M.Tech in Sensors and Internet of Things

Cat.	Course Number, Course Title		L-T-P	Credits		Cat.	Course Number, Course Title		L-T-P	Credits
I Semester						**II Semester**				
C	EEL7040	**Sensors and Measurement**	**3-0-0**	**3**		C	EEL7200	**Data Communication and Networking**	**2-0-2**	**3**
C	EEL7170	**Introduction to IoT Systems**	**2-0-2**	**3**		E	EEL7XX0	Elective	3-0-0	3
C	EEL71570	**Hardware Software Co-Design**	**3-0-0**	**3**		E	EEL7XX0	Elective	3-0-0	3
E	EEL7XX0	Elective	3-0-0	3		E	EEL7XX0	Elective	3-0-0	3
NG1	HSN7XX0	Non-Graded I	1-0-0	S/X		NG2	HSN7XX 0	Non-Graded II	1-0-0	S/X
			Total	**12**					Total	**12**
III Semester						**IV Semester**				
T	MET8XXo	Thesis		16		T	MET8XX 0	Thesis		16
			Total	**16**					Total	**16**

Electives

S.No.	Course Number	Course Title		
1		Microsystem Fabrication Technology	2-0-2	3
2		Analog and Interfacing Circuits	3-0-0	3
3		Vehicular Ad Hoc Networks	3-0-0	3
4		Fundamentals of Machine Learning	3-0-2	4
5		In-memory computing	2-0-0	2
6		Point of care devices/diagnostics	3-0-0	3
7		Wireless Communication	3-0-0	3
8		Nano sensors	3-0-0	3
9		Embedded System Design	3-0-0	3
10		Hardware Design for Artificial Intelligence	3-0-0	3
11		Virtualization and Cloud Computing	3-0-0	3
12		Digital VLSI Design	3-0-0	3

Title	**Introduction to Internet of Things Systems**	Number	**EEL7XX0**
Department	Electrical Engineering	L-T-P [C]	2–0–2 [3]
Offered for	M. Tech. 1st year	Type	Compulsory
Prerequisite			

Objectives

The Instructor will:

1. Provide overview of applications of IoT and relevant technologies

Learning Outcomes

The students are expected to have the ability to:

1. Identify and integrate different components required for IoT applications

Contents

EEL7XX1*: IoT Systems Architecture*

Sensing, Actuation, Basics of IoT Networking (4 Lectures)

IoT Architecture, Communication Protocols for IoT (4 Lectures)

Sensor Networks: Wireless Sensor Network, Sensor nodes (2 Lectures)

Machine to machine Communication: Introduction, Node types and M2M Applications, Integration of Sensors and Actuators for Implementation of IoT (4 Lectures)

EEL7XX2*: Embedded Computing and IoT Applications*

Introduction to Raspberry Pi and other MCUs used in IoT (4 Lectures)

Software defined IoT Networking (2 Lectures)

Introduction to Cloud, Fog, and Edge Computing (4 Lectures)

IoT Use Cases - Smart cities and Smart homes, Industrial IoT, Healthcare IoT, Smart Grid (4 Lectures)

Lab Component

The lab course will be dependent on the various core and elective components of the program. There will be a scope for modifying the contents depending on the recent developments in technology. Experiments from some of the following topics will be part of this lab.

- Implementation of Signal Conditioning Circuits
- Implementation of IoT components using Hardware/Software
- Sensor interfacing using off-the-shelf components
- Programming of MCUs used in IoT like Raspberry Pi
- Implementation of real time examples of IoT using Embedded Systems
- Introduction to EDA tools, hardware-software co-design, computational models in Embedded design.

Indicative Assignments:

The assignments will involve programming of MCUs using C and Python. These programming assignments will complement the lab sessions.

Textbook

1. Kamal, R., (2017), *Internet of Things - Architecture and Design Principles*, 1st Edition, Mcgraw Hill.

Preparatory Course Material

1. Misra, S., *Introduction to Internet of Things*, NPTEL Course Material, Department of Computer Science and Engineering, Indian Institute of Technology Kharagpur, https://nptel.ac.in/courses/106105166/

Course Title	***Sensors and measurements***	Course No.	**EE6XX**			
Department	Electrical Engineering	Structure (LTPC)	3	0	0	3
Offered for	M. Tech. (Sensors and IoT)	Status	Program Core			
Pre-requisite	*Semiconductor Devices*	To take effect from	2019			

Objective

The Instructor will:

1. Introduction to sensors, as transducers from physical parameters to signals
2. Sensing principles for displacement, force, pressure, acceleration, temperature, optical radiation, nuclear radiation
3. Sensor range, sensitivity, accuracy, repeatability, noise

