School of Electronics Engineering

M. Tech. – Embedded Systems

Curriculum and Syllabus

2023-24

VISION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

Transforming life through excellence in education and research.

MISSION STATEMENT OF VELLORE INSTITUTE OFTECHNOLOGY

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 andcompassion.

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 themto be lifelong learners to solve practical problems and to improve the quality of human life

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PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

The graduates of the programme will be able to

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

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PROGRAMME OUTCOMES (POs)

On completion of the Programme the students will have the

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

PO_02: 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_03: Having an ability to design and conduct experiments, as well as to analyse and interpret data, and synthesis of information

PO_04: Having an ability to use techniques, skills, resources and modern engineering and IT tools necessary for engineering practice

PO_05: Having problem solving ability- to assess social issues (societal, health, safety, legal and cultural) and engineering problems

PO_06: Having adaptive thinking and adaptability in relation to environmental context and sustainable development

PO_07: Having a clear understanding of professional and ethical responsibility

PO_08: Having a good cognitive load management skills related to project management and finance

Programme Specific Outcomes (PSOs)

On completion of M. Tech. Embedded Systems, graduates will be able to

PSO1. Apply the advanced concepts of Embedded System Design with real-time constraints using advanced Microcontrollers and FPGA based systems.

PSO2. Use the cutting-edge technologies in both hardware and software, to solve real- world multi-disciplinary problems and arrive at a viable solution.

PSO3. Independently carry out research on diverse Embedded System strategies to address practical problems and present a substantial technical report.

CREDIT INFO		
S.no	**Catagory**	**Credits**
1	Discipline Core	24
2	Discipline Elective	12
3	Projects and Internship	26
4	Open Elective	3
5	Skill Enhancement	5
Total Credits		70

Discipline Core									
sl.no	**Course Code**	**Course Title**	**Course Type**	**Version**	**L**	**T**	**P**	**J**	**Credits**
1	MEDS501L	Embedded System Design	Theory Only	1.0	3	0	0	0	3.0
2	MEDS502L	Microcontroller Architecture and Organization	Theory Only	1.0	3	0	0	0	3.0
3	MEDS502P	Microcontroller Architecture and Organization Lab	Lab Only	1.0	0	0	2	0	1.0
4	MEDS503L	Embedded Programming	Theory Only	1.0	3	0	0	0	3.0
5	MEDS503P	Embedded Programming Lab	Lab Only	1.0	0	0	2	0	1.0
6	MEDS504L	In Vehicle Networking	Theory Only	1.0	3	0	0	0	3.0
7	MEDS505L	Real Time Operating System	Theory Only	1.0	3	0	0	0	3.0
8	MEDS505P	Real Time Operating System Lab	Lab Only	1.0	0	0	2	0	1.0
9	MEDS506L	Wireless and Mobile Communication	Theory Only	1.0	3	0	0	0	3.0
10	MEDS507L	Electronic Hardware System Design	Theory Only	1.0	2	0	0	0	2.0
11	MEDS507P	Electronic Hardware System Design Lab	Lab Only	1.0	0	0	2	0	1.0

Discipline Elective									
sl.no	**Course Code**	**Course Title**	**Course Type**	**Version**	**L**	**T**	**P**	**J**	**Credits**
1	MEDS601L	Electromagnetic Interference and Compatibility	Theory Only	2.0	3	0	0	0	3.0
2	MEDS602L	Advanced Digital Image Processing	Theory Only	1.0	3	0	0	0	3.0
3	MEDS603L	Design and Analysis of Algorithms	Theory Only	1.0	3	0	0	0	3.0
4	MEDS605L	Hardware Software Co-design	Theory Only	1.0	2	0	0	0	2.0
5	MEDS606L	Modern Automotive Electronics Systems	Theory Only	1.0	3	0	0	0	3.0
6	MEDS608L	Intelligent IoT System Design and Architecture	Theory Only	1.0	2	0	0	0	2.0
7	MEDS608P	Intelligent IoT System Design and Architecture Lab	Lab Only	1.0	0	0	2	0	1.0
8	MEDS609L	Fault Tolerance and Dependable Systems	Theory Only	1.0	3	0	0	0	3.0
9	MEDS611L	Parallel Processing and Computing	Theory Only	1.0	3	0	0	0	3.0
10	MEDS613L	Cloud computing	Theory Only	1.0	3	0	0	0	3.0
11	MEDS614L	Cyber Physical Systems	Theory Only	1.0	3	0	0	0	3.0
12	MEDS614P	Cyber Physical Systems Lab	Lab Only	1.0	0	0	2	0	1.0
13	MEDS615L	5G and Future Generation Communication Systems	Theory Only	1.0	3	0	0	0	3.0
14	MEDS616L	Machine Learning and Deep Learning	Theory Only	1.0	3	0	0	0	3.0

Discipline Elective									
15	MVLD611L	Advanced Computer Architecture	Theory Only	1.0	3	0	0	0	3.0
16	MVLD613L	System Design with FPGA	Theory Only	1.0	3	0	0	0	3.0
17	MVLD616L	Scripting Language for Electronic Design Automation	Theory Only	1.0	3	0	0	0	3.0

Projects and Internship									
sl.no	Course Code	Course Title	Course Type	Version	L	T	P	J	Credits
1	MEDS696J	Study Oriented Project	Project	1.0	0	0	0	0	2.0
2	MEDS697J	Design Project	Project	1.0	0	0	0	0	2.0
3	MEDS698J	Internship I/ Dissertation I	Project	1.0	0	0	0	0	10.0
4	MEDS699J	Internship II/ Dissertation II	Project	1.0	0	0	0	0	12.0

Open Elective									
sl.no	Course Code	Course Title	Course Type	Version	L	T	P	J	Credits
1	MFRE501L	Francais Fonctionnel	Theory Only	1.0	3	0	0	0	3.0
2	MGER501L	Deutsch fuer Anfaenger	Theory Only	1.0	3	0	0	0	3.0
3	MSTS601L	Advanced Competitive Coding	Soft Skill	1.0	3	0	0	0	3.0

Skill Enhancement									
sl.no	Course Code	Course Title	Course Type	Version	L	T	P	J	Credits
1	MENG501P	Technical Report Writing	Lab Only	1.0	0	0	4	0	2.0
2	MSTS501P	Qualitative Skills Practice	Soft Skill	1.0	0	0	3	0	1.5
3	MSTS502P	Quantitative Skills Practice	Soft Skill	1.0	0	0	3	0	1.5

Course Code	Course Title	L	T	P	C
MEDS501L	Embedded System Design	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course aimed at

1. Ability to understand comprehensively the technologies and techniques underlying in building an embedded solution to a wearable, mobile and portable system.
2. Analyze UML diagrams and advanced Modelling schemes for different use cases.
3. Understand the building process of embedded systems

Course Outcome

The students will be able to

1. Define an embedded system and compare with general purpose system.
2. Appreciate the methods adapted for the development of a typical embedded system.
3. Get introduced to RTOS and related mechanisms.
4. Classify types of processors and memory architecture
5. Differentiate the features of components and networks in embedded systems
6. Develop real-time working prototypes of different small-scale and medium-scale embedded Systems.
7. Apprehend the various concepts in Multi-Tasking

Module:1	**Introduction to Embedded System**	**5 hours**
Embedded system processor, hardware unit, software embedded into a system, Example of an embedded system, Embedded Design life cycle, Layers of Embedded Systems.		
Module:2	**Embedded System Design Methodologies**	**5 hours**
Embedded System modelling [FSM, SysML, MARTE], UML as Design tool, UML notation, Requirement Analysis and Use case Modelling, Design Examples		
Module:3	**Building Process For Embedded Systems**	**4 hours**
Preprocessing, Compiling, Cross Compiling, Linking, Locating, Compiler Driver, Linker Map Files, Linker Scripts and scatter loading, Loading on the target, Embedded File System.		
Module:4	**System design using general purpose processor**	**7 hours**
Microcontroller architectures (RISC, CISC), Embedded Memory, Strategic selection of processor and memory, Memory Devices and their Characteristics, Cache Memory and Various mapping techniques, DMA.		
Module:5	**Component Interfacing & Networks**	**9 hours**
Memory Interfacing, I/O Device Interfacing, Interrupt Controllers, Networks for Embedded systems- USB, PCI,PCI Express, UART, SPI, I2C, CAN, Wireless Applications - Bluetooth, Zigbee,Wi-Fi.,6LoWPAN , Evolution of Internet of things (IoT).		
Module:6	**Operating Systems**	**7 hours**
Introduction to Operating Systems, Basic Features & Functions of an Operating System, Kernel & its Features [polled loop system, interrupt driven system, multi rate system], Processes/Task and its states, Process/Task Control Block, Threads, Scheduler, Dispatcher.		
Module:7	**Multi Tasking**	**6 hours**
Context Switching , Scheduling and various Scheduling algorithms, Inter-process Communication (Shared Memory, Mail Box, Message Queue), Inter Task Synchronization (Semaphore, Mutex), Dead Lock, Priority Inversion (bounded and unbounded), Priority Ceiling Protocol & Priority Inheritance Protocol		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)			
1.	Raj Kamal, “Embedded systems Architecture, Programming and Design”, Tata McGraw- Hill, 2016.		
2.	Wayne Wolf “Computers as components: Principles of Embedded Computing System Design”, The Morgan Kaufmann Series in Computer Architecture and Design, 2013.		
Reference Books			
1.	Lyla B. Das," Embedded Systems an Integrated Approach", Pearson Education, 2013.		
2.	Shibu K V," Introduction to Embedded Systems", McGraw Hill Education(India) Private Limited, 2014		
3.	Sriram V Iyer, Pankaj Gupta " Embedded Real Time Systems Programming", Tata McGraw- Hill, 2012		
4.	Steve Heath, “Embedded Systems Design”, EDN Series, 2013.		
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS502L	Microcontroller Architecture and Organization	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course aimed at

1. Describing the architecture of 8051 microcontroller and ARM processor
2. Teaching the instruction set of 8051 and ARM microcontroller to efficient programs
3. Designing system in block level using microcontroller, memory devices, buses and other peripheral devices
4. Solving real life problem using microcontroller-based systems

Course Outcome

At the end of the course, the students will be able to

1. Describe the architectures of processors
2. Develop Assembly program applying Digital logic and mathematics using 8051
3. Develop Assembly Language Program for ARM
4. Develop ALP with minimum instructions and memory.
5. Analyze and evaluate the given program in terms of code size and computational time
6. Design Microcontroller based system within realistic constraint like user specification, availability of components etc
7. Solve real life problem and construct a complete system as a solution

Module:1	**Introduction to Microcontrollers**	**5 hours**
Microprocessors Vs Microcontrollers; Classification – bits, memory architecture, ISA; Little Endian Vs Big Endian.		
Module:2	**8051 Microcontroller**	**6 hours**
Architecture – Timers, Interrupts, Register Architecture (banks), PSW register, Memory architecture; Instruction set.		
Module:3	**8051 Programming and Interfaces**	**8 hours**
Programming in C & Assembly for – Interrupts, Timers and Interfaces – PORTS, LED, ADC, SENSORS, LCD, DAC, Serial Communication		
Module:4	**ARM Architecture**	**4 hours**
ARM Design Philosophy; Overview of ARM architecture; States [ARM, Thumb, Jazelle]; Registers, Modes; Conditional Execution; Pipelining; Vector Tables; Exception handling.		
Module:5	**ARM Instruction Set**	**6 hours**
ARM Instruction- data processing instructions, branch instructions, load store instructions, SWI instruction, Loading instructions, conditional Execution, Assembly Programming.		
Module:6	**Thumb Instruction Set**	**6 hours**
Thumb Instruction-Thumb Registers, ARM Thumb interworking, branch instruction, data processing instruction, single/multiple load store instruction, Stack instruction, SWI instruction, Assembly Programming.		
Module:7	**ARM Core based Microcontroller**	**8 hours**
Architecture of LPC214X, Memory Addressing, IO ports, Timers/counter, Watch Dog Timer, PWM, ADC/DAC, UART, Interrupts, Displays, C programming.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Andrew N.Sloss, Dominic Symes, Chris Wright, ARM Developer's Guide, 2010, 1st Edition, Elsevier, United States

