaimi, SepehrNaimi, "TI ARM Peripherals Programming and Interfacing: Using C Language", 2015, 2nd ed., Mazidi and Naimi publishing, New York.

Mode of Evaluation:CAT, Digital Assignments, Quiz, Online course, Paper publication, Projects, Hackathon/Makeathon and FAT.

<table>
<tr><td>List of Experiments: (Indicative)</td><td></td></tr>
<tr><td>1. Working with MSP430 (CCStudio)
• 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.
• Sub Task 4: Timer</td><td>6 hours</td></tr>
<tr><td>2. Working with ARM (Keil and energia)
• Sub Task 1: Peripheral programming of ARM7 board
• Sub Task 2: PWM generation
• Sub Task 3:Configuring CC3200, wifi configuration ,HTTP and MQTT Protocol</td><td>8 hours</td></tr>
<tr><td>3. Low power wireless 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.</td><td>8 hours</td></tr>
<tr><td>4. IoT systems
• Working with Raspberry pi using Python.
• Arduino platform
• Working with open source clouds</td><td>8 hours</td></tr>
</table>

		Total Laboratory Hours	30 hours
Mode of Evaluation:Continuous Assessment and FAT			
Recommended by Board of Studies	26/04/2019		
Approved by Academic Council	55	Date	13/06/2019

Course Code	**Course Title**	**L**	**T**	**P**	**J**	**C**
ECE6001	**WIRELESS SENSOR NETWORKS AND IoT**	**2**	**0**	**0**	**4**	**3**
Pre-requisite	**ECE 5061- IoT Fundamentals and Architecture**	**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

Course Outcomes

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

SLO : 5,6,7

Module:1	**Network for embedded systems**	**3 hours**
RS232, RS485, SPI, I2C, CAN, LIN, FLEXRAY.		
Module:2	**Embedded wireless communication and Protocols**	**5 hours**
Bluetooth, Zigbee, Wifi, MiWi, Nrf24, Wireless LAN &PAN, UWB		
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: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.		
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 Book(s)	
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, Digital Assignments, Quiz, Online course, Paper publication, Projects, Hackathon/Makeathon and FAT	

List of Projects: (Indicative) 15 Hours	**SLO: 6,7**

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. 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. 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. 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. 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.

Mode of Evaluation:Review I,II,III

Recommended by Board of Studies	26/04/2019		
Approved by Academic Council	No. 55	Date	13/06/2019

Course Code	Course Title	L	T	P	J	C
ECE6030	SIGNAL PROCESSING AND DATA ANALYTICS	2	0	2	0	3
Pre-requisite	ECE5062 - Data Acquisition	Syllabus version				
		v.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 Outcomes:

1. Apply FFT, DCT wavelet techniques for extracting the features from the big data
2. Develop algorithms that can be used to analyse 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):	7,14,17

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:	**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, Digital Assignments, Quiz, Online course, Paper publication, Projects, Hackathon/Makeathon and FAT			
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 Evaluation:Continuous Assessment and FAT			
Recommended by Board of Studies	26/04/2019		
Approved by Academic Council	No.55	Date	13/06/2019

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
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
ECE5066	**Chemical and Environmental Sensor**	**2**	**0**	**2**	**0**	**3**
Pre-requisite:	**ECE5060-Principles of Sensors and Signal Conditioning**	**Syllabus Version**				
		1.0				

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.

Course Outcomes

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 site specific antigen-antibody sensors design for most common diseases like metabolic disorders

   Evaluate process design criteria for gas treatment and air quality analysis

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

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: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: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: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, Amperometric enzyme electrodes: substrate and enzyme activity, Detection mode and transduction method, mediated and modified electrodes, pH glass and ion selective electrodes, solid state and redox electrodes,

Module:5	**Optical Biosensor and Immunosensors Biosensor**	**4 hours**

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

chemiluminescence based biosensors, Non labled and labled immune sensors, Microbial Biosensors: electrochemical, photomicrobial, Microbial thermistor. Application of microbial biosensors in glucose, ammonia, acetic acid, alcohol, BOD, methane sensing			
Module:6	**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:7	**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:8	**Contemporary Issues**	**2 hours**	
	Total Lecture:	**30 hours**	

