MLRITM

MARRI LAXMAN REDDY INSTITUTE OF TECHNOLOGY AND MANAGEMENT

Outcome Based Education (OBE) Manual

Department of Electronics and Communication Engineering

Regulation: UGR22

Contents

OVERVIEW

Outcome Based Education (OBE) is an educational model that forms the base of a quality education system. There is no single specified style of teaching or assessment in OBE. All educational activities carried out in OBE should help the students to achieve the set goals. The faculty may adapt the role of instructor, trainer, facilitator, and/or mentor, based on the outcomes targeted.

OBE enhances the traditional methods and focuses on what the Institute provides to students. It shows the success by making or demonstrating outcomes using statements “able to do” in favor of students. OBE provides clear standards for observable and measurable outcomes.

National Board of Accreditation (NBA) is an authorized body for the accreditation of higher education institutions in India. NBA is also a full member of the Washington Accord. NBA accredited programs and not the institutions.

Higher Education Institutions are classified into two categories by NBA

Tier – 1: Institutions consists of all IITs, NITs, Central Universities, State Universities and Autonomous Institutions. Tier - 1 institution can also claim the benefits as per the Washington Accord.

Tier-2: Institutions consists of affiliated colleges of universities.

What is Outcome Based Education (OBE)?

Institutions adopting OBE try to bring changes to the curriculum by dynamically adapting to the requirements of the different take holders like Students, Parents, Industry Personnel and Recruiters. OBE is all about feedback and outcomes.

Four levels of outcomes from OBE are:

1. Program Educational Objectives (PEOs)
2. Program Outcomes (POs)
3. Course Outcomes (COs)

Why OBE?

1. International recognition and global employment opportunities.
2. More employable and innovative graduates with professional and soft skills, social responsibility and ethics.
3. Better visibility and reputation of the technical institution among stakeholders.
4. Improving the commitment and involvement of all the stakeholders.
5. Enabling graduates to excel in their profession and accomplish greater heights in their careers.

6. Preparing graduates for the leadership positions and challenging them and making them aware of the opportunities in the technology development.

Benefits of OBE

Clarity: The focus on outcome creates a clear expectation of what needs to be accomplished by the end of the course.
Flexibility: With a clear sense of what needs to be accomplished, instructors will be able to structure their lessons around the students' needs.
Comparison: OBE can be compared across the individual, class, batch, program and institute levels.
Involvement: Students are expected to do their own learning. Increased student's involvement allows them to feel responsible for their own learning, and they should learn more through this individual learning.

- Teaching will become a far more creative and innovative career
- Faculty members will no longer feel the pressure of having to be the "source of all knowledge".
- Faculty members shape the thinking and vision of students towards a course.

India, OBE and Accreditation:

From 13 June 2014, India has become the permanent signatory member of the Washington Accord Implementation of OBE in higher technical education also started in India. The National Assessment and Accreditation Council (NAAC)and National Board of Accreditation (NBA) are the autonomous bodies for promoting global quality standards for technical education in India. NBA has started accrediting the programs running with OBE from 2013.

The National Board of Accreditation mandates establishing a culture of outcome-based education in institutions that offer Engineering, Pharmacy, and Management program Reports of outcome analysis help to find gaps and carryout continuous improvements in the education system of an Institute, which is very essential.

1. Vision, Mission, Quality Policy, Philosophy & Core Values

Vision

To provide quality technical education in Electronics and Communication Engineering through research, innovation, striving for global recognition in specified domain, leadership, and sustainable societal solutions

Mission

DM1: To create a transformative learning environment that empowers students in electronics and communication engineering, fostering excellence in technical skills and leadership.

DM2: To drive innovation through research, deliver a transformative education grounded in ethical principles, and nurture the development of professionals

DM3: To cultivate strong industry partnerships, and engaging actively with the community for societal and technological progress.

Quality Policy

- Ensure excellence in education through innovative teaching and continuous improvement.
- Promote ethical, skilled, and employable graduates who drive sustainable technologies
- Encourage research, industry collaboration, and community engagement for societal benefit.

Philosophy

The essence of learning lies in pursuing the truth that liberates one from the darkness of ignorance and Marri Laxman Reddy Institute of Technology and management firmly believes that education is for liberation.

Contained therein is the notion that engineering education includes all fields of science that plays a pivotal role in the development of world-wide community contributing to the progress of civilization. This institute, adhering to the above understanding, is committed to the development of science and technology in congruence with the natural environs. It lays great emphasis on intensive research and education that blends professional skills and high moral standards with a sense of individuality and humanity. We thus promote ties with local communities and encourage transnational interactions in order to be socially accountable. This accelerates the process of transfiguring the students into complete human beings making the learning process relevant to life, instilling in them a sense of courtesy and responsibility.

