Course Details for Post-Graduate Programs

School of Electronic Systems and Automation

Digital University Kerala

February, 2026

Contents

1. Curricula of Programs Offered by the SoESA

UC- University Core, PC - Program Core, PE - Program Elective, OE - Open Elective

Format : Course name (Course Level) - Credits (UC/PC/PE/OE)

1.1. MSc Electronics

Specialization - VLSI and Embedded Systems
1st Semester (21 credits)
Digital Access for Community Empowerment (500) – 5 (UC)
Programming with Micropython (500)-4 OE
Electronic devices and circuits (400) – 3 (PC1) Linear circuit theory (400) – 3 (PC2) Verilog programming (400) – 3 (PC3) Digital Signal Processing (400) - 3 (PC4)
2nd Semester (21 credits in total)
Intellectual Property Rights and Finance (500) – 4 (OE)
Sensors & Transducers (500) -3 (PE)
CMOS integrated Operational amplifiers (400) – 3 (PC6) AI Hardware and Embedded IoT lab (400) – 2 (PC5) VLSI physical design of Neural Processors (400) – 3 (PC) Embedded Systems Architecture (400)-3(PC) Digital Chip Design and Verification (400) – 3 (PC)
3rd Semester (23 credits in total)
Neuromorphic VLSI (500) – 4 (OE) (SWAYAM/NPTEL) Data converters (500) – 4 (OE) (SWAYAM/NPTEL)
Project/Internship (500) – 15 (PE)
4th Semester (20 credits in total)
Capstone Project (500) – 20

1.2. MSc Applied Physics

Specialization - Applied Materials
1st Semester (21 credits)
Digital Access for Community Empowerment (500) – 5 (UC)
Programming with Micropython (500)-4 OE
Electronic devices and circuits (400) – 3 (PC1) Linear circuit theory (400) – 3 (PC2) Quantum Mechanics (400) – 3 (PC3) Statistical Physics (400) – 3 (PC4)
2nd Semester (21 credits)
Intellectual Property Rights and Finance (500) – 4 (OE)
Sensors & Transducers (500) -3 (PE)
AI Hardware and Embedded IoT lab (400) – 2 (PC5) CMOS integrated Operational amplifiers (400) – 3 (PC6) Spectroscopic and Microscopic Techniques for Materials Analysis (400) – 3 (PC7) Advanced Materials for Electronic Devices (400) –3 (PC8) Solid State Physics (400) – 3 (PC9)
3rd Semester (23 credits)
Project/Internship (500) – 15 (PE)
Mathematical methods in Physics (500) – 4 (OE) (SWAYAM/NPTEL) Computational Materials Modelling (500) 4 (OE) (SWAYAM/NPTEL)
4th Semester (20 credits in total)
Capstone Project (500) – 20

1.3. MTech Electronics Engineering

Specialization -VLSI Design
1st Semester (20 credits in total)
Digital Access for Community Empowerment (500) – 5 UC
Programming with Micropython (400) – 4 (OE)
Non-linear Circuit Theory (400) – 3 (PC)
Electronics for Edge AI (400) –3 (PC)
Sensors for Drones and Robotics (400) – 3 (PC)
Embedded Systems Essentials with Arm 1 (400) – 2 (PE)
2nd Semester (23 credits in total)
Intellectual Property Rights and Finance (500) – 4 (OE)
CMOS integrated Operational amplifiers (400) – 3 (PC)
VLSI physical design of Neural Processors (400) – 3 (PC)
Mixed Signal VLSI physical design (400) – 3 (PC)
VLSI Technology (400) – 3 (PE)
Digital Chip Design and Verification (500) – 3 (PE)
Group Project (500) – 4 (PE)
3rd Semester (20 credits in total)
Research Topics in Electronics Engineering (500) – 20
4th Semester (20 credits in total)
Thesis (500) – 20

1.4. Program Learning Outcomes

UC- University Core, PC - Program Core, PE - Program Elective, OE - Open Elective

Format : Course name (Course Level) - Credits (PC/PE/OE)

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and engg. specialization in the solution of complex engineering problems.

PO2. Problem analysis: Identity, formulate, research literature, and analyze engineering problems to arrive at substantiated conclusions using first principles of mathematics, natural, and engineering sciences.

PO3. Design/development of solutions: Design solutions for complex engineering problems and design system components, and processes to meet the specifications with consideration for public health and safety, and cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis, and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. The engineer and society: Apply to reason informed by the contextual knowledge to assess societal, health, *safety, legal*, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and teamwork: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

PO10. Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations, and give and receive clear instructions

PO11. Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

2. Course Details

2.1 Creativity and Art for Engineering Sciences (500) – 3 (PC)

Course Title:	**Creativity and Art for Engineering Sciences**
Course Code:	M3122011, M3120605, M3110041
Credits:	3
Level	500
Prerequisites:	Nil
Course Split	1-0-2 (L-T-P)

❖ **Course overview:**

Course description: The primary objective of the "Creativity and Art for Engineering Sciences" course is to empower engineering and science students with a unique blend of creative thinking, storytelling skills, and prompt engineering techniques. Through this course, students will develop the ability to harness their creativity to solve complex engineering problems, communicate their ideas effectively, and innovate in their field. The course aims to achieve the following learning objectives:

Cultivate Creative Thinking: Develop a deep understanding of creativity and its importance in engineering. Encourage students to explore creative solutions to engineering challenges.

Enhance Storytelling Skills: Equip students with the art of storytelling, enabling them to communicate technical information compellingly, fostering collaboration, and making engineering concepts accessible to a broader audience.

Apply Prompt Engineering: Teach students the principles and techniques of prompt engineering, demonstrating how to craft prompts effectively for various engineering applications, such as machine learning, data analysis, and simulation.

Integrate Art and Engineering: Explore the intersection of art and engineering, emphasizing how creativity can drive innovation in engineering projects.

Problem-Solving: Enable students to employ creative thinking and storytelling to tackle real-world engineering problems, emphasizing interdisciplinary approaches to engineering challenges.

Collaboration and Communication: Foster effective collaboration by teaching students to articulate their engineering ideas and solutions through storytelling, presentations, and project discussions.

Ethical Considerations: Encourage ethical considerations in engineering design and storytelling, emphasizing responsible innovation and its societal impacts.

Project Development: Guide students in developing engineering projects that integrate creative thinking, storytelling, and prompt engineering.

Critical Analysis: Train students to critically evaluate engineering projects, considering their creative elements, storytelling efficacy, and prompt engineering techniques.

Reflect and Adapt: Encourage self-assessment and reflection, enabling students to adapt their creative thinking, storytelling, and prompt engineering skills throughout their engineering careers.

- ❖ **Course learning outcomes:**

CO1: Students will demonstrate the ability to apply creative thinking techniques to analyze and solve complex engineering problems effectively.

CO2: Students will be able to craft and deliver engaging and persuasive narratives that effectively communicate technical engineering concepts to diverse audiences.

CO3: Students will acquire the skills to design and optimize prompts for engineering applications, leveraging prompt engineering principles to enhance data analysis, machine learning, and simulation processes.

CO4: Students will demonstrate the capacity to integrate artistic and creative elements into engineering projects, fostering innovative solutions that address real-world challenges.

CO5: Students will develop an ethical framework for engineering practice, considering the societal implications of their innovations and the responsible use of prompt engineering in decision-making processes.

CO6: Students will acquire the skills to translate the lab level prototype to commercialized model. Understanding various TRLs.

- **Outcome Mapping:**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3											
CO2										3		
CO3					3							
CO4			3				3					
CO5						3		3				

Level of impact: 3 - high, 2 - medium, 1 - low.

- **Syllabus:**

Introduction to Creativity and Engineering
- The role of creativity in engineering
- Historical and contemporary examples of creative engineering solutions

Creative Problem Solving in Engineering
- Creative thinking techniques for engineering challenges
- Applying creativity to optimize engineering processes and designs

The Art of Storytelling in Engineering
- Storytelling fundamentals: structure, elements, and principles
- Crafting narratives to effectively communicate technical ideas

Prompt Engineering Principles
- Fundamentals of prompt engineering
- Designing effective prompts for engineering applications

Interdisciplinary Innovation
- Integrating artistic elements into engineering projects
- Collaborative exercises to foster innovative thinking

Engineering and Ethical Considerations
- Ethical engineering practices and responsible innovation
- Ethical storytelling in engineering contexts

Creative Project Proposal
- Developing project proposals that integrate creativity, storytelling, and engineering principles

Creative Project Implementation
- Hands-on work on creative engineering projects
- Translation of lab to real time usable products
- Feedback and guidance from the instructor

Project Presentation and Evaluation

- Presentation of creative engineering projects
- Peer evaluation and discussion

❖ **Tools and equipment required**

Miro or Jamboard: These digital whiteboarding tools are excellent for collaborative brainstorming, mind mapping, and visualizing ideas.

Online Idea Generation Platforms: Platforms like Ideaflip, Stormboard, or MindMeister can facilitate idea generation and organization.

Zoom or Microsoft Teams: For virtual lectures, discussions, and collaborative activities.

Google Docs and Google Drive: For sharing documents, collaborative writing, and storing course materials.

Learning Management System (LMS): Platforms like Moodle, Canvas, or Blackboard for organizing course content, assignments, and communication with students.

Creative Thinking Models: Use books, articles, and online resources to explore creative thinking models such as the SCAMPER method, CPS (Creative Problem Solving) framework, and TRIZ.

Creative Problem-Solving Tools: Tools like the Six Thinking Hats, SWOT analysis, and Fishbone diagrams for problem-solving activities.

Video Conferencing and Recording Tools: Tools like OBS Studio or Screencast-O-Matic for recording lectures, demonstrations, and guest speaker sessions.

Collaborative Document Editing: Tools like Microsoft Word Online, Google Docs, or Dropbox Paper for collaborative writing and editing of lesson plans and projects.

Online Survey Tools: To collect feedback and conduct assessments, tools like Google Forms or SurveyMonkey can be valuable.

Digital Whiteboard Tools: Tools like Microsoft Whiteboard or Explain Everything for collaborative drawing, diagramming, and visual explanations.

Creative Assessment Tools: Tools like RubiStar or Kahoot for creating creative assessment rubrics and quizzes.

Creative Content Creation Tools: Software like Canva, Adobe Spark, or Piktochart for creating visually engaging content.

Learning Analytics Tools: Tools like Tableau or Edpuzzle to analyze student engagement and learning patterns.

Communication Tools: Use communication platforms like Slack or Microsoft Teams to facilitate ongoing discussions and group collaborations.

Podcasting and Audio Tools: Tools like Audacity or Anchor for creating and sharing audio content, which can be a unique way to encourage creative expression.

Collaborative Project Management Tools: Tools like Trello, Asana, or Basecamp for managing group projects and assignments.

Presentation Tools: Use tools like Microsoft PowerPoint, Google Slides, or Prezi for creating engaging presentations during lectures.

Social Media: Utilize platforms like Twitter, Instagram, or Facebook for sharing creative thinking resources and fostering online discussions.

Online Communities: Encourage students to join online communities related to creative thinking, innovation, and education to explore additional resources and network with like-minded individuals.

❖ **Reference books and articles**

Books on Creative Thinking and Teaching:

1. Chung HD. Creative Confidence: Unleashing the Creative Potential Within Us All by Tom Kelley and David Kelley: New York, NY: Crown Business, 2013, 304 pp., $28, ISBN 978-0-3853-4936-9.
2. Dyer J, Gregersen H, Christensen CM. The Innovator's DNA, Updated, with a New Preface: Mastering the Five Skills of Disruptive Innovators. Harvard Business Press; 2019 May 14
3. Robinson K, Aronica L. Creative schools: The grassroots revolution that's transforming education. Penguin books; 2016 Apr 19.
4. Doorley S, Witthoft S. Make space: How to set the stage for creative collaboration. John Wiley & Sons; 2012 Jan 3
5. Michalko M. Thinkertoys: A handbook of creative-thinking techniques. Ten Speed Press; 2006 Jun 8
6. Van Der Pijl P, Lokitz J, Solomon LK. Design a better business: New tools, skills, and mindset for strategy and innovation. John Wiley & Sons; 2016 Sep 21

❖ **Materials and Resources:**

- **TED Talks**: Explore TED Talks on creativity, innovation, and education for inspiring talks and ideas to share with students.
- **Creative Thinking Exercises**: Curate a collection of creative thinking exercises, puzzles, and challenges to use during the course.
- **Research Papers and Articles**: Provide students with academic papers and articles on creative thinking in education and related fields.
- **Online Creative Communities**: Encourage students to join online creative

communities, such as forums, groups, or social media channels dedicated to creativity and education.

- **Creative Thinking Assessment Tools**: Utilize assessment tools like the Torrance Tests of Creative Thinking (TTCT) to evaluate and measure creative thinking skills.
- **Case Studies**: Gather case studies of innovative teaching methods and approaches that incorporate creative thinking.
- **Hands-on Materials**: Depending on the course's focus, consider using materials for hands-on creative projects, such as art supplies, prototyping materials, or digital design tools.
- **Creative Software**: If applicable, provide access to creative software tools like Adobe Creative Cloud or digital art platforms for students to experiment with.

2.2. Electronic Devices and Circuits (400) – 3 (PC)

Course Title:	**Electronic devices and circuits**
Course Code:	M4122001, M4120601
Credits:	3
Level	400
Prerequisites:	None
Course Split	2-0-1 (L-T-P)

- **Course Overview**

Course description: This course explores electronic devices and circuits in the context of creative engineering. While covering the fundamental concepts of semiconductor types, PN junctions, diodes, passive and active elements, and nonlinear resistors, it emphasizes the integration of creative thinking, innovative problem-solving, and artistic design into electronics. This course aims to achieve the following learning objectives:

Cultivate Creative Thinking in Electronics: Develop a deep understanding of creativity's role in engineering while exploring creative solutions to electronic challenges.

Enhance Artistic Expression in Electronics: Equip students with the ability to communicate technical information compellingly and artistically, fostering collaboration and making electronic concepts accessible to a broader audience.

Innovate with Electronic Components: Explore the creative applications of electronic components such as diodes, passive and active elements, and nonlinear resistors in engineering projects.

Design and Construct Rectifiers and Filters: Apply creative design principles to rectifier and filter circuits, showcasing artistry in electronics.

Harness the Power of Bipolar Junction Transistors (BJTs): Understand BJTs and their equivalent circuits, employ creative biasing techniques, and explore artistic amplifier design.

Embrace MOSFETs and Their Creative Potential: Learn about MOSFETs, their small-signal and large-signal models, and how to creatively design current mirrors, amplifiers, and CMOS gates.

Explore Dynamic Logic and Pass Transistors with an Artistic Touch: Investigate dynamic logic, pass transistors, and multiplexers while emphasizing the fusion of creativity and engineering.

Design Artistic Adders and Subtractors: Create innovative adder and subtractor circuits, showcasing the art of electronics.

Utilize Ideal Op-amps as Creative Tools: Understand ideal op-amps, and their models, and explore creative applications such as log amplifiers and filters.

- ❖ **Course learning outcomes**

CO1: Students will learn to recognize and classify a diverse set of fundamental electronic components, including diodes, transistors, and operational amplifiers, equipping them with essential knowledge for electronics engineering applications.

CO2: Students will develop the skill to interpret and analyze the characteristics of various electronic devices. This proficiency will empower them to make informed decisions when selecting and utilizing electronic components in engineering designs and applications.

CO3: Students will learn to identify and comprehend the real-world applications of diverse electronic devices. This knowledge will enable students to make informed choices when designing and implementing electronic systems to address specific engineering challenges.

CO4: Students will delve into the underlying principles governing both active and passive electronic devices. This knowledge will equip students with a profound insight into the behavior of these devices, enabling them to design and analyze complex electronic circuits effectively.

CO5: Students will acquire the skills to systematically compare and contrast various types of electronic devices. Through these comparisons, students will be able to make informed decisions in selecting the most suitable devices for specific engineering applications, considering factors like performance, efficiency, and compatibility within electronic systems.

CO6: Students will be able to design a variety of electronic circuits using the electronic components covered in the course, for applications such as amplifier design, voltage stabilization, signal multiplexing, and more.

- ❖ **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	0	0	0	0	0	0	0	0	0	0	3
CO2	0	0	3	3	3	0	0	0	3	0	0	0
CO3	3	0	1	1	0	3	0	0	0	0	0	3
CO4	3	3	3	3	3	0	0	2	3	3	3	0
CO5	3	3	3	3	1	3	3	3	2	3	2	2
CO6	3	3	3	3	3	2	3	2	3	3	2	3

❖ Syllabus

Semiconductor types, PN junction, PN diode, passive and active elements, nonlinear resistors, rectifier, filters, BJT, BJT equivalent circuits, biasing circuits, amplifiers, current mirrors, MOSFET, Small-signal and large signal models, current mirrors, amplifiers, CMOS gates, Dynamic logic, pass transistors, multiplexers, adders, Ideal Op-amp, Op-amp model, Op-amp circuits - adders, subtractors, log, filters.

❖ Tools and equipment required

1. **LTSpice software:** Useful to analyze the behavior of the circuits

2. **Internet Access:** Internet access for online materials and software updates.

3. **Test and Measurement Equipment:** For measuring voltage, current, and resistance in circuits and visualize the waveforms of the nodes present in the circuits

4. **Circuit Components:** Resistors, capacitors, inductors, diodes, zener diodes, varactor diodes, BJT, MOSFET, Op-amps, and other circuit components to build the circuits.

5. **Breadboards:** Breadboards for prototyping circuits.

Reference books and articles

[1] Agarwal, Anant, and Jeffrey H. Lang. Foundations of Analog and Digital Electronic Circuits. San Mateo, CA: Morgan Kaufmann Publishers, Elsevier, July 2005. ISBN: 9781558607354.

[2] Donald A. Neamen, Electronic Circuits Analysis and Design, Third Edition, Tata McGraw Hill.

[3] R. A. Gayakwad, Op-Amps and Linear Integrated Circuits, 4th ed. Lafayette, LA, USA: PHI, 2006.

[4] George Clayton and Steve Winder, Operational Amplifiers, 5th ed. Burlington, NJ, USA: Newnes, 2003.

2.3 Linear Circuit Theory (400) – 3 (PC)

Course Title:	**Linear Circuit Theory**
Course Code:	M4122002
Credits:	3
Level	400
Prerequisites:	None
Course Split	2-0-1 (L-T-P)

- **Course overview**

Course description: This course provides a comprehensive exploration of linear circuit theory, focusing on understanding and analyzing electrical circuits. It covers essential topics related to elements, graphs, networks, and circuits, along with in-depth discussions on resistive circuits, transient analysis with energy storage elements, sinusoidal sources, frequency response, power circuits, two-port parameters, synthesis of networks, operational amplifiers, Fourier analysis, and general linear systems. The course aims to achieve the following learning objectives:

Foundations of Circuit Analysis: Introduce the fundamental elements and concepts in circuit theory, including passive and active elements, and develop a strong foundation for circuit analysis.

Graphs, Networks, and Circuits: Explore the representation of circuits as graphs and networks, enabling students to model and analyze complex circuits effectively.

Analysis of Resistive Circuits: Master the analysis of resistive circuits using techniques such as nodal analysis, mesh analysis, and Thevenin/Norton theorems.

Transients with Energy Storage Elements: Understand the behavior of circuits with energy storage elements (capacitors and inductors) during transient conditions and develop analytical skills to analyze transient responses.

Sinusoidal Sources and Response: Study sinusoidal sources and their behavior in linear circuits, including phasor analysis and the calculation of steady-state responses.

Frequency Response of Networks: Analyze the frequency response of linear networks, including Bode plots, transfer functions, and resonance phenomena.

Power Circuits: Investigate the power aspects of circuits, focusing on power dissipation, maximum power transfer, and efficiency calculations.

Generalized Frequency Response: Extend the understanding of frequency response to more complex circuits and systems, including filters and amplifiers.

Two-Port Parameters: Explore two-port network theory and parameter analysis, which is essential for understanding complex interconnected circuits and systems.

Synthesis of Networks: Learn network synthesis techniques, allowing students to design circuits and systems that meet specific performance requirements.

Operational Amplifiers: Study the principles and applications of operational amplifiers in linear circuit design, including amplifier configurations and signal processing.

Fourier Analysis of Signals and Circuits: Understand Fourier analysis and its application to signals and circuits, including harmonic analysis and signal shaping.

General Linear Systems: Explore the broader concept of linear systems, connecting linear circuit theory to broader engineering applications.

- **Course learning outcomes:**

CO1: Students will develop the capability to comprehensively analyze a wide range of basic electrical circuits. This analytical skill will be invaluable for designing and troubleshooting circuits in engineering applications.

CO2: Students will delve into the interpretations of frequency and transient analyses in the context of linear circuits. By comprehending the interpretations of frequency and transient analyses, students will be equipped to design and analyze circuits effectively for a wide range of applications, from signal processing to control systems.

CO3: Students will develop the ability to identify and understand a multitude of practical applications for operational amplifiers. They will explore how op-amps are employed as versatile building blocks in various engineering domains. This knowledge will enable them to effectively apply op-amps in their own engineering projects and designs.

CO4: Students will achieve a deep and comprehensive comprehension of the working principles that underlie operational amplifiers. Students will be well-prepared to analyze, design, and troubleshoot op-amp-based circuits, making them valuable contributors to electronic engineering projects and applications.

CO5: Students will develop the ability to analyze, contrast, and draw parallels between different types of linear systems and their corresponding electrical circuits, fostering a comprehensive understanding of the relationship between these domains.

- **Outcome mapping:**

	General Program Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	0	0	3	0	0	0	0	0	0	0	3
CO2	3	0	3	3	3	0	0	0	3	0	0	0
CO3	3	3	1	1	0	3	0	0	0	0	0	3
CO4	3	3	3	3	3	0	0	2	3	3	3	0
CO5	3	3	3	3	2	2	3	3	3	3	3	3

❖ **Syllabus:**

The Elements; Graphs, Networks and Circuits; Analysis of Resistive Circuits, Transients with Energy Storage Elements; Sinusoidal Sources and Response; Frequency Response of Networks, Power Circuits; Generalized Frequency Response; Two-port Parameters, Synthesis of Networks; Operational Amplifiers, Fourier Analysis of Signals and Circuits; General Linear Systems.

