Updated Program Structure for M Tech SIoT

Overall Program Structure

Category	*M. Tech. Core (MC)*	*M. Tech. Elective (ME)*	*M. Tech. Open (MO)*	*M. Tech.* Project (MP)	Non-graded (NG)	Total
Credits	20	16	6	16	4	62

Semester wise distribution of credits

Cat.	*Course Title*	*L-T-P*	*C*		*Cat.*	*Course Title*	*L-T-P*	*C*
	Bridge Course on Introduction to Programming#	*1-0-2*	*2*					
I Semester					**II Semester**			
MC	***Sensors and Measurement***	**2-0-0**	**2**		**MC**	***Data Communication and Networking***	**2-0-2**	**3**
MC	***Introduction to IoT Systems***	**2-0-2**	**3**		**MC**	**Hardware Software Co-Design**	**3-0-2**	**4**
MC	***Microsystem Fabrication Technology***	**2-0-2**	**3**		ME	*Program Elective-2*	3-0-0	3
MC	***Analog and Interfacing Circuits***	**3-0-2**	**4**		ME	*Program Elective-3*	3-0-0	3
ME	*Program Elective-1*	3-0-0	3		ME	*Program Elective-4*	3-0-0	3
NG	*Technical Communication*	1-0-0	1		NG	*Innovation and IP Management*	1-0-0	1
Total			**16**		*Total*			**17**
Winter Term								
MC	***Winter Internship***		**1**					
Total			**1**					
III Semester					**IV Semester**			
MP	Project-1	0-0-12	6		MP	Project-2	0-0-20	10
ME	*Program Elective-5*	3-0-0	3		MO	*Open Elective-2*	3-0-0	3
ME	*Program Elective-6*	1-0-0	1		NG	*Professional Ethics*	1-0-0	1
MO	*Open Elective-1*	3-0-0	3					
NG	*System Engineering and Project Management*	1-0-0	1					
Total			**14**		*Total*			**14**

#Satisfactory grade in the bridge course will be mandatory for students to be able to participate in on-campus placements

List of Program Electives

Course Title	*L-T-P*	*Credits*		*Course Title*	*L-T-P*	*Credits*
Digital VLSI Design	*3-0-0*	*3*		*Microfluidics Technology*	3-0-0	3
Flexible and Printed Electronics	*3-0-0*	*3*		*Real Time Communications*	3-0-0	3
Antenna Engineering	3-0-0	3		*Mobile and Pervasive Computing*	3-0-0	3
Wireless Communication	3-0-0	3		*RF IC Design Lab*	1-0-2	2
Neuromorphic Computing and Design	3-0-0	3		*Introduction to Wireless Ad Hoc Networks*	3-0-0	3
Advanced Digital Signal Processing	3-0-0	3		*Software Defined Networks*	3-0-0	3
Fog and Edge Computing	3-0-0	3		*Intelligent Radio Networks*	3-0-2	4
Vehicular Ad Hoc Networks	3-0-0	3		*Computation Oriented Communications*	3-0-0	3
Machine Learning	3-0-0	3		*Selected Topics in Sensors & IoT I*	1-0-0	1
Image Sensor Design and Applications	3-0-0	3		*Selected Topics in Sensors & IoT II*	2-0-0	2
Nano Sensors	3-0-0	3		*Selected Topics in Sensors & IoT III*	3-0-0	3
Industry 4.0 Applications in Manufacturing Systems	1-0-0	1		*UAV Assisted Wireless Networks*	3-0-0	3
Resource Constrained AI	3-0-0	3		*Intelligent Buildings*	3-0-0	3
Statistical Methods for Data Analysis	3-0-0	3		*Design and Analysis of Communication Networks*	3-0-2	4
*Energy Harvesting**				*Advanced MEMS**		
*Structural Health Monitoring**				*Advanced Biosensors**		
*Point of care devices/diagnostics**				*MEMS for Medical Devices**		
*Industrial IoT**				*5G Technologies for IoT**		
*IoT Security**				*IoT in Industry 4.0**		
*Digital Signal Processing and Applications**				*Digital Twins**		

*New elective courses to be designed

Detailed Course Contents

Course Title	**Sensors and Measurements**	Number	**EEL7XX0**
Department	Electrical Engineering	L-T-P [C]	2–0–0 [2]
Offered for	M. Tech. 1st year	Type	Compulsory
Pre-requisite	Semiconductor Devices		

Objective

The Instructor will:

1. Introduce the students to sensors, as transducers from physical parameters to signals
2. Explain the sensing principles for displacement, force, pressure, acceleration, temperature, optical radiation, nuclear radiation
3. Explain the sensor range, sensitivity, accuracy, repeatability, noise

Learning Outcomes

Students are expected to have the ability to

1. Understand fundamental principles of sensing technology,
2. Design various sensors and their applications
3. Comprehend Non-destructive characterization methods

Contents

EEL7XX1: Sensor characteristics [1-0-0]

Definitions, terminology, classification, Static vs dynamic properties of transducers, Transfer functions, Ideal and realistic transducer models (4 lectures)