Core Values

Excellence: All activities are conducted according to the highest international standards.

Integrity: Adheres to the principles of honesty, trustworthiness, reliability, transparency and accountability.

Inclusiveness: To show respect for ethics, cultural and religious diversity, and freedom of thought.

Social Responsibility: Promotes community engagement, environmental sustainability, and global citizenship. It also promotes awareness of, and support for, the needs and challenges of the local and global communities.

Innovation: Supports creative activities that approach challenges and issues from multiple perspectives in order to find solutions and advance knowledge.

2. Program Educational Objectives (PEOs)

Program Educational Objectives (PEOs) Program Educational Objectives (PEOs) are general declarations that outline the expected outcomes for graduates of a particular academic program within a few years of earning their degree. The PEOs are intended to direct the growth of students' knowledge, abilities, and competencies within the framework of the B. Tech in Electronics and Communication Engineering program, setting them up for both successful employment and meaningful contributions to society. The purpose of the PEOs for a B. Tech in Electronics and Communication Engineering is to guarantee that graduates are equipped to handle the demands of the contemporary tech industry, contribute significantly to the field, and keep up with the discipline's advancement. They place a strong emphasis on teamwork, communication skills, technical proficiency, ethical awareness, and flexibility in a world that is changing quickly.

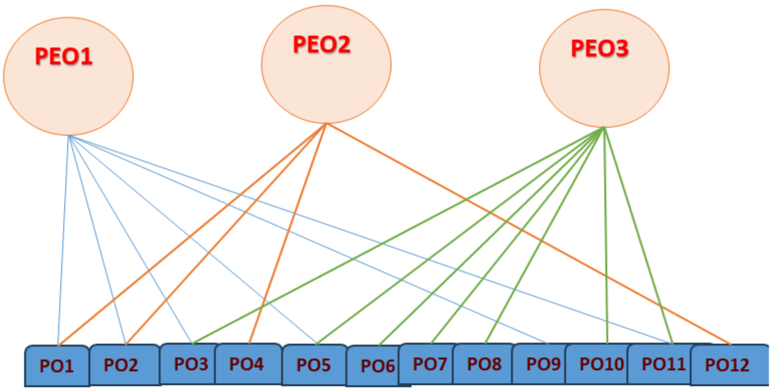
Program Educational Objective - I: Have successful careers in Industry.
Program Educational Objective - II: Show excellence in higher studies/ Research
Program Educational Objective - III: Show good competency towards Entrepreneurship.

2.1. Mapping of program educational objectives to program outcomes and program specific outcomes:

The following Figure 1 shows the correlation between the PEOs and the POs

PEO-I	PEO-II	PEO-III
PO:1,2,3,5,9,11	**PO:**1,2,4,12	**PO:**3,5,6, 7, 8, 10,11

Figure 1: Correlation between the PEOs and the POs



The following Figure 2 shows the correlation between the PEOs and the PSOs

PEO-I	PEO-II	PEO-III
PSO:1	**PSO:**1,2	**PSO:2**

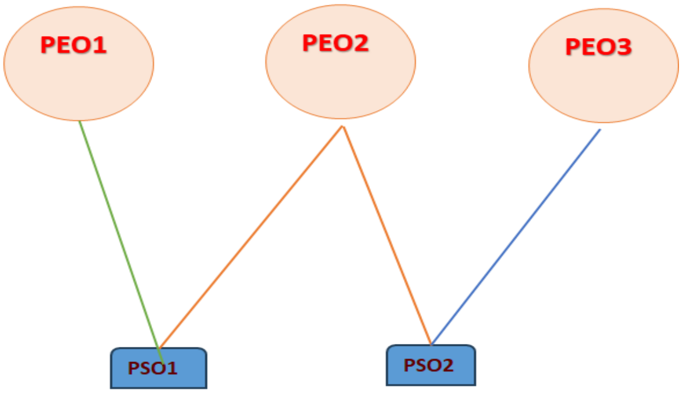


Figure 2: Correlation between the PEOs and the PSOs

3. Program Outcomes (POs)

A Program Learning Outcome is broad in scope and describes what a student should be able to do at the end of the program. POs are aligned with the graduate attributes specified in the Washington Accord. POs should be specific, measurable, and achievable.
The **NBA** has defined **12 POs**, which are common for all institutions in India.

In the syllabus book given to students, there should be a clear mention of **course objectives** and **course outcomes**, along with a **CO-PO course articulation matrix** for all the courses.