❖ **Tools and equipment required:**

1. **LTSpice software:** Useful to analyze the behavior of the circuits

2. **Internet Access:** Internet access for online materials and software updates.

3. **Test and Measurement Equipment:** For measuring voltage, current, and resistance in circuits and visualize the waveforms of the nodes present in the circuits

4. **Circuit Components:** Resistors, capacitors, inductors, Op-amps and other circuit components to build the circuits.

5. **Breadboards:** Breadboards for prototyping circuits.

❖ **Reference books and articles:**

[1] Shynk JJ. Mathematical foundations for linear circuits and systems in engineering. John Wiley & Sons; 2016 Jan 26.

[2] Horowitz, Paul, and Winfield Hill. The Art of Electronics. 2nd ed. Cambridge, UK: Cambridge University Press, 1989. ISBN: 9780521370950.

[3] Blackburn, James. Modern Instrumentation for Scientists and Engineers. New York, NY: Springer, 2000. ISBN: 9780387950563.

[4] Alexander, Charles, and Matthew Sadiku. Fundamentals of Electric Circuits. 2nd ed. New York, NY: McGraw Hill, 2004. ISBN: 9780073048352.

[5] Neamen, Donald. Electronic Circuit Analysis and Design. 2nd ed. New York, NY: McGraw Hill, 2001. ISBN: 9780072451948.

2.4 AI Hardware and Embedded IoT Lab (400) – 2 (PC)

Course Title:	**AI Hardware and Embedded IoT Lab.**
Course Code:	M4123005/M4120604
Credits:	2
Level	400
Prerequisites:	Nil
Course Split	1-0-1 (L-T-P)

- **Course Overview:**

Course description: This course is designed to equip students with the knowledge and practical skills required to excel in the fields of Artificial Intelligence (AI) hardware and Embedded Internet of Things (IoT) systems. In this course, the students design AI and IoT systems using TinyML. The course is application-oriented, and the students are encouraged to develop exciting applications on low-resource hardware. This course offers a comprehensive understanding of the intersection of AI and IoT technologies, preparing students for exciting career opportunities in the rapidly evolving world of smart devices and intelligent systems.

Embedded IoT Development: The course emphasizes hands-on experience in building Embedded IoT systems, covering topics such as sensor integration, wireless communication, and real-time data processing.

AI Hardware Design: Students will learn to design AI-specific hardware, including designing and implementing hardware accelerators for AI.

Machine Learning and Deep Learning: Students will learn and apply the fundamentals of AI and machine learning algorithms to real-world AI hardware projects.

Optimization for IoT: The course teaches optimization techniques to ensure AI models can run efficiently on resource-constrained IoT devices, minimizing power consumption and latency.

Research and Innovation: Students will be able to engage in cutting-edge research and innovation projects related to AI hardware and Embedded IoT.

Industry Relevance: Stay up-to-date with industry trends and emerging technologies in AI and IoT. Develop AI-driven IoT applications for industries like healthcare, agriculture, and smart cities.

❖ **Course Learning Outcomes(COs)**

CO1: Students will acquire the skills to design and optimize low-resource microprocessor or microcontroller boards

CO2: Students will be able to develop various neural and machine learning solutions with TinyML

CO3: Students will acquire the skills to design and optimize Hardware and Embedded IoT implementation with TinyML

CO4: Students will be able to apply the concepts of hardware-software co-design in application development

CO5: Students will develop the working design of TinyML-based AI/IoT implementation to address real-world challenges.

❖ **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO1 1**	**PO12**
CO1	0	3	0	0	0	0	0	0	0	3	0	0
CO2	0	3	0	0	0	0	0	0	0	0	0	3
CO3	0	0	0	0	3	0	0	0	3	0	0	0
CO4	0	0	0	3	0	0	0	0	0	0	0	3
CO5	3	0	3	0	0	0	0	3	3	0	0	3

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus:**

Introduction to Machine Learning, Introduction to Neural Networks, Audio classification

The Future of ML is Tiny and Bright: TinyML Challenges, Introduction to (Tiny) ML, The Machine Learning Paradigm, The Building Blocks of Deep Learning, Exploring Machine Learning Scenarios, Building a Computer Vision Model, Responsible AI Design.

Applications of TinyML, AI Lifecycle and ML Workflow, Machine Learning on Mobile and Edge IoT Devices, Data Engineering for TinyML Applications, Anomaly Detection, Responsible AI Development.

Introduction to the TinyML Kit, Deploying TinyML Applications on Embedded Devices, Collecting a Custom TinyML Dataset.

Optimization of TinyML Applications.

❖ **Tools and equipment required:**

1. IoT development boards - Arduino/ Raspberry Pi/ various IoT sensors

2. Interface modules/ circuits and sensors for capturing and analyzing experimental data.

3. Software- Python IDE/ TinyML packages (open source)

4. PCs/Laptops for writing codes and result analysis

5. Internet Access: Reliable internet access for accessing online resources, simulation updates, and research

6. Test and Measurement Equipment: For measuring voltage, current, and resistance in circuits.

7. Circuit Components: Resistors, capacitors, inductors, diodes. Standard electronic components for building and testing circuits.

8. Breadboards and Soldering Stations: Breadboards for prototyping circuits. Soldering stations for creating custom circuit assemblies if necessary.

9. Projector and Screen: For displaying lectures, demonstrations, and simulations.

❖ **Reference books and articles:**

1. Pete Warden, Daniel Situnayake, "Tiny ML: Machine Learning with Tensorflow Lite on Arduino and Ultra-Low-Power Microcontrollers" O'Reilly, 2020

2. Raad, Haider. Fundamentals of IoT and Wearable Technology Design. John Wiley & Sons, 2020. https://onlinelibrary.wiley.com/doi/book/10.1002/9781119617570

3. Unsalan, Cem, Duygun E. Barkana, and H. Deniz Gurhan. Embedded Digital Control with Microcontrollers: Implementation with C and Python. John Wiley & Sons, 2021. https://onlinelibrary.wiley.com/doi/book/10.1002/9781119576600

4. Iniewski, Krzysztof. Embedded Systems: Hardware, Design and Implementation. John Wiley & Sons, 2012.

https://onlinelibrary.wiley.com/doi/book/10.1002/9781118468654

5. https://www.coursera.org/learn/introduction-to-embedded-machine-learning#syllabus

6. https://www.edx.org/course/fundamentals-of-tinyml

7. https://www.edx.org/course/applications-of-tinyml

2.5 Verilog Programming (400) – 3 (PC)

Course Title:	Verilog programing and Deep Learning lab
Course Code:	M4xxxx
Level, Credits:	400, 3
Prerequisites:	None
Course Split	1-0-2 (L-T-P)

❖ **Course aim**

This course provides an in-depth understanding of Verilog HDL for digital circuit design, covering dataflow, structural, and behavioral modeling. It introduces functional simulation and testbench development for verification. The course explores FPGA design flow, emphasizing implementation using Xilinx tools. Advanced topics include FSM design and HDL coding best practices. The course also covers aspects related to the application of Verilog in deep learning.

❖ **Course learning outcomes**

CO1: Develop Verilog models for combinational and sequential circuits using dataflow, structural, and behavioral modeling.

CO2: Design, simulate, and verify digital circuits using testbench architecture in Verilog HDL.

CO3: Implement finite state machines (FSM) using Moore and Mealy designs with optimized coding techniques.

CO4: Gain hands-on experience in FPGA design flow, including synthesis, simulation, and bitstream generation using Xilinx tools.

CO5: Implement and test deep learning architectures such in Verilog for neural computing applications.

❖ **Outcome mapping**

	General Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO 1 1	PO12
CO1		3								3		
CO2		3										3
CO3					3				3			
CO4				3								3

CO5	3		3					3	3			3

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ Syllabus

Introduction to Data flow modeling – Continuous Assignment – Sequential Logic – Modeling D Latch / T Latch, D FF / T FF Master Slave Configuration Introduction to Structural modeling – Module Instantiation – Gate Level Design, Hierarchical design – Modeling Ripple carry adder, Carry look ahead adder, Multipliers Introduction to Behavioral modeling – Procedural Assignment – Procedural Assignment vs Continuous Assignment, Rules for Procedural Block, Always Block and Initial Block, Conditional statements and Looping statements

Introduction to Functional Simulation – Testbench Architecture – Writing Test Bench in Verilog HDL – Test Bench for Combinational and Sequential Logic Finite State Machine – Moore and Mealy FSM – FSM Coding Techniques HDL Coding Guidelines Simulation-Synthesis mismatch Mini-project

Introduction to FPGA Design Flow, ASIC vs FPGA Design Flow, Xilinx FPGA 7 Families Vivado Design Suite tool flow Demo on Verilog Code to Bitstream generation and FPGA implementation Introduction to Zynq-7000 SoC Vitis tool flow Creating a Simple Embedded Hardware Design Extending Hardware System by Adding Peripherals

Implementations of DNN, CNN, LSTM and RNN in verilog. Writing test bench for testing neural networks. Project in Neural Computing with verilog.

❖ Tools required

EDA Tools: Xilinx Vivado Design Suite, ModelSim/QuestaSim for simulation

FPGA Development Tools: Xilinx Vitis for embedded hardware design
Hardware: Xilinx FPGA (Zynq-7000 SoC or similar)

❖ Lab Requirements

Computers with Xilinx Vivado and ModelSim installed

FPGA development boards (preferably Xilinx Zynq-7000 SoC)

Oscilloscope and logic analyzers for verification

Adequate power supplies and testing accessories for FPGA implementation

Mini-project workspace for neural computing applications in Verilog

- **Reference books and articles**

1. Modern Digital Electronics. Author, R P Jain. Edition, 3. Publisher, Tata McGraw-Hill Education

2. Wakerly, John F. Digital Design Principles and Practices,

3. Verilog HDL, 2/E By Samir Palnitkar,Pearson Education

4. FPGA Users Guides and Datasheets From Xilinx & Altera

5. Verilog by Example: A Concise Introduction for FPGA Design by Blaine C. Readler

6. FPGA Prototyping by Verilog Examples by Pong P. Chu

7. Xilinx Vivado and Vitis tool documentation

2.6 Quantum Mechanics (400) – 3 (PC)

Course Title:	**Quantum Mechanics**
Course Code:	M4120603
Credits:	3
Level	400
Prerequisites:	Basics concepts of quantum physics
Course Split	2-0-1 (L-T-P)

❖ **Course overview:**

Course description: The course aims to provide the concepts and techniques of quantum mechanics essential in many areas of engineering and science, such as materials science, nanotechnology, and electronic devices.

❖ **Course learning outcomes:**

CO1: Identify experimental results incompatible with classical physics and understand the development of a quantum theory.

CO2: Interpret the wave function and apply operators to obtain information about a quantum system

CO3: Solve the Schrödinger equation for standard quantum systems

CO4: Interpret the concepts of quantum physics to understand materials science, nanotechnology and quantum information science.

❖ **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	2	2	2	2	1	1	1	1	2	1	2
CO2	3	3	2	2	2	1	1	1	1	2	1	2
CO3	3	3	3	2	2	1	1	1	1	2	1	2
CO4	3	3	2	3	2	1	1	1	1	2	1	2

❖ **Syllabus**

Introduction to Quantum Mechanics

How quantum mechanics is important in the everyday world, the bizarre aspects and continuing evolution of quantum mechanics, and how we need it for engineering much of modern technology. probability densities and linearity, Fermions & Bosons

Mathematical Tools of Quantum Mechanics

Operators in quantum mechanics - the quantum-mechanical Hamiltonian. Measurement and its paradoxes - the Stern-Gerlach experiment. – The Hilbert Space and Wave Functions, operators, matrices and Dirac notation. Position Representation, Momentum Representation

Postulates of Quantum Mechanics

Probability Density, The Superposition Principle, Measurement in Quantum Mechanics

Time Evolution of the System’s State: Schrodinger's wave equation. The "particle in a box", eigenvalues and eigenfunctions, The harmonic oscillator. Movement in quantum mechanics - wave packets, group velocity and probability current. Time dependence of expectation value.

The hydrogen atom

Angular momentum in quantum mechanics - atomic orbitals. Quantum mechanics with more than one particle. Solving for the hydrogen atom. Nature of the states of atoms.

Applications of quantum physics

Quantum perturbation theory, Quantum confinement of 0-D, 1-D, 2-D nanostructures, Fundamentals of quantum information science

2.7 Signal Processing (400) - 3 (PC)

Course Title:	**Signal Processing**
Course Code:	M4122075
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ **Course Overview:**

Course Description: This course is designed to equip students with the knowledge and practical skills required to excel in the field of signal processing and its various applications in other fields. The main aim of this course is to introduce fundamental concepts and techniques used in the field of signal processing. The course covers a range of topics in signal processing and the influence of signal processing technologies in shaping the future of the industry. The students are expected to work on projects to implement and design advanced signal processing techniques for various research and industrial applications.

❖ **Course learning outcomes (COs):**

CO1: Develop a strong foundation in the theoretical principles of signal processing.

CO2: Students will gain proficiency in mathematical techniques essential for analyzing and manipulating signals.

CO3: Students will understand the application of signal processing in real-world scenarios across various industries.

CO4: Students will acquire practical skills through hands-on projects and laboratory exercises using signal processing software and tools.

CO5: Students will be able to demonstrate the application of signal processing for solving real world research and industrial problems.

❖ **Outcome mapping:**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3	0	3	3	0	0	3	2	0	3	3
CO2	3	3	2	3	2	2	3	3	3	3	0	3
CO3	2	3	1	1	0	0	0	0	2	0	0	3
CO4	3	3	3	3	3	3	0	2	3	3	3	0
CO5	2	2	3	3	3	3	3	3	3	3	3	2

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus:**

Sampling of Continuous Signal, Signal Reconstruction, Analog-to-Digital Conversion, Digital-to-Analog Conversion, and Quantization, Generation of Digital Signals

Linear Time-Invariant, Causal Systems

Difference Equations and Impulse Responses, System Representation Using Its Impulse Response, Bounded-In and Bounded-Out Stability

Discrete Fourier Transform, Discrete cosine transform, wavelet transform

Amplitude Spectrum and Power Spectrum, Spectral Estimation Using Window Functions

Properties of the z-Transform, Inverse z-Transform, Solution of Difference Equations Using the z-Transform

❖ **Tools and equipment required:**

1. Python

2. MATLAB

❖ **Reference Books and Articles:**

1. Alan Oppenheim , Alan Willsky, S. Hamid Nawab , “Signals and Systems” PHI, 2nd edition, 1996.
2. John G. Proakis, Dimitris G. Manolakis, “Digital Signal Processing” Pearson Education India, 2007
3. Li Tan and Jean Jiang, “Digital Signal Processing-Fundamentals and Applications” Elsevier, Second edition 2013.

2.8 Statistical Physics (400) – 3 (PC)

Course Title:	**Statistical Physics**
Course Code:	M4120608
Credits:	3
Level	400
Prerequisites:	Basic knowledge on Quantum mechanics, Probability and statistics
Course Split	2-0-1 (L-T-P)

❖ **Course overview**

Course description: The main aim of this course is to provide an understanding of the principles of statistical physics and its applications. Special emphasis is given to topics such as quantum statistics, solid state systems, diffusion processes, noise generation, and stochastic dynamics. The course also explores relationships between statistical mechanics and information theory.

❖ **Course learning outcomes**

CO1: Understand and apply the fundamental principles of statistical physics

CO2: Analyze and interpret the quantum statistics of systems, including Fermi-Dirac and Bose-Einstein distributions, and apply these concepts to problems in solid-state physics.

CO3: Evaluate the behavior of interacting particle systems and phase transitions using models such as the Ising model and Curie-Weiss model.

CO4: Comprehend the principles of fluctuations, stochastic dynamics, and noise, and apply these concepts to physical systems and engineering problems.

❖ **Outcome mapping:**

	General Program Outcomes											
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	3	2	2	2	2	1	1	1	1	2	1	2
CO2	3	3	2	2	2	1	1	1	1	2	1	2
CO3	3	3	3	2	2	1	1	1	1	2	1	2

CO4	3	3	2	3	2	1	1	1	1	2	1	2
CO5	3	3	2	2	2	1	1	1	1	2	1	2

- ❖ **Syllabus:**

Introduction to Statistical Physics

- ○ Overview of statistical physics and its significance.

Introduction to Probability

- ○ Discrete and Continuous Distributions
- ○ Central Limit Theorem and Statistical Entropy
- ○ Statistical nature of the ideal gas.

Elementary Statistical Physics

- ○ Basic postulates and statistical ensembles.
- ○ Microcanonical, canonical, and grand-canonical ensembles.

Quantum Statistics

- ○ Fermi-Dirac and Bose-Einstein distributions.
- ○ Applications in solid-state physics

Interacting Particle Systems and Phase Transitions

- ○ Models of interacting particles and phase transition theories.
- ○ One-dimensional Ising model and Curie-Weiss model.

Vibrations in Solids

- ○ Phonons and heat capacity.
- ○ Einstein and Debye theories.

Fluctuations, Stochastic Dynamics, and Noise

- ○ Fluctuation theory and Brownian motion.
- ○ Langevin and Fokker-Planck equations.
- ○ Fluctuation-dissipation theorem and noise in quantum-mechanical regimes.

- ❖ **Reference books and articles**

Books:

- Merhav, Neri. *Statistical Physics for Electrical Engineering*. Springer, 2010.
- Pathria, R.K., and Paul D. Beale. *Statistical Mechanics*. 3rd ed., Elsevier, 2011.

- Kardar, Mehran. *Statistical Physics of Particles*. Cambridge University Press, 2007.

Links

· https://ocw.mit.edu/courses/8-333-statistical-mechanics-i-statistical-mechanics-of-particles-fall-2013/

· https://archive.nptel.ac.in/courses/115/106/115106126/

2.9 Non-linear Circuit Theory (400) – 3 (PC)

Course Title:	**Non-linear Circuit Theory**
Course Code:	M4110003
Credits:	3
Level	300
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ **Course overview**

Course description: This course provides an in-depth exploration of non-linear circuit analysis and the use of SPICE (Simulation Program with Integrated Circuit Emphasis) for circuit modeling and simulation. Topics covered include linear and non-linear resistors, IV characteristics, transient behavior, memristors, cellular nonlinear networks, chaos in electronic circuits, and complexity in dynamic systems. The course will also introduce students to the concept of using SPICE for analyzing complex circuit behavior. The aim of this course is:

- To introduce students to the fundamental concepts of non-linear circuit analysis.
- To familiarize students with the use of SPICE for circuit modeling and simulation.
- To explore advanced topics such as memristors, chaos, and complexity in electronic circuits.
- To develop problem-solving skills in analyzing and designing non-linear circuits.

By the end of this course, students should be able to:

- Understand the principles of linear and non-linear resistors and analyze their IV characteristics.
- Use SPICE software for circuit modeling, simulation, and analysis.
- Explain the fundamental properties of memristors and their applications.
- Analyze transient behavior in linear and non-linear circuits.
- Understand the concepts of chaos and complexity in electronic circuits.

- Apply non-linear circuit analysis techniques to solve practical engineering problems.

❖ **Course learning outcomes:**

CO1: Develop circuit theory skills using mathematical techniques and SPICE

CO2: Apply theoretical concepts of circuit theory in modeling and simulation of circuit behavior

CO3: Obtain circuit conceptual debugging skills

CO4: Analyze the circuit elements and their impact on the circuit performance

CO5: Practice nonlinear circuit theory in an application

❖ **Outcome mapping:**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3				3							
CO2	3				3							
CO3		3							2			
CO4		3		2								
CO5			3			2						

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus:**

Introduction to SPICE. Linear and Non-linear Resistor. IV characteristics, Transient behavior; Linear and Non-linear Elements. IV characteristics, Transient behavior

Once over Lightly, Everything You Wish to Know About Memristors but are

Afraid to Ask, Things You Didn't Know About Memristors.

Brain, CNN Cellular Nonlinear Networks, From Limulus to Sombrero

Chaos, Sights and Sounds of Chaos, Everything You Wish to Know About Complexity, Local Activity and Edge of Chaos

Teaching Monkeys to Compute like a Turing Machine, 137 is a Magic Number, Chaos in Electronic circuits

❖ **Tools and equipment required**

Computer Workstations:

- Desktop or laptop computers with sufficient processing power and memory for running SPICE simulations.

SPICE Simulation Software:

- Software packages such as LTspice, PSpice, or MultiSim for circuit modeling and analysis.

Test and Measurement Equipment:

- Oscilloscopes: For measuring voltage waveforms and analyzing transient behavior.
- Multimeters: For measuring voltage, current, and resistance in circuits.

Memristors and Circuit Components:

- Assortment of memristors: To experiment with memristor-based circuits.
- Resistors, capacitors, inductors, diodes, transistors, and operational amplifiers: Standard electronic components for building and testing circuits.

Breadboards and Soldering Stations:

- Breadboards for prototyping circuits.
- Soldering stations for creating custom circuit assemblies if necessary.

Power Supplies:

- Variable DC power supplies to provide power to circuits for testing.

Signal Generators:

- Function generators or signal generators for generating input signals to circuits.

Printed Circuit Board (PCB) Fabrication Tools (if applicable):

- PCB design software and equipment for creating custom circuit boards.

Computers with SPICE Software:

- Each computer workstation should have SPICE simulation software installed.

Textbooks and Reference Materials:

- Course textbooks, reference books, and online resources for studying circuit theory, SPICE, and memristors.

Safety Equipment:

- Safety goggles and lab coats to ensure safety during lab experiments.

Data Acquisition and Analysis Tools:

- Data acquisition hardware and software for capturing and analyzing experimental data.

Projector and Screen:

- For displaying lectures, demonstrations, and simulations.

Laboratory Manuals:

- Manuals with lab instructions, guidelines, and assignments.

Workshop Tools and Supplies:

- Hand tools, wire cutters, pliers, and other workshop supplies for circuit construction and debugging.

Internet Access:

- Reliable internet access for accessing online resources, simulation updates, and research.

Storage and Organization:

- Storage cabinets, drawers, or racks for organizing components and equipment.

Safety and Emergency Equipment:

- First-aid kit, fire extinguishers, and emergency exits as per safety regulations.