2.	Kenneth Ayala, The 8051 Microcontroller & Embedded Systems Using Assembly and C, 2010, 1st edition, Cengage Learning, United States		
Reference Books			
1. 2.	Steve Furber ARM System on Chip Architecture, 2010, 2nd Edition, Addison Wesley, United States Technical Reference Manual CORTEX M-3, ARM, 2010, United States		
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS502P	Microcontroller Architecture and Organization Lab	0	0	2	1
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at

1. Describing the architecture of 8051 microcontroller and ARM processor
2. Teaching the instruction set of 8051 and ARM microcontroller to efficient programs
3. Designing system in block level using microcontroller, memory devices, buses and other peripheral devices
4. Solving real life problem using microcontroller-based systems

Course Outcome

At the end of the course the students will be able to

1. Develop Assembly program applying Digital logic and mathematics using 8051
2. Develop Assembly Language Program for ARM and ARM peripherals
3. Develop ALP with minimum instructions and memory.
4. Analyze and evaluate the given program in terms of code size and computational time

Indicative Experiments

1	Task-1: Calculator Application Sub task 1: Make the LCD interfaced to 8051 Sub task 2: Get input from switch which is interfaced to 8051 and display it on LCD Sub task 3: Based on switch input, perform basic operation of a Calculator	7 hours
2	Task-2: Speed control of motor Sub task-1: Use timer and generate an exact time delay for T_{ON} and TOFF Sub task-2: Use timer interrupt in generating the waveform Sub tast-3: Controlling speed of a DC motor using Timer	7 hours
3	Task-3: Microcontroller based application Sub task-1: Interface Zigbee with 8051 Sub Task-2: Interface keypad with 8051 Sub Task-3: Interface GSM with 8051 Sub task-4: Based on KEY pressed in keypad, transmit the key info Via Zigbee and make a motor to rotate, which is interfaced with 8051. Using GSM module send the status of motor[run/stop] to the user.	8 hours
4	Task-4: Sensor interfacing with ARM LPC2148 Sub Task-1: Interface IR with LPC2148 Sub Task-2: Interface temperature sensor with LPC2148 Sub Task-3: Interface Bluetooth with LPC2148 Sub Task-4: Transmit the IR detail and sensor data to another LPC2148 via Bluetooth.	8 hours
	Total Laboratory Hours	**30 hours**

Mode of Assessment: Continuous Assessment and Final Assessment Test

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS503L	Embedded Programming	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed

1. To acquaint students with fundamentals of C
2. To familiarize the students with data structures
3. To introduce the students with SHELL programming and Linux
4. To Implement the Device drivers in LINUX environment

Course Outcome

At the end of the course the students will be able to

1. Comprehend the fundamentals of C
2. Comprehend the Data structures
3. Comprehend the basics of Linux
4. Showcase the skill, knowledge and ability of SHELL programming.
5. Exhibit the working knowledge of basic Embedded Linux
6. Comprehend the concepts of Kernel module Programming
7. Write Device driver programs
8. Have hands on experience in using state-of- art hardware and software tools

Module:1	**C Language**	**7 hours**
Basic concepts of C, Embedded C Vs C, Embedded programming aspects with respect to firmware and OS Functions, Arrays, pointers, structures and Inputs/Outputs.		
Module:2	**Data structures of kernel programming**	**6 hours**
Linked list, Single linked list, Double linked list and Queues.		
Module:3	**Linux**	**6 hours**
Command prompt, X windows basics, Navigating file system, finding files, working with folders, reading files text editing in Linux, Compression and archiving tools, Basic shell commands, File Management, I/O Handling, File Locking.		
Module:4	**Shell Programming**	**7 hours**
Processes, giving more than one command at a time, prioritizing and killing processes, Scheduling Commands, pipes and redirection, regular expression, pattern matching, Scripting using for while, if and other commands.		
Module:5	**Embedded Linux**	**6 hours**
Linux Basics, Booting process, make files , using SD card and reader to transfer programs, Introduction to LINUX system calls, API's, device drivers, compiling and installing a device driver.		
Module:6	**Kernel Module Programming**	**6 hours**
Compiling kernel, Configuring Kernel and compilation, Kernel code, browsers.-Static linking, dynamic linking of modules, User space, kernel space concepts, Writing simple modules – Writing, Make-files for modules.		
Module:7	**Device Driver concepts**	**5 hours**
Driver concepts, Block & character driver distinction, Low level drivers, OS drivers etc, Writing character drivers, Device major, minor number.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Neil Mathew, Richard stones, Beginning Linux Programming, 2012 reprint, Wrox – Wiley Publishing, USA.

2.	Eric Foster Johnson, John C. Welch, Micah Anderson, Beginning shell scripting, 2012, reprint, Wrox – Wiley Publishing, USA		
Reference Books			
1.	Derek Molloy, Exploring Beagle Bone: Tools and Techniques for Building with Embedded Linux, 2015, 1st Edition, Wiley Publications, USA		
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS503P	Embedded Programming Lab	0	0	2	1
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed

1. To acquaint students with fundamentals of C
2. To familiarize the students with data structures
3. To introduce the students with SHELL programming and Linux
4. To Implement the Device drivers in LINUX environment

Course Outcome

At the end of the course the students will be able to

1. Comprehend the fundamentals of C
2. Comprehend the Data structures
3. Comprehend the basics of Linux
4. Showcase the skill, knowledge and ability of SHELL programming.
5. Exhibit the working knowledge of basic Embedded Linux
6. Comprehend the concepts of Kernel module Programming
7. Write Device driver programs
8. Have hands on experience in using state-of- art hardware and software tools

Indicative Experiments

1.	Task1: C programming • Implement a binary tree sorting • Implement a dice throw game Implement a command line argument based application of automation	6 hours
2.	Task2: Implementation of data structure for an application Write a SortedMerge() function that takes two lists, each of which is sorted in increasing order, and merges the two together into one list which is in increasing order. SortedMerge() should return the new list. The new list should be made by splicing together the nodes of the first two lists.	6 hours
3.	Task3: Shell Programming Development of inventory management system using Shell scripting with the following features • User may add/update/delete inventory. • User may add/update inventory details. • Details include cost, quantity and description. Includes forms for inventory inwards and outwards.	6 hours
4.	Task4: Build process for an embedded board Build a kernel for a Beagle Bone Black (BBB) board and board bring up, kernel module program on an embedded board	6 hours
5.	Task5: Device driver programming –Implementation of Device Driver	6 hours
	Total Laboratory Hours	**30 hours**

Mode of Assessment: Continuous Assessment and Final Assessment Test

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS504L	In Vehicle Networking	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course aimed at

1. Providing students, a working knowledge of in-vehicle network systems
2. Giving exposure to aspects of design, development, application and performance issues associated with in vehicle networking systems.
3. Illustrating concepts of sensor data capture, storage and exchange of data to access remote services

Course Outcomes

The students will be able to

1. Know the need for In Vehicle Networking and the basics of data communication and networking concepts.
2. Comprehend the general protocols, CAN and their usage in automotive sector.
3. Have an overview of the CAN higher layer protocols like CAN open, Device Net, TTCAN and SAE J1939.
4. Understand the working mechanism of LIN protocol.
5. Get an overview of MOST protocol used in automotive for multimedia applications.
6. Comprehend protocols like FlexRay used in automotive for fault tolerant applications.

Module:1	**Concepts of In-vehicle networking**	**6 hours**
Overview of Data communication and networking–need for In-Vehicle networking–layers of OSI reference model–multiplexing and de-multiplexing concepts–vehicle buses.		
Module:2	**General purpose protocols**	**7 hours**
Overview of general-purpose networks and protocols –Ethernet, TCP, UDP, IP, WiFi, Bluetooth, NFC		
Module:3	**Networks and protocols**	**8 hours**
CAN protocol: principles of data exchange–real time data transmission–message frame formats, bit encoding–bit-timing and synchronization–data rate and bus length–network topology–bus access– physical layer standards.		
Module:4	**CAN higher layer protocol**	**6 hours**
Introduction to CAN open –Device net–TTCAN–SAEJ1939–overview of CAN open and applications in transportation electronics–CAN open standards.		
Module:5	**LIN protocol**	**5 hours**
LIN standard overview – applications – LIN communication concept message frame–development flow.		
Module:6	**MOST**	**5 hours**
MOST overview–data rates–data types–topology –application areas.		
Module:7	**FlexRay**	**6 hours**
Flex Ray introduction–network topology–ECU sand bus interfaces–controller host interface and protocol operation controls–media access control and frame and		

symbol processing–coding/decoding unit–Flex Ray scheduling–message processing– wakeup/startup–applications.				
Module:8	**Contemporary Topics**			**2 hours**
Guest Lectures from Industry and, Research and Development Organizations				
	Total Lecture hours:			**45 hours**
Text Book(s)				
1.	Dominique Paret, Multiplexed Networks for Embedded Systems CAN, LIN, FlexRay, Safeby-Wire, 2014, 1st edition, Wiley, United States.			
Reference Books				
1.	Chung Ming Huang, YuhShyan Chen, Telematics Communication Technologies and Vehicular Networks: Wireless Architectures and Application, 2010, 1st edition, Information Science Reference, United States.			
2.	Ronald K Jurgen, Distributed Automotive Embedded Systems, 2010, 4th Edition, SAE International, United States.			
3.	Richard Zurawski, Industrial Communication Technology Handbook, 2015, 2nd Edition, CRC press, United States.			
4.	KonradReif, Automotive Mechatronics: Automotive Networking, Driving Stability Systems Electronics, 2015, 2nd Edition, Springer, United States.			
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test				
Recommended by Board of Studies	07-06-2023			
Approved by Academic Council	No. 70	Date	24-06-2023	

Course Code	Course Title	L	T	P	C
MEDS505L	Real Time Operating System	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at

1. Introducing the students about Operating Systems and acquainting students to Real Time Operating Systems
2. Teaching the students about Task Management and Enabling students to understand RTOS Scheduling
3. Introducing the students about interprocess communication and Memory Management

Course Outcome

At the end of the course the will should be able to

1. Comprehend the basic components of an operating system
2. Learn about the basics of real-time concepts
3. Acquire knowledge about task management
4. Acquaint with RTOS scheduling
5. Learn about IPC synchronization
6. Learn about IPC data exchange
7. Perform memory management in RTOS
8. Apply the knowledge for developing practical applications of modern real-time systems.