B. Tech (ECE) – PROGRAM OUTCOMES (PO's)	
A graduate of the Electronics and Communication Engineering Program will be demonstrated:	
PO1	**Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem Analysis:** Identify, formulate, review research literature, and analyse complex engineering problems, reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/Development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, as well as cultural, societal, and environmental considerations.
PO4	**Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods, including the design of experiments, analysis and interpretation of data, and synthesis of information, to provide valid conclusions.
PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, andmodernengineeringandITtoolsincludingpredictionandmodelingtocomplex engineering activities with an understanding of the limitations.
PO6	**The Engineer and Society:** Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues, and the consequent responsibilities relevant to professional engineering practice.
PO7	**Environment and Sustainability:** Understand the impact of professional engineering solutions in societal and environmental contexts, and demonstrate knowledge of and the need for sustainable development.
PO8	**Ethics:** Apply ethical principles and commit to professional ethics, responsibilities, and norms of engineering practice.
PO9	**Individual and Teamwork:** Function effectively as an individual, as well as a member or leader in diverse teams and multidisciplinary settings.
PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and society at large. This includes the ability to comprehend and write effective reports and design 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 to 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.

4. Program Specific Outcomes (PSOs)

Program Specific Outcomes (PSOs) are statements that describe what the graduates of a specific engineering program should be able to do.

A list of PSOs written for the Department of Electronics and Communication Engineering are given below.

B. Tech (ECE) – PROGRAM SPECIFIC OUTCOMES (PSO's)	
A graduate of the Electronics and Communication Engineering Program will demonstrate:	
PSO1	Analyze and design analog & digital circuits or systems for a given specification and function.
PSO2	Implement functional blocks of hardware-software co-design for signal processing and communication applications.

5. Relation between the Program Educational Objectives and the POs

Broad relationship between the program objectives and the program outcomes is given in the following Table below:

PEO's→ ↓PO's		(1) Have successful careers in Industry	(2) Show excellence in higher studies/ Research	(3) Show good competency towards Entrepreneurship
PO1	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	3	
PO2	Identify, formulate, review research literature, and analyse complex engineering problems, reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	3	
PO3	Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, as well as cultural, societal, and environmental considerations.	3		3
PO4	Use research-based knowledge and research methods, including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.		3	
PO5	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering activities with an understanding of the limitations.	2		3
PO6	Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice.			2
PO7	Understand the impact of professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of and need for sustainable development.			2

PO8	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.			2
PO9	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	3		
PO10	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.			2
PO11	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, to manage projects in multidisciplinary environments.	3		3
PO12	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.		3	

6. Relation between the Program Specific Outcomes and the Program Educational Objectives

PEO's→ ↓PSO's		(1) Have successful careers in Industry	(2) Show excellence in higher studies/ Research	(3) Show good competency towards Entrepreneurship
PSO1	Students acquire necessary technical skills in mechanical engineering that make them an employable graduate.	3	3	2
PSO2	An ability to impart technological inputs towards the development of society by becoming an entrepreneur.	3	2	3

Relationship between Program Specific Outcomes and Program Educational objectives

Key: 3 = High; 2 = Medium; 1= Low

Note:

- The assessment process of POs and PSOs can be director and indirect.
- The direct assessment will be done through interim assessment by conducting continuous internal exam and semester end exams.
- The indirect assessment on the other hand could be done through student's program exit questionnaire, alumni survey and employer survey.

7. Blooms Taxonomy

Bloom's taxonomy is considered the global language for education. Bloom's Taxonomy is frequently used by teachers in writing course outcomes as it provides a ready-made structure and a list of action verbs. The stages ascend in complexity and what they demand of students.

First, students need to simply remember information provided to them, but reciting something doesn't demonstrate having learned it, only memorization. With understanding comes the ability to explain the ideas and concepts to others. The students are then challenged to apply the information and use it in new ways, helping to gain a deeper understanding of previously covered material and demonstrating it moving forward.

Questioning information is a vital part of learning, and both analysis and evaluation do just this. Analysing asks a student to examine the information in a new way, and evaluation demands the student appraise the material in a way that lets them defend or argue against it as they determine.

The final step in the revised taxonomy is creating, which entails developing a new product or point of view. How does this learned information impact your world? How can it be used to impact not just your education but the way you interact with your surroundings? By utilizing Bloom's Taxonomy, students are not going to forget the information as soon as the class ends, rather, they retain and apply the information as they continue to grow as a student and in their careers, staying one step ahead of the competition.