❖ **Reference books and articles**

- SPICE Circuit Handbook by Steven Sandler, McGraw-Hill Professional; 1 edition
- Chua LO. CNN: A paradigm for complexity. World Scientific Series on Nonlinear Science Series A. 1999;26:529-838.
- The Chua Lectures: From Memristors and Cellular Nonlinear Networks to the Edge of Chaos
- Leon O Chua (University of California at Berkeley, USA)

● World Scientific Series on Nonlinear Science Series A. October 2020 Volume I. Memristors: New Circuit Element with Memory

● Volume II. Memristors and CNN: The Right Stuff for AI and Brain-Like Computers Volume III. Chaos: Chua's Circuit and Complex Nonlinear Phenomena

● Volume IV. Local Activity Principle: Chua's Riddle, Turing Machine, and Universal Computing Rule 137

● Muret, P. (2017). Fundamentals of Electronics 1: Electronic Components and Elementary Functions. John Wiley & Sons. https://onlinelibrary.wiley.com/doi/book/10.1002/9781119422051

● Yang, Won Y., Jaekwon Kim, Kyung W. Park, Donghyun Baek, Sungjoon Lim, Jingon Joung, Suhyun Park, Han L. Lee, Woo June Choi, and Taeho Im. Electronic Circuits with MATLAB, PSpice, and Smith Chart. John Wiley & Sons, 2020. https://onlinelibrary.wiley.com/doi/book/10.1002/9781119598961

● Myers, Chris J. Asynchronous circuit design. John Wiley & Sons, 2001. https://onlinelibrary.wiley.com/doi/book/10.1002/0471224146

●Spence, Robert. Introductory circuits. John Wiley, 2008. https://onlinelibrary.wiley.com/doi/book/10.1002/9780470694466

● Shynk, John J. Mathematical Foundations for Linear Circuits and Systems in Engineering. John Wiley & Sons, 2016. https://onlinelibrary.wiley.com/doi/book/10.1002/9781119073444

2.10 Electronics for Edge AI (400) –3 (PC)

Course Title:	**Electronics for Edge AI**
Course Code:	M4110004
Credits:	4
Level	400
Prerequisites:	Undergraduate degree in Electronics or related fields
Course Split	2-0-1 (L-T-P)

- **Course Overview**

Course Description

This course is designed to equip students with the knowledge and practical skills required to excel in the fields of Edge AI technologies and developmental needs from an electronics design perspective. The focus is on edge AI chips, edge AI boards, and related interface circuits. The course is application-oriented, and the students are encouraged to develop exciting applications on edge AI boards. The students are expected to work on various problem-solving scenarios and projects, including PCB level design, circuit simulations, and writing case study style reports.

Fundamentals of Edge Computing: Students will gain a foundation in edge computing concepts, including edge devices, edge servers, and the edge-cloud continuum, and understand their significance in the context of AI applications.

AI Fundamentals: Develop a strong understanding of artificial intelligence, including machine learning, deep learning, neural networks, and their practical applications.

Edge AI Architectures: Explore various architectures and hardware platforms that support AI at the edge, such as GPUs, TPUs, and specialized AI accelerators.

Edge AI Algorithms: Learn about AI algorithms optimized for edge devices, focusing on real-time processing, energy efficiency, and resource constraints.

Deployment and Optimization: Understand the challenges and best practices for deploying AI models on edge devices, including model compression, quantization, and optimization techniques.

Edge AI Applications: Investigate a wide range of practical use cases for Edge AI, such as autonomous vehicles, smart cities, healthcare monitoring, industrial automation, and more.

Edge AI Development Tools: Gain hands-on experience with popular Edge AI development frameworks, libraries, and tools, enabling you to build, deploy, and manage edge AI solutions.

❖ Course learning outcomes (COs)

CO1: Students will acquire the skills to develop system-level and architecture-level design skills for understanding Edge platforms

CO2: Students will be able to develop various neural and machine learning solutions with edge AI devices

CO3: Students will acquire the logical skills for system integration of various edge AI system blocks

CO4: Students will be able to analyze the blocks of the edge AI platform by presenting case study

CO5: Students will be able to implement edge AI systems to address real-world challenges.

❖ Outcome mapping

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	0	0	3	0	0	0	0	0	0	0	3
CO2	3	0	3	3	3	0	0	0	3	0	0	0
CO3	3	3	1	1	0	3	0	0	0	0	0	3
CO4	3	3	3	3	3	0	0	2	3	3	3	0
CO5	3	3	3	3	2	3	3	3	3	3	3	3

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ Syllabus

What is EDGE AI ? Distributed computing overview. Introduction to Tiny ML for Arduino.

Introduce Jetson platform, GPU-based platforms, TPU-based platforms, and Programming GPU-based systems.

Deep learning overview Introduction to TensorFlow, Programming AI platforms from TensorFlow, Face recognition case study,

Implementations in MyRio Power and energy calculations, energy efficiency, on-chip area, Performance metrics, FPGA, DSP processors

Performance comparisons of edge AI computing platforms, system analysis, circuit analysis, device specific analysis.

- ❖ **Tools and equipment required**

1. Edge AI development boards - Arduino/ Raspberry Pi/ Jetson Nano/ MyRio

2. Interface modules/ circuits and sensors for capturing and analyzing experimental data.

3. Software- Python IDE/ TinyML packages (open source)

4. PCs/Laptops for writing codes and result analysis

5. *Internet Access*: Reliable internet access for accessing online resources, simulation updates, and research

6. *Test and Measurement Equipment*: For measuring voltage, current, and resistance in circuits.

7. *Circuit Components*: Resistors, capacitors, inductors, diodes. Standard electronic components for building and testing circuits.

8. *Breadboards and Soldering Stations*: Breadboards for prototyping circuits. Soldering stations for creating custom circuit assemblies if necessary.

9. *Projector and Screen*: For displaying lectures, demonstrations, and simulations.

- ❖ **Reference Books and Articles**

1. Wang X, Han Y, Leung VC, Niyato D, Yan X, Chen X. Edge AI: Convergence of Edge Computing and Artificial Intelligence. Springer Nature; 2020.

2. Sze V, Chen YH, Yang TJ, Emer JS. Efficient processing of deep neural networks. Synthesis Lectures on Computer Architecture. 2020 Jun 24;15(2):1-341.

3. Pete Warden, Daniel Situnayake, “Tiny ML: Machine Learning with Tensorflow Lite on Arduino and Ultra-Low-Power Microcontrollers” O'Reilly, 2020

4. Raad, Haider. Fundamentals of IoT and Wearable Technology Design. John Wiley & Sons, 2020. https://onlinelibrary.wiley.com/doi/book/10.1002/9781119617570

5. Chu, Pong P. Embedded SOPC design with NIOS II processor and VHDL examples. John Wiley & Sons, 2011.https://onlinelibrary.wiley.com/doi/book/10.1002/9781118146538

6. Unsalan, Cem, Duygun E. Barkana, and H. Deniz Gurhan. Embedded Digital Control with Microcontrollers: Implementation with C and Python. John Wiley & Sons, 2021.

https://onlinelibrary.wiley.com/doi/book/10.1002/9781119576600

7. Iniewski, Krzysztof. Embedded Systems: Hardware, Design and Implementation. John Wiley & Sons, 2012. https://onlinelibrary.wiley.com/doi/book/10.1002/9781118468654

2.11 Sensors for Drones and Robotics (400) – 3 (PC)

Course Title:	**Sensors for Drones and Robotics**
Course Code:	M4110005
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ **Course overview**

Course description

This course is designed to provide in-depth understanding of the working principle and applications of micro and nano scale sensors and transducers. It covers the design, fabrication and implementation aspects of most common physical, chemical, and biological sensors and transducers. Basic instrumentation techniques for sensors and transducers will also be covered in the course. By the end of the course, students should be able to develop fundamental understanding on the vital sensors and transducers in present-day use.

❖ **Course learning outcomes:**

CO1: Summarize the historical perspective and relevance of sensors and transducers.

CO2: Demonstrate basic understanding on micro/nanofabrication techniques.

CO3: Identify practical considerations for the design of sensors and transducers.

CO4: Devise the methodology behind sensor development and packaging.

CO5: Discuss instrumentation for sensors and transducers.

❖ **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	2	3	0	2	2	3	2	3	3	3	0	3

CO2	3	2	3	3	2	2	3	3	2	2	1	3
CO3	3	3	2	3	3	3	3	2	3	3	3	3
CO4	3	2	3	2	3	3	3	3	2	1	3	2
CO5	3	3	2	3	3	2	2	3	2	3	3	2

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus** (No module wise splitting)

Overview of microfabrication techniques

Acceleration and motion sensors, Proximity sensors and cameras for drones and robotic applications

Pressure sensors, Light sensors, Acoustic sensors and ultrasound transducers for drones and robotic applications

Gas sensors and Smoke detectors, Temperature sensors for drones and robotic applications

Instrumentation techniques for sensors and transducers

❖ **Tools and equipment required**

Sensors and Transducer Elements: Basic sensors and transducers such as temperature sensors, humidity sensors, pressure sensors, gas sensors, smoke detectors, ultrasound transducers, etc.
Devices to Source and Measure: Equipment to provide AC and DC voltage to sensor elements and circuits such as DC power supply, Arbitrary waveform generators, etc. Equipment to measure waveforms such as Digital Storage Oscilloscope, Analog Discovery Kit, NI-Elvis, etc.
Circuit and Device Simulation Tools: Software packages for circuit simulation such as LTspice, TI Tina, etc. and finite element analysis tools such as COMSOL.
Zoom or Microsoft Teams: For virtual lectures, discussions, and collaborative activities.
Google Docs and Google Drive: For sharing documents, collaborative writing, and storing course materials.
Learning Management System (LMS): Platforms like Moodle, Canvas, or Blackboard for organizing course content, assignments, and communication with students.
Video Conferencing and Recording Tools: Tools like OBS Studio or Screencast-O-Matic for recording lectures, demonstrations, and guest speaker sessions.
Collaborative Document Editing: Tools like Microsoft Word Online, Google Docs, or Dropbox Paper for collaborative writing and editing of lesson plans and projects.

Online Survey Tools: To collect feedback and conduct assessments, tools like Google Forms or SurveyMonkey can be valuable.

Digital Whiteboard Tools: Tools like Microsoft Whiteboard or Explain Everything for collaborative drawing, diagramming, and visual explanations.

Creative Content Creation Tools: Software like Canva, Adobe Spark, or Piktochart for creating visually engaging content.

Learning Analytics Tools: Tools like Tableau or Edpuzzle to analyze student engagement and learning patterns.

Communication Tools: Use communication platforms like Slack or Microsoft Teams to facilitate ongoing discussions and group collaborations.

Podcasting and Audio Tools: Tools like Audacity or Anchor for creating and sharing audio content, which can be a unique way to encourage creative expression.

Collaborative Project Management Tools: Tools like Trello, Asana, or Basecamp for managing group projects and assignments.

Presentation Tools: Use tools like Microsoft PowerPoint, Google Slides, or Prezi for creating engaging presentations during lectures.

Social Media: Utilize platforms like Twitter, Instagram, or Facebook for sharing creative thinking resources and fostering online discussions.

Online Communities: Encourage students to join online communities related to creative thinking, innovation, and education to explore additional resources and network with like-minded individuals.

❖ Reference books and articles

1. Bakhoum, Ezzat G. Micro-and nano-scale sensors and transducers. CRC Press, 2016.
2. Sinclair, Ian. Sensors and transducers. Elsevier, 2000.
3. Safari, Ahmad, and E. Koray Akdogan, eds. Piezoelectric and acoustic materials for transducer applications. Springer Science & Business Media, 2008.
4. Usher, Mike J., and D. A. Keating. Sensors and transducers: characteristics, applications, instrumentation, interfacing. Macmillan International Higher Education, 1996.
5. Madou, Marc J. Manufacturing techniques for microfabrication and nanotechnology. Vol. 2. CRC press, 2011.

6. Ergun, Arif S., Goksen G. Yaralioglu, and Butrus T. Khuri-Yakub. "Capacitive micromachined ultrasonic transducers: Theory and technology." Journal of aerospace engineering 16.2 (2003): 76-84.

7. Jung, Joontaek, et al. "Review of piezoelectric micromachined ultrasonic transducers and their applications." Journal of Micromechanics and Microengineering 27.11 (2017): 113001.

8. Reyns, P., et al. "A review of combine sensors for precision farming." Precision Agriculture 3.2 (2002): 169-182.

2.12 Programming with Micropython (500) – 4 (OE)

Course Title:	**Programming with Micropython**
Course Code:	Mxxxxx
Credits:	4
Level	500
Prerequisites:	Undergraduate degree in Physics or Electronics
Course Split	1-1-2 (L-T-P)

- ❖ **Course overview**

The course Programming with MicroPython introduces students to programming and embedded system development using Python-based tools. The course begins with core Python programming fundamentals, enabling learners to build a strong foundation in problem-solving and software development. It then transitions to MicroPython, focusing on programming microcontrollers for real-time and hardware-interfaced applications. Students gain hands-on experience in controlling digital and analog I/O, interfacing sensors and actuators, and implementing communication protocols for embedded and IoT applications. The course emphasizes rapid prototyping, practical experimentation, and application-oriented learning, preparing students for careers in embedded systems, IoT, and automation.

- ❖ **Course learning outcomes:**

CO1: Apply fundamental Python programming concepts to solve basic computational problems.

CO2: Develop structured Python programs using functions, data structures, and exception handling.

CO3: Program microcontroller hardware using MicroPython for digital and analog input/output operations.

CO4: Interface sensors, actuators, and peripheral devices using MicroPython and standard communication protocols.

CO5: Design and implement simple embedded and IoT applications using MicroPython-based platforms.

- ❖ **Outcome mapping:**

	General Program Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	0	0	0	0	0	2	1	0	0	0	0
CO2	2	0	0	0	0	0	2	0	0	3	0	0
CO3	3	3	0	3	0	0	0	0	0	0	0	3
CO4	3	0	0	0	3	0	0	0	0	0	2	0
CO5	3	3	3	3	0	3	0	1	3	0	3	3

❖ **Syllabus:**

Introduction to the fundamentals of Python programming, including syntax, data types, operators, conditional statements, loops, functions, and basic input–output operations.

Advanced Python concepts such as lists, tuples, dictionaries, modules, exception handling, file handling, and object-oriented programming basics, with emphasis on writing clean and reusable code.

Introduction to MicroPython and embedded platforms, covering MicroPython architecture, firmware installation, development environments, REPL usage, and basic GPIO programming on microcontroller boards such as ESP32 and Raspberry Pi Pico.

Hardware interfacing using MicroPython, including digital and analog I/O, PWM, timers, interrupts, and interfacing of sensors, actuators, and display modules using I^2C and SPI protocols.

Communication and application development, covering UART, Wi-Fi and Bluetooth communication, introductory IoT concepts, power management, and the development of simple embedded and IoT-based applications using MicroPython.

❖ **Reference books and articles**

1. Beginning Python: From Novice to Professional, Magnus Lie Hetland, Apress Berkeley, CA.
2. MicroPython for the Internet of Things: A Beginner’s Guide to Programming with Python on Microcontrollers, Charles Bell, Apress; 1st ed.
3. https://www.coursera.org/learn/python-programming-intro

2.13 Embedded Systems Essentials with Arm 1 (400) – 2 (PE)

Course Title:	**Embedded System Essentials with Arm 1**
Course Code:	Mxxx
Credits:	2
Level	400
Prerequisites:	None
Course Split	1-0-1 (L-T-P)

Course Overview

Embedded systems are everywhere – and Arm-based technologies are the industry standard. Getting started could not be easier. This course includes instructions on how to access to an Mbed simulator (refer to the prerequisites section for more details) so you can apply your new knowledge and skills to prototype and build real-world embedded applications quickly, without the trouble or expense of sourcing hardware.

From the mobile, wearable, and smart devices of today to the transformative Artificial Intelligence (AI) and 5G powered Internet of Things (IoT) of the near future, embedded systems are the fundamental building blocks of our connected world. As we move from billions to trillions of intelligent, connected devices, it's crucial that the next generation of engineers have a thorough understanding of how to rapidly build and deploy a modern embedded system solution.

In this course, you will learn the fundamentals of an embedded system and discover why the Arm architecture and processors are particularly well suited for IoT applications.

Our interactive labs have been designed to cover the technical fundamentals, developing in-demand skills essential for any aspiring embedded systems engineer.

You will begin by learning the characteristics of an embedded system, its components, benefits, and constraints, identify cost-performance trade-offs, and explore why the Arm architecture and processors are particularly well suited for the IoT.

You will then apply your new knowledge of digital and analog I/O, interrupts, low power features, timer and pulse width modulation to program an audio wave generator and audio player, and control peripherals along the way.

All of this will be supported by the Mbed API – so no additional hardware is required, you can download and use the simulator right on your own computer.

Over the six modules, you will gain a key overview of:

- Embedded systems and their importance in modern computing applications

- Industry-standard Arm-based microcontroller architecture, their features and programming models.

The possibilities for future IoT development and connection are enormous. In order to achieve this vision of the future, many engineers and developers will be needed to imagine and design these connected devices and the technologies they are built on.

The world of embedded systems is your doorway into the IoT, and all the opportunities it has to offer.

Course Learning Outcomes

- **CO1: Learn how to implement real-world embedded system projects on a simulated microcontroller using the Mbed API.**
- **CO2: Modify skeleton code to implement functionality for multiple applications: an audio wave generator, an audio player, and controlling peripherals using analog and digital I/O interfaces, interrupts, timers, and pulse width modulation.**
- **CO3: Learn key features of Arm processors and architectures as the basis of modern embedded computing.**
- **CO4: Analyse how a modern API can help accelerate IoT deployment.**
- **CO5: Evaluate applications of embedded systems**

Program Outcomes (POs)

General Program Outcomes	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	3	2	1	0	1	0	0	0	0	0	0	3
CO2	3	2	1	1	1	0	0	0	1	0	0	1
CO3	3	2	2	3	2	1	1	2	1	0	0	2
CO4	3	3	3	2	3	3	2	2	3	3	2	3
CO5	3	3	3	2	3	3	2	2	3	3	2	3

Syllabus

- **Module 1: Introduction to embedded system**

You will be able to explain the characteristics of an embedded system and evaluate its benefits and challenges.

- **Module 2: Introduction to the Mbed Platform and CMSIS**

  You will be able to identify key features of the Mbed platform and run a basic application using the Mbed simulator.

- **Module 3: Digital I/O**

  You will be able to control GPIO peripherals using digital input/output interfaces from the Mbed API.

- **Module 4: Interrupts and Low Power Features**

  You will be able to explain and implement interrupts for the purpose of controlling peripherals, utilising the Mbed API.

- **Module 5: Analog I/O**

  You will be able to implement an audio wave generator whose pitch and volume are controlled by two analog signal inputs, using the Mbed API.

- **Module 6: Timer and Pulse-width Modulation**

  You will be able to develop an audio player incorporating timers, tickers, and Pulse Width Modulation using the Mbed API.

Tools and Equipment Required

1. Mbed API simulator
2. Arm development boards

Reference Books and Articles

1. Dean AG. Embedded Systems Fundamentals with Arm Cortex-M based Microcontrollers: A Practical Approach. ARM Education Media UK; 2017 Mar 28.

2. Martin T. The designer's guide to the Cortex-M processor family. Newnes; 2016 Jun 6.

3. Lacamera D. Embedded Systems Architecture: Design and write software for embedded devices to build safe and connected systems. Packt Publishing Ltd; 2023 Jan 13.

2.14 Intellectual Property Rights and Finance (500) – 4 (OE)

Course Title:	**Intellectual Property Rights and Finance**
Course Code:	M5110083, M5120034, M5120657
Credits:	4
Level	500
Prerequisites:	Nil
Course Split	2-1-1 (L-T-P)

❖ **Course Overview**

Course description

The first part of this course provides an in-depth exploration of various forms of intellectual property (IP) rights, including patents, copyrights, trademarks, and trade secrets. Participants will learn about the legal frameworks, principles, and policies governing IP protection and the importance of IP rights in fostering innovation, creativity, and economic development. Through case studies, interactive discussions, and practical exercises, participants will develop a comprehensive understanding of IP law and its implications for businesses, entrepreneurs, and society.

The second part of this course is designed to equip individuals from diverse professional backgrounds with essential financial knowledge and skills necessary for making informed business decisions. This part provides a comprehensive overview of financial concepts, terminology, and tools, focusing on practical applications in a business context. Participants will learn how to interpret financial statements, analyze financial performance, budget effectively, and understand the impact of economic decisions on organizational goals.

❖ **Course learning outcomes**

CO1: Understand the fundamental concepts, types, and significance of intellectual property rights

CO2: Develop strategies for protecting and managing intellectual property assets effectively

CO3: Apply knowledge of intellectual property law to identify and address real-world IP-related challenges and opportunities

CO4: Interpret and analyze financial statements to assess the financial health of an organization

CO5: Communicate effectively with financial professionals and stakeholders to drive strategic decision-making

❖ **Outcome mapping:**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	2	3	1	2	2	3	2	3	3	3	0	3
CO2	3	2	3	3	2	2	3	3	3	2	1	3
CO3	3	2	2	2	3	2	3	2	3	3	3	3
CO4	3	3	3	2	3	3	3	2	2	1	3	2
CO5	3	3	2	3	3	2	2	3	2	3	3	2

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus** (No module wise splitting)

Introduction to Intellectual Property Rights

- Overview of intellectual property (IP)
- Types of intellectual property rights (patents, copyrights, trademarks, trade secrets)
- Importance of IP protection in innovation and business

Patent Law and Practice

- Patentability criteria and patent application process
- Patent infringement and enforcement
- Strategies for patent portfolio management

Copyright Law and Fair Use

- Copyright protection for original works of authorship
- Fair use doctrine and exceptions to copyright protection
- Digital copyright issues and challenges
- Ethical considerations in IPR

Introduction to Finance for Non-Finance Managers

- Overview of financial management
- Importance of financial literacy for non-finance professionals
- Role of financial managers in organizations
- Project management

Financial Statements Analysis

- Understanding the balance sheet, income statement, and cash flow statement
- Ratio analysis for assessing liquidity, profitability, and solvency
- Trend analysis and financial performance evaluation

Budgeting and Financial Forecasting

- Basics of budgeting and forecasting
- Techniques for developing budgets and forecasts
- Variance analysis and performance monitoring

❖ **Tools and equipment required**

Computers with basic document writing and editing tools

❖ **Reference books and articles**

Textbooks and General References

- Stim, R. (2001). Intellectual Property: Patents, Trademarks, and Copyrights. United States: West/Thomson Learning.
- Vaidhyanathan, S. (2017). Intellectual Property: A Very Short Introduction. United Kingdom: Oxford University Press.
- Brealey, R. A., Myers, S. C., Allen, F. (2014). Principles of Corporate Finance. United Kingdom: McGraw-Hill Education.
- Brigham, E. F., Ehrhardt, M. C. (2001). Financial Management. Singapore: South-Western/Thomson Learning.