Text Book(s)	
1.	Janata, Jiri,"Principles of Chemical sensors", 2014, 2nd edition, Springer, New York.
Reference Book(s)	
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.
4.	Florinel-Gabriel Banica "Chemical Sensors and Biosensors: Fundamentals and Applications" 2012, 1st edition, Wiley-Blackwell, New Jersey.
5.	M. Campbell, "Sensor Systems for Environmental Monitoring: Volume Two: Environmental Monitoring", 2011, 1st Edition, Springer, New York.
Mode of Evaluation:CAT, Digital Assignments, Quiz, Online course, Paper publication, Projects, Hackathon/Makeathon and FAT	

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	6 hours

	sensor which can measure the humidity and develop asensor system which can measure the relative humidity in the range of 40 to 60 percent.	
5	Develop a potentiostat circuit for a chemoresistive sensor which can be used 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.	6 hours
	Total Laboratory Hours	30hours

Mode of Evaluation: Continuous Assessment and FAT			
Recommended by Board of Studies		26-04-2019	
Approved by Academic Council	No. 55	Date	13-06-2019

Course code	Course Title	L	T	P	J	C
ECE5067	**Cloud and Fog Computing**	**2**	**0**	**2**	**0**	**3**
Prerequisite	ECE5061- IoT Fundamentals and Architecture	**Syllabus Version**				
		1.00				

Objectives:

The course is aimed to

1. Introduce cloud computing and enabling technologies
2. Explore the need for fog and edge computation
3. Impart the knowledge to log the sensor data and to perform further data analytics

Expected Outcome:

At the end of the course student will be able to

1. Deploy their data in the cloud for simple applications
2. Apply the analytics in cloud to extract information
3. Appreciate and deploy fog data processing layers
4. Integrate sensor data to cloud through fog computation layers
5. Understand and implement edge computation
6. Develop edge analytics using python and tensor flow
7. Perform data pushing and processing in commercial clouds.

Student Learning Outcomes (SLO):	**5,7,17**

Module 1	**Cloud Computing basics and enabling technologies**	**5 hours**

Basics of cloud computing-Need for clouds- concepts and models: Roles and boundaries – Cloud characteristics – Cloud delivery models – Cloud deployment models. Broadband Networks and Internet Architecture – Data Center Technology – Virtualization Technology.

Module 2	**Cloud Virtualisation**	**5 hours**

Server oriented – Virtual Machines (IaaS), Modern Serverless Configurations- Functions/ (PaaS) Lambda functions – App, Biz function, logics, data ingestion (elasticity, scalability – on demand)

DB services, Analytics services (SaaS).

Module 3	**Cloud Application Development in Python**	**4 hours**
Python for Cloud: Amazon Web Services – Google Cloud – Windows Azure. Python for MapReduce.		
Module 4	**Federated Cloud Service Management and IoT**	**3 hours**
Cloud Service management (federated) –Cloud Life Cycle-service and management-Cloud architectures -Self organizing cloud architectures		
Module 5	**Fog computing**	**4 hours**
Need for Fog computation, Fog data processing layers – Security and Identity Management – Business process integration – Big data interfaces – Wireless sensors and actuators, Fog in 5G, Architecture Harmonization Between Cloud Radio Access Networks and Fog Networks, Fog applications.		
Module 6	**Fog and edge computing**	**4 hours**
Need for edge computation-Edge computing architectures,Device registration, Remote diagnostics,SW update, Geo distributed computing-concept of cloud orchestration, Edge Networks (Low bandwidth networks/ Security/ protcols),WAN vs Low bandwidth networks.		
Module 7	**Overview of Edge Data Analytics tools**	**3 hours**
Python advance libraries(Pandas, Scikit Learn), Tensor flow and Yolo		
Module 8	**Contemporary Issues**	**2 hours**
	Total Lecture:	**30 hours**
Text Books:		
1.	Thomas Erl, Zaigham Mahmood, and Ricardo Puttini, "Cloud Computing: Concepts, Technology & Architecture", Arcitura Education, 2013.	