7.1. Incorporating Critical Thinking Skills into Course Outcome Statements

Many faculty members choose to incorporate words that reflect critical or higher-order thinking into their learning outcome statements. Bloom (1956) developed a taxonomy outlining the different types of thinking skills people use in the learning process. Bloom argued that people use different levels of thinking skills to process different types of information and situations. Some of these are basic cognitive skills (such as memorization) while others are complex skills (such as creating new ways to apply information). These skills are often referred to as critical thinking skills or higher-order thinking skills.

Bloom proposed the following taxonomy of thinking skills. All levels of Bloom's taxonomy of thinkingskillscanbeincorporatedintoexpectedlearningoutcomestatements. Recently, Anderson and Krathwohl (2001) adapted Bloom's model to include language that is oriented towards the language used in expected learning outcome statements. A summary of Anderson and Krathwohl's revised version of Bloom's taxonomy of critical thinking is provided in Figure 3.

Figure 3: Revised version of Bloom's taxonomy

7.2. Definitions of the different levels of thinking skills in Bloom's taxonomy:

Remember: Recalling relevant terminology, specific facts, or different procedures related to information and/or course topics. At this level, a student can remember something but may not really understand it.

Understand – The ability to grasp the meaning of information (facts, definitions, concepts, etc.) that has been presented.

Apply – Being able to use previously learned information in different situations or in problem-solving.

Analyse – The ability to break information down into its component parts. Analysis also refers to the process of examining information in order to make conclusions regarding cause and effect, interpreting motives, making inferences, or finding evidence to support statements/arguments.

Evaluate – Being able to judge the value of information and/or sources of information based on personal values or opinions.

Create–the ability to creatively or uniquely apply prior knowledge and /or skills to produce new and original thoughts, ideas, processes, etc. At this level, students are involved in creating their own thoughts and ideas.

7.3.List of Action Words Related to Critical Thinking Skills

Here is a list of action words that can be used when creating the expected student learning outcomes related to critical thinking skills in a course. These terms are organized according to the different levels of higher-order thinking skills contained in Anderson and Krathwohl's (2001) revised version of Bloom's taxonomy. Here is the revised Bloom's document with action verbs, which we frequently refer to while writing COs for our courses.

The cognitive process dimensions - categories:

Lower Order of Thinking (LOT)			**Higher Order of Thinking (HOT)**		
Remember	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Interpreting	Recognizing	Executing	Differentiating	Checking	Planning
Illustrating	(identifying)	Implementing	Organizing	(Coordinating)	Generating
Classifying	Recalling		Attributing	detecting,	Producing

Summarizing Inferring (concluding) comparing explaining	(retrieving)			testing, monitoring) Critiquing (judging)	(constructing)

The Knowledge Dimension			
Concrete Knowledge → Abstract knowledge			
Factual	**Conceptual**	**Procedural**	**Metacognitive**
• Knowledge of terminologies • Knowledge of specific details and elements.	• Knowledge of classifications and categories • Knowledge of principles and generalizations • Knowledge of theories, models and structures	• Knowledge of subject specific skills and algorithms • Knowledge of subject specific techniques and methods • Knowledge of criteria for determining when to use appropriate procedures	• Strategic Knowledge • Knowledge about cognitive task, including gap propriate contextual and conditional Knowledge • Self-Knowledge

Action Verbs for Course Out comes

Lower Order of Thinking (LOT)				**Higher Order of Thinking (HOT)**		
Definitions	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Bloom's Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts,	Demonstrate understanding off acts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and	Solve problem s to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based	Compile information together in a different way by combining elements in a new pattern or proposing alternative solution.

	and answers.	Stating main ideas.			on a set of criteria.	
Verbs	• Choose • Define • Find • How • Label • List • Match • Extend	• Classify • Compare • Contrast • Demonstrate • Explain • Illustrate • Infer • Interpret	• Apply • Build • Choose • Construct • Develop • Interview • Make use of • Model	• Analyze • Assume • Categorize • Classify • Compare • Discover • Dissect • Distinguish	• Agree • Appraise • Assess • Award • Choose • Criticize • Decide • Deduct • Importanc e	• Adapt • Build • Solve • Choose • Combine • Invent • Compile • Compose • Construct
Verbs	• Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	• Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with	• Organize • Plan • Select • Solve • Utilize • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize • Identify	• Divide • Examine • Function • Inference • Inspect • List Motive • Simplify • Survey • Take part in • TestforTheme • Conclusion • Contrast	• Defend • Determine • Disprove • Estimate • Evaluate • Influence • Interpret • Judge • Justify Mark • Measure • Opinion • Perceive • Prioritize • Prove • Criteria • Criticize • Compare • Conclude	• Create • Design • Develop • Estimate • Formulate • Happen • Imagine • Improve • Makeup • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution

8. Guidelines for writing Course Outcome Statements:

Well-written course outcomes involve the following parts:

1. Action verb
2. Subject content
3. Level of achievement as per BTL
4. Modes of performing task (if applicable)

8.1. Course Outcomes (COs)

A Course Outcome is a formal statement of what students are expected to learn in a course. When creating Course Outcomes, remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning. Course learning outcome statements refer to specific knowledge, practical skills, areas of professional development, attitudes, higher-order thinking skills, etc., that faculty members expect students to develop, learn, or master during a course.