2.15 CMOS integrated Operational amplifiers (400) – 3 (PC)

Course Title:	**CMOS integrated Operational amplifiers**
Course Code:	M4110042, M4120002 , M4120606
Credits:	3
Level	400
Prerequisites:	None
Course Split	2-0-1 (L-T-P)

❖ **Course Overview**

Course description: This course explores the advanced properties and applications of operational amplifiers (op-amps). It covers ideal and non-ideal op-amp characteristics, as well as practical circuit design techniques. Topics include ideal op-amp circuits (inverting and non-inverting amplifiers, differential amplifiers, integrators, differentiators), op-amp active filters (Butterworth, Chebyshev, Thompson, elliptic), nonlinear applications (precision rectifier, peak detector, wave-shaping, log-converter circuits), characteristics of non-ideal op-amps (bandwidth, gain-bandwidth product, slew rate, offset voltages, stability, noise), op-amp signal generator circuits (sine-wave oscillators, triangle-wave generators, square-wave generators, pulse generators), and other applications (digital-to-analog and analog-to-digital converters, electronic switching circuits, voltage-to-current converters, voltage-to-frequency and frequency-to-voltage converters).

❖ **Learning Objectives:**

Understanding Op-Amp Fundamentals: Gain a comprehensive knowledge of operational amplifier (op-amp) properties, ideal and non-ideal characteristics, and basic circuit configurations.

Advanced Op-Amp Circuit Design: Develop skills in designing and analyzing complex op-amp circuits, including active filters, nonlinear applications, and signal generator circuits.

Creative Application in Engineering: Apply op-amp circuits creatively to various engineering applications, demonstrating innovative problem-solving and design skills.

Practical Implementation: Gain hands-on experience in simulating and implementing op-amp circuits using simulation software and laboratory equipment.

Communication and Collaboration: Effectively communicate technical information related to op-amp circuits and collaborate with peers in designing and analyzing circuits.

Critical Thinking and Problem Solving: Enhance critical thinking skills through the analysis and troubleshooting of op-amp circuits, fostering innovative solutions to engineering challenges.

- ❖ **Course Learning Outcomes**

CLO1: Students will gain a comprehensive knowledge of operational amplifier (op-amp) properties, ideal and non-ideal characteristics, and basic circuit configurations.

CLO2: Students will learn the static and dynamic limitations of practical op-amps, their causes, and their impacts on application circuits based on op-amps. Static limitations of practical op-amps include input offset voltage, input bias current, and input offset current. Dynamic limitations include slew rate, bandwidth, and settling time.

CLO3: Students will learn basic filter theory, filter responses, and filter synthesis techniques. Filter theory involves the study of circuits that selectively allow certain frequencies to pass while attenuating others. Filter responses describe how filters behave with respect to frequency. Filter synthesis involves designing a filter with specific characteristics to meet a particular application's requirements.

CLO4: Students will apply design concepts for linear op-amp circuits, including amplifiers, I-V/V-I converters, instrumentation amplifiers, integrators, and differentiators. Applying the design concepts involves understanding the behavior of op-amp circuits, selecting appropriate component values, and ensuring stability and proper operation of the circuit. Simulation tools can be used to validate the design before implementation.

CLO5: Students will design the nonlinear circuits (e.g., comparators, Schmitt triggers, rectifiers, and peak detectors) based on op-amps. In each case, understanding the characteristics of op-amps, diodes, and feedback networks is crucial for designing nonlinear circuits accurately. Simulations can help verify the circuit's behavior and performance before implementation.

CLO6: Students will develop proficiency in analyzing and designing op-amp-based signal generator circuits and advanced application circuits, such as oscillators, waveform generators, and converters (e.g., DACs and ADCs), while understanding the practical limitations and optimization techniques for real-world implementations.

- ❖ **Outcome mapping:**

	General Program Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CLO 1	3	1	1	0	0	0	0	0	0	0	0	3
CLO 2	3	0	1	0	2	0	0	0	1	0	0	1
CLO 3	3	1	2	3	2	0	0	0	1	0	0	2
CLO 4	3	3	3	2	3	3	2	2	3	3	2	3
CLO 5	3	3	3	2	3	3	2	2	3	3	2	3
CLO 6	2	3	1	3	2	3	3	2	0	3	2	3

❖ **Syllabus:**

Properties of Op-Amps: The ideal op-amp, Open-loop gain, input resistance, and output resistance, Ideal Op-Amp Circuits: Inverting and non-inverting amplifiers, Differential input and output amplifiers, Integrators and differentiators, Single-pole low-pass and high-pass amplifiers, The op-amp as a comparator, Op-Amp Active Filters: Filter transfer functions. Butterworth, Chebyshev, Thompson, and elliptic approximations. Sallen-Key,

infinite-gain-multi-feedback, state variable, generalized impedance converter, and switched capacitor topologies. Nonlinear Applications: Precision rectifier, peak detector, wave-shaping, and log-converter circuits, Characteristics of Non-Ideal Op-Amps: Open-loop transfer function, bandwidth, gain-bandwidth product, slew rate, power bandwidth, clipping, rise time, offset voltages and currents, stability, frequency compensation, noise, Op-Amp Signal Generator Circuits: Sine-wave oscillators, triangle-wave generators, square-wave generators, and pulse generators, Other Applications of op-Amps: Applications to digital-to-analog and analog-to-digital converters, electronic switching circuits, voltage-to-current converters, and voltage-to-frequency and frequency-to-voltage converters.

❖ **Tools and equipment required**

1. **LTSpice software:** Useful to analyze the behavior of the circuits

2. **Internet Access:** Internet access for online materials and software updates.

3. **Test and Measurement Equipment:** For measuring voltage, current, and resistance in circuits and visualize the waveforms of the nodes present in the circuits

4. **Circuit Components:** Resistors, capacitors, inductors, diodes, zener diodes, BJT, MOSFET, Op-amps, and other circuit components to build the circuits.

5. **Breadboards:** Breadboards for prototyping circuits.

- **Reference books and articles**

[1] Franco, Design with Operational Amplifiers and Analog Integrated Circuits (4th edition), McGraw Hill, 2014. ISBN 9780078028168

[2] R. A. Gayakwad, Op-Amps and Linear Integrated Circuits, 4th ed. Lafayette, LA, USA: PHI, 2006.

[3] George Clayton and Steve Winder, Operational Amplifiers, 5th ed. Burlington, NJ, USA: Newnes, 2003.

2.16 VLSI physical design of Neural Processors (400) – 3 (PE)

Course Title:	VLSI physical design of Neural Processors
Course Code:	M4110034 , M4120035, M4120625
Credits:	3
Prerequisites:	None
Course Split	2-0-1 (L-T-P)

❖ Course aim

In this course, the students learn various practical aspects of chip design and layout. By the end of the course, the students are expected to be familiar with open-source tools for VLSI and be able to send a design for tape-out.

❖ Course learning outcomes

CO1: Experiment with digital logic design at transistor level

CO2: Evaluate various design challenges with digital circuits

CO3: Explain the formal verification of a logic design with examples

CO4: Analyse the functional logic of physical designs

CO5: Demonstrate a working design of an example AI core

❖ Outcome mapping

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1		3								3		
CO2		3										3
CO3					3				3			
CO4				3								3
CO5	3		3					3	3			3

Level of impact: 3 - high, 2 - medium, 1 - low.

- ❖ **Syllabus**

MOSFET, Schematic and layout - NGSPICE, Introduction to MAGIC, Introduction to ElectricVLSI, Standard cells, Projects in basic circuits
Designing digital circuits, data flow and control. Combinatorial logic. Sequential logic. Finite state machines. Modularity. Projects in digital design
Formal verification - Open Source Formal Verification tools, Bounded model checking. Assumptions and assertions. Safety of design.
OpenLANE, The different stages of the flow. How to interpret results, logs and errors. Design Rule Check, Layout vs Schematic, Basic configuration setting.
Skywater, Caravel, Building a neural core

- ❖ **Tools required:**

None

- ❖ **Lab**

None

Reference books and articles

- https://caravel-harness.readthedocs.io/en/latest/
- http://riscv.org/
- http://riscv.org/software-status/
- https://riscv.org/technical/specifications
- https://github.com/cliffordwolf/picorv32
- https://github.com/google/skywater-pdk
- https://github.com/efabless/caravel

2.17 Robotics and Industrial Automation 4.0 (400) – 3 (PE)

Course Title:	**Robotics and Industrial Automation 4.0**
Course Code:	M4110082, M4129005
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ **Course Overview**

Course Description: This course is designed to equip students with the knowledge and practical skills required to excel in the fields of robotics and industrial automation 4.0 and developmental needs from an electronics design perspective. The main aim of this course is to provide an introduction to robotics and Industrial automation 4.0/5.0 and its implications for the future of industry. The course covers a range of topics in automation and the influence of robotics and AI technologies in shaping the future of the industry. The students are expected to work on projects to implement and design a minuscule industry 4.0/5.0 factory.

❖ **Course learning outcomes (COs)**

CO1: Students will acquire the skills to develop an in-depth understanding of various components in industry 4.0/5.0 and its impact on society

CO2: Students will be able to apply the ideas from AI and robotics in planning and designing the modern factory of today and tomorrow

CO3: Students will obtain critical insights into various challenges and ethical issues with the use of AI technologies

CO4: Students will be able to analyze different case studies on the application of robots in industrial settings for rapid prototyping and mass customization

CO5: Students will be able to demonstrate the application of AI and allied technologies in designing a domain-specific minuscule industry 4.0/5.0 factory

❖ **Outcome mapping:**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3	0	3	3	0	0	3	2	0	3	3
CO2	3	3	2	3	2	2	3	3	3	3	0	3
CO3	2	3	1	1	0	0	0	0	2	0	0	3
CO4	3	3	3	3	3	3	0	2	3	3	3	0
CO5	2	2	3	3	3	3	3	3	3	3	3	2

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus**

Introduction to industry 4.0, Differences between industry 4.0 and industry 5.0

Society 4.0 and its relations to industrial automation, Ethical issues of using AI technologies

Fundamentals of Machine Vision, Object Detection Techniques, NLP and speech technologies in the factory AI and Machine Learning for Robotics: Path Planning, Object Recognition, Predictive Maintenance, Role of Edge Computing in Industrial Automation

Degrees of Freedom (DoF) and Workspace Analysis, Sensors and Actuators in Robotics, Types of Sensors: Proximity Sensors, Vision Sensors, Force Sensors, LIDAR, Ultrasonic Sensors; Types of Actuators: Electric Motors, Stepper Motors, Servo Motors, Pneumatic and Hydraulic Actuators, Sensor Fusion and Feedback Control

Augmented reality for factory automation, Security and privacy questions in factory automationPlanning and managing human resources in Industry 5.0, health sector, electronics manufacturing sector

❖ **Tools and equipment required**

1. Python/ TensorFlow/ PyTorch

3. Arduino/ Raspberry PI/ Jetson Nano

❖ **Reference Books and Articles**

[1] Gilchrist A. Industry 4.0: the industrial internet of things. Apress; 2016 Jun 28.

[2] Nahavandi, S., 2019. Industry 5.0—A human-centric solution. Sustainability, 11(16), p.4371.

[3] Salgues, Bruno. Society 5.0: industry of the future, technologies, methods and tools. John Wiley & Sons, 2018 https://onlinelibrary.wiley.com/doi/book/10.1002/9781119507314

[4] André, Jean-Claude. Industry 4.0: paradoxes and conflicts. John Wiley & Sons, 2019. https://onlinelibrary.wiley.com/doi/book/10.1002/9781119644668

[5] Tromp, Jolanda G., Dac-Nhuong Le, and Chung Van Le, eds. Emerging Extended Reality Technologies for Industry 4.0: Early Experiences with Conception, Design, Implementation, Evaluation and Deployment. John Wiley & Sons, 2020. https://onlinelibrary.wiley.com/doi/book/10.1002/9781119654674

[6] Kenett, Ron S., Robert S. Swarz, and Avigdor Zonnenshain, eds. Systems engineering in the fourth industrial revolution: Big data, novel technologies, and modern systems engineering. John Wiley & Sons, 2019. https://onlinelibrary.wiley.com/doi/book/10.1002/9781119513957

2.18 Graphene and 2D Materials (400) – 3 (PE)

Course Title:	**Graphene and 2D Materials**
Course Code:	M4120655
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ **Course overview**

Course description: This course provides an in-depth understanding of the various methods for synthesizing advanced materials. Starting with an introduction to materials and their classifications, the course covers a broad range of chemical and physical approaches to material synthesis. Topics include sol-gel methods, hydrothermal routes, vapor deposition techniques, nanolithography, and mechanical alloying. Special emphasis is placed on nanoporous materials, their properties, applications, and safety aspects in material synthesis. Also, covers the applications of the advanced materials in various interdisciplinary fields.

❖ **Course learning outcomes (CLO's)**

CLO1- Understand the classifications and fundamental concepts of materials.

CLO2- Learn and apply various chemical approaches for the synthesis of nanomaterials.

CLO3- Analyze and utilize physical methods for material deposition and nanofabrication.

CLO4- Evaluate the properties, synthesis, and applications of nanoporous materials.

CLO5- Demonstrate proficiency in mechanical alloying and milling techniques, recognizing safety hazards associated with these processes.

❖ **Outcome mapping:**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3			3	3	3	3	3			3
CO2	3	3	3	3	3	3	3		3			
CO3		3	3	3	3	3	3		3			
CO4			3	3	3	3	3		3			
CO5			3	3	3	3	3		3			3

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus**

The course begins with an introduction to materials and their classifications, providing a foundation for understanding the significance of different material types. It then explores various approaches to synthesis, including chemical methods such as the sol-gel method, solvothermal and hydrothermal routes, precipitation, spray pyrolysis, electro-spraying, spin coating, self-assembled monolayers (SAMs), Langmuir-Blodgett (LB) films, micro emulsion polymerization, template-based synthesis, electrochemical deposition, and electrophoretic deposition.

Physical approaches are covered in detail, including inert gas condensation, arc plasma, laser ablation, vapor deposition, epitaxial growth techniques (CVD, MOCVD, MBE, ALD), pulsed laser deposition, sputtering, magnetron sputtering, lithography (Photo/UV/EB/FIB techniques), dip pen nanolithography, and etching processes (dry and wet etching), as well as micro contact printing.

The course also delves into nanoporous materials, discussing the synthesis, properties, and applications of zeolites and mesoporous materials, the role of nanomaterials and nanomembranes in water purification, and advanced materials such as carbon nanotubes, graphene, core shell nanostructures, and hybrid nanocomposites.

Finally, the course covers mechanical alloying and milling, including bottom-up and top-down approaches, equipment for mechanical alloying, process variables in milling, mechanism of alloying, mechanochemical processing, thermodynamic aspects, powder contamination, and safety hazards related to mechanical alloying processes.

❖ **Tools and equipment required**

- Minor instruments for synthesis purposes such as spin coating, hot plate with magnetic stirrer, hot air oven, muffle furnace, etc.
- To confirm materials purity, physicochemical characterization such as UV, FTIR, etc
- To study & conduct the electrical characterization parametric analyser, source meter, etc.
- Computers or workstations with interpretation software installed related the theory.
- Workstations equipped with necessary peripherals such as keyboards, mice, and monitors.
- Measurement instruments for characterizing performance in real-time.
- Workbenches or lab stations for conducting experiments
- Safety equipment such as goggles, gloves, and lab coats for handling materials if applicable.

❖ **Reference books and articles**

1. Guozhong Cao, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press, London 2004.

2. T. Pradeep, Nano: The Essentials Understanding nanoscience and nanotechnology, Tata

McGrawHill Publishing Company Limited NEW DELHI, 2007.

3. Petersen, Nils O. Foundations for nanoscience and nanotechnology. CRC Press, 2017.

4. A S Edelstein and R C Cammarata, Nanomaterials Synthesis, Properties and Applications,

IOP Publishing Ltd 1996.

5. Frank J. Owens and Charles P.Poole, The Physics and Chemistry of Nano Solids, Wiley-Interscience, 2008

2.19 Mixed Signal VLSI physical design (400) – 3 (PE)

Course Title:	Mixed Signal VLSI physical design lab
Course Code:	M4110040, M4120033, M4120658
Credits:	3
Prerequisites:	None
Course Split	2-0-1 (L-T-P)

- **Course aim:**

In this course, students learn various physical design methods and custom VLSI design techniques. The students then use these foundations to build mixed-signal chips using open-source design tools.

- **Course learning outcomes:**

CO1 Experiment with physical design flow and custom VLSI

CO2 Develop various design challenges with digital and analog circuits

CO3 Explain the physical design logic with examples

CO4 Apply the functional logic of physical designs

CO5 Show a working design of a mixed signal chip with example

- **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1		3								3		
CO2		3										3
CO3					3				3			
CO4				3								3
CO4	3		3					3	3			3

Level of impact: 3 - high, 2 - medium, 1 - low.

- ❖ **Syllabus:**

Physical Design Big picture 1:

Physical Design Flow Overview: Floor-Planning Steps, Netlist Binding And Placement Optimization, Placement Timing And Clock Tree Synthesis, Clock Net Shielding, Route - DRC Clean - Parasitics Extraction - Final STA

Floorplanning: Utilization Factor And Aspect Ratio, Concept Of Pre-Placed Cells, De-coupling Capacitors, Power Planning, Pin Placement And Logical Cell Placement Blockage
Placement: Net-list Binding And Placement, Optimize Placement Using Estimated Wire Length And Capacitance, Optimize Placement Conitnued
Timing Analysis With Ideal Clocks: Setup Timing Analysis And Introduction to Flip-Flop Setup Time, Introduction To Clock Jitter and Uncertainty, Setup Timing Analysis with Multiple Clocks, Multiple Clock Timing Analysis And Introduction To Data Slew Check, Data Slew Check

Physical Design Big picture 2:

Clock Tree Synthesis And Signal Integrity, Clock Tree Routing And Buffering using H-Tree Algorithm, Crosstalk And Clock Net Shielding, Static Timing Analysis With Real Clocks, Hold Timing Analysis Concluded, Multiple Clocks Setup Timing Analysis With Real Clocks
Routing And Design Rule Check (DRC): Introduction to Maze Routing - Lee's Algorithm, Lee's Algorithm Conclusion, Design Rule Check
Parasitics Extraction: Introduction to IEEE 1481 - 1999 SPEF format, SPEF Representation of a NET, Distributed Resistance And Capacitance Representation in SPEF, SPEF Header Description, Physical Design Flow Conclusion and What Next !!
Technological advances happening in the world of opensource: Next Generation Education Technology for VLSI Design Flow

Custom Physical Design 1:

Create active regions, Formation of N-well and P-well, Formation of gate terminal, Source drain formation, Local interconnect formation, Higher level metal formation
Corner stitching introduction, Corner stitch to planes to tiles, Active tile types and tech file content, Contacts and styles, Connect section for circuit extraction

Custom Physical Design 2:

Introduction to DRC and lambda design rules, Poly extension and poly to diffusion spacing rules, Poly to diffusion spacing and diffusion contact width rules, Metal1 width and poly to metal1 spacing rules, Contact spacing and minimum active width rules, From logic to layout to SPICE

Introduction to simple path, euler's path and euler's circuit, Introduction to stick diagram, Derive actual dimension from stick diagram, Pre-layout simulation, Layout using 'only' stick diagram, Euler's path for Fn - Input gate ordering, Improved stick diagram for new gate input ordering, Abstract layout from stick diagram, Derive actual dimension for Fn, Script to create layout

Mixed Signal Flow with Sky130

Generating hard-macro LEF for basic analog block: Introduction to mixed-signal flow and EDA tools used, Macro LEF file modification, Steps to create pins in macro LEF, Steps to modify LEF class, origin and site properties, Steps to modify LEF bounding box property, Steps to modify LEF port property, LEF file modifications summary

Macro based RTL2GDS using OpenLANE/Sky130: Steps to setup new OpenLANE project, Steps to setup input files in OpenLANE project, Steps to setup macro LEF files for OpenLANE flow, Final OpenLANE config file settings, Prep design and add LEFs in OpenLANE flow

RTL2GDS Physical Design flow steps: Short theory on RTL2GDS flow, RTL synthesis and floorplan step, Global and detailed placement, Tap-Decap detailed placement, PDN generation, Final routing and GDS generation, Final layout review and conclusion

- **Tools required:**

None

- **Lab**

None

- **Reference books and articles**

NA- class notes

2.20 Sensors and transducers for IoT (400) – 3 (PE)

Course Title:	**Sensors and Transducers for IoT**
Course Code:	M4110039, M4120032, M4120656
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ **Course overview**

Course description: This course introduces the fundamentals and applications of sensors and transducers in IoT systems across diverse domains, including environmental monitoring, health monitoring, industrial automation, smart homes, and agriculture. Students will explore the working principles, interfacing circuits, and practical use cases of sensors like temperature, pressure, motion, and biomedical sensors. Additionally, the course covers transducers and actuators critical for IoT applications, enabling students to design and implement smart systems. Emphasis is placed on hands-on activities, simulations, and experiential learning to foster a deeper understanding of IoT sensor technologies and their transformative role in modern industries.

❖ **Course Learning Outcomes**

CLO1: Explain the working principles and applications of various environmental monitoring sensors, including temperature, humidity, pressure, gas, light, and soil moisture sensors.

CLO2: Analyze motion and position sensing technologies such as accelerometers, gyroscopes, magnetometers, and proximity sensors for IoT applications.

CLO3: Demonstrate the principles and use cases of health monitoring sensors, including heart rate, SpO2, body temperature, ECG, and glucose sensors.

CLO4: Evaluate the role of industrial and structural monitoring sensors like vibration sensors, strain gauges, flow sensors, and load cells in IoT systems.