2.	Arshdeep Bahga, Vijay Madisetti, "Cloud Computing: A Hands-on Approach", 2013.
3.	Ovidiu Vermesan, Peter Friess, "Internet of Things – From Research and Innovation to Market Deployment", River Publishers, 2014.
4.	Michael Missbach, Thorsten Staerk, Cameron Gardiner, Joshua McCloud, Robert Madl, Mark Tempes, George Anderson, "SAP on Cloud", Springer, 2016.
5	John Mutumba Bilay , Peter Gutsche, Mandy Krimmel, Volker Stiehl , "SAP Cloud Platform Integration: The Comprehensive Guide", Rheinwerg publishing, 2nd edition, 2019,
Reference Books:	
1.	Honbo Zhou, "The Internet of Things in the Cloud: A Middleware Perspective", CRC Press, 2012.
2.	S.-C. Hung et al.: Architecture Harmonization Between Cloud RANs and Fog Networks, IEEE Access: The Journal for rapid open access publishing, Vol.3, pp: 3019 – 3034, 2015.

Lab Tasks (30 Hours)	**SLOs : 5,14**

Cloud Platforms: Microsoft Azure/IBM Bluemix

Language: Python

1. Pushing documents
2. Pushing Images and Processing
3. Mini Weather Station
4. Image analytics at cloud
5. Python Scikit learn
6. Tensor flow
7. Live video

Recommended by Board of Studies	13-09-2019		
Approved by Academic Council	No. 56	Date	24-09-2019

<table>
<tr><td>Course code</td><td colspan="3">Course Title</td><td>L</td><td>T</td><td>P</td><td>J</td><td>C</td></tr>
<tr><td>ECE5068</td><td colspan="3">IoT Security and Trust</td><td>2</td><td>0</td><td>0</td><td>4</td><td>3</td></tr>
<tr><td>Pre-Requisite:</td><td colspan="3">ECE6001-Wireless Sensor Networks and IoT</td><td colspan="5">Version</td></tr>
<tr><td colspan="4"></td><td colspan="5">1.0</td></tr>
<tr><td colspan="9">Objectives:</td></tr>
<tr><td colspan="9">To impart the knowledge and technical skills in designing secured and trustable IoT systems.</td></tr>
<tr><td colspan="9">Expected Outcome:</td></tr>
<tr><td colspan="9">At the end of the course students will be able to
1. Design and implement cryptography algorithms using C programs
2. Solve network security problems in various networks
3. Build security systems using elementary blocks
4. Build Trustable cloud based IoT systems
5. Solve IoT security problems using light weight cryptography
6. Appreciate the need for cyber security laws and methods.</td></tr>
<tr><td colspan="2">Student Learning Outcomes (SLO):</td><td colspan="7">5,6,14</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td>Module 1</td><td colspan="2">Fundamentals of encryption for cyber security.</td><td colspan="6">5 hours</td></tr>
<tr><td colspan="9">Cryptography – Need and the Mathematical basics- History of cryptography, symmetric ciphers, block ciphers, DES – AES. Public-key cryptography: RSA, Diffie-Hellman Algorithm,Elliptic Curve Cryptosystems, Algebraic structure, Triple Data Encryption Algorithm (TDEA) Block cipher,</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td>Module 2</td><td colspan="2">IoT security framework</td><td colspan="6">5 hours</td></tr>
<tr><td colspan="9">IIOT security frame work, Security in hardware,Bootprocess, OS & Kernel, application,run time environment and containers. Need and methods of Edge Security, Network Security: Internet, Intranet, LAN, Wireless Networks, Wireless cellular networks, Cellular Networks and VOIP.</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td>Module 3</td><td colspan="2">Elementary blocks of IoT Security & Models for Identity Management</td><td colspan="6">4 Hours</td></tr>
<tr><td colspan="9">Vulnerability of IoT and elementary blocks of IoT Security, Threat modeling – Key elements. Identity management Models and Identity management in IoT, Approaches using User-centric, Device-centric and Hybrid.</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td>Module 4</td><td colspan="2">Identity Management and Trust Establishment</td><td colspan="6">4 Hours</td></tr>
<tr><td colspan="9">Trust management lifecycle, Identity and Trust, Web of trust models. Establishment: Cryptosystems – Mutual establishment phases – Comparison on security analysis. Identity management framework.</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td>Module 5</td><td colspan="2">Access Control in IoT and light weight cryptography</td><td colspan="6">3 Hours</td></tr>
<tr><td colspan="9">Capability-based access control schemes,Concepts, identity-based and identity-driven, Light weight cryptography, need and methods , IoT use cases</td></tr>
<tr><td>Module 6</td><td colspan="2">Security and Digital Identity in Cloud Computing</td><td colspan="6">4 Hours</td></tr>
<tr><td colspan="9">Cloud security , Digital identity management in cloud, Classical solutions, alternative solutions,</td></tr>
</table>