A well-formulated set of Course Outcomes will describe what a faculty member hopes to successfully accomplish in offering their particular course(s) to prospective students, or what specific skills, competencies, and knowledge the faculty member believes that students will have attained once the course is completed. The learning outcomes need to be concise descriptions of what learning is expected to take place by course completion.

8.2. Developing Course Outcomes

When creating course outcomes consider the following guidelines as you develop them either individually or as part of a multi-section group:

Limit the course outcomes to 5-6 statements for the entire course [more detailed outcomes can be developed for individual units, assignments, chapters, etc. if the instructor(s) wish (es)].

Focus on overarching knowledge and/or skills rather than small or trivial details.

Emphasize knowledge and skills that are central to the course topic and/or discipline.

Create statements that have a student focus rather than an instructor-centric approach. (Example:

Student-focused outcome: "Upon completion of this course, students will be able to list the names of the 28 states and 8 union territories."

Instructor-centric objective (to avoid): "One objective of this course is to teach the names of the 28 states and 8 union territories.").

Focus on the learning that results from the course rather than describing activities or lessons that are in the course.

Incorporate and/or reflect the institutional and departmental mission.

Include various ways for students to show success (e.g., outlining, describing, modelling, depicting, etc.) rather than using a single statement such as "At the end of the course, students will know" as the stem for each expected outcome statement.

When developing learning outcomes, here are the core questions to ask yourself:

- What do we want students in the course to learn?
- What do we want the students to be able to do?
- Are the outcomes observable, measurable, and able to be performed by the students?

Course outcome statements at the course level describe:

- What faculty members want students to know at the end of the course **AND**
- What faculty members want students to be able to do at the end of the course.

Course outcomes have three major characteristics:

- They specify an action by the students/learners that is **observable**.

- They specify an action by the students/learners that is **measurable**.
- They specify an action that is **done by the students/learners** rather than the faculty members.

Effectively developed expected learning outcome statements should possess all three of these characteristics.

When this is done, the expected learning outcomes for a course are designed so that they can be assessed. When stating expected learning outcomes, it is important to use **verbs that describe exactly what the student(s)/learner(s) will be able to do upon completion of the course**.

8.3. Relationship of Course Outcome to Program Outcome

Learning outcomes formula:
STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE

The Course Outcomes need to link to the Program Outcomes.

For example, you can use the following template to help you write an appropriate course level learning outcome.
"Upon completion of this course students will be able to (knowledge, concept, rule or skill you expect them to acquire) by (how will they apply the knowledge or skill/how will you assess the learning)."

8.4. Characteristics of Effective Course Outcomes

Well written course outcomes:

- Describe what you want your students to learning your course.
- A realigned with program goals and objectives.
- Tell how you will know an instructional goal has been achieved.
- Use action words that specify definite, observable behaviors.
- Arrases able through one or more indicators (papers, quizzes, projects, presentations, journals, portfolios, etc.)
- Are realistic and achievable.
- Use simple language.

8.5. Examples of Effective Course Outcomes

After successful completion of the course, Students will be ablet o:

- Understand the fundamental principles of semiconductor diodes, including their construction, operation and applications for evaluating the device parameters.
- Analyze the performance characteristics of BJT configurations based on parameters like gain and impedance.
- Analyze transistor circuits with appropriate biasing and stabilization techniques for operating BJTs and MOSFETs in different regions.
- Apply the low-frequency small signal equivalent circuit models of BJTs for measuring amplifier parameters, including gain and impedance
- Demonstrate the working principle of special purpose semiconductor diodes and transistors for triggering and voltage regulation applications.
- Explain the fundamental concepts of digital signal processing for understanding system characteristics.
- Evaluate various discrete Fourier transformations for real world problems.
- Design IIR digital filters for evaluating their performance in discrete-time signal processing systems.
- Apply different design techniques for FIR filters for achieving specific frequency-domain requirements.
- Analyze the realization of digital filters in various forms, in relation to multi-rate digital signal processing systems.
- Understand the mechanism of radiation and gain knowledge on antenna parameters.
- Examine the working principles, radiation patterns, and performance characteristics of various antennas for communication systems.
- Illustrate the geometry, parameters, and characteristics of VHF, UHF, and microwave antennas to meet specific application requirements.
- Distinguish the performance characteristics of 2-cavity klystrons, reflex klystrons, and magnetrons, and estimate their efficiency levels.
- Analyze various solid-state devices for different microwave junctions to set up a microwave bench based on their S-Matrix.
- Understand the operation of MOS transistors and CMOS device modeling concepts for the analysis of integrated circuits.
- Analyze fundamental analog CMOS sub-circuits and various current mirror configurations by considering their design principles, current matching accuracy, and applications.
- Design efficient, high-performance analog circuits through the analysis of fundamental CMOS amplifier architectures.
- Apply measurement techniques for designing CMOS operational amplifiers
- Classify the characteristics and efficiency of various comparator circuits and explore techniques for enhancing their practical application.