Resolution, linearization, dynamic range, detection threshold, Selectivity & sensitivity, Calibration, Errors of the experimental measurements (4 lectures)

Physical Principle of Sensing: Resistance, Capacitance, Piezoelectric effect, Pyroelectric effect, Hall effect, Thermal and Optical phenomenon (6 lectures)

EEL7XX2: Sensor Interface and Applications [1-0-0]

Input characteristics of interface circuits, Amplifiers, Light to voltage converters, Capacitance to voltage converters, Bridge Circuits, Excitation circuits (4 lectures)

Case Studies:

Inertial Sensors (Accelerometer & gyroscope) (3 lectures)

Smart building Sensors (Smoke & occupancy sensors) (3 lectures)

Healthcare Sensors (Glucometer, Oximeter, ECG & MRI) (4 lectures)

Indicative Assignments:

Read-out interface circuit design for various sensors like Accelerometers, Gyroscope, Gas, Smoke, Occupancy sensors, etc. keeping various applications in view.

Text Books

1. Jacob Fraden, (2010), Handbook of Modern Sensors, 5th Edition, Springer.
2. J. W. Gardner, (1996), Microsensors, Principles and Applications, 1st Edition, Wiley.
3. S. M. Sze, (1994), Semiconductor Sensors, 1st Edition, Wiley.

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	***Microsystems Fabrication Technology***	Course No.	**EEL7XX0**
Department	Electrical Engineering	L-T-P [C]	2–0–2 [3]
Offered for	M. Tech. (Sensors and IoT)	Type	Core
Pre-requisite	*Semiconductor Devices*	To take effect from	2020

Objective

1. To introduce the essentials of micro-electronics fabrication technology required for the realization of MEMS and integrated circuits
2. To introduce the basic concepts of MEMS based sensors and actuator design, process integration and advanced micro-machining technologies for high aspect ratio MEMS structures.
3. To expose the students with semiconductor/ MEMS unit processes and their integration.

Learning Outcomes

Students will have the capability to:

1. Comprehend the unit fabrication processes for MEMS and ICs
2. Design and fabricate MEMS based sensors and actuators

Contents

Unit processes common to IC and MEMS fabrication:

(i) Clean room practices, substrate pre-processing, thermal oxidation, diffusion. *(3 lectures)*

(ii) Photolithography, Thin Film deposition (CVD, PVD) and Etching (dry and wet). *(5 lectures)*

Unit processes specific to MEMS:

(i) Surface and bulk micro-machining, DRIE *(4 lectures)*

(ii) Thick film deposition, wafer bonding, and MEMS packaging. *(4 lectures)*

Case studies of MEMS:

(i) Basic concepts of MEMS sensing and actuation. Process design/ integration *(6 lectures)*

(ii) Aspects for selected MEMS based sensors and actuators including Comb drives, pressure sensor, Biochemical sensors. *(6 lectures)*

Lab Component (14 Sessions):

(i) Introduction to layout design tools for various device layers generation, Materials selection aspects and Process integration considerations for selected MEMS based transducers.

(ii) Experiments related various unit processes (like Metal deposition, Photolithography and etching), their integration, related measurements and their optimization aspects.

Indicative Assignments: Process flow design and layout designing of various layers for the fabrication of micro-heaters, beams, cantilever, diaphragms, comb-drives, etc. for micro sensors.

Text books:

1. Tai-Ran Hsu, (2017), *MEMS & Microsystems Design and Manufacture*, Indian Edition, Tata McGraw-Hill
2. J. D. Plummer, M. D. Deal, and P. B. Griffin (2009), *Silicon VLSI technology: Fundamentals, practice, and modelling*, 1st Edition, Prentice Hall

Self study and Reference material

1. M. Bao, (2005), Analysis and Design Principles of MEMS Devices, 1st Edition, Elsevier
2. Marc J. Madou, (2011), *Fundamentals of Microfabrication and Nanotechnology*: *The Science of Miniaturization*, 3rd Edition, CRC Press.
3. M. Sze, (2003), *VLSI Technology*, 2nd edition McGraw Hill Education.
4. S. D. Senturia, Microsystem Design (2013), 1st Edition, Springer

Course Title	***Analog and Interfacing Circuits***	Number	**EEL7XX0**
Department	Electrical Engineering	L-T-P [C]	3–0–2 [4]
Offered for	M. Tech. 1st year	Type	Compulsory
Pre-requisite	*Digital and Analog Electronics*		

Objectives

The Instructor will:

1. Familiarize students with the concepts of Analog IC Design and give them a comprehensive overview of various amplifiers.
2. Familiarize the students with different building blocks of a mixed signal interface circuit design essential for sensors and IoT.