Module:1	**Introduction to Operating Systems**	**6 hours**
Layers of Operating Systems, Operating systems functions, System Boot up - BIOS & Boot Process, Kernel – Monolithic and Microkernel		
Module:2	**Real Time Operating Systems**	**7 hours**
Tradeoffs for RTOS, POSIX		
Module:3	**Task Management**	**7 hours**
Process and Threads, Process Control Block, Process Attributes, POSIX Threads		
Module:4	**RTOS Scheduling**	**7 hours**
Priority based scheduling, Rate-Monotonic scheduling, Earliest Deadline first scheduling, Linux RT scheduler.		
Module:5	**IPC - Synchronization**	**7 hours**
IPC, Race conditions and critical sections, Signals, Atomic operations, Semaphore, Mutex, Spinlock, Priority Inversion and Priority ceiling.		
Module:6	**IPC – Data Exchange**	**7 hours**
Shared memory, FIFO, Messages and Mailbox, Circular and swinging buffers, RPC		
Module:7	**Memory Management**	**2 hours**
Memory Management, shared memory		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Herma K., Real Time Systems, Design for distributed Embedded Applications, 2011, 2nd edition, Springer, USA.
2.	Tanenbaum, Andrew, Modern Operating Systems, 2015, 4th ed.,, Pearson Prentice Hall, USA

Reference Books

1.	Ivan CibrarioBertolotti, Politecnico di Torino and Gabriele Manduchi, Real-Time Embedded Systems: Open-Source Operating Systems Perspective, 2012, 1st ed., CRC Press, USA

2.	Lyla B. Das, Embedded Systems an Integrated Approach, 2012, 1st ed., Pearson Education, India.		
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS505P	Real Time Operating System Lab	0	0	2	1
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at

1. Introducing the students about Operating Systems and acquainting students to Real Time Operating Systems
2. Teaching the students about Task Management and Enabling students to understand RTOS Scheduling
3. Introducing the students about interprocess communication and Memory Management

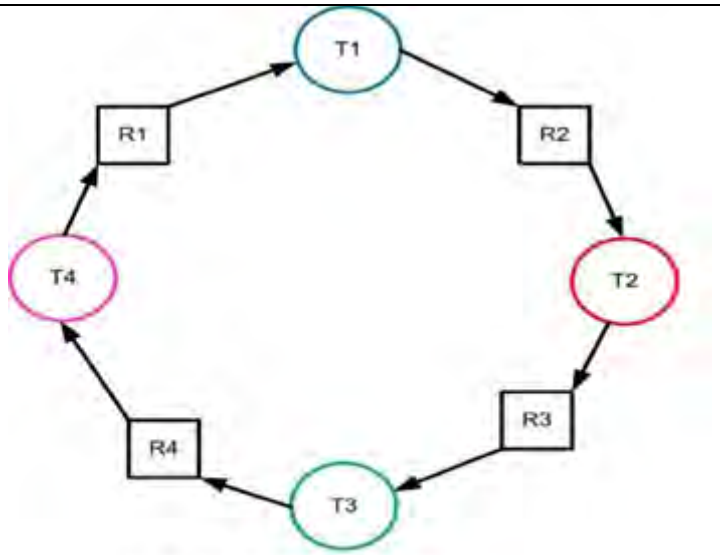
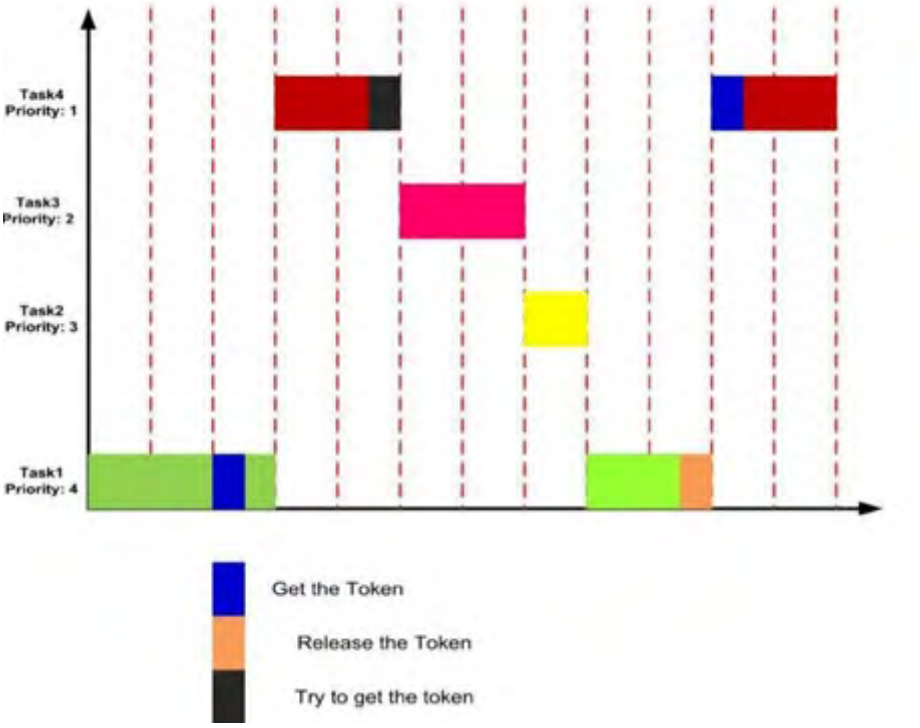
Course Outcome

At the end of the course the will should be able to

1. Comprehend the basic components of an operating system
2. Learn about the basics of real-time concepts
3. Acquire knowledge about task management
4. Acquaint with RTOS scheduling
5. Learn about IPC synchronization
6. Learn about IPC data exchange
7. Perform memory management in RTOS
8. Apply the knowledge for developing practical applications of modern real-time systems.

Indicative Experiments

1.	Write a C code for a simple calculator (+, -, *, /) using functional pointer as argument in a function int add (int x, int y) int sub (int x, int y) intmul (int x, int y) int div (int x, int y) int (*mathop)(int, int) intdomath(int (*mathop)(int , int), int x, int y)	6 hours
2.	Write a program to create multiple threads carrying out different functions. Thread 1: Accepting a string from the user. Thread 2: Display the string in upper case. Thread 3: Count the number of vowels in the string Thread 4: Count the number of special characters in the string.	6 hours
3.	Write a program to create three threads, which are implemented using function pointers. First thread is for getting a list of numbers from the keyboard, second thread is helpful to extract the ODD and EVEN list from the given list, and the third one is used to arrange the ODD and EVEN list of numbers in an order. Use Mutex semaphore. Note: First Thread for getting input data from keyboard. Second Thread to identify the ODD and EVEN list Third Thread to get descending ordered ODD list Fourth Thread to get ascending ordered EVEN list Input data: 56, 23, 12, 64, 87, 02, 45, 88, 35, 67.	6 hours
4.	Write a Vx Works code for the given scenario. Also identify the proper mechanism to avoid this problem.	6 hours

	 • T1, T2, T3 and T4 → Tasks • R1, R2, R3 and R4 → Resources	
5.	Write a VxWorks code for the given scenario. Also identify the proper mechanism to avoid this problem. 	6 hours
	Total Laboratory Hours	**30 hours**
Mode of Assessment: Continuous Assessment and Final Assessment Test		
Recommended by Board of Studies	28-07-2022	
Approved by Academic Council	No. 67	Date 08-08-2022

Course Code	Course Title	L	T	P	C
MEDS506L	Wireless and Mobile Communication	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course aimed at

1. To know about wireless mobile communication system & related issues, and
2. To keep abreast of the future of mobile communication

Course Outcome

The students will be able to

1. Get introduced Cellular Mobile Communication systems
2. Understand and solve telecommunication design issues using cellular and trunking theory.
3. Analyze the effect of multipath channels and suggest a suitable model for indoor or outdoor applications.
4. Demonstrate the implications of multipath parameters in mobile communication.
5. Will train the Channel coding for Mobile Radio
6. Interpret the Modulation techniques for Mobile Radio
7. Get introduced to Advanced Communication Systems and Wireless Standards

Module:1	**Cellular Mobile Systems**	**4 hours**
Cellular Mobile Communication Evolution - Types of mobile wireless services/systems – 1G & 2G Mobile Communication Technology		
Module:2	**Cellular Concept**	**7 hours**
Cellular concept – Frequency reuse – Channel assignment strategies – Handoff strategies – Interference & system capacity – Trunking & Grade of service – Improving coverage and capacity in cellular system.		
Module:3	**Mobile Radio Propagation**	**9 hours**
Free Space Propagation Model – Basic Propagation mechanism – Two Ray Ground Reflection (Two Ray) model – Outdoor Propagation Models: Okumura Model, Hata Model – Indoor Propagation Model: Attenuation Factor Model.		
Module:4	**Small Scale Propagation models**	**4 hours**
Parameters of mobile multipath channels – Types of small scale fading – Fading effects due to Multipath time delay spread and Doppler spread		
Module:5	**Information Theory and Coding**	**6 hours**
Information and entropy - Coding of memoryless sources: Shannon-Fano / Huffman coding - Sources with memory: Markov model – Source Coding: Linear and non-linear quantisation, companding - Channel Coding: Convolutional coding, Viterbi decoding, LBC, Turbo Codes.		
Module:6	**Multiplexing & Modulation Schemes**	**6 hours**
Shared memory, FIFO, Messages and Mailbox, Circular and swinging buffers, RPC		
Module:7	**Advanced Communication Systems and Wireless Standards**	**7 hours**
3G, 4G and 5G and beyond wireless standards – WLAN Architecture design and WIMAX – VANETS		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Randy L. Haupt, Wireless Communications Systems: An Introduction, Wiley-IEEE Press, January 2020.
2.	T.S.Rappaport, Wireless Communication -Principle and Practice ,Prentice Hall, 2010.

Reference Books

1.	W.C.Y.Lee, Wireless and Cellular Communication, McGraw Hill, 2006		
2.	Schiller, Mobile Communications; Pearson Education Asia Ltd., 2008		
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS507L	Electronic Hardware System Design	2	0	0	2
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at

1. Emphasing students the significant role of FPGA in System design and development.
2. Teaching the students to develop program using Hardware Descriptive Language and model digital logic combinational and sequential circuits.
3. Enabling the students acquire knowledge in Interfacing peripherals, Board Design, Packaging, PCB Design and Analysis
4. Motivating students to solve real life problem using FPGA based systems.

Course Outcome

At the end of the course the student will be able to

1. Comprehend the architecture of FPGA and design flow
2. Understand Hardware Description Language
3. Design and develop combinational logic circuits using Verilog and VHDL program.
4. Design and develop sequential logic circuits using Verilog and VHDL program.
5. Interface peripherals with FPGA.
6. Design the PCB
7. Design FPGA based system
8. Comprehend upcoming trends in FPGA.

Module:1	**Programmable Logic Devices & FPGAs**	**4 hours**

Introduction to FPGAs, FPGA technologies, FPGA Architectures [Xilinx, Altera, ACTEL, LATTICE], FPGA Design Flow Prototyping with Xilinx FPGAs, FPGA based Testing.

Module:2	**Hardware Descriptive Language (Verilog/VHDL)**	**3 hours**

Cellular concept – Frequency reuse – Channel assignment strategies – Handoff strategies – Interference & system capacity – Trunking & Grade of service – Improving coverage and capacity in cellular system.

Module:3	**Modeling of Combinational logic circuits**	**3 hours**

Free Space Propagation Model – Basic Propagation mechanism – Two Ray Ground Reflection (Two Ray) model – Outdoor Propagation Models: Okumura Model, Hata Model – Indoor Propagation Model: Attenuation Factor Model.

Module:4	**Modeling of Sequential logic circuits**	**4 hours**

Flip Flops-Realization of Shift Register -Realization of a Counter-Synchronous and Asynchronous – BCD counter, Mealy and Moore State Machines, Sequence detector, FIFO, Memory Design, Serial Data Receiver, Serial to parallel data converter.

Module:5	**Interfacing peripherals and Board Design**	**5 hours**

Interfacing to 7 segment display, Stepper Motor, ADC and Sensors, FPGA System Architecture, Constraints –Logical –Electrical -Physical, Power distribution for FPGAs, Clock design, I/O buses

Module:6	**Introduction to Packaging &PCB Design**	**4 hours**

Physical integration of circuits, packages, boards and full electronic systems - Package classifications (Through hole and SMDs) and packaging trends, Hierarchy of Interconnection Levels -Signal integrity - The PCB Design Process - Defining the Layout Cross Section - Design Rules Checking - Working with Properties & Constraints- PCB Electrical Design Consideration - Design tips for Placement / Fan-out and Wiring - Multi - Layer Design Issues.