CLO5: Illustrate the applications of sensors in smart homes, building automation, and agriculture, including gas leak sensors, smoke detectors, PIR motion sensors, soil moisture, pH, and NPK sensors.

CLO6: Design IoT systems using transducers (actuators), such as servos, stepper motors, DC motors, piezoelectric actuators, and LEDs, for various real-world scenarios.

❖ **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CLO1	2	3	2	3	0	2	1	3	3	2	0	3
CLO2	3	3	3	2	2	2	0	3	3	3	1	2
CLO3	3	3	3	3	3	3	2	3	2	2	1	3
CLO4	3	2	3	3	3	3	2	3	2	2	1	3
CLO5	3	2	3	3	3	3	2	3	2	2	1	3
CLO6	3	2	3	3	3	3	2	3	2	2	1	3

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus:**

Environmental Monitoring

Temperature Sensors, Humidity Sensors, Pressure Sensors, Gas Sensors, Light Sensors: LDR (Light Dependent Resistor), UV Sensors, Rain/Soil Moisture Sensors.

Motion and Position Sensing

Accelerometers, Gyroscopes, Magnetometers – GMR, Proximity Sensors, Position Sensors: Rotary encoders, linear potentiometers.

Health Monitoring

Heart Rate Sensors, SpO2 (Oxygen Saturation) Sensors, Body Temperature Sensors (non-contact infrared), Electrocardiogram (ECG) Sensors, Glucose Sensors.

Industrial and Structural Monitoring

Vibration Sensors, Strain Gauges, Flow Sensors, Load Cells.

Smart Home and Building Automation

Gas Leak Sensors, Smoke Detectors, CO and CO2 Sensors, Sound Sensors, PIR Motion Sensors, Contact Sensors.

Smart Agriculture

Soil Moisture Sensors, pH Sensors, NPK Sensors, Water Level Sensors.

Transducers (Actuators for IoT systems)

Servos, Stepper Motors, DC Motors, Thermal Actuators, Piezoelectric Actuators, LEDs.

- ❖ **Tools and equipment required**

Sensors and transducer elements: Basic sensors and transducers such as temperature sensors, humidity sensors, pressure sensors, gas sensors, smoke detectors, etc. for students to experiment.

Devices to source and measure: Equipment to provide AC and DC voltage to sensor elements and circuits such as DC power supply, Arbitrary waveform generators, etc. Equipment to measure output waveforms of circuits such as Digital Storage Oscilloscope, Analog Discovery Kit, NI-Elvis, etc.

Circuit and device simulation tools: Software packages for circuit simulation such as LTspice, TI Tina, etc. and finite element analysis tools such as COMSOL.

Online Idea Generation Platforms: Platforms like Ideaflip, Stormboard, or MindMeister can facilitate idea generation and organization.

Zoom or Microsoft Teams: For virtual lectures, discussions, and collaborative activities.

Google Docs and Google Drive: For sharing documents, collaborative writing, and storing course materials.

Learning Management System (LMS): Platforms like Moodle, Canvas, or Blackboard for organizing course content, assignments, and communication with students.

Video Conferencing and Recording Tools: Tools like OBS Studio or Screencast-O-Matic for recording lectures, demonstrations, and guest speaker sessions.

Collaborative Document Editing: Tools like Microsoft Word Online, Google Docs, or Dropbox Paper for collaborative writing and editing of lesson plans and projects.

Online Survey Tools: To collect feedback and conduct assessments, tools like Google Forms or SurveyMonkey can be valuable.

Digital Whiteboard Tools: Tools like Microsoft Whiteboard or Explain Everything for collaborative drawing, diagramming, and visual explanations.

Creative Content Creation Tools: Software like Canva, Adobe Spark, or Piktochart for creating visually engaging content.

Learning Analytics Tools: Tools like Tableau or Edpuzzle to analyze student engagement and learning patterns.

Communication Tools: Use communication platforms like Slack or Microsoft Teams to facilitate ongoing discussions and group collaborations.

Podcasting and Audio Tools: Tools like Audacity or Anchor for creating and sharing audio content, which can be a unique way to encourage creative expression.

Collaborative Project Management Tools: Tools like Trello, Asana, or Basecamp for managing group projects and assignments.

Presentation Tools: Use tools like Microsoft PowerPoint, Google Slides, or Prezi for creating engaging presentations during lectures.

❖ **Reference books and articles**

1. Sinclair, Ian. *Sensors and transducers*. Elsevier, 2000.
2. Usher, Mike J., and D. A. Keating. *Sensors and transducers: characteristics, applications, instrumentation, interfacing*. Macmillan International Higher Education, 1996.
3. Yasuura, Hiroto, et al., eds. *Smart sensors at the IoT frontier*. Cham, Switzerland: Springer International Publishing, 2017.
4. Mitsubayashi, Kohji, Osamu Niwa, and Yuko Ueno, eds. *Chemical, gas, and biosensors for internet of things and related applications*. Elsevier, 2019.
5. Gupta, Deepak, et al. *Smart Sensors for Industrial Internet of Things*. Springer International Publishing, 2021.
6. “Sensors and Transducers” by D. Patranabis
7. “IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things” by David Hanes et al.
8. “Sensors and Signal Conditioning” by Ramon Pallas Areny and John G. Webster.

2.21 Introduction to System on Chip Design (400) – 3 (PE)

1 Course Title:	Introduction to System on Chip Design
Course Code:	M4110029, M4120037
Credits:	3
Level	300
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ **Course overview**

Course description

Introduction to System on Chip Design Education Kit covers the fundamentals of System-on-Chip design, including how the theories and concepts can be applied in the design and programming of a simple SoC implemented on an FPGA.

Course learning outcomes:

CO1: Outline the components of the AHB VGA peripheral, AHB UART peripheral, AHB Timer, GPIO and 7-segment display peripherals and describe their functions.

CO2: Describe the Cortex Microcontroller Software Interface Standard (CMSIS) and identify how to write device drivers to access AHB peripherals

CO3: Implement a simple SoC which consist of Cortex-M0 processor, AHB-Lite bus and AHB peripherals (Memory, LED, VGA) on an FPGA and write a simple program to display text on a connected VGA.

CO4: Implement an SoC which contains a Cortex-M0 processor, AHB-Lite bus and AHB peripherals (Program memory and LED, VGA, UART, Timer, GPIO and 7-Segment) on an FPGA and write simple programs to control the peripherals.

CO5: Implement the AHB timer and UART interrupt mechanism at both hardware and software domains by adding appropriate interrupt registers and writing suitable interrupt handler.

❖ **Outcome mapping:**

	General Program Outcomes											
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO1 2**

CO1	3	0	3	3	3	0	0	0	0	0	0	3
CO2	3	2			3					2		
CO3	3		3	3	3						3	
CO4	3		3	3	3				3			
CO5	3	2		3	3			2				

❖ **Syllabus:**

1. Introduction to Arm-based System-on-Chip Design
2. The Arm Cortex-M0 Processor Architecture: Part 1
3. The Arm Cortex-M0 Processor Architecture: Part 2
4. AMBA 3 AHB-Lite Bus Architecture
5. AHB VGA Peripheral
6. AHB UART Peripheral
7. Timer, GPIO and 7-Segment Peripherals
8. Interrupt Mechanisms
9. Programming an SoC using C Language
10. Arm CMSIS and Software Drivers
11. Application Programming Interface and Final Application

❖ **Lab details**

1. Implement a simple SoC which consist of Cortex-M0 processor, AHB-Lite bus and AHB peripherals (Memory, LED, VGA) on an FPGA and write a simple program to display text on a connected VGA.

2. Implement an SoC which contains a Cortex-M0 processor, AHB-Lite bus and AHB peripherals (Program memory and LED, VGA, UART, Timer, GPIO and 7-Segment) on an FPGA and write simple programs to control the peripherals.

3. Implement the AHB timer and UART interrupt mechanism at both hardware and software domains by adding appropriate interrupt registers and writing suitable interrupt handler.

4. Implement a timer interrupt handler and UART interrupt handler in a high-level language such as C.

❖ Tools and equipment required

FPGA and ARM development boards

❖ Reference books and articles

https://github.com/arm-university/Introduction-to-SoC-Design-Education-Kit

2.22 Introduction to Microbots (400) - 3 (PE)

Course Title:	**Introduction to Microbots**
Course Code:	M4110037, M4120030
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ Course overview

This course offers an in-depth exploration of microbots, miniature robotic systems operating at the microscale or below. Key topics encompass microbot design, fabrication methods, sensing technologies, actuation principles, control systems, practical applications, and associated challenges. The theoretical knowledge will be reinforced through hands-on exercises and real-world case studies.

❖ Course learning outcomes

CO1: Analyze the principles of microbot design and operation.

CO2: Outline the sensing and actuation mechanisms used in microbots.

CO3: Apply theoretical concepts in basic microbotic system design.

CO4: Deduce various fabrication techniques for microbots.

CO5: Analyze real-world applications in medicine, engineering, and environmental monitoring

❖ Outcome mapping

	General Program Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	0	2	2	3	2	3	3	3	0	3
CO2	3	2	3	3	2	2	3	3	3	2	1	3
CO3	3	3	2	2	3	3	3	2	3	3	3	3
CO4	3	3	3	2	3	3	3	2	2	1	3	2
CO5	3	3	2	3	3	2	2	3	2	3	3	2

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus**

Fundamentals of Microbots

- History and evolution of robotics to microbots
- Applications that drove the development of microbots
- Properties and challenges at the microscale (physics and mechanics)

Microbot Design and Manufacturing

- Materials for microbots: biocompatible, MEMS, soft robotics
- Fabrication techniques:
  - Photolithography
  - 3D printing (microscale)
  - Self-assembly methods
- Miniaturization challenges

Sensing and Actuation at Microscale

- Sensing mechanisms: optical, magnetic, chemical, and mechanical
- Actuation techniques:
  - Magnetic fields
  - Light (optical tweezers)
  - Chemical gradients
  - Electric and acoustic fields

Control and Navigation

- Autonomous vs. remote control
- Swarm robotics principles
- Algorithms for microscale navigation

Applications of Microbots

- Medical applications: targeted drug delivery, microsurgery
- Environmental monitoring: pollutant detection, water purification

- Industrial applications: precision assembly, inspection

- ❖ **Tools and equipment required**

Devices to Source and Measure: Equipment to provide AC and DC voltage to sensor elements and circuits such as DC power supply, Arbitrary waveform generators, etc. Equipment to measure waveforms such as Digital Storage Oscilloscope, Analog Discovery Kit, NI-Elvis, etc.
Circuit and Device Simulation Tools: Software packages for circuit simulation such as LTspice, TI Tina, etc. and finite element analysis tools such as COMSOL.
Zoom or Microsoft Teams: For virtual lectures, discussions, and collaborative activities.
Google Docs and Google Drive: For sharing documents, collaborative writing, and storing course materials.
Learning Management System (LMS): Platforms like Moodle, Canvas, or Blackboard for organizing course content, assignments, and communication with students.
Video Conferencing and Recording Tools: Tools like OBS Studio or Screencast-O-Matic for recording lectures, demonstrations, and guest speaker sessions.
Collaborative Document Editing: Tools like Microsoft Word Online, Google Docs, or Dropbox Paper for collaborative writing and editing of lesson plans and projects.
Online Survey Tools: To collect feedback and conduct assessments, tools like Google Forms or SurveyMonkey can be valuable.
Digital Whiteboard Tools: Tools like Microsoft Whiteboard or Explain Everything for collaborative drawing, diagramming, and visual explanations.
Creative Content Creation Tools: Software like Canva, Adobe Spark, or Piktochart for creating visually engaging content.
Learning Analytics Tools: Tools like Tableau or Edpuzzle to analyze student engagement and learning patterns.
Communication Tools: Use communication platforms like Slack or Microsoft Teams to facilitate ongoing discussions and group collaborations.
Podcasting and Audio Tools: Tools like Audacity or Anchor for creating and sharing audio content, which can be a unique way to encourage creative expression.
Collaborative Project Management Tools: Tools like Trello, Asana, or Basecamp for managing group projects and assignments.
Presentation Tools: Use tools like Microsoft PowerPoint, Google Slides, or Prezi for creating engaging presentations during lectures.
Social Media: Utilize platforms like Twitter, Instagram, or Facebook for sharing creative thinking resources and fostering online discussions.
Online Communities: Encourage students to join online communities related to creative thinking, innovation, and education to explore additional resources and network with like-minded individuals.

- ❖ **Reference books and articles**

Textbooks and General References

- *Microrobotics for Biomedical Applications* by Minjun Kim and Hyesu Jang
  Focuses on biomedical applications, microbot designs, and case studies.
- *Micro and Nanorobotics: Components and Applications* by Nicholas X. Randall
  Covers components, fabrication, and real-world applications of micro- and nanorobots.
- *Foundations of Robotics: Analysis and Control* by Tsuneo Yoshikawa
  Fundamental concepts of robotics, useful for understanding control systems in microbots.
- *Microsystem Design* by Stephen D. Senturia
  Comprehensive coverage of MEMS technologies relevant to microbot manufacturing.
- *Bioinspired Actuators and Sensors* by Minoru Taya and Kazuo Asaka
  Explores bioinspired mechanisms that can be applied in microbot systems.

Advanced and Specialized References

- *Micro and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices* by Brian J. Kirby
  Detailed study of fluid mechanics at low Reynolds numbers, crucial for microbot propulsion.
- *Molecular Machines and Motors* edited by J.-P. Sauvage
  Focuses on molecular-scale mechanisms applicable to nanoscale robotics.

2.23 VLSI Technology (400) – 3 (PE)

Course Title:	**VLSI Technology**
Course Code:	M4110038, M4120031, M4120652
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

- **Course overview**

Course description

The primary objective of this course is to develop a comprehensive understanding of the principles and techniques involved in the fabrication of Very Large-Scale Integration (VLSI) devices and circuits. Students will explore various processes, materials, and technologies used in VLSI fabrication, along with practical applications and industry standards.

Introduction to VLSI Fabrication Technology: Overview of VLSI technology, its importance, applications in modern electronics, and course objectives and structure.

Introduction to Clean Room Environment, Common instruments and cleaning process. CMOS IC/multilayer Fabrication process and related Semiconductor and Properties. Study the properties of silicon and other semiconductor, including crystal structure and doping.

Silicon Wafer Preparation. Explore crystal growth techniques (CZ and FZ), wafer slicing, orientation, and polishing. Flexible Substrate Preparation. Explore different conductive, insulating substrates and their usage in device fabrication.

Oxidation Processes: Learn about thermal oxidation processes, comparing dry and wet oxidation, and understanding oxide quality and applications.

Photolithography: Understand the principles of photolithography, photoresist materials, and patterning techniques. direct writing methods-mask less optical lithography, electron beam, x-ray, and ion beam lithography, and nanoimprint lithography and soft lithography.

Etching Techniques: Examine wet and dry etching methods, focusing on selectivity, anisotropy, and etch rates.

Ion Implantation: Study the process of ion implantation, its advantages over diffusion, and damage annealing.

Diffusion Mechanisms: Analyze diffusion mechanisms, dopant profiles, and junction depth in semiconductor devices.

Metallization/Interconnects: Explore metal interconnects and methods of metallization such as PVD and CVD.

Real-Time FET Design and Simulation: Hands-on design of FETs using simulation software, including practical sessions on simulating VLSI circuits and analyzing their performance.

Fabrication Techniques: Apply learned techniques in a real-time VLSI fabrication project.

Testing and Packaging: Understand the testing methods for VLSI circuits and various packaging techniques. Focus on Interconnects, interconnect options. System-in-Package & Multi-chip Modules Technology.

Chemical Vapor Deposition (CVD), Physical Vapor Deposition (PVD), and Atomic Layer Deposition (ALD): Learn and understand CVD, sputtering and evaporation techniques, including their applications with limitations and its use in advanced VLSI fabrication.

Chemical Mechanical Planarization (CMP): Understand the principles of CMP, its applications, and its importance in multi-level metallization.

Project Work: Engage in hands-on projects that involve designing, simulating, and optimizing VLSI devices and circuits, culminating in the presentation and analysis of simulation results.

Course learning outcomes (CLO's)

CLO1-Understand the fundamentals of VLSI technology and its applications: This aims to help students grasp the essential concepts of Very Large Scale Integration (VLSI) technology, including its historical development, key components, and its wide range of applications across various industries. Students will gain insights into how VLSI technology has transformed electronics and driven advancements in fields like computing and communication.

CLO2-Demonstrate knowledge of IC fabrication (CMOS), semiconductor materials and their properties: This focuses on providing students with a comprehensive understanding of Integrated Circuit (IC) fabrication processes and semiconductor materials. Students will explore the characteristics of materials such as silicon, germanium, and compound semiconductors, including their conductivity, bandgap, and doping effects. They will also learn about IC fabrication techniques and the utilization of different materials in these processes.

CLO3-Explain various VLSI fabrication processes, including oxidation, lithography, and etching: This is to elucidate the complex processes involved in VLSI fabrication. Students will study key fabrication techniques such as oxidation (the growth of oxide layers on semiconductor substrates), lithography and its types (patterning intricate structures on semiconductor surfaces), and etching (selective removal of material to create desired patterns and features).

CLO4-Analyze doping techniques and their impact on semiconductor devices: This emphasizes the importance of doping in semiconductor device fabrication. Doping involves the intentional introduction of impurities into semiconductor materials to modify their electrical properties. Students will explore various doping techniques (NMOS/PMOS doping and gate formation), such as diffusion and ion implantation, and analyze their effects on semiconductor device characteristics, including conductivity, carrier concentration, and junction formation.

CLO5 - Apply advanced deposition techniques and process integration (CMOS) in VLSI fabrication: This involves the application of advanced deposition techniques and process integration methods in VLSI fabrication, with a focus on NMOS/PMOS (N/P-type Metal-Oxide-Semiconductor) and CMOS (Complementary Metal-Oxide-Semiconductor) technologies. Design and fabrication of FET based device and applications. Students will learn about advanced deposition methods like Chemical Vapor Deposition (CVD), Physical Vapor Deposition (PVD), and Atomic Layer Deposition (ALD), and understand how these techniques are integrated into the fabrication process to create complex VLSI circuits and systems. Testing and Packaging: Understand the testing methods for VLSI circuits and various packaging techniques. Focus on Interconnects, interconnect options. System-in-Package & Multi-chip Modules Technology.

- ❖ **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3			3	3	3	3	3			3
CO2	3	3	3	3	3	3	3		3			
CO3		3	3	3	3	3	3		3			
CO4			3	3	3	3	3		3			
CO5			3	3	3	3	3		3			3

Level of impact: 3 - high, 2 - medium, 1 - low.

- ❖ **Syllabus:**

Understanding VLSI Technology: Exploration of historical development and wide-ranging applications in electronics, computing, and communication.

Introduction to cleanroom environment, common tools & instruments engaged.

Semiconductor and CMOS IC Fabrication: Comprehensive study of semiconductors like silicon, germanium, and compound semiconductors.

Understanding conductivity, bandgap, and doping effects. Overview of CMOS IC fabrication techniques and material utilization.

VLSI Fabrication Processes: Elucidation of complex processes including oxidation, lithography, and etching in VLSI fabrication.

Semiconductor Device Doping: Importance of doping in modifying electrical properties of semiconductor devices. NMOS/PMOS doping and gate formation.

Exploration of various doping techniques such as diffusion and ion implantation. Advanced Deposition Techniques and Process Integration

Application of advanced deposition methods like Chemical Vapor Deposition (CVD), Physical Vapor Deposition (PVD), and Atomic Layer Deposition (ALD).

Understanding integration of techniques in NMOS and CMOS technologies for complex circuit creation. Testing and Packaging: Understand the testing methods for VLSI circuits and various packaging techniques. Fabrication of FET, design consideration, and applications. Focus on Interconnects, interconnect options. System-in-Package & Multi-chip Modules Technology.

❖ **Tools and equipment required**

- Minor instruments such as spin coating, hot plate with magnetic stirrer, hot air oven, muffle furnace, etc.
- To conduct the electrical characterization parametric analyser, source meter, etc.
- Computers or workstations with TCAD, COMSOL Multiphysics and Intellisuite software installed.
- Workstations equipped with necessary peripherals such as keyboards, mice, and monitors.
- FET design and modelling libraries and modules within TCAD, COMSOL and Intellisuite.
- Access to simulation tools for VLSI device modeling in both software platforms.
- Internet connectivity for accessing online resources and support materials
- Sensors and actuators for hands-on experimentation and validation
- Power supplies for driving VLSI devices during testing
- Measurement instruments for characterizing VLSI device performance
- Workbenches or lab stations for conducting experiments

- Safety equipment such as goggles, gloves, and lab coats for handling materials if applicable.

❖ **Reference books and articles**

1. Silicon Process Technology, S K Gandhi,2nd Edition, Wiley India,2009
2. VLSI Technology, S. M. Sze, 2nd Edition, McGraw Hill, 2003.
3. Fundamental of Semiconductor Fabrication, Sze and May,2nd Edition, Wiley India,200
4. Silicon VLSI Technology, Plummer, Deal and Griffin ,1st Edition, Pearson Education,2009

❖ **Materials and Resources:**

v https://www.comsol.com/

v https://www.intellisense.com/intellisuite.html

2.24 NEMS/MEMS Systems (400) – 3 (PE)

Course Title:	**NEMS/MEMS systems**
Course code	M4120654
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

- **Course overview**

Course description

The primary objective of this course is to develop a comprehensive understanding of simulation techniques and software tools commonly used in the design and analysis of Nano-Electro-Mechanical Systems and Micro-Electro-Mechanical Systems (NEMS/MEMS). Undertake project-based learning activities that involve designing, simulating, and optimizing NEMS/MEMS devices, fostering critical thinking, problem-solving skills, and the ability to communicate technical concepts effectively.

Introduction to NEMS/MEMS Simulation: Understand the fundamentals of simulation techniques for Nano-Electro-Mechanical Systems and Micro-Electro-Mechanical Systems (NEMS/MEMS).

Simulation Software: Explore various simulation software tools commonly used in NEMS/MEMS design, such as COMSOL Multiphysics, IntelliSuite, ANSYS, and Lumerical.

Finite Element Analysis (FEA): Learn the principles of FEA and its application to model and analyze the mechanical behavior of NEMS/MEMS devices under different loading conditions.