Learning Outcomes

Students are expected to learn

1. Fundamental principles of sensing technology,
2. Design of various sensors, and implementation,
3. Nondestructive characterization methods

Course Content

Introduction to Transducers and Sensor characteristics: Definitions, terminology, classification, Static vs dynamic properties of transducers, Transfer functions, Ideal and realistic transducer models, Resolution, linearization, dynamic range, detection threshold, Selectivity & sensitivity, Calibration, Errors of the experimental measurements, Noise: electronics, environmental & internal (14 lectures)

Physical Principle of Sensing: Capacitance, Magnetism, Induction, Resistance, Piezoelectric effect, Pyroelectric effect, Hall effect, Thermoelectric effect, Temperature and thermal properties of materials and heat transfer, Optics, Fiber optics and waveguides (14 lectures)

Interface Electronic Circuits: Input characteristics of interface circuits, Amplifiers, Light to voltage converters, Capacitance to voltage converters, Bridge Circuits, Excitation circuits (4 Lectures)

Case Studies: Inertial Sensors (**A**ccelerometer & gyroscope), Healthcare Sensors (Glucometer, ECG & MRI), Smart building Sensors (Smoke & occupancy sensors) (10 lectures)

Reference Books

1. Jacob Fraden, Handbook of Morden Sensors, Springer 2010.
2. D. V. S. Murthy, Transducers in Instrumentation, Prentice Hall, 1995.
3. J. W. Gardner, Microsensors, Principles and Applications, Wiley, 1996.
4. S. M. Sze, Semiconductor Sensors, Wiley, 1994

Title	**Data Communication and Networking**	Number	**EEL7XX0**
Department	Electrical Engineering	L-T-P [C]	2–0–2 [3]
Offered for	M. Tech. 1st Year	Type	Compulsory
Prerequisite	Fundamentals of Wireless Communications, Probability Theory and Random Process		

Objectives

The Instructor will:

1. Expose the students to distinguished features of Wireless Networks.

Learning Outcomes

The students are expected to have the ability to:

1. Design and optimize wireless network architectures
2. Develop end-to-end IoT applications utilizing suitable data communication and networking technologies

Contents

Fundamentals (4 Lectures):

- Overview of the communication layers' architecture (1 Lecture)
- QoS parameters, Data communication technologies: QoS perspective and layer-wise technologies used (3 Lectures)

Network Deployment and Management (3 Lectures):

- Network Topologies (1 Lecture)
- Node/network localization and deployment map generations (2 Lectures)

MAC Layer Analysis (7 Lectures):

- Markov process, Single and Multi-Server Queues (M/M/1, M/M/c) with finite and infinite queue sizes (3 Lectures)
- Contention and contention-free channel access mechanisms (2 Lectures)
- Performance modeling and analysis of CSMA/CA with finite packet queues (2 Lectures)

Network Layer Analysis (8 Lectures):

- Design constraints, Bounded latency networks (2 Lectures)
- Routing algorithms - Analysis and optimization (3 Lectures)
- Self-organizing Networks (1 Lecture)
- Motivation for cross-layer protocol design (2 Lectures)

Transport Layer (2 Lectures):

- TCP, UDP, Congestion Control

Discussion on Recent Advancements (4 Lectures)

- Introduction to NFV, Network slicing (2 Lectures)
- Energy efficient protocols and energy harvesting techniques (2 Lectures)

Lab Component (14 sessions):

- Introduction to existing simulation tools, and hands on-session for Simulation Tool
- NS3 simulations for MAC layer and Network layer performance analysis for WPANs
- Analytical and Simulation co-validation for MAC and Network protocols
- End-to-End IoT Application Development (Multi-node multi-parameter sensing system development, Edge processing, RF communication, Cloud integration, Data analytics and alerts)

Indicative Assignments and Self-Study Components:

- Assignments on MAC layer analysis, network layer analysis, and transport layer using tools such as Wireshark, NS3 will be provided
- Self-study topics include deeper analytical analysis of MAC layer, network layer, and transport layer protocols will be suggested.