Module:7	**High Speed PCB design and Analysis Wireless Standards**	**5 hours**

High speed PCB design -EMI/EMC analysis - Thermal management of electronic devices and systems -Thermal interface material, Cooling mechanisms-System level design of electronic hardware for automotive applications -System level testing and validation of

automotive electronics systems for reliability. Layout constraints for FPGAs, FPGA-based PCB schematics.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**30 hours**

Text Book(s)	
1.	Simon Monk, Make Your Own PCBs with EAGLE: From Schematic Designs to Finished Boards, 2014, First Edition, McGraw Hill Education, India.
2.	Wayne Wolf, FPGA-based System Design, 2011, Re-Print, Prentice Hall, India
Reference Books	
1.	Clyde Coombs, Printed Circuits Handbook, 2011, Sixth Edition, McGraw Hill Professional, USA
2.	Ian Grout, Digital Systems, Design with FPGAs and CPLDs, 2012, Re-Print, Newness, UK.
3.	Ronald R. Sass and Andrew Schmidt, Embedded Systems Design with Platform FPGAs: Principles and Practices, 2010, First Edition, Morgan Kaufman Publishers, USA.

Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS507P	Electronic Hardware System Design Lab	0	0	2	1
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at

1. Emphasing students the significant role of FPGA in System design and development.
2. Teaching the students to develop program using Hardware Descriptive Language and model digital logic combinational and sequential circuits.
3. Enabling the students acquire knowledge in Interfacing peripherals, Board Design, Packaging, PCB Design and Analysis
4. Motivating students to solve real life problem using FPGA based systems.

Course Outcome

At the end of the course the student will be able to

1. Understand Hardware Description Language
2. Design and develop combinational logic circuits using Verilog and VHDL program.
3. Design and develop sequential logic circuits using Verilog and VHDL program.
4. Interface peripherals with FPGA.

Indicative Experiments

1.	Task 1: Combination Logic:- Design a 16-bit microprocessor that is capable of performing both logical and arithmetic operation.	8 hours
2.	Task 2: Sequential Logic:- Design a controller for vending machine which sells candy bars for Rs 5, 10 and 20.	8 hours
3.	Task 3: Peripheral Interfacing:- Design a car speed monitor using the following components (a) 7 segment display (b) LEDs (c) Switches for speed selection and (d) Buzzer. The cars electronic speedometer provides a clock signal whose frequency is proportional to the speed. To check the functioning of the design use function generator to provide the speedometer clock.	8 hours
4.	Task 4:PCB Design:- Design a PCB for a circuit with a mixture of analog and digital parts, multiple power planes, and a single Ground plane split into analog and digital sections that have a common reference point using open source tool.	6 hours
	Total Laboratory Hours	**30 hours**

Mode of Assessment: Continuous Assessment and Final Assessment Test

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS601L	Electromagnetic Interference and Compatibility	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at:

1. Imparting knowledge about EMI environment
2. Teaching EMI coupling principles, EMI control techniques and design of PCBs for EMC
3. Giving exposure to EMI Standards, Regulations and Measurements

Course Outcomes

At the end of the course, the student will be able to

1. Understand terminologies of EMI and EMC
2. Analyze and understand various EMI coupling mechanisms
3. List various EMI Test and Measurement methods
4. Analyze various techniques needed to suppress EMI
5. Perceive different EMC regulations followed worldwide
6. Ability to design an Electromagnetic Compatible systems.
7. Analyze and comprehend different techniques needed for Signal Integrity and ability to understand various models for EMI/EMC

Module:1	EMI Environment	4 hours

EMI-EMC Definitions and units of Parameters, Sources of EMI, conducted and radiated EMI, Transient EMI

Module:2	EMI Coupling Mechanisms	6 hours

Conducted, Radiated and Transient Coupling, Common Impedance Ground Coupling, Radiated Common Mode and Ground Loop Coupling, Radiated Differential Mode Coupling, Near Field Cable to Cable Coupling, Power Mains and Power Supply Coupling.

Module:3	EMI Test and Measurements	8 hours

EMI Specification / Standards / Limits: Units of specifications, Civilian standards Military standards. EMI Test Instruments / Systems, EMI Test, EMI Shielded Chamber, Open Area Test Site, TEM Cell Antennas, Conductors Sensors/Injectors/Couplers. EMI Measurement Methods: Military Test Method and Procedures, Calibration Procedures, Modeling interferences

Module:4	EMI Control Techniques	7 hours

Shielding, Filtering, Grounding, Bonding, Isolation Transformer, Transient Suppressors, Cable Routing, Signal Control, Component Selection and Mounting, Electrostatic discharge protection schemes

Module:5	EMC Standards and Regulations	5 hours

National and Intentional standardizing organizations- FCC, CISPR, ANSI, DOD, IEC, CENEEC, FCC CE and RE standards, CISPR, CE and RE Standards, IEC/EN, CS standards, SAE Automotive EMC standard, Frequency assignment - spectrum conversation.

Module:6	System Design for EMC	8 hours

PCB Traces Cross Talk, Impedance Control, Power Distribution Decoupling, Zoning, Motherboard Designs and Propagation Delay Performance Models,

System Enclosures, Power line filter placement, Interconnection and Number of Printed Circuit Boards, PCB and subsystem decoupling		
Module:7	**Signal Integrity and EMI/EMC Models**	**5 hours**
Effect of terminations on line wave forms, Matching schemes for Signal Integrity, Effects of line discontinuities, Statistical EMI/EMC models.		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lectures from Industry and, Research and Development Organizations		
	Total Lecture hours:	**30 hours**
Text Book(s)		
1.	Clayton R. Paul,IntroductiontoElectromagneticcompatibility,2010, 2nd edition., Wiley & Sons, New Jersey	
Reference Books		
1.	HenryW.ott, Electromagnetic Compatibility Engineering, 2011, 1sted. John Wiley and Sons, NewJersey.	
2.	Patrick G. André and Kenneth Wyatt, EMI Troubleshooting Cookbook for Product Designers 2014, 1st ed., SciTech Publishing, New Jersey	
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test		
Recommended by Board of Studies	07-06-2023	
Approved by Academic Council	No. 70	Date 24-06-2023

Course Code	Course Title	L	T	P	C
MEDS602L	Advanced Digital Image Processing	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at:

1. Revising the basics of digital image processing namely; image acquisition, digitizing, enhancing images in spatial domain, image transforms and enhancing images in frequency domain.
2. Enabling the students to acquire knowledge in image restoration, image compression, image segmentation and object recognition.
3. Motivating the students to apply image processing and classification algorithms for solving real life problems and introducing students to upcoming trends in Computer Vision.

Course Outcome

At the end of the course, the student will be able to

1. Comprehend the image acquisition, digitization, and processing in spatial domain.
2. Understand algorithms and programs for processing an image in transform domain
3. Acquaint with the image enhancement and restoration techniques
4. Implement different compression techniques to compress an image
5. Adopt different segmentation and image representation techniques for image processing.
6. Understand the pattern recognition approaches for implementing the visual system.
7. Identify computer vision techniques in various real-time applications.

Module:1	Image Processing in Spatial Domain	7 hours

Fundamental steps in DIP – Elements of visual perception - Image Sampling and Quantization - Basic relationship between pixels. Image enhancement - Spatial Domain: Basic Grey level Transformations – Histogram Processing – Smoothing spatial filters- Sharpening spatial filters.
Colour image Processing: Models, Transformation

Module:2	Image Transforms	6 hours

Image Transforms: Two dimensional Fourier Transform- Discrete cosine transform - Multi-resolution analysis – Haar Transform- Discrete Wavelet Transform. Karhunen – Loeve transform. and SVD

Module:3	Frequency domain filtering and Image Restoration	6 hours

Smoothing frequency domain filters- sharpening frequency domain filters- Homomorphic filtering.
Image Restoration: Image deformation and geometric transformations, Restoration techniques, Noise characterization, Linear, Position invariant degradations, Adaptive filters.

Module:4	Image Compression	6 hours

Image Compression Techniques - Lossy and Lossless compression- Entropy Encoding- JPEG and MPEG standards

Module:5	Image Segmentation	7 hours

Detection of discontinuities – point, corner, edge detection- thresholding -edge based segmentation-region based segmentation- morphological segmentation - watershed algorithm Descriptors: Boundary descriptors-Region descriptors- Texture descriptors, RANSAC.

Module:6	Recognition and Classification	7 hours

Patterns and pattern classes – Introduction to classification – Decision theoretic methods –

structural and syntactic classifiers – Clustering techniques – similarity measures – hierarchical methods – K-Means algorithm – Cluster evaluation methods. Convolution neural networks, Region-based CNN, fully convolution networks, Multi-modal networks, Hybrid learning methods.		
Module:7	**Computer Vision Applications**	**4 hours**
Face recognition application: personal photo collections – Instance recognition application : Location recognition – Machine learning applications: Deep voting, transfer learning and structured regression for image analysis and categorization.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Rafael C. Gonzalez & Richard E. Woods, "Digital Image Processing", 4th Edition, 2018, Pearson, USA
2.	David A. Forsyth and Jean Ponce, "Computer Vision: A Modern Approach", 2ndEdition, 2012, Prentice Hall, Pearson Education
Reference Books	
1.	Richard Szeliski, "Computer vision: Algorithm and Applications", Springer- Verlag, London, 2010.
2.	K. Jain, Fundamentals of Digital Image Processing, 2015, 3rd Edition, Pearson Education, USA.
3.	K.P.Soman, K.I. Ramchandran, N.G.Resmi, Insights into Wavelets, From Theory to Practice, 2013, 3rd Edition, PHI Learning Private Limited, New Delhi, India.
4.	Mark Nixon & Alberto Aguado, Feature Extraction, and Image Processing, 2013, 3rd Edition, Elsevier's Science & Technology Publications, USA
5.	William K. Pratt, Digital Image Processing, 2013, John Wiley & Sons, USA.

Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS603L	Design and Analysis of Algorithms	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

This course is aimed at

1. Enabling the students to carry out analysis of various algorithms for mainly time and space complexity.
2. Teaching the students how to decide the appropriate data type and data structure for a given problem.
3. Teaching the students how to select the best algorithm to solve a problem by considering various problem characteristics, such as the data size, the type of operations, etc.

Course Outcome

At the end of the course the student will be able to

1. Develop proficiency in problem solving and programming.
2. Comprehend Combinatorial Optimization
3. Analyse various algorithms for mainly time and space complexity.
4. Comprehend Cryptographic Algorithms
5. Learn Geometric Algorithms
6. Analyse Parallel Algorithms
7. Analyse and evaluate the given program in terms of code size and computational time.
8. Select the best algorithm to solve a problem by considering various problem characteristics, such as the data size, the type of operations, etc.