Multiphysics Simulation: Understand the importance of multiphysics simulation in capturing the coupled interactions between different physical phenomena in NEMS/MEMS devices, such as mechanical, electrical, thermal, and fluidic effects.

Material Modeling: Gain insights into material modeling techniques for simulating the mechanical, electrical, and thermal properties of materials commonly used in NEMS/MEMS fabrication.

Device Design Optimization: Use simulation tools to optimize the design parameters of NEMS/MEMS devices, including geometry, material properties, and operating conditions, to achieve desired performance metrics.

Parametric Studies: Conduct parametric studies using simulation software to understand the sensitivity of NEMS/MEMS device performance to various design parameters and operating conditions.

Sensing and Actuation Simulation: Simulate the operation of NEMS/MEMS sensors and actuators to analyze their sensitivity, response time, and energy efficiency for different applications.

MEMS Resonators and Filters: Study the simulation of MEMS resonators and filters, including their frequency response, quality factor, and noise performance, for use in communication and sensing systems.

Project Work: Engage in hands-on projects that involve designing, simulating, and optimizing NEMS/MEMS devices, culminating in the presentation and analysis of simulation results.

- **Course learning outcomes (CLO's)**

CLO1: Demonstrate proficiency in utilizing simulation techniques and software tools for the design and analysis of Nano-Electro-Mechanical Systems and Micro-Electro-Mechanical Systems (NEMS/MEMS).
CLO2: Apply multiphysics simulation methods to accurately model and predict the mechanical, electrical, thermal, and fluidic behavior of NEMS/MEMS devices.
CLO3: Evaluate and select appropriate material models to simulate the mechanical, electrical, and thermal properties of materials used in NEMS/MEMS fabrication, enabling informed design decisions.
CLO4: Utilize simulation-based design optimization techniques to iteratively refine the design parameters of NEMS/MEMS devices, optimizing performance metrics such as sensitivity, response time, and energy efficiency.
CLO5: Analyze and assess the performance characteristics of NEMS/MEMS sensors and actuators through simulation, including sensitivity, resolution, and reliability, for real-world applications in sensing and actuation systems.

- **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3			3							

CO2	3	3	3	3	3							
CO3		3	3	3	3							
CO4			3	3	3							3
CO5			3	3	3							3

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus:**

Introduction to NEMS/MEMS Simulation: Understand the fundamentals of simulation techniques for Nano-Electro-Mechanical Systems and Micro-Electro-Mechanical Systems (NEMS/MEMS).

Simulation Software: Explore various simulation software tools commonly used in NEMS/MEMS design, such as COMSOL Multiphysics, IntelliSuite, ANSYS, and Lumerical.

Multiphysics Simulation: Understand the importance of multiphysics simulation in capturing the coupled interactions between different physical phenomena in NEMS/MEMS devices, such as mechanical, electrical, thermal, and fluidic effects.

Device Design Optimization: Use simulation tools to optimize the design parameters of NEMS/MEMS devices, including geometry, material properties, and operating conditions, to achieve desired performance metrics.

Parametric Studies: Conduct parametric studies using simulation software to understand the sensitivity of NEMS/MEMS device performance to various design parameters and operating conditions.

Sensing and Actuation Simulation: Simulate the operation of NEMS/MEMS sensors and actuators to analyze their sensitivity, response time, and energy efficiency for different applications.

Project Work: Engage in hands-on projects that involve designing, simulating, and optimizing NEMS/MEMS devices, culminating in the presentation and analysis of simulation results.

Project Presentation and Evaluation: Presentation of creative engineering projects, Peer evaluation and discussion.

❖ **Tools and equipment required**

- ❖ Computers or workstations with COMSOL Multiphysics and Intellisuite software installed.
- ❖ Workstations equipped with necessary peripherals such as keyboards, mice, and monitors.
- ❖ MEMS design libraries and modules within COMSOL and Intellisuite.
- ❖ Access to simulation tools for MEMS device modeling in both software platforms.
- ❖ Internet connectivity for accessing online resources and support materials
- ❖ Sensors and actuators for hands-on experimentation and validation
- ❖ Power supplies for driving MEMS devices during testing
- ❖ Measurement instruments for characterizing MEMS performance

- Workbenches or lab stations for conducting experiments
- Safety equipment such as goggles, gloves, and lab coats for handling materials if applicable.

- **Reference books and articles**

- Tai-Ran Hsu, "MEMS and Microsystems: design, manufacture, and Nanoscale"- 2nd Edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2008.
- Tai Ran Hsu, MEMS and Microsystems Design and Manufacture, Tata Mcgraw Hill, 2002.
- Lyshevski, S.E. "Nano- and Micro-Electromechanical Systems: Fundamentals of Nano- and Microengineering "(2nd ed.). CRC Press,2005.
- Mahalik N.P, MEMS, Tata McGraw Hill, 2007.
- Sze S.M, Semiconductor Sensors, John Wiley and Sons, 1994.

- **Materials and Resources:**

- https://www.comsol.com/
- https://www.intellisense.com/intellisuite.html

2.25 AI System Analysis and Design (400) – 3 (PE)

Course Title:	**AI System Analysis and Design**
Course Code:	M4110081, M4120036
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ **Course Overview**

Course description: This course is designed to equip students with the knowledge and practical skills required to excel in the field of Artificial Intelligence (AI) systems. The main aim of this course is to introduce various system analysis and design strategies for implementing and scaling AI systems. The course covers various examples of AI algorithms, the performance metrics to evaluate AI algorithms, their significance and benchmarking techniques. The students are expected to work on projects designing and analysing AI systems and preparing students for exciting career opportunities in the rapidly evolving world of smart devices and intelligent systems.

❖ **Course learning outcomes**

CO1: Students will acquire the skills of AI system design and analysis for implementing practical AI systems

CO2: Students will be able to apply the concepts of system analysis to understand the working of AI systems

CO3: Students will acquire the skills for benchmarking AI algorithms and mapping to the specific design problem

CO4: Students will be able to analyze an AI algorithm and benchmark it with different alternatives for a specific problem

CO5: Students will be able to demonstrate the use of AI system analysis in an example data-driven problem with multiple unknown variables

❖ **Outcome mapping:**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**

CO1	3	3	0	3	3	0	0	3	2	0	0	3
CO2	3	3	2	3	2	2	3	3	3	3	0	3
CO3	2	3	1	1	0	0	0	0	2	0	0	3
CO4	3	3	3	3	3	0	0	2	3	3	0	0
CO5	2	2	3	3	3	3	3	3	3	3	3	2

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus**

Introduction to system identification, Nonparametric identification methods, Parametric identification methods

Neural architectures, CNN, RNN, Theory of reinforcement learning

Importance of data in AI system development, Data collection methods, Data preprocessing techniques (cleaning, transformation, feature engineering), Handling missing data and data imbalances

Architectural patterns for AI systems, Model selection and algorithm design, Designing data pipelines and workflows

Selecting the right AI model for a given problem, Model training, validation, and testing, Evaluation metrics for AI systems (accuracy, precision, recall, F1-score, etc.), Cross-validation and hyperparameter tuning, Performance testing and optimization

Neural architecture search with neural networks, Neural architecture search with evolutionary algorithms, Case study on neural architecture search

Benchmarking learning algorithms, Benchmarking learning algorithms in hardware, case study

❖ **Tools and equipment required**

[1] Software- Python/ MATLAB

[2] Development boards

❖ **Reference books and articles**

[1] Géron A. Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow: Concepts, tools, and techniques to build intelligent systems. O'Reilly Media; 2019 Sep 5.

[2] Michelucci, U., 2019. Advanced applied deep learning: convolutional neural networks and object detection. Apress.

[3] Howard J, Gugger S. Deep Learning for Coders with fastai and PyTorch. O'Reilly Media; 2020.

[4] Warr K. Strengthening Deep Neural Networks: Making AI Less Susceptible to Adversarial Trickery. O'Reilly Media; 2019 Jul 3.

[5] Rao, Dattaraj. Keras to Kubernetes. Wiley, 2019.
https://onlinelibrary.wiley.com/doi/book/10.1002/9781119564843

2.26 Digital Chip Design and Verification (500) – 3 (PE)

Course Title:	Digital Chip Design and Verification
Course Code:	M4110011 , M4123007 , M4122630
Credits:	3
Prerequisites:	NIL
Course Split	2-0-1 (L-T-P)

❖ **Course description**

The main aim of this course is to provide an in-depth understanding on the fundamentals of digital chip design and verification. The course covers topics from the fundamentals of MOSFETS that are needed for the digital chip design process, to applying these fundamentals to design basic digital circuits. The course will also introduce formal verification methods used in the digital chip verification industry.

❖ **Course learning outcomes**

CO1 Develop basic understanding on the physics and operation of MOSFETs
CO2 Apply the concepts of MOSFET in designing fundamental digital circuits
CO3 Obtain design skills for identifying and troubleshooting digital blocks
CO4 Analyze a digital chip using system Verilog verification methods
CO5 Demonstrate the use of system Verilog in the verification of an example digital chip

❖ **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	2	3	0	2	2	3	2	3	3	3	0	3
CO2	3	2	3	3	2	2	3	3	2	2	1	3
CO3	3	3	2	3	3	3	3	2	3	3	3	3
CO4	3	2	3	2	3	3	3	3	2	1	3	2
CO5	3	3	2	3	3	2	2	3	2	3	3	2

- ❖ **Syllabus :**

MOSFET fundamentals - threshold voltage, Current equations, Body effect; Short channel devices - DIBL, Sub-threshold leakage; Transistor capacitance

CMOS inverter construction - Voltage transfer characteristics, load line analysis, trip points for long channel and short channel devices, noise margin analysis; Inverter transient response - dynamic power, short circuit power, leakage power

Implementing boolean logic functions - Gate sizing, logic gate capacitance, gate delay, parasitic delay;

Combinational circuit - Logical effort, gate delay, path delay calculation and optimization, buffer insertion, Input ordering and asymmetric gates, skewed gates

Pseudo NMOS logic; dynamic circuits and input monotonicity, domino logic and weak keepers, transmission gate logic

Adder implementations - ripple adder, full adder, carry skip adder, carry select adder, linear and square root carry select adder

Multiplier implementations - Array multiplier, carry save multiplier

Formal Verification Techniques (I) (Circuit Modeling), Formal Verification Techniques (II) (ATPG and SAT Basics), Formal Verification Techniques (III) (Sequential Verification Techniques)

- ❖ **Tools and equipment required**

[1] Verilog, Xilinx, NI
[2] Matlab

- ❖ **Lab details**

[1] Write and test the SystemVerilog model for NAND, NOR, and 16X1 Mux logic. Write suitable test benches.
[2] Show how positive and negative edge triggered flip flops can be implemented with SystemVerilog.
[3] Write system verilog model and testbench for N-bit parallel to serial counter.
[4] Write and test the system verilog model for a state machine to detect bit '1' in a sequences of1's and 0's.
[5] Develop a test sequence for analysing the single stuck at fault in a N-bit parallel to serial counter.
[6] Write a synthesizable System Verilog model of the IEEE 119.1 TAP controller.
[7] Write a Verilof-AMS model of the flash ADC

- ❖ **Reference books and articles**

[1] Sze, Simon M., et al. Physics of Semiconductor Devices. United Kingdom, Wiley, 2021.

[2] Williams, John Michael. Digital VLSI Design with Verilog: A Textbook from Silicon Valley Polytechnic Institute. Germany, Springer International Publishing, 2014.

[3] Spear C. SystemVerilog for verification: a guide to learning the testbench language features.Springer Science & Business Media; 2008 Apr 22.

[4] Sutherland S, Mills D. Verilog and SystemVerilog Gotchas: 101 Common Coding Errors and How to Avoid Them. Springer Science & Business Media; 2010 Apr 30.

[5] Bergeron J, Cerny E, Hunter A, Nightingale A. Verification methodology manual for SystemVerilog. Springer Science & Business Media; 2006 Jan 16.

[6] Taraate, V., 2020. SystemVerilog for Hardware Description: RTL Design and Verification. Springer Nature.

2.27 Solid State Physics (400) – 3 (PE)

Course Title:	**Solid State Physics**
Course Code:	M4120653
Credits:	3
Level	400
Prerequisites:	Basic knowledge of Quantum mechanics and statistical physics
Course Split	2-0-1 (L-T-P)

❖ **Course Overview**

This course explores the fundamental principles of solid-state physics and their applications in materials science and electronics. Topics include crystal structures, band theory, semiconductors, dielectrics, magnetic materials, optical properties, and superconductors. Through the theoretical study and experiments, students will gain a comprehensive understanding of the properties of solids and their role in modern technology.

❖ **Course Learning Outcomes (CLOs):**

CLO1: Understand crystal structures and their influence on material properties.

CLO2: Explain bonding, electronic structure, and band theory in solids.

CLO3: Analyze thermal, electrical, and magnetic properties of materials.

CLO4: Explore optical properties and their applications in materials and devices.

CLO5: Summarize advanced topics such as nanomaterials, superconductors, and their technological implications.

❖ **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**

CO1	1	3	3	2	2	1	2	1	2	1	0	3
CO2	1	3	3	2	2	1	2	1	2	1	0	3
CO3	1	3	3	2	2	1	2	1	2	1	0	3
CO4	1	3	3	2	2	1	2	1	2	1	0	3
CO5	1	3	3	2	2	1	2	1	2	1	0	3

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus:**

1. Crystal Structures: Unit cells, Bravais lattices, Miller indices, reciprocal lattice, Bragg's law.

2. Bonding in Solids: Ionic, covalent, metallic, van der Waals bonding, cohesive energy.

3. Lattice Vibrations: Phonons, heat capacity models (Einstein, Debye), thermal conductivity.

4. Band Theory of Solids: Free electron theory, Bloch's theorem, band gaps, effective mass.

5. Semiconductors: Intrinsic and extrinsic types, carrier concentration, doping, p-n junctions.

6. Magnetic Properties: Types of magnetism, magnetic domains, hysteresis, spintronics.

7. Optical Properties: Reflectivity, absorption, plasma frequency, excitons, and their applications.

8. Dielectrics and Ferroelectrics: Polarization, dielectric constants, piezoelectric materials.

9. Superconductivity: Meissner effect, BCS theory, Type I and Type II superconductors.

10. Nanostructures and Advanced Topics: Quantum wells, dots, nanomaterials, 2D materials.

❖ **Reference Books and Articles**

- **Primary Textbooks:**
    - Charles Kittel, *Introduction to Solid State Physics* (9th ed.)
    - N. W. Ashcroft and N. D. Mermin, *Solid State Physics*
- **Supplementary References:**
    - S. M. Sze and K. K. Ng, *Physics of Semiconductor Devices*
    - M. Ali Omar, *Elementary Solid-State Physic*

2.28 Neuromorphic VLSI (500) – 3 (PE)

Course Title:	**Neuromorphic VLSI**
Course Code:	M5120040
Credits:	3
Level	500
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

Course Overview

This course provides a comprehensive introduction to Neuromorphic VLSI (Very-Large-Scale Integration), focusing on its theoretical foundations and practical applications. Students will explore key concepts such as neuromorphic architectures, synaptic plasticity, neuron models, and circuit design. The course will also cover applications of Neuromorphic VLSI in artificial intelligence, sensory processing, and brain-machine interfaces.

Course Learning Outcomes

- CO1: Design and analyze neuromorphic circuits using VLSI technology.
    - By the end of the course, students will be able to create and evaluate circuits that mimic neural processes, facilitating the understanding and manipulation of complex neuromorphic systems.
- CO2: Implement synaptic plasticity mechanisms in hardware.
    - Students will have the ability to implement various learning mechanisms in neuromorphic circuits, enabling adaptive and intelligent behavior in hardware systems.
- CO3: Evaluate the performance of neuromorphic systems.
    - Graduates of this course will be proficient in assessing the functionality and efficiency of neuromorphic circuits, using metrics such as power consumption, speed, and accuracy.
- CO4: Integrate neuromorphic circuits with sensors and actuators.
    - Students will gain practical skills in interfacing neuromorphic systems with external devices, enhancing the functionality and applicability of their designs.
- CO5: Apply neuromorphic VLSI principles to innovative applications.

    - The course will equip students with the ability to design and implement neuromorphic systems for advanced applications, demonstrating their understanding of theoretical concepts in practical contexts.

Outcome mapping

General Program Outcomes	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO12
CO1	3	2	1	0	1	0	0	0	0	0	0	3
CO2	3	2	1	1	1	0	0	0	1	0	0	1
CO3	3	2	2	3	2	1	1	2	1	0	0	2
CO4	3	3	3	2	3	3	2	2	3	3	2	3
CO5	3	3	3	2	3	3	2	2	3	3	2	3

Syllabus

- Introduction to Neuromorphic Systems
    - Overview of neuromorphic engineering and its significance
    - Basic components: Neurons, synapses, and neural networks
- Neuromorphic Architectures
    - Analog and digital neuromorphic systems
    - Hardware implementations of neural models
- Synaptic Plasticity and Learning Mechanisms
    - Hebbian learning
    - Spike-Timing-Dependent Plasticity (STDP)
    - Other learning rules and their hardware implementations
- Circuit Design for Neuromorphic Systems
    - Design and simulation of neuromorphic circuits using VLSI
    - Power consumption, speed, and accuracy considerations
- Sensory Processing and Integration
    - Interfacing neuromorphic circuits with sensors

    - Real-time sensory processing applications
- Applications of Neuromorphic VLSI
    - Pattern recognition
    - Sensory processing
    - Brain-machine interfaces
    - Robotics

Tools and Equipment Required

1. LTSpice software: For analyzing the behavior of circuits.
2. Matlab software: To understand the behavior of various systems.
3. Internet Access: For online materials and software updates.
4. Test and Measurement Equipment: For measuring voltage, current, and resistance in circuits.
5. Circuit Components: Resistors, capacitors, inductors, diodes, BJT, MOSFET, Op-amps, etc.
6. Breadboards: For prototyping circuits.

Reference Books and Articles

1. "Neuromorphic Engineering" by Carver Mead
2. "Analog VLSI and Neural Systems" by Carver Mead
3. "Neuromorphic Systems Engineering: Neural Networks in Silicon" by Tor Sverre Lande
4. "Learning in Silicon" by Gert Cauwenberghs and Misha Mahowald
5. "Biologically Inspired Computing Systems" by Steffen Wermter

2.29 Mechatronics and Control Systems (500) – 3 (PE)

Course Title:	**Mechatronics and control systems**
Course Code:	M5129202
Credits:	3
Level	500
Prerequisites:	None
Course Split	2-0-1 (L-T-P)

- **Course Overview**

Course description: This course provides a comprehensive introduction to linear control systems, focusing on their theoretical foundations and practical applications. Students will explore key concepts such as system modeling, feedback principles, stability analysis, and compensation techniques. The course will also cover applications of control systems in mechatronics, including robotic arm control, automated guided vehicles, mechatronic sensor systems, automotive cruise control systems, and CNC machine tool control.

- **Learning Objectives:**

Understand the basic components and principles of control systems.

Students will learn about the fundamental building blocks of control systems, including sensors, actuators, and controllers. They will explore how these components interact to form a complete system and the principles underlying their operation.

Develop skills in modeling and analyzing linear time-invariant (LTI) systems.

Through this course, students will gain proficiency in representing physical systems using mathematical models such as transfer functions and state space representations. They will learn various techniques to analyze the behavior of LTI systems in both the time and frequency domains.

Gain proficiency in stability analysis using various criteria and techniques.

Students will explore different methods to determine the stability of control systems, including Routh-Hurwitz, Nyquist, Bode, and root-locus criteria. They will understand how to apply these techniques to ensure that a system performs reliably under different conditions.

Learn to design compensators for control systems.

The course will cover the design of compensators, such as lag, lead, and lag-lead compensators, to enhance system performance. Students will learn how to modify system dynamics to meet specific design requirements and improve overall system stability and response.

Apply control system concepts to practical mechatronic applications.

Students will apply theoretical knowledge to real-world scenarios, designing control systems for applications such as robotic arms, automated guided vehicles, and automotive cruise control. This will involve integrating various control strategies and analyzing their effectiveness in practical implementations.

- ❖ **Course learning outcomes**

CO1: Analyze and design control systems using transfer functions and block diagrams: By the end of the course, students will be able to represent control systems using transfer functions and block diagrams, facilitating the understanding and manipulation of complex systems. They will be skilled in simplifying these representations to analyze system behavior and design appropriate control strategies.

CO2: Perform transient and steady-state analysis of LTI systems: Students will have the ability to evaluate the performance of linear time-invariant systems by examining their transient and steady-state responses. They will be adept at determining key performance metrics such as rise time, settling time, overshoot, and steady-state error.

CO3: Evaluate system stability using Routh-Hurwitz, Nyquist, Bode, and root-locus methods: Graduates of this course will be proficient in assessing the stability of control systems using various analytical methods. They will be able to apply these techniques to predict system behavior and make necessary adjustments to ensure robust and stable operation.

CO4: Design and implement lag, lead, and lag-lead compensators: Students will gain practical skills in designing compensators to modify system dynamics and achieve desired performance characteristics. They will learn to implement these compensators in control systems to improve stability, response time, and overall efficiency.

CO5: Apply control system principles to real-world mechatronic applications: The course will equip students with the ability to apply control theory to practical applications in mechatronics. They will be able to design, simulate, and implement control systems for various mechatronic devices, demonstrating their understanding of theoretical concepts in real-world contexts.

❖ **Outcome mapping:**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	2	1	0	1	0	0	0	0	0	0	3
CO2	3	2	1	1	1	0	0	0	1	0	0	1
CO3	3	2	2	3	2	1	1	2	1	0	0	2
CO4	3	3	3	2	3	3	2	2	3	3	2	3
CO5	3	3	3	2	3	3	2	2	3	3	2	3

❖ **Syllabus:**

Basic control system components; Feedback principle; Transfer function; Block diagram representation; Signal flow graph; Transient and steady-state analysis of LTI systems; Frequency response; Routh-Hurwitz and Nyquist stability criteria; Bode and root-locus plots; Lag, lead and lag-lead compensation; Controllers; State variable model and solution of state equation of LTI systems.

Applications of control systems in mechatronics: Robotic Arm Control, Automated Guided Vehicles, Mechatronic Sensor Systems, Automotive Cruise Control Systems, CNC Machine Tool Control, Drone control systems.