A more comprehensive approach to defining learning objectives involves three essential components: a condition, an observable behavior, and a standard. The table below illustrates three examples based on this model.

S. No	Condition	Observable Behavior	Standard
1	Given a set of electronic components (resistors, capacitors, diodes, etc.)	The student will identify each component and explain its function.	With at least 80% accuracy.
2	Given a circuit diagram of an amplifier	The student will analyze the circuit and calculate gain and impedance values.	With an accuracy of at least 85%
3	After performing an experiment on modulation techniques	The student will compare AM, FM, and PM in terms of bandwidth and efficiency.	Listing at least two differences for each pair.
4	Given a MATLAB or Python simulation of a signal processing system	The student will interpret the output and suggest improvements.	Providing at least one valid optimization approach.
5	After attending a lecture on microcontrollers	The student will write a basic program for GPIO control using an embedded system.	Ensuring correct compilation and expected output.

The following examples illustrate a Course Outcome that lacks measurability, the rationale for why it is deemed un measurable, and a proposed revision that enhances the clarity and measurability of the outcome.

Initial Course Outcome	Assessment of Language Used in the Course Outcome	Revised Course Outcome
Understand the fundamentals of digital signal processing.	"Understand" is not measurable. Understanding must be demonstrated through an observable action.	Upon completion of this course, students will be able to: analyze discrete-time signals and systems using Fourier and Z-transforms.
Gain knowledge of modulation techniques.	"Gain knowledge" is vague and not directly measurable. It does not specify how students will demonstrate their learning.	Upon completion of this course, students will be able to: compare AM, FM, and PM modulation techniques based on bandwidth,

		efficiency, and noise performance.
Learn about microcontroller programming.	"Learn about" is not an observable action. There is no way to measure whether learning has occurred.	Upon completion of this course, students will be able to: write and debug C programs for microcontroller-based embedded systems.
Get familiar with VLSI design methodologies.	"Get familiar with" is too subjective and cannot be measured directly.	Upon completion of this course, students will be able to: design and simulate combinational and sequential circuits using VHDL/Verilog.

Examples that are TOO general and VERY HARD to measure. . .

• . . . will appreciate the benefits of learning a foreign language.
• . . . will be able to access resources at the Institute library.
• . . . will develop problem-solving skills.
• . . . will have more confidence in their knowledge of the subject matter. Examples that are still general and HARD to measure. . .
• . . . will value knowing a second language as a communication tool.
• . . . will develop and apply effective problem-solving skills that will enable one to adequately
navigate through the proper resources within the institute library.
• . . . will demonstrate the ability to resolve problems that occur in the field.

• . . . will demonstrate critical thinking skills, such as problem solving as it relates to social issues

Examples that are SPECIFIC and relatively EASY to measure...

- ...will be able to analyze and design basic electronic circuits using appropriate simulation tools and demonstrate functionality through testing and measurement.
- ...will demonstrate the ability to design and implement digital systems using hardware description languages (HDLs) and programmable logic devices.
- ...will be able to interpret and troubleshoot signals using tools such as oscilloscopes, spectrum analyzers, and signal generators.
- ...will demonstrate the ability to apply fundamental principles of communication systems to analyze modulation techniques and compute performance metrics.
- ...will be able to evaluate and integrate appropriate components and design methodologies to propose and simulate embedded systems solutions.
- ...will demonstrate proficiency in using industry-standard software (e.g., MATLAB, Simulink, Multisim) for modeling and analyzing ECE problems.
- ..will be able to conduct basic experiments in electronics and communication, analyze experimental data, and draw valid conclusions based on observed trends.