Module:1	**Introduction**	**7 hours**
Role of Algorithms in computing, Analysis of Algorithms, Asymptotic notation, Euclid's algorithm, Problem, Instance, RAM model, Principles of Algorithm Design, Sorting Algorithm - Insertion Sort & Complexity Analysis, Divide and Conquer Technique, Solving recurrences - substitution, Iteration, Recursion tree, Changing variable and Master's Method.		
Module:2	**Combinatorial Optimization**	**5 hours**
Backtracking; Dynamic programming; Greedy Technique ; Branch & Bound		
Module:3	**Advanced Algorithmic Analysis**	**5 hours**
Amortized analysis; Online and offline algorithms; Randomized algorithms, NP Completeness		
Module:4	**Cryptographic Algorithms**	**9 hours**
Historical overview of cryptography; Private-key cryptography and the key-exchange problem; Public-key cryptography; Digital signatures; Security protocols; Applications (zero-knowledge proofs, authentication etc..		
Module:5	**Geometric Algorithms**	**7 hours**
Line segments: properties, intersections; convex hull finding algorithms, Voronoi Diagram, Delaunay Triangulation		
Module:6	**Parallel Algorithms**	**5 hours**
PRAM model; Exclusive versus concurrent reads and writes; Pointer jumping; Brent's theorem and work efficiency .		
Module:7	**RNNs, Auto encoders and GANs**	**5 hours**
Consensus and election; Termination detection; Fault tolerance; Stabilization;		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Anany Levitin, “Introduction to the Design and Analysis of Algorithms”. 3rd edition.,2011, Addison Wesley , 2011			
2.	Cormen, Leiserson, Rivest and Stein , “Introduction to Algorithms”, 3rd edition, McGraw-Hill, 2009			
Reference Books				
1.	Ellis Horowitz, "Fundamentals of Computer Algorithms", 2nd Edition, Universities Press, 2008			
2.	M. J. Quinn, Parallel computing – theory and practice, McGraw Hill, 2002			
3.	Sukumar Ghosh, “Distributed Systems: An Algorithmic Approach” ,1st edition, Chapman & Hall/CRC Computer & Information Science Series, 2006			
4.	William Stallings, “Cryptography & Network Security”, 4th Edition , Prentice Hall, 2005			
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test				
Recommended by Board of Studies		28-07-2022		
Approved by Academic Council		No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS605L	Hardware Software Co-design	2	0	0	2
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at

1. Providing adequate knowledge in the modeling of heterogeneous embedded systems based on design constraint and provide alternate solution exploring trade-off.
2. Introducing the importance of estimating the cost analysis in terms of hardware and software parameters.
3. Introducing various co-synthesis and co-simulation tools for the effective design of embedded systems with better communication between different modules.

Course Outcome

At the end of the course, the Students will be able to

1. Apply different MOCs based on system design specification.
2. Propose an alternate design solution based on constraint analysis.
3. Identify the partitioning solution based on the algorithms.
4. Understand various co-synthesis approaches.
5. Ability to pre-estimate and estimate the performance metrics for hardware and software based on cost analysis.
6. Approximate the pre-estimate and estimate the performance metrics for software based cost analysis.
7. Decide on proper co-simulation method based on system specification.

Module:1	**Specification of embedded systems**	**4 hours**
Introduction to Co-design - Comparison of co-design approaches – Unified representation-Model–MoCs: State oriented, Activity oriented, Structure oriented, Data oriented and Heterogeneous –Software CFSMs–Processor Characterization.		
Module:2	**HW/SW partitioning Constraints & tradeoffs**	**4 hours**
Cost modeling, Principle of hardware / software mapping - Real time scheduling - design specification & constraints on Embedded systems -Tradeoffs		
Module:3	**HW/SW partitioning methodologies**	**4 hours**
Partitioning - Types of partitioning – Partition in granularity – Kernigan -Lin Algorithm-Extended Partitioning – Binary Partitioning: GCLP Algorithm		
Module:4	**Co-synthesis**	**4 hours**
Software synthesis – Hardware Synthesis- Interface Synthesis – Co-synthesis Approaches: Vulcan, Cosyma, Cosmos, Polis and COOL.		
Module:5	**Estimation: Hardware**	**4 hours**
Hardware area, execution timing and power, Case studies		
Module:6	**Estimation: Software**	**4 hours**
Software memory and execution timing, Worst Case Execution Time, Case studies		
Module:7	**Co-simulation & Co-verification**	**4 hours**
Principles of Co-simulation – Abstract Level; Detailed Level – Co-Simulation as Partitioning support – Co- simulation using Ptolemy approach, Virtual Prototyping, Rapid Prototyping.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**30 hours**

Text Book(s)			
1.	Soonhoi Ha, Jürgen Teich, “Handbook of Hardware/Software Co-design”, Springer, 2017		
Reference Books			
1.	Schaumont, Patrick, A,” A Practical Introduction to Hardware/Software Codesign”, 2013, reprint, Springer, India.		
2.	FeliceBalarin, Massimiliano Chiodo, Paolo Giusto, Harry Hsieh, Attila Jurecska, Luciano Lavagno, Claudio Passerone, Alberto Sangiovanni - Vincentelli, Ellen Sentovich, Kei Suzuki, BassamTabbara, “Hardware-Software Co-Design of Embedded Systems: The POLIS Approach”, Springer, 2012.		
3.	http://ptolemy.eecs.berkeley.edu/ptolemyII/ptII10.0/ptII10.0.1_20141217/ptolemy/domains/continuous/doc/index.htm		
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS606L	Modern Automotive Electronics Systems	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at

1. Instilling fundamental understanding of various automatic control systems and basic instrumentation involved in automobiles.
2. Learning various automobile condition measurement and monitoring mechanisms.
3. Acquire with advanced electronic elements and their functional aspects in automobiles

Course Outcome

At the end of the course the student will be able to

1. Comprehend engine management system.
2. Understand the various Ignition and Injection systems
3. Explain the automotive control mechanisms.
4. Learn the different monitoring systems for automobiles
5. Understand the typical sensors for transportation.
6. Acquire knowledge about upcoming trends in automotive electronics systems
7. Use the knowledge attained and develop appropriate systems for societal issues

Module:1	**Engine management systems**	**8 hours**
Introduction - components for engine management system - Open loop and closed loop control system – Engine cranking and warm up control –Acceleration, deceleration and idle speed control.		
Module:2	**Injection and ignition systems**	**8 hours**
Feedback carburetor system–Throttle body injection and multi point fuel injection system–Injection system controls –Advantage of electronic ignition systems–Types of solid state ignition systems and their principles of operation –Electronic spark timing control, Exhaust emission control engineering		
Module:3	**Automotive control mechanism**	**6 hours**
Electronic management of chassis systems, Vehicle motion control, anti – lock braking system, Tyre pressure monitoring system, Collision avoidance system, Traction control system.		
Module:4	**Automotive Electronics systems**	**6 hours**
Active suspension system Keyless entry system and Electronic power steering system, Electronic controls - lighting design - Horn – Warning systems – Brake actuation warning systems, Infotainment		
Module:5	**Monitoring of Automotive systems**	**6 hours**
Speed warning systems, oil pressure warning system, engine over heat warning system, air pressure warning system, safety devices-Wind shield wiper and washer, VANET		
Module:6	**Sensors for transportation - I**	**5 hours**
Basic sensor arrangement–Types of sensors, Oxygen Sensor –Cranking Sensor –Position Sensors		
Module:7	**Sensors for transportation - II**	**4 hours**
Engine cooling water temperature Sensor–Engine oil pressure Sensor–Fuel metering –Vehicle speed sensor and detonation sensor.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Tom Denton, Automobile Electrical and Electronic Systems, 2012, 4th Edition,

	Butter Worth Heinemann, United States			
2.	Bosch Automotive Electrics and Automotive Electronics, 2014, 5th Edition, Springer Vieweg, United States			
3.	Beckwith, T.G, Roy D.Marangoni, John H.Lienhard, Mechanical Measurements, 2011, 6th Edition, Addison Wesley, United States			
Reference Books				
1.	Ernest O Doeblin, Measurement Systems, Application and design, 2013, 5th Edition McGraw Hill Book Co., United States			
2.	Holman, J.P, Experimental methods for Engineers, McGraw Hill Book Co., 2011, 8th Edition, United States			
3.	Robert Bosch Gmph, Automotive Hand Book, 2014, 9th Edition, Wiley, United States			
4	William, B. Ribbens, Understanding Automotive Electronics, 2014, 8th Edition Butter Worth Heinemann, United States			
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test				
Recommended by Board of Studies		28-07-2022		
Approved by Academic Council		No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS608L	Intelligent IOT System Design and Architecture	2	0	0	2
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at:

1. To explore the characteristics of the Internet of things and its design.
2. To enable the students to get familiar with IoT architecture models.
3. To acquaint the students with various security concepts and data analytics in the IoT system.
4. To develop and deploy an IoT enabled prototypes for real-life use cases.

Course Outcome

At the end of the course, the student will be able to

1. Assimilate the technologies that enable IoT and to interpret the different components in IoT architecture.
2. Comprehend the concepts of edge computing and edge enabled solutions for real-time industrial applications.
3. Envision the IoT communication architecture models and the protocol stack for the cost-effective design of IoT applications on different platforms.
4. Interpret the security threats and to design a resilient IoT Architecture.
5. Perceive the data analytics tools and gain knowledge to devise an intelligent IoT system.
6. Analyze cloud platform services to perform IoT data analytics and make the system intelligent.
7. Design and develop smart IoT prototypes for use cases under discussion.

Module:1	IoT Essentials	4 hours

Evolution of IoT, IoT characteristics, IoT enabling technologies, Planning for an IoT solution, IoT use case development - Need and goals, IoT Architecture reference model, Functional blocks of IoT- Communication and security Model, Service oriented architecture, Event-driven architecture, Applications and standards.

Module:2	Edge Computing	5 hours

Introduction to Edge/Fog computing, Edge nodes and gateway, Node to edge interfaces, Protocol and standards for edge devices, IoT edge architecture, IoT supported hardware- Raspberry pi, ARM Cortex Processors, Software Platforms for IoT Edge - Raspbian Pi OS, RIOT, Python packages for edge computing, Edge security, Real time applications of edge computing.

Module:3	IoT Communication Architecture and Protocols	5 hours

Communication models for IoT, 6LoWPAN, IPv4/IPv6, IoT communication protocols - MQTT, CoAP, LoRaWAN, RTLS, RPL, Communication API's.

Module:4	IoT Security and Privacy	4 hours

IoT risks and security challenges, IoT security architecture - A trust model, Restricting network access through security groups- Specific user access control, Data confidentiality and availability, User Authentication/Authorization methods, Block chain for IoT security and privacy.

Module:5	Smart Data Analytics	4 hours

Need for data analytics, Data generation, Data pre-processing, Handling imbalanced data sets, Missing values, Outliers, Intelligent IoT systems –Supervised and Unsupervised machine learning algorithms, Deep learning for IoT- Predictive analytics, Python functions and modules for data analytics, Big Data analytics and frameworks

Module:6	Data Analytics in Cloud Concepts	4 hours

Layered cloud architecture for data analytics, Elasticity in cloud for data warehousing,

Virtualization for Data-center automation, Real-time cloud data analytics tools, AI Services-Data based decisions, Cloud data lake, Exploratory data analysis, Open source cloud platforms and services.		
Module:7	**IoT Architecture for specific use cases**	**2 hours**
Roadmap for complete IoT solution, Open source IoT platforms, IoT solution to Health care,Automotive applications, Smart IoT architecture for Retail, Logistics and Farming, Intelligent IoT architecture for Home automation, Industry applications, Smart city and other applications to cater the societal requirements.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**30 hours**

Text Book(s)	
1.	ArshdeepBahga, Vijay Madisetti, “Internet of Things – A hands-on approach”, Universities Press, 2015.
2.	John R. Vacca, “Cloud Computing Security: Foundations and Challenges”, CRC Press, 2016.
3.	Dey, Hassanien, Bhatt, Ashour and Satapathy “Internet of Things and Big Data Analytics towards Next-Generation Intelligence”, Springer, 2018.
Reference Books	
1.	Adrian McEwen & Hakim Cassimally, “Designing the Internet of Things”, Wiley, 2013.
2.	OvidiuVermesan, Peter Friess, “Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems”, River Publishers, 2013.
3.	Olivier Hersent, David Boswarthick, Omar Elloumi, “The Internet of Things – Key applications and Protocols”, Wiley Publication, 2012

Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS608P	Intelligent IOT System Design and Architecture Lab	0	0	2	1
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at:

1. To explore the characteristics of the Internet of things and its design.
2. To enable the students to get familiar with IoT architecture models.
3. To acquaint the students with various security concepts and data analytics in the IoT system.
4. To develop and deploy an IoT enabled prototypes for real-life use cases.