Management of privacy and personal data in Cloud.				
Module 7	**Cyber Crimes, Hackers and Forensics**			**3 Hours**
Cyber Crimes and Laws – Hackers – Dealing with the rise tide of Cyber Crimes – Cyber Forensics and incident Response – Network Forensics.				
Module:8	**Contemporary Issues**			**2 Hours**
	Total Lecture:	**30**	**Hours**	

Text Books:	
1.	John R. Vacca, "Computer and Information Security Handbook", Elsevier, 2013. Parikshit Narendra Mahalle , Poonam N. Railkar, "Identity Management for Internet of Things", River Publishers, 2015.
2.	William Stallings, "Cryptography and Network security: Principles and Practice", 5th Edition, 2014, Pearson Education, India.
3.	Maryline Laurent, Samia Bouzefrane, "Digital Identity Management", Elsevier, 2015.
4.	Joseph Migga Kizza, "Computer Network Security", Springer, 2005.
Reference Books:	
1.	Christof Paar and Jan Pelzl, "Understanding Cryptography – A Textbook for Students and Practitioners", Springer, 2014.
2.	Behrouz A.Forouzan : Cryptography & Network Security – The McGraw Hill Company, 2007.
3.	Charlie Kaufman, Radia Perlman, Mike Speciner, Network Security: "Private Communication in a public World", PTR Prentice Hall, Second Edition, 2002.
4.	Alasdair Gilchrist, "IoT security Issues", Oreilly publications, 2017.

Typical List of Projects(not limited to)	**SLO: 5,6,14**
1. Light weight cryptography	
2. Hybrid block ciphers.	
3. Encryption using applets	
4. Digital signatures	
5. Review of Trust in IoT transactions.	
6. Crypt analysis	
7. Cloud security	
8. Trust management in clouds	

Recommended by Board of Studies	13-09-2019		
Approved by Academic Council	No. 56	Date	24-09-2019

Course code	Course Title	L	T	P	J	C
ECE5069	IoT Applications and Web development	2	0	0	4	3
Pre-requisite	ECE5061-IoT fundamentals and Architecture	Syllabus version				
		v. 1.00				

Course Objectives:

1. To acquire specific scripting knowledge to develop interactive applications.
2. To understand the basics of android application development.
3. To apply the programming skills in developing application pertaining to Industrial, medical, agricultural, etc.

Expected Course Outcome: Students will be able to

1. Design dynamic web forms to acquire and process user & sensor data
2. Interactive forms using Java Script with a focus on internet of things
3. Implement mobile application using android SDK
4. Solve the need for smart systems in a distributed environment
5. Understand the IoT architecture and building blocks for various domains
6. Devise multidisciplinary case to case modelling and execute wide range of application

Student Learning Outcomes (SLO):	5,7,20

5. Having design thinking capability
7. Having computational thinking (Ability to translate vast data in to abstract concepts and to understand database reasoning)
20. Having a good digital footprint

Module:1	Markup Language	3 hours

Introduction to Markup language, HTML document structure, HTML forms, Style (CSS), Multiple CSS stylesheets, DHTML, Tools for image creation and manipulation, User experience design, IoT development using charts