❖ **Tools and equipment required**

1. **LTSpice software:** Useful to analyze the behavior of the circuits

2. **Matlab software:** Useful to understand the behavior of various systems.

3. **Internet Access:** Internet access for online materials and software updates.

4. **Test and Measurement Equipment:** For measuring voltage, current, and

resistance in circuits and visualize the waveforms of the nodes present in the circuits

5. **Circuit Components:** Resistors, capacitors, inductors, diodes, zener diodes, BJT, MOSFET, Op-amps, and other circuit components to build the circuits.

6. **Breadboards:** Breadboards for prototyping circuits.

❖ **Reference books and articles**

1. “Modern Control Engineering" by Katsuhiko Ogata
2. “Automatic Control Systems" by Benjamin C. Kuo
3. “Feedback Control of Dynamic Systems" by Gene F. Franklin, J. Da Powell, and Abbas Emami-Naeini
4. “Control Systems Engineering" by Norman S. Nise
5. “Linear Systems and Signals" by B.P. Lathi

2.30 Data converters (500) – 3 (PE)

Course Title:	**Data converters**
Course Code:	M5122603
Credits:	3
Level	500
Prerequisites:	None
Course Split	2-0-1 (L-T-P)

Course Overview

This course provides a comprehensive introduction to data converters, focusing on their theoretical foundations and practical applications. Students will explore key concepts such as analog-to-digital converters (ADCs), digital-to-analog converters (DACs), sampling theory, quantization, and converter architectures. The course will also cover applications of data converters in communication systems, instrumentation, and signal processing.

Course Learning Outcomes

- **CO1: Analyze and design data conversion systems using ADC and DAC principles.**
    - By the end of the course, students will be able to represent data conversion systems using block diagrams and mathematical models, facilitating the understanding and manipulation of complex systems. They will be skilled in simplifying these representations to analyze system behavior and design appropriate conversion strategies.
- **CO2: Perform sampling and quantization analysis.**
    - Students will have the ability to evaluate the performance of data conversion systems by examining their sampling and quantization processes. They will be adept at determining key performance metrics such as signal-to-noise ratio (SNR), total harmonic distortion (THD), and effective number of bits (ENOB).
- **CO3: Evaluate system performance using various criteria and techniques.**
    - Graduates of this course will be proficient in assessing the performance of data converters using various analytical methods. They will be able to apply these techniques to predict system behavior and make necessary adjustments to ensure optimal operation.
- **CO4: Design and implement various converter architectures.**
    - Students will gain practical skills in designing ADC and DAC architectures to meet specific design requirements. They will learn to implement these architectures in data conversion systems to improve resolution, speed, and overall efficiency.
- **CO5: Apply data converter principles to real-world applications.**
    - The course will equip students with the ability to apply data conversion theory to practical applications in communication systems, instrumentation, and signal processing. They will be able to design, simulate, and implement data conversion systems for various devices, demonstrating their understanding of theoretical concepts in real-world contexts.

Program Outcomes (POs)

General Program Outcomes	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	3	2	1	0	1	0	0	0	0	0	0	3
CO2	3	2	1	1	1	0	0	0	1	0	0	1

CO3	3	2	2	3	2	1	1	2	1	0	0	2
CO4	3	3	3	2	3	3	2	2	3	3	2	3
CO5	3	3	3	2	3	3	2	2	3	3	2	3

Syllabus

- **Introduction to Data Converters**
  - Overview of data conversion and its significance
  - Basic components: Sampling, quantization, and digital signal processing
- **Analog-to-Digital Converters (ADC)**
  - Principles and types of ADCs
  - Architectures: Flash, sigma-delta, SAR, and pipeline ADCs
  - Performance metrics: Resolution, speed, power consumption
- **Digital-to-Analog Converters (DAC)**
  - Principles and types of DACs
  - Architectures: Binary-weighted, R-2R ladder, and sigma-delta DACs
  - Performance metrics: Resolution, linearity, monotonicity
- **Sampling Theory and Quantization Techniques**
  - Nyquist sampling theorem
  - Oversampling and undersampling techniques
  - Quantization noise and error analysis
- **Converter Architectures and Design**
  - Design and simulation of ADC and DAC systems
  - Power consumption, speed, and accuracy considerations
- **Applications of Data Converters**
  - Data converters in communication systems
  - Instrumentation and measurement systems
  - Audio and video processing

Tools and Equipment Required

3. **LTSpice software:** For analyzing the behavior of circuits.
4. **Matlab software:** To understand the behavior of various systems.
5. **Internet Access:** For online materials and software updates.
6. **Test and Measurement Equipment:** For measuring voltage, current, and resistance in circuits.

7. **Circuit Components:** Resistors, capacitors, inductors, diodes, BJT, MOSFET, Op-amps, etc.
8. **Breadboards:** For prototyping circuits.

Reference Books and Articles

4. "Data Converters" by Franco Maloberti
5. "CMOS Data Converters for Communications" by Mikael Gustavsson, J. Jacob Wikner, and Nianxiong Tan
6. "Understanding Delta-Sigma Data Converters" by Richard Schreier and Gabor C. Temes
7. "Analog-to-Digital Conversion" by Marcel J.M. Pelgrom
8. "Digital Signal Processing" by John G. Proakis and Dimitris G. Manolakis

2.31 Characterization Techniques (500) – 3 (PE)

Course Title:	**Characterization Techniques**
Course Code:	M5121605

Credits:	3
Level	500
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ **Course overview**

Course description: This course offers an in-depth exploration of various characterization techniques used in the study of advanced materials. Students will learn about molecular spectroscopy, including UV-visible, Raman, and FTIR spectroscopy, and their applications. The principles, mechanism, and applications of X-ray diffraction, photoelectron spectroscopy, and fluorescence will be covered, with emphasis on real data interpretation. Imaging techniques such as optical microscopy, SEM, TEM, and AFM will be discussed along with real sample analysis. The course also includes electrical characterization techniques for measuring resistivity, conductivity, and dielectric properties, with a focus on semiconductor behavior and doping effects. Advanced electrical characterization methods like impedance spectroscopy will be introduced. Additionally, the course covers thermal characterization techniques such as TGA, DSC, and LOI, as well as various mechanical testing methods including nano-indentation, hardness testing, fatigue testing, and tribology testing. Practical case studies and real data interpretation are integral parts of this course.

❖ **Course learning outcomes (CLO's)**

CLO1-Spectroscopic and X-ray characterization: Introduction to characterization techniques to analyze materials using light and X-rays.

CLO2- Imaging characterization: Learn to visualize and analyze the morphology and topography of the advanced material structures.

CLO3- Electrical characterization: Understand and measure advanced materials' electrical properties.

CLO4-Thermal Analysis: Study nanomaterials' response to temperature changes.

CLO5-Mechanical Understanding: Explore how nanomaterials respond to physical forces.

- **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3			3	3	3	3	3			3
CO2	3	3	3	3	3	3	3		3			
CO3		3	3	3	3	3	3		3			
CO4			3	3	3	3	3		3			
CO5			3	3	3	3	3		3			3

Level of impact: 3 - high, 2 - medium, 1 - low.

- **Syllabus** (No module wise splitting)

Molecular spectroscopy – introduction; differences between molecular and atomic spectroscopy; UV–visible spectroscopy; Raman spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy

X-ray diffraction: principles, mechanism and application. Real data interpretation. X-ray photoelectron spectroscopy, X-ray fluorescence. principles, mechanism and application. Real data interpretation.

Imaging techniques: optical microscopy, Scanning electron microscopy, Transmission electron microscopy, Atomic force microscopy: principles, mechanism and application. Real data interpretation.

Electrical characterization: resistivity & conductivity, dielectric measurements. Basics of electrical properties, Overview of electrical characterization techniques. Real data interpretation.

Semiconductor characterization: Semiconductor behavior and doping effects. Instrumentation and Techniques: Carrier concentration measurement, mobility analysis. Real data interpretation.

Advanced electrical characterization. Introduction to advanced techniques like impedance spectroscopy. Application examples and case studies

Thermal characterization: Thermogravimetric analysis (TGA), differential scanning calorimeter (DSC), limiting oxygen index (LOI).

Mechanical testing: Nano-indentation, hardness test-Vickers, Rockwell, etc. Mechanical Fatigue Testing: Creep Testing, Scratch Testing, Bending Test, Torsion Testing, Tribology Testing (friction, wear, and lubrication), Ultrasonic Testing.

❖ Tools and equipment required

- Minor instruments such as spin coating, hot plate with magnetic stirrer, hot air oven, muffle furnace, etc.
- Physicochemical characterization such as UV, FTIR, etc
- To conduct the electrical characterization parametric analyser, source meter, etc.
- Computers or workstations with interpretation software installed related the theory.
- Workstations equipped with necessary peripherals such as keyboards, mice, and monitors.
- Measurement instruments for characterizing performance in real-time.
- Workbenches or lab stations for conducting experiments
- Safety equipment such as goggles, gloves, and lab coats for handling materials if applicable.

❖ Reference books and articles

1. J.Goldstein, D. E. Newbury, D.C. Joy, and C.E. Lym, “Scanning Electron Microscopy and X-ray Microanalysis”, 2003.
2. S.L. Flegler, J.W. Heckman and K.L. Klomparens, “Scanning and Transmission Electron Microscopy: A Introduction”, WH Freeman & Co, 1993.
3. P.J.Goodhew, J.Humphreys, R.Beanland, “Electron Microscopy and Analysis”,
4. R.Haynes, D.P.Woodruff and T.A.Talchar, “Optical Microscopy of Materials” Cambridge University press, 1986.

2.32 IoT System Development and Integration (500) – 3 (PE)

Course Title:	**IoT System Development and Integration**
Course Code:	M5120038
Credits:	3
Level	500
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

- **Course overview**

Course description: This course focuses on designing, developing, and integrating Internet of Things (IoT) systems with a strong emphasis on sensors and interface circuitry. Students will be introduced to key concepts in sensor physics and fabrication, interface circuit design, hardware platforms, communication protocols, data processing, and cloud integration. The course will involve practical applications and projects that demonstrate IoT technologies in real-world scenarios.

- **Course Learning Outcomes**

CO1: Understand the fundamental concepts of IoT and its applications.

CO2: Explain the working principle of various sensors for IoT applications and their fabrication process

CO3: Implement data acquisition, processing, and storage techniques for IoT devices.

CO4: Integrate IoT devices with communication networks and cloud platforms

CO5: Design and develop IoT systems using sensors and transducers for real-world scenarios.

❖ **Outcome mapping**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CLO1	2	3	2	3	0	2	1	3	3	2	0	3
CLO2	3	3	3	2	2	2	0	3	3	3	1	2
CLO3	3	3	2	3	3	3	2	3	2	2	1	2
CLO4	2	2	3	3	3	3	2	3	2	2	1	3
CLO5	3	2	3	2	3	3	2	3	2	2	1	3

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus:**

Introduction to IoT & System Design

- Overview of IoT systems, components, and architecture
- Basics of sensors and transducers used in IoT
- Fabrication processes for sensors and transducers
- Hands-on: Setting up IoT devices and sensors

IoT System Development

- Design of IoT systems
- Development of interface and signal processing circuits
- Fundamentals of microcontroller interfacing
- Hands-on: Building an IoT system with sensors and microcontroller units

IoT Communication & Data Management

- IoT communication protocols (wireless, Bluetooth, Zigbee, etc.)
- Cloud platforms for IoT and data storage solutions
- Real-time data processing, edge computing, and basic data analytics
- Hands-on: Connecting IoT devices to cloud platforms and processing data

IoT System Integration & Industrial Applications

- Integrating multiple IoT devices and platforms
- IoT system design considerations: scalability, reliability, and power
- Introduction to Industrial IoT (IIoT) and smart systems (manufacturing,

logistics)
- Hands-on: Integrating IoT components into a complete system

IoT Project Development & Final Evaluation

- ❖ Designing and prototyping IoT systems
- ❖ Students develop and integrate IoT projects from concept to deployment
- ❖ Final project presentations, evaluations, and peer feedback
- ❖ Discussion of IoT future trends and career opportunities

❖ **Tools and equipment required**

Sensors and transducer elements: Basic sensors and transducers such as temperature sensors, humidity sensors, pressure sensors, gas sensors, smoke detectors, etc. for students to experiment.

Devices to source and measure: Equipment to provide AC and DC voltage to sensor elements and circuits such as DC power supply, Arbitrary waveform generators, etc. Equipment to measure output waveforms of circuits such as Digital Storage Oscilloscope, Analog Discovery Kit, NI-Elvis, etc.

Circuit and device simulation tools: Software packages for circuit simulation such as LTspice, TI Tina, etc. and finite element analysis tools such as COMSOL.

Online Idea Generation Platforms: Platforms like Ideaflip, Stormboard, or MindMeister can facilitate idea generation and organization.

Zoom or Microsoft Teams: For virtual lectures, discussions, and collaborative activities.

Google Docs and Google Drive: For sharing documents, collaborative writing, and storing course materials.

Learning Management System (LMS): Platforms like Moodle, Canvas, or Blackboard for organizing course content, assignments, and communication with students.

Video Conferencing and Recording Tools: Tools like OBS Studio or Screencast-O-Matic for recording lectures, demonstrations, and guest speaker sessions.

Collaborative Document Editing: Tools like Microsoft Word Online, Google Docs, or Dropbox Paper for collaborative writing and editing of lesson plans and projects.

Online Survey Tools: To collect feedback and conduct assessments, tools like Google Forms or SurveyMonkey can be valuable.

Digital Whiteboard Tools: Tools like Microsoft Whiteboard or Explain Everything for collaborative drawing, diagramming, and visual explanations.

Creative Content Creation Tools: Software like Canva, Adobe Spark, or Piktochart for creating visually engaging content.

Learning Analytics Tools: Tools like Tableau or Edpuzzle to analyze student engagement and learning patterns.

❖ **Reference books and articles**

1. Sinclair, Ian. *Sensors and transducers*. Elsevier, 2000.
2. Usher, Mike J., and D. A. Keating. *Sensors and transducers: characteristics, applications, instrumentation, interfacing*. Macmillan International Higher Education, 1996.
3. Yasuura, Hiroto, et al., eds. *Smart sensors at the IoT frontier*. Cham, Switzerland: Springer International Publishing, 2017.
4. Mitsubayashi, Kohji, Osamu Niwa, and Yuko Ueno, eds. *Chemical, gas, and biosensors for internet of things and related applications*. Elsevier, 2019.
5. Gupta, Deepak, et al. *Smart Sensors for Industrial Internet of Things*. Springer International Publishing, 2021.
6. “Sensors and Transducers” by D. Patranabis
7. “IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things” by David Hanes et al.
8. “Sensors and Signal Conditioning” by Ramon Pallas Areny and John G. Webster.

2.33 Advanced Materials for Electronic Devices (400) – 3 (PE)

Course Title:	**Advanced Materials for Electronic Devices**
Course Code:	M4120659
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

Course overview

❖ Course description

This course provides an in-depth exploration of advanced materials and their applications in electronic devices, energy storage, healthcare, and environmental sustainability. Students will study the principles, properties, and technologies of materials used in energy conversion devices like supercapacitors, batteries, and fuel cells, as well as in water purification systems. The course also covers the design and integration of wearable sensors for healthcare diagnostics and environmental monitoring, highlighting the role of advanced materials in real-time sensing and data analysis. Further, the course delves into the application of advanced materials in drug delivery systems, IoT devices, and nanoelectronics, with a focus on their impact on healthcare, defence, and industry. Through case studies and practical examples, students will develop a comprehensive understanding of how advanced materials are shaping the future of electronics, energy, and sustainability.

By the end of the course, students will gain a multidisciplinary perspective on the transformative potential of advanced materials, preparing them to contribute to cutting-edge research and innovation in applied physics, electronics, and materials science.

❖ Course learning outcomes (CLO’s)

CLO1- Understand the principles and applications of advanced materials in energy storage and conversion devices and water purification technologies, focusing on supercapacitors, batteries, fuel cells, and filtration systems.

CLO2- Explore the integration of wearable sensors in healthcare diagnostics and environmental monitoring, emphasizing their role in real-time data acquisition and analysis.

CLO3- Analyze the use of advanced materials in advanced drug delivery systems and their applications in personalized healthcare, including biosensors and other smart medical devices.

CLO4- Investigate the role of nanoelectronics and advanced materials in the development of IoT devices and systems, with applications in defense, industry, and communication technologies. Explore the advancement in quantum devices and systems.
CLO5- Examine the contributions of advanced materials to environmental sustainability, including their role in energy conversion and waste-to-energy systems for sustainable development.

- ❖ **Syllabus (No module wise splitting)**

Course Syllabus:

Energy Storage, Conversion & Thermal Management.
Principles of Energy Storage:Supercapacitors: Physics of the electric double-layer, pseudocapacitance, and high-power applications. Batteries: Advanced Lithium-ion chemistry, solid-state electrolytes, and emerging post-lithium technologies (Sodium-ion, Zinc-air).

Energy Conversion Systems: Solar Cells, Fuel Cells.
Waste-to-Energy: Material considerations for converting thermal waste into electricity.
Thermal Management: Advanced materials for heat dissipation in high-performance energy systems.

Water Purification & Environmental Sustainability
Advanced Water Treatment: Materials for high-efficiency filtration: Nanofibers, graphene-based membranes, and MOFs (Metal-Organic Frameworks). Sustainable desalination and purification technologies.

Nano-Scale Devices: Introduction to nanoelectronics and the physics of nano-sensor devices. Advanced materials (2D materials, nanowires) for next-generation transistors.

Wearable Sensors & Environmental Monitoring Wearable Technology: Design and fabrication of flexible/stretchable wearable sensors.Healthcare Diagnostics: Continuous disease monitoring, vital sign tracking, and wearable medical devices.Targeted drug delivery using functionalized nanomaterials.

Environmental Sensing: Sensors for air and water quality monitoring. Advanced materials for high-sensitivity pollution detection and chemical sensing.

- ❖ References

1. Pang, Huan, Xiaoyu Cao, Limin Zhu, and Mingbo Zheng. Synthesis of functional

nanomaterials for electrochemical energy storage. Singapore: Springer, 2020.
2. Waser, Rainer, ed. Nanoelectronics and information technology: advanced electronic materials and novel devices. John Wiley & Sons, 2012.
3. Sazonov, Edward, ed. Wearable Sensors: Fundamentals, implementation and applications. Academic Press, 2020.
4. Mukhopadhyay, Subhas C., ed. Wearable electronics sensors: For safe and healthy living. Vol. 15. Springer, 2015.
5. Morales-Narváez, Eden, and Can Dincer, eds. Wearable Physical, Chemical and Biological Sensors: Fundamentals, Materials and Applications. Elsevier, 2022.
6. O'hayre, Ryan, Suk-Won Cha, Whitney Colella, and Fritz B. Prinz. Fuel cell fundamentals. John Wiley & Sons, 2016.

7. Razeghi, Manijeh. Technology of quantum devices. New York: Springer, 2010.
8. Marrocchi, Assunta, ed. Sustainable Strategies in Organic Electronics. Woodhead Publishing, 2022.
9. Cheong, Kuan Yew, and Allen W. Apblett, eds. Sustainable Materials and Green Processing for Energy Conversion. Elsevier, 2021.
10. Hu, Anming, and Allen Apblett, eds. Nanotechnology for water treatment and purification. Vol. 22. Switzerland: Springer International Publishing, 2014.

2.33 NEMS/MEMS (400) – 3 (PE)

Course Title:	**NEMS/MEMS**
Course Code:	M4120670
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

- **Course overview**

This course is designed to cover the aspects pertaining to the design and fabrication of Nano/Micro Electromechanical Systems (N/MEMS). This course encompasses both theory and practical sessions. Lumped element & Finite element modelling, and fabrication aspects of N/MEMS will be covered in the theory sessions, whereas the practical sessions focus on the finite element modelling of N/MEMS devices using COMSOL Multiphysics. By the end of the course, students should be able to design N/MEMS devices that closely mimic the characteristics of the fabricated device.

- **Course learning outcomes**

CO1 Identify N/MEMS devices in practical applications and their working principles.

CO2 Discuss the modelling principles of N/MEMS devices.

CO3 Apply the modelling concepts in practical applications.

CO4 Use the modelling concepts in developing new N/MEMS devices.

CO5 Prepare fabrication and characterization methods for new N/MEMS devices.

- **Syllabus**

Introduction and basic concepts

Fabrication of NEMS/MEMS devices: Oxidation, Physical Vapor Deposition, Chemical Vapor Deposition, Lithography, Etching, Critical Point Drying

Packaging of NEMS/MEMS devices

Introduction to NEMS/MEMS Simulation: Understand the fundamentals of simulation techniques for Nano-Electro-Mechanical Systems and Micro-Electro-Mechanical Systems (NEMS/MEMS).

Simulation Software: Explore various simulation software tools commonly used in NEMS/MEMS design, such as COMSOL Multiphysics, IntelliSuite, ANSYS, and Lumerical.

Multiphysics Simulation to capture the coupled interactions between different physical phenomena in NEMS/MEMS devices, such as mechanical, electrical, thermal, and fluidic effects.

Project Work: Engage in hands-on projects that involve designing, simulating, and optimizing NEMS/MEMS devices, culminating in the presentation and analysis of simulation results.

❖ **Tools and equipment required**

- Computers or workstations with COMSOL Multiphysics and Intellisuite software installed.
- Workstations equipped with necessary peripherals such as keyboards, mice, and monitors.
- MEMS design libraries and modules within COMSOL and Intellisuite.
- Access to simulation tools for MEMS device modeling in both software platforms.
- Internet connectivity for accessing online resources and support materials
- Workbenches or lab stations for conducting experiments
- Safety equipment such as goggles, gloves, and lab coats for handling materials if applicable.

❖ **Reference books and articles**

- Tai-Ran Hsu, "MEMS and Microsystems: design, manufacture, and Nanoscale"- 2nd Edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2008.
- Tai Ran Hsu, MEMS and Microsystems Design and Manufacture, Tata Mcgraw Hill, 2002.
- Lyshevski, S.E. "Nano- and Micro-Electromechanical Systems: Fundamentals of Nano-and Microengineering "(2nd ed.). CRC Press,2005.
- Mahalik N.P, MEMS, Tata McGraw Hill, 2007.
- Sze S.M, Semiconductor Sensors, John Wiley and Sons, 1994.