Course Outcome

At the end of the course, the student will be able to

1. Assimilate the technologies that enable IoT and to interpret the different components in IoT architecture.
2. Comprehend the concepts of edge computing and edge enabled solutions for real-time industrial applications.
3. Envision the IoT communication architecture models and the protocol stack for the cost-effective design of IoT applications on different platforms.
4. Interpret the security threats and to design a resilient IoT Architecture.
5. Perceive the data analytics tools and gain knowledge to devise an intelligent IoT system.
6. Analyze cloud platform services to perform IoT data analytics and make the system intelligent.

Indicative Experiments

1	Task-1 Program the gateways to interface the sensors and implement various IoT communication protocols to perform secured edge computing.	8 hours
2	Task -2 Explore the open source IoT platforms to build data driven intelligent Industry 4.0 applications using virtual things.	8 hours
3	Task-3: Build prototypes and explore UI/UX, data analytics tools for Internet of Medical Applications.	7hours
4	Task-4: Explore the open source cloud platforms to perform environmental monitoring / smart agriculture / internet of vehicles and other innovative intelligent IoT use cases.	7 hours
	Total Laboratory Hours	**30 hours**

Mode of Assessment: Continuous Assessment and Final Assessment Test

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS609L	Fault Tolerance and Dependable Systems	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at:

1. Providing students with a working knowledge of the potential faults and errors occurring in an embedded system.
2. Providing knowledge in concepts of fault detection and fault tolerance.
3. Teaching students dependability concepts
4. Exposing the fault tolerance strategies and design techniques.

Course Outcome

At the end of the course, the student will be able to

1. Gain knowledge in concepts involving fault detection
2. Comprehend dependability concepts
3. Understand tolerance and correction mechanisms in real world scenarios.
4. Design and develop dependable systems for mission critical applications.
5. Understand Fault tolerance in interconnected systems.
6. Understand Fault tolerance in distributed systems.
7. Apply Dependability evaluation techniques and Tools

Module:1	**Faults and Failures**	**4 hours**
Fault - error, failure - faults and their manifestation - classification of faults and failures		
Module:2	**Dependability Concepts**	**5 hours**
Dependable system - techniques for achieving dependability - dependability measures		
Module:3	**Fault Tolerance Strategies**	**6 hours**
Fault detection – masking – containment – location – reconfiguration - recovery		
Module:4	**Fault tolerant design techniques**	**8 hours**
Hardware redundancy - software redundancy - time redundancy - information redundancy		
Module:5	**Fault tolerance in Interconnects**	**6 hours**
Hypercube - star graphs - fault tolerant ATM switches		
Module:6	**Fault Tolerance in Distributed Systems**	**8 hours**
Byzantine General problem - consensus protocols - check pointing and recovery – stable storage and RAID architectures - data replication and resiliency		
Module:7	**Dependability evaluation techniques and tools**	**6 hours**
Fault trees - Markov chains - HIMAP tool		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Israel Koren, C. Mani Krishna, Fault-Tolerant Systems, 2011, Morgan Kaufmann, San Francisco.
2. Elena Dubrova, Fault-Tolerant Design, 2013, Springer, Sweden.

Reference Books

1.	D. P. Siewiorek and R. S. Swarz, Reliable Computer Systems: Design and Evaluation, 2014,3rded., Digital Press, Pennsylvania.		
2.	Alessandro Birolini, Reliability Engineering: Theory and Practice, 2017, 8th ed., Springer-Verlag Berlin Heidelberg, Spain.		
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS611L	Parallel Processing and Computing	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at

1. Teaching the students to understand the scope, design and model of parallelism and to know the parallel computing architecture
2. Teaching students to do analytical modelling and performance of parallel programs
3. Teaching students to solve a complex problem with message passing model
4. Programming with CUDA and analyse complex problems with shared memory programming

Course Outcome

At the end of the course the student will be able to

1. Understand the fundamentals of parallel processing
2. Illustrate the scheduling loops and process execution
3. Realize the parallel system architecture with CUDA
4. Comprehend the kernel based parallel programming concepts
5. Apply the performance consideration for parallel processing
6. Analyse various parallel computation patterns
7. Perform spare matrix vector multiplications

Module:1	**Introduction to Parallel Processing**	**5 hours**
Parallel processing – Concepts and Terminology- Parallel Computer Memory Architectures - Parallel Programming Models - Designing Parallel Programs- Performance Analysis		
Module:2	**Shared Memory Programming**	**6 hours**
Processes and Threads - Scope of Variables – Reduction Clause – Directives – Scheduling Loops – Caches, Cache coherence and False Sharing – Thread Safety – Examples: Bubble-sort, Odd- even transposition sort		
Module:3	**Parallel Computing**	**6 hours**
Portability and Scalability- Introduction to CUDA, Data Parallelism and Threads-Memory Allocation and Data Movement API- Kernel-Based SPMD Parallel Programming-Kernel based Parallel Programming, Multidimensional Kernel Configuration- Basic Matrix-Matrix Multiplication		
Module:4	**Kernel-Based Parallel Programming**	**6 hours**
Thread Scheduling-Control Divergence- Memory Model and Locality - CUDA Memories-Tiled Parallel Algorithms- Tiled Matrix Multiplication- Tiled Matrix Multiplication Kernel-Handling Boundary Conditions in Tiling-- A Tiled Kernel for Arbitrary Matrix Dimensions		
Module:5	**Performance Considerations**	**6 hours**
Warps and Thread execution - Global Memory Bandwidth - DRAM Bandwidth - Memory Coalescing -Dynamic partition of execution resources		
Module:6	**Introduction to Packaging &PCB Design**	**8 hours**
Convolution- Tiled Convolution- 2D Tiled Convolution Kernel- Data Reuse in Tiled Convolution-Reduction- A Basic Reduction Kernel- Scan (Prefix Sum) - A Work-Inefficient Scan Kernel- A Work-Efficient Parallel Scan Kernel		
Module:7	**High Speed PCB design and Analysis Wireless Standards**	**6 hours**
Parallel SpMV Using CSR-Padding and Transposition-Using Hybrid to Control Padding-Sorting and Partitioning for Regularization		
Module:8	**Contemporary Issues**	**2 hours**

	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	AnantaGrama, Anshul Gupta, George Karypis, Vipin Kumar, Introduction to Parallel Computing, 2011, Second Edition, Addison Wesley Professional, UK.
2.	David B. Kirk and Wen-mei W. Hwu, Programming Massively Parallel Processors: A Hands-on Approach, 2016, Third Edition, Morgan Kaufmann Publishers, US.
Reference Books	
1.	Pacheco, Peter. An Introduction to Parallel programming, 2011, First Edition, Morgan Kaufmann Publishers, USA
Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test	

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MEDS613L	Cloud Computing	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at making the students to

1. To explore the cloud computing concepts.
2. To get familiar with cloud orchestration to support elasticity and edge device availability.
3. To impart knowledge on cloud security and to develop large scale embedded applications.

Course Outcomes

At the end of the course, the students will be able to

1. Comprehend the basics of cloud computing, cloud models and its connectivity to develop smart applications.
2. Envision the virtualization techniques and Interpret a suitable cloud model to capture the business needs by interpreting different service delivery and deployment models.
3. Perceive the division of responsibility and managing risks in the cloud environment.
4. Analyse the system level security threats and to design a resilient cloud Architecture.
5. Assimilate the OS security concepts and ability to design a resilient cloud architecture.
6. Design and develop platform-specific tools and management consoles to build real-time embedded system applications.

Module:1	Cloud Computing Fundamentals	6 hours

Characteristics of Cloud computing – Cloud Architecture– Design considerations- Edge device discovery, Cloud orchestration, Cloud connectivity for edge devices, Cloud Models – Cloud Services – IaaS, PaaS, SaaS, XaaS.

Module:2	Cloud Technologies	6 hours

Virtualization, Load Balancing and fault tolerance, Scalability, Elasticity, Deployment, Replication, Monitoring, Software defined Networking, Network function Virtualization, Mapreduce programming model.

Module:3	Cloud Computing Services	6 hours

Compute Services, Storage Services, Database services, Application Services, Data Analytics Services for predictive maintenance, Deployment and Management Services, Identity and Access management services.

Module:4	Cloud Risk Analysis	6 hours

Managing Risks in the Cloud. Retaining Information Security Accountability. Managing User Authentication and Authorization. Negotiating Security Requirements with Vendors, Service Level Agreement.

Module:5	Secure Cloud Architecture	6 hours

Restricting Network Access through Security Groups. Specific User Access Control, Integrating Cloud Authentication/Authorization, Data Confidentiality and Availability, Securing Data in Motion and Data at Rest, Identifying Your Security Perimeter, Key Management.

Module:6	**OS Security**	**6 hours**
Program threats, System threats, Locking Down Cloud Servers. Patching Vulnerabilities, Filtering Traffic by Port Number, Operating System Security Policies and Procedures.		
Module:7	**Cloud Platforms**	**7 hours**
Google cloud, Microsoft Azure, Amazon Web services, Cloud application development using third party APIs, Resource pooling, Cloud service migration, Federated cloud platform, Embedded systems applications on cloud.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Cloud Computing theory and Practice, 3rd Edition by Dan Marinescu, Elsevier, 2021.
2.	Cloud computing: Methodology, Systems and Applications, Lizhe Wang, Rajiv Ranjan, Jinjun Chen, CRC Press, 2017.
3.	Cloud Computing Principles and Paradigms, Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley & Sons, Inc. 2011.

Reference Books	
1.	John R. Vacca, "Cloud Computing Security: Foundations and Challenges", CRC Press, 2016.
2.	Pearson, Siani, Yee, George, "Privacy and Security for Cloud Computing", Springer, 2013.
3.	Nick Antonopoulos, Lee Gillam, Cloud Computing: Principles, Systems and Applications, Springer, 2015.
4.	Toby Velte, Anthony Velte, Robert Elsenpeter, Cloud Computing, A Practical Approach, McGraw Hill, 2010.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	07-06-2023		
Approved by Academic Council	No. 70	Date	24-06-2023

Course Code	Course Title	L	T	P	C
MEDS614L	Cyber Physical Systems	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at:

1. To introduce the fundamentals of modelling cyber-physical systems (CPS) consisting of both discrete and continuous dynamics
2. To provide an overview of design automation and verification problems with a systems perspective for designing, monitoring, and managing large scale infrastructure
3. To provide exposure to practical applications of modelling and verification through case studies and able to address real-world problems through Cyber Physical Systems.

Course Outcomes

At the end of the course, the student will be able to

1. Understand the need and purpose of the different components of Cyber Physical Systems.
2. Ideate, design, and prototype
3. Design their own system with different applications
4. Build systems with mathematical modelling in various fields with parametric measures
5. Evaluate the performance of a Cyber Physical System
6. Have hands on experience in using state-of- art hardware and software tools by synthesis and learning for cyber-physical system design and adaptation
7. Verify safety, privacy, and security for the designed cyber physical systems
8. Deploy cyber physical systems in practical applications like Internet of things (IoT), swarm systems, edge computing, and smart gateways.