Module:2	Scripting Language	4 hours

Introduction to JavaScript, Functions, DOM, Forms, and Event Handlers, Object Handlers, Input validation, J2ME, application design using J2ME , IoT development using Real time rules, platforms, alerts

Module:3	Android Programing Framework	5 hours

Mobile app development: Android Development environment, Simple UI Layouts and layout properties, GUI objects, Event Driven Programming, opening and closing a Database

Module:4	Industrial Internet Application	4 hours

IIoT Fundamentals and Components, Industrial Manufacturing, Monitoring, Control, Optimization and Autonomy, Introduction to Hadoop and big data analytics

Module:5	Applications in agriculture	3 hours

Smart Farming: Weather monitoring, Precision farming, Smart Greenhouse, Drones for pesticides.

Module:6	Applications in IoT enabled Smart Cities	4 hours

Energy Consumption Monitoring, Smart Energy Meters, Home automation, Smart Grid and Solar Energy Harvesting, Intelligent Parking, Data lake services scenarios.

Module:7	**Healthcare applications**		**5 hours**
Architecture of IoT for Healthcare, Multiple views coalescence, SBC-ADL to construct the system architecture. Use Cases : Wearable devices for Remote monitoring of Physiological parameter, ECG, EEG, Diabetes and Blood Pressure.			
Module:8	**Contemporary issues:**		**2 hours**
	Total Lecture hours:	**30 hours**	

Text Book(s)	
1.	John Dean, Web Programming with HTML5, CSS and JavaScript, 2018, Jones and Bartlett Publishers Inc., ISBN-10: 9781284091793
2.	DiMarzio J. F., Beginning Android Programming with Android Studio, 2016, 4th ed., Wiley, ISBN-10: 9788126565580
Reference Books	
1.	Fadi Al-Turjman, Intelligence in IoT- enabled Smart Cities, 2019, 1st edition, CRC Press, ISBN-10: 1138316849
2.	Giacomo Veneri, and Antonio Capasso, Hands-on Industrial Internet of Things: Create a powerful industrial IoT infrastructure using Industry 4.0, 2018, Packt Publishing.
3.	Subhas Chandra Mukhopadhyay, Smart Sensing Technology for Agriculture and Environmental Monitoring, 2012, Springer, ISBN-10: 3642276377
4.	
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar	

List of Challenging Experiments (Indicative)		
1.	Design and development of wireless video surveillance robot	15 hours
2.	Design and implementation of wearable glove to enable sign to speech conversation	
3.	IoT based home automation with security features	
4.	Smart farming : IoT based system for smart agriculture	
5.	IoT application to improvise industrial automation	
6.	Smart Energy meters to minimize power consumptions with a statistical approach	
7.	Bringing intelligence body area network – Smart Healthcare systems	
Mode of assessment: Mid CAT, FAT		

Recommended by Board of Studies	13-09-2019		
Approved by Academic Council	No. 56	Date	24-09-2019

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:	15 hours

	In this topic, you need to design a piezoresistive pressure sensor that has the 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
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
ECE6087	**Multi-disciplinary Product Development**	**3**	**0**	**0**	**4**	**4**
Prerequisite:	Nil	**Syllabus Version**				
		1.0				

Course Objectives:

1. To develop the students for integrative thinking on good engineering practices.
2. To emphasis the students from shifting their mindset from theoretical to practical multi-disciplinary skills through installing the know-how of actual practice in industry field.

Expected Outcomes:

The student will be able

1. To demonstrate an understanding of the overview of all the product development processes and knowledge of concept generation and selection tools
2. To value the voice of the customer in getting the feedback
3. To demonstrate an understanding of quality in a product or service through tools.
4. To improve the design of the product in accordance with the quality standards
5. To apply various strategies of designing experiments, methods to uphold the status of six sigma and improve the reliability of a product.
6. Strive towards efficient manufacturing process by systematic resource procurement
7. Analyze and demonstrate knowledge in product development

Student Learning Outcomes (SLO): **4,9,12,20**

Module:1	Customer Value and Market Segmentation	6 hours

The way to measure value by what a customer is willing to pay. It is used as critical input for product function requirement development. No product can satisfy all the customers. Market Segmentation shows the methodology to target a specific customer group for product positioning.