❖ **Materials and Resources:**
❖ https://www.comsol.com/

https://www.intellisense.com/intellisuite.html

2.34 Control System Design (400) – 3 (PE)

Course Title:	**Control System Design**
Course Code:	M4120039/M4110084
Credits:	3
Level	400
Prerequisites:	None
Course Split	2-0-1 (L-T-P)

Course overview

This course provides a comprehensive understanding of the dynamics of linear systems and their control using both classical and modern techniques. Students will learn to model systems using Laplace transforms and analyze their stability and performance through Nyquist plots, Bode plots, and Root Locus methods. The course covers control system design using proportional-integral-derivative (PID) controllers, lead-lag compensation, and Bode sensitivity integrals to achieve desired performance criteria. State variable analysis is introduced to offer insights into modern control techniques, including state feedback and observer design. Additionally, students will explore challenges associated with nonminimum phase systems and nonlinearities, utilizing describing functions for compensation. By the end of the course, students will be equipped with the skills to design and analyze control systems for various engineering applications.

Course learning outcomes:

CO1: Analyze and Model Linear Systems – Develop mathematical models of dynamic systems using Laplace transforms and state variable representations to analyze their behavior in the time and frequency domains.

CO2: Evaluate Stability and Performance – Assess the stability and transient/steady-state performance of feedback control systems using Nyquist plots, Bode plots, and Root Locus techniques.

CO3: Design and Tune Controllers – Design control systems for single-degree-of-freedom configurations using proportional-integral-derivative (PID) controllers, lead-lag compensation, and Bode sensitivity integrals to meet desired specifications.

CO4: Address Nonlinearities and Nonminimum Phase Systems – Apply describing functions to analyze and compensate for nonlinearities in control systems and understand the challenges in controlling nonminimum phase systems.

CO5: Apply State-Space Methods – Utilize state variable analysis techniques for control system design, including state feedback and observer design, to improve system performance.

Outcome mapping:

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO 1	3	0	0	3	0	0	0	0	0	0	0	3
CO 2	3	0	3	3	3	0	0	0	3	0	0	0
CO 3	3	3	1	1	0	3	0	0	0	0	0	3
CO 4	3	3	3	3	3	0	0	2	3	3	3	0
CO 5	3	3	3	3	2	2	3	3	3	3	3	3

Syllabus:

Dynamics of linear systems,

Laplace transforms,

analysis and control of feedback control systems using Nyquist plots,

Bode plots and Root Locus,

design of control systems in single-degree of-freedom configuration,

proportional-integral-derivative control,

lead-lag compensation, state variable analysis,

control of nonminimum phase systems,

bode sensitivity integrals,

use of describing functions to analyze and compensate for nonlinearities.

Tools Required:

1. **LTSpice software**: Useful to analyze the behavior of the circuits
2. **Matlab software**: Useful to understand the behavior of various systems.
3. **Internet Access**: Internet access for online materials and software updates.
4. **Test and Measurement Equipment**: For measuring voltage, current, and resistance in circuits and visualize the waveforms of the nodes present in the circuits
5. **Circuit Components**: Resistors, capacitors, inductors, diodes, zener diodes, BJT, MOSFET, Op-amps, and other circuit components to build the circuits.
6. **Breadboards**: Breadboards for prototyping circuits.

Reference books and articles:

1. “Modern Control Engineering" by Katsuhiko Ogata
2. “Automatic Control Systems" by Benjamin C. Kuo
3. “Feedback Control of Dynamic Systems" by Gene F. Franklin, J. Da Powell, and Abbas Emami-Naeini
4. “Control Systems Engineering" by Norman S. Nise
5. “Linear Systems and Signals" by B.P. Lathi

2.35 Digital Signal Processing (400) – 3 (PC)

Course Title:	**Digital Signal Processing**
Course Code:	M4120041
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

❖ **Course Overview:**

Course Description: This course is designed to equip students with the knowledge and practical skills required to excel in the field of signal processing and its various applications in other fields. The main aim of this course is to introduce fundamental concepts and techniques used in the field of digital signal processing (DSP). The course covers a range of topics in DSP and the influence of digital signal processing technologies in shaping the future of the industry. The students are expected to work on projects to implement and design advanced DSP techniques for various research and industrial applications.

❖ **Course learning outcomes (COs):**

CO1: Develop a strong foundation in the theoretical principles of DSP.

CO2: Students will gain proficiency in mathematical techniques essential for analyzing and manipulating DSP.

CO3: Students will understand the application of DSP in real-world scenarios across various industries.

CO4: Students will acquire practical skills through hands-on projects and laboratory exercises using DSP software and tools.

CO5: Students will be able to demonstrate the application of DSP for solving real world research and industrial problems.

❖ **Outcome mapping:**

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3	0	3	3	0	0	3	2	0	3	3

CO2	3	3	2	3	2	2	3	3	3	3	0	3
CO3	2	3	1	1	0	0	0	0	2	0	0	3
CO4	3	3	3	3	3	3	0	2	3	3	3	0
CO5	2	2	3	3	3	3	3	3	3	3	3	2

Level of impact: 3 - high, 2 - medium, 1 - low.

❖ **Syllabus:**

Sampling of Continuous Signal, Signal Reconstruction, Analog-to-Digital Conversion, Digital-to-Analog Conversion, and Quantization, Generation of Digital Signals

Linear Time-Invariant, Causal Systems

Difference Equations and Impulse Responses, System Representation Using Its Impulse Response, Bounded-In and Bounded-Out Stability

Discrete Fourier Transform, Discrete cosine transform, wavelet transform

Amplitude Spectrum and Power Spectrum, Spectral Estimation Using Window Functions

Properties of the z-Transform, Inverse z-Transform, Solution of Difference Equations Using the z-Transform.

❖ **Tools and equipment required:**

1. Python

2. MATLAB

❖ **Reference Books and Articles:**

4. Alan Oppenheim , Alan Willsky, S. Hamid Nawab , “Signals and Systems” PHI,

2nd edition, 1996.

5. John G. Proakis, Dimitris G. Manolakis, “Digital Signal Processing” Pearson Education India, 2007

6. Li Tan and Jean Jiang, “Digital Signal Processing-Fundamentals and Applications” Elsevier, Second edition 2013.

2.36 Embedded Systems Architecture (400) – 3 (PC)

Course Title:	**Embedded Systems Architecture**
Course Code:	M4xxxx
Credits:	3
Level	400
Prerequisites:	Digital electronics
Course Split	2-0-1 (L-T-P)

Course overview

This course introduces the architecture and design of embedded systems by integrating fundamental concepts from Digital Electronics, ARM processor, and Microcontroller-based systems. The course focuses on understanding how digital hardware blocks, processor architectures, and embedded software work together to implement dedicated real-time applications.

Students will learn the internal architecture of ARM processor, principles of microcontroller-based system design, and the role of digital logic circuits in embedded hardware. Emphasis is placed on interfacing techniques, embedded programming, and system-level design considerations relevant to real-world applications such as industrial control, consumer electronics, and defense systems.

The course prepares students to design, program, and analyze basic embedded systems, providing a strong foundation for advanced courses in IoT, robotics, VLSI, and real-time systems.

Course learning outcomes:

CLO1: Explain fundamental digital electronics concepts and their application in embedded system hardware design.

CLO2: Understand and analyze ARM processor architecture..

CLO3: Develop embedded applications using ARM-based microcontrollers.

CLO4: Design and implement microcontroller-based embedded systems using Embedded C with timers, interrupts, and I/O peripherals.

CLO5: Interface sensors, actuators, and peripheral devices and analyze basic real-time constraints in embedded system applications.

Outcome mapping:

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO 1	3	0	0	3	0	0	0	0	0	0	0	3
CO 2	3	0	3	3	3	0	0	0	3	0	0	0
CO 3	3	3	1	1	0	3	0	0	0	0	0	3
CO 4	3	3	3	3	3	0	0	2	3	3	3	0
CO 5	3	3	3	3	2	2	3	3	3	3	3	3

Syllabus:

Digital Electronics Foundations for Embedded Systems

Number systems and codes (Binary, Octal, Hexadecimal, BCD, Gray), Boolean algebra and logic gates, Combinational logic circuits, Adders, subtractors, multiplexers, decoders, encoders, Sequential logic circuits, Latches, flip-flops, registers, counters, Timing concepts, clocking, propagation delay, Introduction to PLDs, CPLDs, and FPGAs, Role of digital electronics in embedded hardware design

Introduction to Embedded Systems

Definition and characteristics of embedded systems, Embedded systems vs general-purpose computing, Classification: standalone, real-time, networked, mobile embedded systems, Embedded system architecture overview, Hardware–software co-design concept, Applications: consumer electronics, automotive, medical, defense, IoT

ARM Processor Architecture

Overview of RISC architecture, Evolution of ARM processors, ARM architecture overview (Cortex-M / Cortex-A concepts), ARM processor core architecture, Register organization, Program Status Register (PSR), Pipeline concept, Instruction set overview, Addressing modes, Exception and interrupt handling, Memory architecture (Harvard vs Von Neumann), Introduction to ARM assembly programming (basic concepts)

Microcontroller Architecture

Difference between microprocessor and microcontroller, Internal architecture of microcontrollers, Memory organization (Program, Data, SFR), I/O ports and port programming, Timers and counters, Interrupt structure and priority, Serial communication (UART), Introduction to popular microcontrollers (AVR / ARM overview)

Embedded System Interfacing

Interfacing digital input/output devices, ADC and DAC interfacing, Sensor interfacing basics, Actuator interfacing (relays, motors), Keyboard and display interfacing, Communication interfaces, UART, SPI, I^2C (basic concepts)

Case Studies and Applications

Embedded system design using microcontroller, Simple embedded system case studies: Temperature monitoring system, Digital clock, Motor control system, Overview of embedded systems in: Industrial automation, Automotive electronics, Defense and communication systems

Reference books and articles:

1. Raj Kamal, Embedded Systems: Architecture, Programming and Design, McGraw-Hill Education.
2. A. K. Ray & K. M. Bhurchandi, Advanced Microprocessors and Peripherals, McGraw-Hill.
3. M. Morris Mano, Digital Design, Pearson Education.
4. Muhammad Ali Mazidi, Janice Gillispie Mazidi, The 8051 Microcontroller and Embedded Systems, Pearson.
5. David Simon, An Embedded Software Primer, Addison-Wesley.
6. Jonathan W. Valvano, Embedded Systems: Introduction to ARM Cortex-M Microcontrollers, Cengage Learning.

2.37 Spectroscopic and Microscopic Techniques for Materials Analysis (400) – 3 (PC)

Course Title:	**Spectroscopic and Microscopic Techniques for Materials Analysis**
Course Code:	M4xxxx
Credits:	3
Level	400
Prerequisites:	Nil
Course Split	2-0-1 (L-T-P)

Course overview

The objective of this course is to provide a comprehensive understanding of radiation-matter interactions and the operational principles of advanced imaging and resonance tools like SEM, TEM, NMR, and Mössbauer spectroscopy. It aims to equip students with the analytical skills necessary to interpret complex datasets and strategically select characterization techniques for solving real-world materials research problems.

Course learning outcomes:

CO1 Explain the physics of radiation-matter interactions across electron, optical, and

nuclear scales.

CO2 Analyse XRD and Microscopic data to quantify material morphology and crystal

structure.

CO3 Interpret NMR and Mössbauer spectra to determine local atomic environments and

oxidation states.

CO4 Formulate a multi-technique characterisation strategy to solve complex materials

science problems.

Outcome mapping:

	General Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO 1	3	0	0	3	0	0	0	0	0	0	0	3
CO 2	3	0	3	3	3	0	0	0	3	0	0	0
CO 3	3	3	1	1	0	3	0	0	0	0	0	3
CO 4	3	3	3	3	3	0	0	2	3	3	3	0
CO 5	3	3	3	3	2	2	3	3	3	3	3	3

Syllabus:

Module 1: Diffraction and Electron Microscopy
X-Ray Diffraction (XRD): Bragg's Law, phase identification, and crystallinity, structure factor, atomic form factor
Electron Microscopy: Principles of SEM (topography) and TEM (internal

structure/diffraction).
Probe Microscopy: AFM for surface roughness and 3D profiling.

Module 2: Optical and Elemental Spectroscopy
Vibrational: FTIR and Raman for chemical bonding and structural defects.
Electronic: UV-Vis for bandgap determination and XPS for surface elemental states.

Module 3: Nuclear Characterization Techniques (NMR & Mössbauer)
Nuclear Magnetic Resonance (NMR): * Basics: Nuclear spin, Larmor precession, and
the resonance condition, Chemical shift, spin-spin coupling, and relaxation time.
Mössbauer Spectroscopy: Recoil-free nuclear resonance fluorescence and the Doppler
effect. Parameters: Isomer shift, Quadrupole splitting, and Hyperfine splitting.

Reference books and articles:

1. C.N. Banwell & E.M. McCash, Fundamentals of Molecular Spectroscopy
2. Yang Leng, Materials Characterization
3. B.D. Cullity, Elements of X-Ray Diffraction

2.38 Group Project (500) – 4 (PE)

Course Title:	**Group Project**
Course Code:	M4xxxx
Credits:	3
Level	500
Prerequisites:	Nil

Course Split	0 - 0 - 0 - 4 (L - T - S - P)

Course Description

This course provides a collaborative platform for students to apply advanced design principles to a significant engineering challenge. Teams will work independently to move a
project from initial concept through design, simulation, and physical realisation. The
emphasis is on developing high-level problem-solving skills and professional technical
documentation as required for advanced research and industry practice.

Course Objective

To enable students to work in teams to design, simulate, and verify a complex VLSI subsystem (Digital, Analog, or Mixed-Signal) using industry-standard EDA tools, following
a complete design flow from specification to GDSII.

Course Outcomes (COs)

CO1 Design and develop a functional electronic system or component starting from basic
requirements.

CO2 Test and refine the design to optimize performance factors like speed, size, and energy efficiency.

CO3 Transform logical designs into physical hardware layouts ready for manufacturing or prototyping.

CO4 Document and present the team’s technical process and final outcomes in a professional report.

Implementation Milestones

Students must complete the following phases:

1. Architecture & Planning: Defining the system structure and technical specifications.

2. Verification & Optimization: Using software tools to ensure the design meets all

performance targets.

3. Physical Realization: Finalizing the hardware map or blueprint for the system.

4. Reporting: Compiling an original technical investigation report and presenting the

final artifact.

Evaluation & Assessment

There is no end-of-semester examination. The assessment for this course is purely continuous and milestone-based, with 60% of the grade awarded through periodic phase reviews of the team;s design choices. The remaining 40% is split equally between the technical quality of the final hardware artifact and a comprehensive research report documenting the project’s outcomes.

2.39 Research Topics in Electronics Engineering (500)

Course Title:	**Research Topics in Electronics Engineering (500)**
Course Code:	M4xxxx
Credits:	3
Level	500
Prerequisites:	Nil
Course Type	Research Project / Dissertation

Course Objective

The objective of this course is to immerse students in an autonomous research environment where they identify, investigate, and solve complex problems in Electronics Engineering. It aims to develop advanced skills in literature survey, experimental design, technical writing, and peer-level presentation of research findings.

Course Outcomes (COs)

CO1 (Analyze): Critically review existing literature to identify research gaps and formulate a specific problem statement.

CO2 (Create): Design and implement an engineering solution, prototype, or simulation model using advanced hardware/software tools.

CO3 (Evaluate): Validate research results through rigorous testing and comparative analysis against established benchmarks.

CO4 (Create): Communicate findings through the publication of a technical term paper and a comprehensive research dissertation.

Course Execution Plan

This course is delivered through three primary phases:

1. Literature Survey , Term Paper: Students identify a few niche areas (e.g., Neuromorphic Computing, 6G Wireless, or Nano-electronics) and produce a high-quality review paper.

2. Implementation: Independent research work under the guidance of a faculty mentor,

involving hardware fabrication or software modelling.

3. Dissemination: Formal presentation of results and submission of a research report.

2.40 Research Topics in VLSI Design (500)

Course Title:	**Research Topics in VLSI Design (500)**
Course Code:	M4xxxx
Credits:	3
Level	500
Prerequisites:	Nil
Course Type	Research Project / Dissertation

Course Objective

The objective of this course is to immerse students in an autonomous research environment where they identify, investigate, and solve complex problems in VLSI Design. It aims to develop advanced skills in literature survey, experimental design, technical writing, and peer-level presentation of research findings.

Course Outcomes (COs)

CO1 (Analyze): Critically review existing literature to identify research gaps and formulate a specific problem statement.

CO2 (Create): Design and implement an engineering solution, prototype, or simulation model using advanced hardware/software tools.

CO3 (Evaluate): Validate research results through rigorous testing and comparative analysis against established benchmarks.

CO4 (Create): Communicate findings through the publication of a technical term paper and a comprehensive research dissertation.

Course Execution Plan

This course is delivered through three primary phases:

1. Literature Survey , Term Paper: Students identify a few niche areas (e.g., Neuromorphic Computing, 6G Wireless, or Nano-electronics) and produce a high-quality review paper.

2. Implementation: Independent research work under the guidance of a faculty mentor,

involving hardware fabrication or software modelling.

3. Dissemination: Formal presentation of results and submission of a research report.

2.41 Mathematical Methods in Physics (500) – 3 (OE)

Course Title:	**Mathematical Methods in Physics**
Course Code:	M4xxxx
Credits:	4
Level	500
Mode of Delivery	SWAYAM/NPTEL (MOOC) https://onlinecourses.nptel.ac.in/noc22_ma37/preview

Course Description

This course, hosted on the SWAYAM/NPTEL platform, provides an advanced mathematical framework for graduate students in Physics and Engineering. It covers the transition from abstract linear spaces to practical differential equations. By leveraging the digital platform, students engage with high-quality video lectures, automated assignments, and a nationwide standardized examination.

Course Outcomes (COs)

CO1 (Apply): Solve linear systems and operator problems using eigenvalues, eigenvectors, and diagonalization techniques.

CO2 (Analyze): Apply Fourier and Laplace transforms to analyze periodic signals and solve
transient system behaviors.

CO3 (Create): Develop mathematical models for physical phenomena such as mechanical
vibrations and resonance using second-order ODEs.

CO4 (Evaluate): Utilize advanced series methods and Green's functions to solve complex
inhomogeneous boundary value problems

Course layout

Week 1:Linear Algebra 1 : vectors, linear vector spaces, inner product, C-S inequality, linear independence, row-reduction
Week 2:Linear Algebra 2 : Matrices, determinants, span, basis, orthonormal basis, subspaces, linear operators.
Week 3: Linear Algebra 3: Direct sum, eigenvalues and eigenvectors, unitary, Hermitian,
normal operators, transformations, defective matrices, diagonalization.
Week 4: Fourier Series and Transforms: periodic functions, series expansion, Fourier
coefficients, Completeness relation, Fourier transforms.
Week 5: Ordinary Differential Equations 1: Introduction, Separable variables, orthogonal
trajectories, linear first-order ODEs, Wronksian, exact ODEs, auxiliary equation.
Week 6: Ordinary Differential Equations 2: Inhomogeneous second order ODEs, method of
undetermined coefficients, vibrations in mechanical systems, forced vibrations, resonance, linear superposition.
Week 7: Ordinary Differential Equations 3: Laplace transforms, Solving ODEs using Laplace transforms, Dirac Delta function.
Week 8: Ordinary Differential Equations 4: Green's function method, power series method, Frobenius method.

Books and references

Mathematical Methods in the Physical Sciences (Mary Boas), Mathematical Physics (Joglekar), Mathematical Methods for Physicists (Arfken, Weber, Harries)

2.42 Computational Materials Modelling (500) – 3 (OE)

Course Title:	**Computational Materials Modelling**
Course Code:	M4xxxx

Credits:	4
Level	500
Mode of Delivery	SWAYAM/NPTEL (MOOC) https://nptel.ac.in/courses/112106289

Course Description

The objective of this course is to provide students with a rigorous foundation in constructing computational crystal models and understanding the statistical mechanics that govern atomistic behavior. It aims to develop practical expertise in executing molecular dynamics simulations using industry-standard software like LAMMPS to study material properties.

Course Outcomes (COs)

CO1 (Create): Construct and visualize 2D and 3D crystal structures in MATLAB by applying principles of symmetry, plane groups, and space groups.

CO2 (Analyze): Correlate macroscopic properties with microscopic states using the principles of statistical mechanics and ensemble theory.

CO3 (Apply): Execute Molecular Dynamics (MD) simulations using the LAMMPS package to model atomic interactions and evolution.

CO4 (Evaluate): Evaluate material behavior (such as stress, diffusion, or radiation damage) by interpreting output data from computational experiments

Course layout

Week Module Core Content

1-2 Crystallography Basics Intro to modeling; Geometry of 2D and 3D crystals.

3-5 Symmetry Operations Symmetry, Plane groups, and Space groups.

6 Computational Build Programming crystal structures using MATLAB.

7-8 Theoretical Foundation Detailed Statistical Mechanics and its role in simulations.

9 MD Fundamentals Introduction to the Molecular Dynamics algorithm.

10-12 Software Training Advanced MD implementation and analysis using LAMMPS.

Books and references

1. C. Kittel, Introduction to Solid State Physics (for Week 2-5).
2. LAMMPS Documentation, Open-source Molecular Dynamics Simulator User Manual.

3. BOARD OF STUDIES (BoS)

MEMBER LIST (2024-26)

1. Bhaskar Choubey, Chair Professor, Seigen University
2. Deepu John, Assistant Professor, University College Dublin
3. Rajesh Panicker, Senior Lecturer, National University of Singapore
4. Rahul Nair, Professor, University of Manchester
5. Paul Kollanoor Ittoopunny, Principal Engineer - IC Design at Broadcom
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11. Dean Academics, Digital University Kerala
12. Sumit Datta, Assistant Professor, SoESA, Digital University Kerala
13. Christie Thomas Cherian, Assistant Professor, SoESA, Digital University Kerala (Committee Convener)
14. Jose Joseph, SoESA, Assistant Professor, Digital University Kerala
15. Alex James, Professor, SoESA, Digital University Kerala (Committee Chair)

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