Module:1	Cyber Physical Systems	5 hours

Motivation, overview, requirements, features and examples of Cyber-Physical Systems (CPS) in the real world; Key design drivers and quality attributes of CPS. Attributes of high confidence CPS, Interface between Physical and Cyber World: Industry 4.0, AutoSAR, IIOT implications, Building Automation, Medical CPS, Transportation, Energy, etc.

Module:2	CPS - Modelling Dynamic Behavior	7 hours

Basic principles of design and validation of CPS, Relationship between embedded systems and CPS, Design Process- Modeling, Design, Analysis, Continuous Dynamics - Discrete Dynamics. Hybrid Systems - State Machines - Concurrent Models of Computation

Module:3	CPS- Design and Implementation	7 hours

Real-Time Operating Systems. Networking Embedded Systems. Sensors and Actuators. Embedded Processors - Memory Architecture - Input and Output. Multitasking – Scheduling, CPS case study- design, implementation

Module:4	CPS- Analysis and Verification	5 hours

Invariants and Temporal Logic - Equivalence and Refinement. Evaluate the performance. Reachability analysis - Quantitative analysis. CPS Case Study- Analysis, Verification, etc.

Module:5	**CPS- Network and Protocol**	**7 hours**
CPS Communications, CPS Network – Wireless Hart, CAN, Automotive Ethernet, Scheduling Real Time CPS tasks, data analysis, and visualization. Secure Hardware, CPS Models and Aspects, Internet of Things Architectures, Properties, and Security Requirements; CPS vs IoT; Network and Protocol Case Studies; Constrained Application Protocol: Application Layer Connection-Less Lightweight Protocol for the Internet of Things; Datagram Transport Layer Security. Overview and Supporting Constrained Application Protocol.		
Module:6	**CPS- Security Issues and Controls**	**6 hours**
Security Challenges – Quantifying Security & Risk – Trustworthy Operational Readiness –Security Technologies. CPS Security Vulnerabilities, Real-World CPS Attacks, Security Control and Solutions. Securing Case Studies- the Future Autonomous Vehicle, Networking Technologies, Wireless Sensor Networks, Transportation, IPv6-Connected Internet of Things, Machine-to-Machine Communications, Mobile Cloud Computing.		
Module:7	**Machine Learning for Cyber Physical Systems**	**6 hours**
Introduction to Machine Learning. Mathematical Optimization - Planning and guidance. Basics of Neural Networks. Deep Learning. Supervised Learning, Unsupervised Learning, Ensemble Learning, Machine Learning for Cyber Physical Systems: Vehicular CPS, Smart Cities and the Internet of Everything, Drones as CPS.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	E.A.Lee and S A Shesia, (2018), Embedded system Design: A Cyber-Physical Approach, Second Edition, MIT Press.
2.	Ragunathan (Raj) Rajkumar, Dionisio de Niz and Mark Klein, (2017), Cyber Physical Systems, Pearson Education; First edition, ISBN-10 : 9386873567
3.	Rajeev Alur, "Principles of Cyber-Physical Systems", MIT Press, 2015.

Reference Books

1.	Houbing Song, Danda B Rawat, Sabina Jeschke, and Christian Brecher, "Cyber-Physical Systems: Foundations, Principles and Applications (Intelligent Data-Centric Systems: Sensor Collected Intelligence)", Academic Press, 2016.
2.	Peter Marwedel, "Embedded System Design-Embedded Systems Foundations of Cyber-Physical Systems", 2nd edition, SIE, 2013.
3.	André Platzer. Foundations of Cyber-Physical Systems. Lecture Notes, Computer Science Department, Carnegie Mellon University. 2013.
4.	Alexander Romanovsky, Fuyuki Ishikawa (eds,) - Trustworthy Cyber-Physical Systems Engineering-Chapman and Hall CRC (2016).

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test

Recommended by Board of Studies	07-06-2023		
Approved by Academic Council	No. 70	Date	24-06-2023

Course Code	Course Title	L	T	P	C
MEDS614P	Cyber Physical Systems Lab	0	0	2	1
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at:

1. To introduce the fundamentals of modeling cyber-physical systems (CPS) consisting of both discrete and continuous dynamics
2. To provide an overview of design automation and verification problems with a "systems" perspective for designing, monitoring, and managing large scale infrastructure
3. To provide exposure to practical applications of modeling and verification through case studies and able to address real-world problems through Cyber Physical Systems.

Course Outcomes

At the end of the course, the student will be able to

1. Ideate, design, and prototype
2. Design their own system with different applications
3. Build systems with mathematical modeling in various fields with parametric measures
4. Have hands on experience in using state-of- art hardware and software tools.
5. Understand automotive electronics architecture (sensors, actuators, computing, connectivity, control) design.
6. Understand highly dynamic networked systems (lifetime management, connectivity, adaptation).
7. Understand Security/safety for automotive systems.
8. Understand Integration of learning and optimization into safety-critical systems.

Indicative Experiments

1	Task-1: Embedded C/C++ Programming for CPS Sub task 1: Port Handling, Timer initialization Sub task 2: Waveform Generation. Sub task 3: Serial Port Controller Sub task 4: Interrupt Generation Sub task 5: Motor Control using Embedded C Sub task 6: PLC Emulation using Embedded C Sub task 7: Pulse Width Modulation	7 hours
2	Task-2: Benchmark IoT for CPS Sub task 1: Deployment of Sensors and IoT devices Sub task 2: Control of sensors using Open APIs like MQTT, COAP Sub task 3: Addition of new sensors to CPS-IoT. Sub task 4: Control of Servo Motors using Embedded Software	6 hours
3	Task-3: Modeling and Simulation of CPS using Ptolemy Sub task 1: Computation Models Sub task 2: Process Networks	9 hours

	Sub task 3: Discrete Events Sub task 4: Data Flow Sub task 5: Rendezvous Based models Sub task 6: Synchronous/Reactive Sub task 7: 3D Visualization Sub task 8: Continuous Time Model Sub task 9: Hybrid Systems Modeling Sub task 10: Sensor Network Design Sub task 11: Scientific workflows Sub task 12: Modeling and Simulation of Wireless Networks	
4	Task-4: Matlab toolboxes Sub task 1: Simulink, Stateflow, Define embedded systems and cyber-physical systems (CPS) and give examples Sub task 2: Understand various modeling formalisms for CPS, such as hybrid automata, state-space methods, etc. Sub task 3: Understand CPS design, modeling, and analysis Compare architectural design trade-offs in CPS Sub task 4: Design CPS and analyze models of CPS to see if they meet their specifications and requirements Sub task 5: Understand methods for verification and validation of CPS such as simulation, testing, model checking, etc. Sub task 6: Understand and appreciate engineering design and analysis difficulties in CPS disciplines	8 hours
5	Additional Exercises Matlab and Simulink Robotic Control and Simulation Drone Control Automotive Systems	
	Total Laboratory Hours	**30 hours**
Mode of Assessment: Continuous Assessment and Final Assessment Test		
Recommended by Board of Studies	07-06-2023	
Approved by Academic Council	No.70 Date	24-06-2023

Course Code	Course Title	L	T	P	C
MEDS615L	5G and Future Generation Communication Systems	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at making the students to

1. To understand standardization and the evolution of neXt Generation networks.
2. To explore the new terminologies and concepts relating to NR.
3. To provide exposure to different 5G use cases and practical applications.

Course Outcomes

At the end of the course, the students will be able to

1. Understand the 3GPP 5G standards and spectrum.
2. Comprehend the key concepts, terminologies and access methods of 5G NR.
3. Envisage the 5G Random Interface Architecture.
4. Analyze the MIMO techniques for 5G NR.
5. Evaluate different 5G use cases and applications.
6. Explore the future Generation and private networks relating to applications.

Module:1	5G - Introduction	4 hours

Evolution of Wireless Technologies (1G to 4G), What is 5G? Why do we need 5G? 5G Standardization - 3GPP and IMT2020 - Spectrum for 5G, 5G deployment - Options, Challenges.

Module:2	5G NR – Terminologies and Concepts	7 hours

5G Network Terminology and concepts - Channel Access methods - Comparison, Massive centralised RAN, Cognitive Radio, Vehicular communication, Network slicing.

Module:3	5G NR Radio Interface architecture	8 hours

Overall system architecture - Radio Protocol Architecture, QoS handling, User Plane Protocols-Radio Link Control - Medium-Access Control – Physical Layer functions - Control Plane Protocols, Mobility.

Module:4	Advance Multiple access and MIMO techniques	8 hours

Overview of Multi-Antenna Techniques in LTE, Moving to 5G Cellular with Large-scale Antenna Arrays, Antenna-array Architectures for 5G Cellular, Massive MIMO for Evolved LTE Systems (Below 6 GHz), Massive MIMO for cmWave and mmWave Systems (Above 6 GHz), Advanced Multiple-access and MIMO Techniques - NOMA.

Module:5	5G NR use-cases and applications	4 hours

5G NR Service Classes Overview: Enhanced Mobile Broadband (eMBB), Massive Machine-Type Communications (m-MTC), Ultra Reliable Low Latency Communications (URLLC), Application of NFV and SDN to 5G Infrastructure.

Module:6	M2M Communications	8 hours

LTE evolution for M2M, 5G for M2M communication, Low-latency Radio-interface Perspectives for Small-cell 5G Networks - New Radio-interface Design for Low-latency 5G Wireless Access, Massive Internet of Things.

Module:7	Future Generation networks	4 hours

NR beyond 52.6 GHz, IAB enhancements, NR – Broadcast / Multicast, General enhancements, Towards 6G.

Module:8	**Contemporary Issues**	**2 hours**
Industry expert lecture on different 5G use cases		
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Erik Dahlman, Stefan Parkvall, Johan Skold "5G NR: The Next Generation Wireless Access Technology", Academic Press, 1st Edition, 2018.
2. R. Vannithamby and S. Talwar, "Towards 5G: Applications, Requirements and Candidate Technologies", John Willey & Sons, 1st Edition, 2017.
3. Saad Z. Asif, "5G Mobile Communications Concepts and Technologies, CRC Press, 1st Edition, 2019.
4. Jonathan Rodriguez, "Fundamentals 5G Mobile Networks", John Wiley & Sons, 1st Edition, 2015.

Reference Books

1. Robert W. Heath Jr., Angel Lozano, "Foundations of MIMO Communication", Cambridge University Press, 1st Edition, 2019.
2. Long Zhao, Hui Zhao, Kan Zheng, Wei Xiang, "Massive MIMO in 5G Networks: Selected Applications", Springer, 1st Edition, 2018

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test

Recommended by Board of Studies	07-06-2023		
Approved by Academic Council	No. 70	Date	24-06-2023

Course Code	Course Title	L	T	P	C
MEDS616L	Machine Leaning and Deep Learning	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed at

1. Understanding about the fundamentals of machine learning and neural networks
2. Enabling the students to acquire knowledge about pattern recognition.
3. Motivating the students to apply deep learning algorithms for solving real life problems.

Course Outcomes

At the end of the course the student will be able to

1. Comprehend the categorization of machine learning algorithms.
2. Understand the types of neural network architectures, activation functions
3. Acquaint with the pattern association using neural networks
4. Explore various terminologies related with pattern recognition
5. Adopt different feature selection and classification techniques
6. Understand the architectures of convolutional neural networks and Comprehend advanced neural network architectures such as RNN, Autoencoders, and GANs.