Module:2	Voice of customer	6 hours

Voice of customer: A disciplined approach to directly collecting feedback and input from customers. Used throughout the Engineering and Marketing process.

Module:3	Quality Function deployment	6 hours

Critical to Quality and Quality function Deployment: Specify and quantify customer needs. Flow down those customer needs in each step of product development.

Module:4	Design of Six Sigma	6 hours

Integrate statistics into quality continuous improvement operation model. Design for Six Sigma used throughout the product development process in order to improve the correction of the first design delivery.

Module:5	Design Principles	6 hours

Sample design Principles: As little design as possible to satisfy customer expectations and eliminating any unnecessary complexity helps maximize business benefit.

Module:6	**Design of Manufacturing**			**6 hours**
Design of Manufacturing: Consider product manufacturability during design phase. Manufacture product efficiently increases the organization competitive power.				
Module:7	**Strategic sourcing and e-sourcing**			**7 hours**
Strategic Sourcing and Standardized Parts: Leverage the expertise of external source is one of the key strategies to success. Parts standardization improves the manufacturing flexibility and reduces the quality issue. e-sourcing: Leverage web-based applications to deliver savings and productivity gains while conducting the strategic sourcing.				
Module:8	**Contemporary Issues**			**2 hours**
	Total Lecture:	**30**	**hours**	

Text Books:	
1.	Tempelman, Shercliff, Van Eyben, "Manufacturing and Design, Elsevier, 1st edition, 2014
2.	Art Weinstein, "Handbook of Market Segmentation: Strategic Targeting for Business and Technology Firms, Third Edition (Haworth Series in Segmented, Targeted, and Customized Market), 3rd ed. Routledge, Taylor and Francis group, 2004.
3.	Michael Lamoureux, "The e-Sourcing Handbook: A Modern Guide to Supply and Spend Management Success, Lasta publishing, 2008

Mode of Evaluation:Continuous Assessment and FAT		
Recommended by Board of Studies	26-04-2019	
Approved by Academic Council	No. 55	13-06-2019

Course Code	Course Title	L	T	P	J	C
ECE6088	DEEP LEARNING - AN APPROACH TO ARTIFICIAL INTELLIGENCE	3	0	0	0	3
Prerequisite:	Nil	Syllabus Version				
		1.0				

Course Objectives:

1. To introduce the fundamental theory and concepts of machine learning and artificial intelligence
2. To provide a comprehensive foundation to artificial neural networks, neuro-modeling, and their applications to pattern recognition.
3. To explore the learning paradigms of supervised and unsupervised shallow/deep neural networks.
4. To provide exposure to the recent advances in the field of and facilitate in depth discussions on chosen topic
5. To impart adequate knowledge on deep learning frameworks and their applications to solving engineering problems

Course Outcomes:

1. Gain knowledge about basic concepts of machine learning algorithms and identify machine learning techniques suitable for the given problem.
2. Understand the differences between shallow neural networks and deep neural networks for supervised and unsupervised learning.
3. Develop and train neural networks for classification, regression and clustering.
4. Understand the foundations of neural networks, how to build neural networks and learn how to lead successful machine learning projects
5. Identify the deep feed forward, convolution and recurrent neural networks which are more appropriate for various types of learning tasks in various domains
6. Implement deep learning algorithm and solve real world problems

Student Learning Outcomes (SLO): 1, 5, 7

Module:1	Foundations of Machine Learning-I	5 hours

Supervised and unsupervised learning, parametric vs non-parametric models, parametric models for classification and regression- Linear Regression, Logistic Regression, Naïve Bayes classifier, simple non-parametric classifier-K-nearest neighbour,support vector machines.