Textbook:

1. Dargie, W., and Poellabauer, C., (2010), Fundamentals of Wireless Sensor Networks: Theory and Practice, Wiley
2. Stallings, W., (2007), Data and Computer Communications, 8th Edition, Pearson
3. Bertsekas, D. P. and Gallager, R. G., (1992), Data Networks, 2nd Edition, Prentice Hall
4. Stallings, W., High-speed Networks and Internets: Performance and Quality of Service, 2nd Edition, Prentice Hall

Reference Book

1. Ian F. Akyildiz and Mehmet Can Vuran, (2010), Wireless Sensor Networks, A John Wiley and Sons Ltd. Publication.

Course Title	**Hardware Software Co-Design**	Number	**EEL7XX0**
Department	Electrical Engineering	L-T-P [C]	3–0–2 [4]
Offered for	M. Tech. 1st year	Type	Compulsory
Pre-requisite	Digital Logic and Design		

Objectives

The Instructor will:

1. Make the students analyze the functional and nonfunctional performance of system early in the design process to support design decisions.
2. Make the students appreciate issues in system-on-chip (SoC) design associated with co-design, such as intellectual property, reuse, and verification.
3. Explain the hardware, software, and interface synthesis

Learning Outcomes

The students are expected to have the ability to:

1. Analyze hardware/software trade-offs, algorithms, and architectures to optimize the system based on requirements and implementation constraints.
2. Understand issues in interface design.
3. Use co-simulation to validate system functionality.

Contents

Introduction to ASIC design, combinational and sequential circuit design process (design using Verilog and VHDL), Finite state machines, Modelling styles and their applications (Concurrency, Communication and Computation models), RTL and memory models, Brief introduction to interfacing circuits/systems connecting analog & digital world, Motivation for HW/SW co-design (Embedded controller application etc.) (7 lectures)

Programmable logic devices and FPGAs: PALs, PLDs, FPGA programming concepts and techniques, design synthesis using FPGA kits, Design optimization techniques (5 lectures)

System-level and SoC design methodologies and tools; HW/SW co-specification and co-design (co-design Finite state machines, CFSM) principles: analysis, partitioning, real-time scheduling (7 lectures)

Hardware acceleration; Virtual platform models, co-simulation methodologies and FPGAs for prototyping of HW/SW systems (5 lectures);

Transaction-Level Modeling (TLM), Electronic System-Level (ESL) languages, UML:SystemC, Design development with SystemC; (5 lectures)

High-Level Synthesis(HLS) and associated optimization techniques at each stage: allocation, scheduling, binding, resource sharing, pipelining, co-synthesis methods (6 lectures);

SoC and IP integration issues (on-chip bus, network-on-chip) and optimization for resource-constrained operation in different usage environments, Introduction to SoC verification, test & pre-/post-silicon debug methodologies, ARM-based System-on-Chip Design Techniques with HW/SW approach, One practical SoC design case study in complete detail (7 lectures)

Lab Component: Interfacing, data analytics and data processing of different types of sensors at the system level using FPGA, system level implementation of various digital correction and calibration techniques. This will internally include combinational circuit and sequential logic design, clock issues and timing constraints. Application-specific System/Processor Design and Simulation, SystemC -based Microprocessor & Accelerator design implementation, performance evaluation and optimization, On-chip interconnect network analysis (e.g.- Network-on-chip simulation), Realization of co-designed HW system on FPGA board(s) and analysis of observed results (complete project beginning from co-specification to co-design, co-synthesis and verification)

Indicative Assignments: (a) Design of moderately complex system (e.g.- sequence detector/ router/ multi-level elevator controller) in any HDL and its simulation using Modelsim (Mentor)/ GHDL(open source)/ Icarus(open source)/ VCS (Synopsys) tools

(b) Implementation of designed system on FPGAs using Quartus/ Xilinx Vivado tools

(c) Implementation of partitioning/scheduling algorithm in Python/C

(d) Realization of RTL synthesis with Yosys(open source)/ RTL Compiler(Cadence)/ Design Compiler(Synopsys) tools

(e) Implementing standalone designs in SystemC, its compilation, simulation and debug.

Text Books

1. Jørgen Staunstrup, Wayne Wolf (1997), Hardware/Software Co-design: Principles and Practice, Springer
2. Unsalan, C., Tar, B., (2017), *Digital System Design with FPGA Implementation UsingVerilog and VHDL*, McGraw-Hill
3. D. Black, J. Donovan, (2010), *SystemC: From the Ground Up*, 2 nd Edition, Springer
4. D. Gajski, S. Abdi, A. Gerstlauer, G. Schirner, (2009), *Embedded System Design: Modeling, Synthesis, Verification*, Springer

Preparatory Course material

1. Nelson, V.P., Carroll, B.D., Nagle, H.T., Irwin, J.D., (2020), *Digital Logic Circuitanalysis and Design*, 2nd Edition, Pearson
2. G. De Micheli, (2017), *Synthesis and Optimization of Digital Circuits*, McGraw-Hill.