- ...will demonstrate the ability to research current trends in wireless communication or IoT and present findings through technical reports or presentations.
- ...will be able to identify practical engineering problems, propose viable circuit- or system-level solutions, and justify them using theoretical knowledge and technical standards.
- ...will demonstrate effective collaboration and communication skills through participation in team-based design projects and technical documentation.

A Self-Assessment – Evaluate Your Own Course Outcomes

Reflecting on the course, begin by listing four to six of the most important student outcomes you aim to achieve, based on either previously written course goals or a thoughtful analysis of your teaching objectives. Identify the single most crucial outcome, if only one could be realized which one would hold the greatest value? Cross-reference this key outcome with recognized societal or professional key competencies to determine its relevance and alignment; if it is not represented, consider whether there is a compelling reason. Evaluate the rest of your important outcomes in the same way, assessing how many align with broadly recognized competencies. Through this exercise, gain insight into your goals as an educator, how clearly and meaningfully your outcomes are defined, how well they align with student needs, and how specifically they are worded to ensure clarity and impact in guiding student learning.

Write Your Course Outcomes!

One of the first steps you take in identifying the expected learning outcomes for your course is identifying the purpose of teaching the course. By clarifying and specifying the purpose of the course, you will be able to discover the main topics or themes related to students' learning. Once discovered, these themes will help you to outline the expected learning outcomes for the course. Ask yourself:

- What role does this course play within the program?
- How is the course unique or different from other courses?
- Why should/do students take this course? What essential knowledge or skills should they gain from this experience?
- What knowledge or skills from this course will students need to have mastered to perform well in future classes or jobs?
- Why is this course important for students to take?

8.6. CO-PO Course Articulation Matrix (CAM)Mapping

A **Course Articulation Matrix** shows the educational relationship (Level of Learning achieved) between course outcomes and program outcomes for a course. This matrix strongly indicates whether the students are able to achieve the course learning objectives. The matrix can be used for any course and is a good way to evaluate a course syllabus.

Table 1 provides information about the action verbs used in the Program Outcomes (POs) and the nature of POs, stating whether the POs are technical or non-technical.

You need to understand the intention of each PO and the **Bloom's Taxonomy level** to which each of the section verbs in the POs correlates. Once you have understood the POs, you can write the **Course Outcomes (COs)** for a course and see to what extent each of those COs correlates with the POs.

TABLE 9: Process for mapping the values for CO-PO Matrix

Experiential learning	Experiential learning	Experiential learning	Experiential learning	Experiential learning
Technical	PO1	Apply	L3	Bloom's L1 to L4 for theory courses. Bloom'sL1toL5forlaboratory courses. Bloom'sL1toL6for Project work, experiential learning
	PO2	Identify	L2	
		Formulate	L6	
		Review	L2	
	PO3	Design	L6	
		Develop	L3, L6	
	PO4	Analyze	L4	
		Interpret	L2, L3	
		Design	L6	
	PO5	Create	L6	
		Select	L1, L2, L6	
		Apply	L3	
Non-Technical	PO6	**Thumb Rule:** If Bloom's L1 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 1. If Bloom's L2 to L3 Action Verbs of a CO: Correlates with Any of PO6 to PO12, then assign 2. If Bloom's L4 to L6 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign3		
	PO7			
	PO8			
	PO9			
	PO10			
	PO11			
	PO12			

At the end, the Program Outcomes (POs) can be calculated using various descriptors that you may define. The mapping of Course Outcomes (COs**)** towards a PO is evaluated using descriptors such as High, Medium, Low, etc.

Observations:

1. The first five Program Outcomes (POs) are purely technical in nature, while the other POs are non-technical.

2. For theory courses, while writing the Course Outcomes (COs), you need to restrict yourself between Bloom's Level 1 to Level 4. However, if it is a programming course, restrict yourself between Bloom's Level 1 to Level 3, but for other courses, you can go up to Bloom's Level 4.

3. For laboratory courses, while composing COs, you need to restrict yourself between Bloom's Level 1 to Level 5.

4. Only for mini-projects and main projects, you may extend up to Bloom's Level 6 while composing COs.

5. For a given course, the course in-charge must involve all other professors who teach that course and ask them to come up with the CO-PO mapping. The course in-charge must take the average value of all these CO-PO mappings and finalize the values. Alternatively, the course in-charge can proceed with what the majority of faculty members prefer. Ensure that none of the professors handling the course discuss with each other while marking the CO-PO values.

6. If you want to match your COs with non-technical POs, correlate the action verbs used in the COs with the thumb rule given in the table and map the values. (This applies only for mapping COs to non-technical POs).