Module:2	Foundations of Machine Learning-II	5 hours

Clustering- distance based- K-means, density based, association rule mining, validation techniques-cross validations, feature selection and dimensionality reduction, principal component analysis-Eigen values, Eigen vectors, Orthogonality- challenges motivating deep learning

Module:3	Neural Networks for Classification and Regression	6 hours

ANN as a technique for regression and classification, structure of an artificial neuron, activation functions- linear activation, sigmoid andsoftmax. Feedforward neural networks- shallow model-single layer perceptron,multi-layer perceptron as complex decision classifier- learning XOR-Gradient based learning, Backpropagation algorithm, risk minimization, loss function, regularization, heuristics for faster training and avoiding local minima.

Module:4	Deep Feed Forward Neural Networks	6 hours

Feed forward neural networks- deep model- output units and hidden units, training deep models- hyper parameters and validation sets-cross validation, capacity, overfitting and under fitting, bias vs variance trade off, cross validation - vanishing gradient problem, new optimization methods (adagrad, adadelta, rmsprop, adam), regularization methods (dropout, batch normalization, dataset augmentation), early stopping.			
Module:5	**Convolutional Neural Networks**	**7 hours**	
Convolution operation- kernel and feature map, sparse connectivity, equivariance through parameter sharing, pooling function for invariant representation, convolution and pooling as strong prior, convolution with stride, effect of zero padding, single-channel and multi-channel data types used in ConvNet, variants of basic convolution- locally connected, tiled ConvNet- spatial separable and depthwise separable convolutions, fully connected layers, ConvNet architecture- layer patterns, layer sizing parameters,case studies- LeNet, AlexNet			
Module:6	**Recurrent Neural Networks**	**6 hours**	
Sequence learning with neural nets, unrolling the recurrence, training RNN- Backpropagation through time (BPTT), vanishing gradient problem, Gated recurrent unit (GRU), Long short term memory (LSTM), Bidirectional LSTMs, bidirectional RNNs			
Module:7	**Deep Learning Tools and Applications**	**8 hours**	
Tools:TensorFlow, Keras, PyTorch, Caffe, Theano, MXNet. Applications: Object detection with RCNN - YOLO, SSD. Speech recognition with RNN.			
Module:8	**Contemporary Issues**	**2 hours**	
	Total Lecture:	**45 hours**	
Text Book(s)			
1.	Bengio, Yoshua, Ian J. Goodfellow, and Aaron Courville. "Deep learning" 2015, MIT Press		
2.	Josh Patterson and Adam Gibson, “Deep Learning- A Practitioner’s Approach” O’Reilly Media Inc., 2017, USA.		
Reference Book(s)			
1.	Bishop, C. ,M., Pattern Recognition and Machine Learning, Springer, 2011		
2.	Rich E and Knight K, “Artificial Intelligence”, 2011, 2nd ed., TMH, New Delhi,		
3.	Bengio, Yoshua. "Learning deep architectures for AI- Foundations and trends in Machine Learning, 2(1)- 2009		
4.	Tom M. Mitchell, “Machine Learning”, McGraw-Hill Education (India) Pvt Ltd, 2013.		
Mode of Evaluation: CAT, Digital Assignments, Quiz, Online course, Paper publication, Projects, Hackathon/Makeathon and FAT.			
Recommended by Board of Studies	26-04-2019		
Approved by Academic Council	No. 55	Date: 13-06-2019	

Course Code	Course Title	L	T	P	J	C
ECE6089	**AUTOMOTIVE SENSORS AND IN-VEHICLE NETWORKING**	**2**	**0**	**2**	**0**	**3**
Pre-requisite	**ECE5060- Principles of Sensors and Signal Conditioning**	**Syllabus version**				
		1.00				

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.

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.
7. Develop and create analytical designing of novel prototype models for various automotive electronic systems.