Module:1	Learning Problems and Algorithms	4 hours

Various paradigms of learning problems, Supervised, Semi-supervised and Unsupervised algorithms

Module:2	Neural Network – I	8 hours

Differences between Biological and Artificial Neural Networks - Typical Architecture, Common Activation Functions, Multi-layer neural network, Linear Separability, Hebb Net, Perceptron, Adaline, Standard Back propagation

Module:3	Neural Network – II	8 hours

Training Algorithms for Pattern Association - Hebb rule and Delta rule, Hetero associative, Auto associative, Kohonen Self Organising Maps, Examples of Feature Maps, Learning Vector Quantization, Gradient descent, Boltzmann Machine Learning

Module:4	Machine Learning: Terminologies	7 hours

Classifying Samples: The confusion matrix, Accuracy, Precision, Recall, F1- Score, the curse of dimensionality, training, testing, validation, cross validation, overfitting, under-fitting the data, early stopping, regularization, bias and variance

Module:5	Machine Learning: Feature Selection and Classification	7 hours

Feature Selection, normalization, dimensionality reduction, Classifiers: KNN, SVM, Decision trees, Naïve Bayes, Binary classification, multi class classification, clustering.

Module:6	Convolutional Neural Networks	5 hours

Feed forward networks, Activation functions, backpropagation in CNN, optimizers, batch normalization, convolution layers, pooling layers, fully connected layers, dropout, Examples of CNNs.

Module:7	**RNNs, Auto encoders and GANs**	**4 hours**
State, Structure of RNN Cell, LSTM and GRU, Time distributed layers, Generating Text, Auto encoders: Convolutional Auto encoders, De-noising auto encoders, Variational auto encoders, GANs: The discriminator, generator, DCGANs		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lectures from Industry and, Research and Development Organizations		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	J. S. R. Jang, C. T. Sun, E. Mizutani, Neuro Fuzzy and Soft Computing - A Computational Approach to Learning and Machine Intelligence, 2012, PHI learning
2.	Deep Learning, Ian Good fellow, Yoshua Bengio and Aaron Courville, MIT Press, ISBN: 9780262035613, 2016.
Reference Books	
1.	The Elements of Statistical Learning. Trevor Hastie, Robert Tibshirani and Jerome Friedman. Second Edition. 2009.
2.	Understanding Machine Learning. ShaiShalev-Shwartz and Shai Ben-David. Cambridge University Press. 2017.

Mode of Evaluation: Continuous Assessment, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	07-06-2023		
Approved by Academic Council	No. 70	Date	24-06-2023

Course Code	Course Title	L	T	P	C
MVLD611L	Advanced Computer Architecture	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed to

1. Introduce advanced concepts of computer architecture.
2. Acquire knowledge on various interconnect topology for multiprocessor system and Different pipelining techniques.
3. Understanding different memory hierarchy for multiprocessor and multicomputer systems.

Course Outcomes

At the end of the course the student will be able to:

1. Understand the architecture of the various multiprocessors and multicomputer.
2. Determine the required static or dynamic interconnect network for a multiprocessor system.
3. Understand the Data level parallelism in Vector architecture, SIMD, GPU
4. Apply different pipelining techniques to reduce computation time.
5. Analyse the various memory design for multiprocessor and multicomputer.
6. Design scalable parallel architecture for multiprocessor system.

Module:1	Parallel computer models	5 hours

The state of computing - Conditions of parallelism - Data and resource Dependences - Hardware and software parallelism - Program partitioning and scheduling - Grain Size and latency Classification of parallel computers - Multiprocessors and Multicomputer

Module:2	System Interconnect Architectures	7 hours

Network properties and routing - Static interconnection Networks - Dynamic interconnection Networks - Multiprocessor system Interconnects - Hierarchical bus systems - Crossbar switch and multiport memory - Multistage and combining network.

Module:3	Data level Parallelism in Vector and GPU Architectures	7 hours

Vector Architecture- RISC-V Vector extension- Vector computation instructions, Registers and dynamic typing, loads and store, parallelism during vector execution, SIMD Instruction extension for multimedia-Graphics Processing Units- Detecting and enhancing loop-level parallelism

Module:4	Pipelining	7 hours

Linear pipeline processor - nonlinear pipeline processor - Instruction pipeline Design - Mechanisms for instruction pipelining - Dynamic instruction scheduling - Branch Handling techniques - branch prediction - Arithmetic Pipeline Design.

Module:5	Memory Hierarchy Design	6 hours

Cache basics & cache performance - reducing miss rate and miss penalty - multilevel cache hierarchies - main memory organizations - design of memory hierarchies.

Module:6	Shared Memory Architectures	6 hours

Symmetric shared memory architectures – distributed shared memory architectures – cache coherence protocols – scalable cache coherence – directory protocols – memory-based directory protocols – cache-based directory protocols.		
Module:7	**Multiprocessor Architectures**	**5 hours**
Computational models – An Argument for parallel Architectures – Scalability of Parallel Architectures – Benchmark Performances.		
Module:8	**Contemporary Issues**	**2 hours**
Guest lectures from Industries and R & D Organizations		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Kai Hwang, NareshJotwani, Advanced Computer Architecture: Parallelism, Scalability, Programmability, 2017, Third edition, Tata McGraw Hill Education, India.
2.	David Patterson, Andrew Waterman, The RISC-V Reader: An Open Architecture Atlas, 2017, First edition, Strawberry Canyon, USA.
Reference Books	
1.	John L. Hennessy, David A. Patterson, Computer Architecture: A Quantitative Approach, 2011, Fifth edition, Morgan Kaufmann.
2.	DezsoSima, Terence Fountain, Peterr Karsuk, Advanced computer Architectures – A Design Space Approach, 2014, Pearson Education, India.
3.	Ananth Grama, Anshul Gupta, George Karypis and Vipin Kumar, —Introduction to Parallel Computing, 2009, Second edition, Pearson Education, India.
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.	

Recommended by Board of Studies	07-06-2023		
Approved by Academic Council	No. 70	Date	24-06-2023

Course Code	Course Title	L	T	P	C
MVLD613L	System Design with FPGA	3	0	0	3
Prerequisite	NIL	Syllabus version			
		1.0			

Course Objectives :

This course is aimed to

1. Provide an overview of FPGA architectures and expound on the softcore and hard- core processors in association with hardware and software co-design.
2. Understand the specification and operation of Programming for peripheral Interfaces and Interconnect Fabrics.
3. Implement digital system and IP blocks for various DSP algorithms.

Course Outcomes :

After completion of the course the student will be able to:

1. Understand and get an idea about SoC and FPGA architectures.
2. Understand the NIOS II soft core processor architecture.
3. Analyze the working of hardware and software co-design flow.
4. Interpret the usage of various peripheral interfaces for system design.
5. Develop a system by choosing suitable interconnect fabrics.
6. Design the system using NIOS II soft core processor, model the system by using IP block and design and develop embedded synthesis using FPGA.

Module:1	**SoC Architecture**	**6 hours**
An Overview of System on Design – FPGA SoC Architecture – Case Study: Xilinx / Intel FPGA		
Module:2	**Soft Core and Hard Core Processor**	**10 hours**
Processor Architecture and Configurability Features: Nios II Processor – Nios V Processor – ARM cortex A9 architecture		
Module:3	**Hardware – Software Co-design Flow**	**2 hours**
Hardware Design Flow – Software Design Flow - EDA Tool Hardware and Software design flow		
Module:4	**Programming for peripheral Interfaces**	**5 hours**
LCD, PS2, RS232, SDRAM, SRAM Controller, VGA, Audio and Video, PIO, External Bus bridge, and IrDA		
Module:5	**Interconnect Fabrics**	**4 hours**
Avalon Switch Fabric Interconnect - Implementation and Functions-Integrated Design Environment		
Module:6	**System Design**	**8 hours**
Traffic light Controller, Real Time Clock - Interfacing using FPGA: VGA, LCD, Camera		
Module:7	**IP cores based SoC design**	**8 hours**
Edge detection algorithm- Image edge detection in FPGA using SOBEL Edge Detection/ Canny Edge Detection Algorithm, Colour and Brightness Enhancement algorithm- Contrast enhancement using RGB to HSV algorithm based on FPGA – SRAM Configuration using Controllers		
Module:8	**Contemporary Issues**	**2 hours**
Guest lecture from Industry and R & D Organizations		
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	ZainalabedinNavabi, "Embedded Core Design with FPGAs", 2011, Tata McGraw Hill Ltd, India.
2.	Pong P. Chu, Embedded SoPC Design with NIOS II Processor and VERILOG examples", 2012, Wiley, USA.
Reference Books	
1	Donald G. Bailey," Design for Embedded Image Processing on FPGAs", 2012, Wiley, USA.
2	Jivan S. Parab, Rajendra S Gad, G.M. Naik, "Hands-on Experience with Altera FPGA Development Boards", 2018, Springer, USA.
3	Joseph Yu, System-on-Chip Design with Arm Cortex-M Processors, 2019, ARM Education Media
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.	
Recommended by Board of Studies	07-06-2023
Approved by Academic Council	No. 70 Date 24-06-2023

Course Code	Course Title	L	T	P	C
MVLD616L	Scripting Languages For Electronic Design Automation	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives:

The course is aimed to

1. To write scripts in the LINUX environment.
2. To study the principles of Scripting Languages like Perl, TCL and Python.
3. To write the scripts for automation using the languages like Perl, TCL and Python.

Course Outcomes:

At the end of the course the student will be able to

1. Explain and apply commands in LINUX environment.
2. Develop and execute the Perl scripts.
3. Analyze and Handle files, directories and manage processes using Perl scripts.
4. Use TCL scripts for automation.
5. Build TCL scripts to Handle files, directories and manage process.
6. Develop Python scripts to interpret files and directories.

Module:1	**LINUX Basics**	**5 hours**
Introduction to Linux, File System of Linux, General usage of Linux Kernel and Basic Commands, Linux users and group, Permissions for file, directory and users, Searching a file and directory, zipping and unzipping concepts.		
Module:2	**PERL Basics**	**7 hours**
History and Concepts of PERL - Scalar Data - Arrays and List Data - Control structures – Hashes - Basics I/O - Regular Expressions – Functions - Miscellaneous control structures - Formats.		
Module:3	**Advanced Topics in PERL**	**6 hours**
Directory access - File and Directory manipulation - Process Management - Packages and Modules -Applications of PERL scripts to Electronic Design Automation.		
Module:4	**TCL Basics**	**7 hours**
An Overview of TCL and Tk -Tcl Language syntax – Variables – Expressions – Lists - Control flow – procedures - Errors and exceptions - String manipulations.		
Module:5	**Advanced Topics in TCL**	**6 hours**
Accessing files- Processes. Applications - Controlling Tools - Basics of Tk.		
Module:6	**Python Basics**	**6 hours**
Introduction to Python – Using Python interpreter – Brief tour on standard library - Control flow Tools – Data structures – Regular Expressions.		
Module:7	**Advanced Topics in Python**	**6 hours**
Input and Output – Errors and Exceptions – Classes – Modules- Applications of Python scripts to Electronic Design Automation.		
Module:8	**Contemporary Issues:**	**2 hours**
Guest lectures from Industry and R&D Organizations		
	Total Lecture hours:	**45 hours**

Text Book(s)				
1.	Larry Wall, Tom Christiansen, John Orwant, Programming PERL, 2012, Fourth Edition, Oreilly Publications.			
2.	John K. Ousterhout, Ken Jones, Tcl and the Tk Toolkit, 2010, Second Edition, Pearson Education, India			
Reference Books				
1.	Guido van Rossum Fred L. Drake, Jr., editor, Python Tutorial Release 3.2.3, 2012, Python Software Foundation.			
2.	Randal L. Schwartz, Brian D Foy, Tom Phoenix, Learning Perl, 2021, 8th Edition, O'Reilly Media, Inc.			
3.	Mark Lutz, Learning Python, 2013, 5th Edition, O'Reilly Media, Inc.			
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test				
Recommended by Board of Studies		07-06-2023		
Approved by Academic Council		No. 70	Date	24-06-2023