Learning Outcomes

Students are expected to have the ability to:

1. Understand fundamental principles of CMOS Analog IC Design and interfacing of analog signals with the digital signal processing circuits.
2. Apply the circuit design fundamentals for IoT applications.
3. Work on design tools like Cadence/Mentor Graphics

Contents

Introduction to Analog VLSI and design issues in CMOS technologies, MOS models and SPICE Models [3 lectures]

Single stage amplifiers, Biasing circuits, Voltage and Current reference circuits, Feedback analysis, Multistage amplifiers [6 lectures]

Differential amplifiers, Mismatch and noise analysis, (6 Lectures)

Switch capacitor circuits: Principles and applications in filter design; switches and related design issues [3 lectures]

Variable gain amplifier, Instrumentation amplifier, low noise and high speed amplifier topologies [3 lectures]

Analog to digital converters: Types, static and dynamic characteristics; track and hold, and sample and hold circuits; comparators; [6 lectures]

Detail design analysis for successive approximation register (SAR) ADCs, [3 lectures]

Digital to Analog Converters: Voltage-based DACs; charge-based DACs; current- based DACs – binary and thermometer currents (3 Lectures)

Phase-locked loop: Basics; PLL dynamics; voltage controlled oscillator, frequency synthesis [5 lectures]

Communication ports and devices [3 lectures]

Applications: Wearable Biomedical IoT nodes [1 Lecture]

Lab Experiments: It will include design and analysis of various analog and interfacing circuits like single stage and instrumentational amplifiers, signal conditioning circuits like preamplifier, variable gain amplifiers, followed by comparators and data converters.

Indicative Assignments: Analysis of cascaded and cascoded amplifier topologies in terms of gain, input and output impedance with and without feedback, switch capacitor circuit design and issues, comparators and voltage controlled oscillators. The theoretical calculations will be verified through different simulations performed using Cadence design tool.

Text Books

1. Razavi, B., (2016), *Design of Analog CMOS Integrated Circuits*, 2nd Edition, McGraw-Hill Education.
2. R. Jacob Baker, H.W.Li, and D.E. Boyce, (2009), – *CMOS Circuit Design ,Layout and Simulation*, 2nd

Edition, Prentice-Hall of India
3. David A. Johns, Ken Martin, (2013), "Analog Integrated Circuit Design", 2nd Edition, John Wiley and Sons.

Self Learning material

1. Shanthi Pavan, VLSI Data Conversion Circuits, NPTEL Course Material, Department of Electrical Engineering, Indian Institute of Technology Madras, https://nptel.ac.in/courses/117106034/
2. Nagendra Krishnapura, Analog Integrated Circuit Design, Department of Electrical Engineering, Indian Institute of Technology Madras, https://nptel.ac.in/courses/117106030/

Preparatory Course Material

1. P. E. Allen, D. R. Holberg (2013), *CMOS Analog Circuit Design*, 3rd Edition, Oxford University Press.
2. R. Gregorian, G. C. Temes, (2008), "*Analog MOS Integrated Circuits for Signal Processing*", John Wiley and Sons.

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.

Title	**Introduction to Programming**	Number	**EEP5XXX**
Department	**Electrical Engineering**	L-T-P [C]	**1-0-2 [2]**
Offered for	**MTech (CPS and SIoT)**	Type	**Bridge Course**
Prerequisite	**--**		

Objectives
To familiarize students with the basics and applications of programming using C and Python

Learning Outcomes
On completion, the student should be able to

- implement mathematical and algorithmic concepts using C/Python
- apply programming concepts to various applications, such as numerical analysis, dynamical system analysis, etc.

Contents
***Programming in C* [11 *Lectures*]**
C Compiler setup and Execution in Windows and Linux, Data Types, Operators and Expressions, Decision and Control Statements [3 *lectures*]
Arrays – Single and Multi-Dimensional, Pointers, Functions, Data Structures [5 *lectures*]
Dynamic Memory Allocation, Working with files, Using gcc and gdb + Introduction to Eclipse IDE and debugging [3 *lectures*]

***Python* [3 *Lectures*]**
Fundamentals of Python, File Handling, String processing, Function definition, Dictionaries & Tuples, Iterators, Numpy

Lab Exercises

- Implementation of basic concepts
- Applications, such as solving dynamical systems using differential equations
- Numerical applications in C/Python

Textbook(s)

1. Kanetkar, Y. (2016), *Let us C*, 17^{th} edition, BPB Publications
2. Balagurusamy (2013), *Data Structures Using C*, Tata McGraw-Hill Education
3. Brown, M.C. (2018), *Python: The Complete Reference*, 4^{th} Edition, McGraw Hill Education
4. Press, W. H., Teukolsky, S. A., Vetterling, W. T., & Flannery, B. P. (1988), *Numerical recipes in C*, Cambridge University Press

Self-Learning Material

1. Weller, D., and Chikkerur, S. (2010), 6.087 Practical Programming in C. January IAP 2010, Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-087-practical-programming-in-c-january-iap-2010/
2. Iyengar, S (2018) *The Joy of Computing using Python*, https://nptel.ac.in/courses/106/106/106106182/

**Students who successfully demonstrate the ability to implement concepts and numerical algorithms would be awarded the Satisfactory grade. Students should be able to complete all programming assignments.*