Student Learning Outcomes (SLO):	**2,5,14**

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: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: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:4	**Sensors for vehicle body management,**	**6 hours**

	Sensors for automotive vehicle convenience and security systems	
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, etc.		
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	**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, IwaoYokomori, 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, Digital Assignments, Quiz, Online course, Paper publication, Projects, Hackathon/Makeathon and FAT	

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	6 hours

	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.	
2	After studying the characteristics of various types of thermal sensors, develop a suitable system which can measure the automotive engine temperature in a non-contact method with an accuracy of +/-0.5°C.	6 hours
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 Evaluation: Continuous Assessment and FAT			
Recommended by Board of Studies	26-04-2019		
Approved by Academic Council	No. 55	Date	13-06-2019

Course Code	Course Title	L	T	P	J	C
ECE6090	**Fiber optic Sensors and Photonics**	**3**	**0**	**0**	**0**	**3**
Prerequisite	ECE5060 Principles of Sensors and Signal Conditioning	**Syllabus Version**				
		1.0				

Course Objectives

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

Course Outcomes

1. Attainment of basic knowledge of optical waveguides and optical devices employed in optical sensors.
2. Will be conversance in optical parameters involved in active and passive components
3. Entrust the characteristics of a suitable optical materials for the sensing device in a given application.
4. Identify and apply the knowledge in designing interferometric devices which is more effectively used in sensing.
5. Will be aware of different polymers and their chemical, optical characteristics to formulate miniaturized optical devices.

Student Learning Outcomes (SLO): 2, 6, 12

Module:1	**Theory of Optical Waveguides**	**7 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. Basic characteristic of Optical Fiber Waveguides, Acceptance angle, Numerical aperture, skewrays- Electromagnetic Modes in Cylindrical Waveguides.

Module:2	**Active and Passive Optical Components**	**7 hours**

Electro-optic and acousto optic wave guide devices, directional couplers, optical switch, phase and amplitude modulators,filtersetc,Yjunction,powersplitters,arrayedwaveguidedevices,fiberpigtailing, end-fiber prism coupling, FBG and fabrication of FBG,Tapered couplers.

Module:3	**Intensity and Polarization Sensors**	**7 hours**

Intensity sensor: Transmissive concept –Reflective concept-Micro bending concept–Transmission and Reflection with other optic effect-Interferometers –Mach Zehnder-Michelson-Fabry-Perot and Sagnac–Phase sensor: Phase detection-Polarization maintaining fibers. Displacement and temperature sensors: reflective and Micro bending Technology- Applications of displacement and temperature sensors.

Module:4	**Interferometric Sensors**	**7 hours**

Pressure sensors: Transmissive concepts, Microbending –Intrinsic concepts–Interferometric concepts, Applications. Flow sensors: Turbine flowmeters- Differential pressure flowsensors –Laser Doppler

velocity sensors-Applications- Sagnac Interferometer for rotation sensing. Magnetic and electric field sensors: Intensity and phase modulation types– applications.		
Module:5	**Polymer based waveguide in sensing**	**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-application in sensing		
Module:6	**Fiber based Chemical Senors**	**5 hours**
Fiber based Chemical Sensing : Absorption, Fluorescence, Chemi-luminescence, Vibrational Spectroscopic, SPR.		
Module:7	**Fiber based Bio-Senors**	**3 hours**
Fiber based Bio-molecules sensing: High Index, SPR, Hollow core fiber probes, Label Free bio-molecules.		
Module:8		**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s):

1.	David A. Krohn, Trevor W. MacDougall, Alexis Mendez, "Fiber Optic Sensors: Fundamentals and Applications" SPIE Press, 4th ed. 2015. ISBN: 1628411805
2.	Eric Udd , William B. Spillman Jr., "Fiber Optic Sensors: An Introduction for Engineers and Scientists", Wiley, 2nd Ed., 2011. ISBN: 0470126841

Reference Book(s)

1.	Zujie Fang & et. al., "Fundamentals of Optical Fiber Sensors" Wiley, 1st Ed., 2012.ISBN: 0470575409
2	Shizhuo Yin, Paul B. Ruffin, and Francis T.S. Yu, "Fiber Optic Sensors",CRC Press, 2 Ed, 2017. ASIN: B078JN75QW
3	F.Baldini&et.al.,“Optical Chemical Sensors”, NATO Science Series II: Mathematics, Physics and Chemistry, Springer, 2008. ISBN: 1402046103

Mode of Evaluation:CAT, Digital Assignments, Quiz, Online course and FAT

Recommended by Board of Studies	26/04/2019		
Approved by Academic Council	No. 55	Date	13/06/2019