8.7. Tips for Assigning the values while mapping Cos to PO s.

1. Select action verbs for a Course Outcome (CO) from different Bloom's levels based on the importance of the particular CO for the given course.
2. Stick to a single action verb while composing COs, but you may use multiple action verbs if the need arises.
3. You need to justify the marking of values in the CO-PO articulation matrix. Use a combination of words found in the COs, POs, and your course syllabus for writing the justification. Restrict yourself to one or two lines.
4. Values for the CO-PO (technical POs in particular) matrix can be assigned by:
   (a) Judging the importance of the particular CO in relation to the PO s. If the CO matches strongly with a particular PO criterion, assign 3; if it matches moderately, assign 2; if the match is low, assign 1; otherwise, mark with a "-" symbol.
   (b) If an action verb used in a CO appears at multiple Bloom's levels, then you need to judge which Bloom's level is the best fit for that action verb.

8.8. Method for Articulation

1. Identify the key competencies of POs/PSOs for each CO and create a corresponding mapping table by assigning marks in the corresponding cell. One important observation is that the first five POs are purely technical in nature, while the other POs are non-technical.

2. Justify each CO-PO/PSO mapping with a justification statement and recognize the number of vital features mentioned in the justification statement that match the given Key Attributes for Assessing Program Outcomes. Use a combination of words found in the COs, POs/PSOs, and your course syllabus for writing the justification.
3. Create a table listing the number of key competencies for CO-PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Create a table displaying the percentage of key competencies for CO-PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, prepare a Course Articulation Matrix (CO-PO/PSO Mapping) with COs and POs and COs and PSOs on a scale of 0 to 3, where:

- 0 = No correlation (marked as "-")
- 1 = Low/slight correlation
- 2 = Medium/moderate correlation
- 3 = Substantial/high correlation

The correlation is based on the following strategy:

Range (C%)	**Correlation Level**
$0 \le C \le 5\%$	No correlation (0)
$5\% < C \le 40\%$	Low/Slight correlation (1)
$40\% < C < 60\%$	Moderate correlation (2)
$60\% \le C < 100\%$	Substantial/High correlation (3)

9. Key Competencies for Assessing Program Outcomes:

PO No.	NBA Statement / Vital Features	Key Components	No. of Key Components
PO1	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems (Engineering Knowledge).).	1. **Scientific Principles:** Application of scientific principles and methodologies. 2. **Mathematical Principles:** Utilization of mathematical concepts in problem-solving. 3. **Interdisciplinary Integration:** Integration of knowledge from various engineering disciplines. 4. **Engineering Specialization:** Application of specialized engineering	**4**

<table>
<tr><td></td><td></td><td>knowledge in complex engineering problems.</td><td></td></tr>
<tr><td>PO 2.</td><td>Identify, formulate, review research literature, and analyze complex engineering problems, reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences (Problem Analysis).</td><td>• Identity: Recognizing and defining complex engineering problems or opportunities.

1. Formulate: Structuring and abstracting the problem for systematic analysis.
2. Review: Examining research literature
3. Analyze: Investigating problems using data collection and relevant methodologies.
4. First Principles: Applying mathematical, natural, and engineering sciences in problem-solving.
5. Substantiated Conclusions: Ensuring accuracy and reliability through validation.
6. Experimental Design: Planning and conducting experiments for problem analysis.
7. Solution Development: Implementing and testing solutions through experimentation.
8. Interpretation: Evaluating results to draw meaningful engineering conclusions.
9. Documentation: Recording findings systematically for future reference and learning.</td><td>10</td></tr>
</table>

PO 3.	Design solutions for complex Engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and Environmental considerations (**Design/Development of Solutions).**	1. **Design:** Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. 2. **Solutions:** Understand customer and user needs while considering factors such as aesthetics. 3. **System Components:** Identify and manage cost drivers in engineering solutions. 4. **Processes:** Use creativity to develop innovative engineering solutions. 5. **Specified Needs:** Ensure fitness for purpose across production, operation, maintenance, and disposal. 6. **Public Health & Safety:** Manage the design process and evaluate outcomes for safety and risk assessment. 7. **Cultural Considerations:** Understand the commercial and economic context of engineering processes. 8. **Societal Considerations:** Apply management techniques to achieve engineering objectives in a broader context. 9. **Environmental Considerations:** Promote sustainable development through engineering activities. 10. **Appropriate Considerations:** Be aware of legal frameworks governing engineering activities, including personnel, health, safety, and environmental risks.	**10**
PO 4.	Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions (**Conduct**	1. **Research-Based Knowledge:** Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. **Research Methods:** Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data.	**10**

	Investigations of Complex Problems).	3. **Design of Experiments:** Address complex problems in various engineering contexts, including operations, management, and technology development. 4. **Analysis:** Leverage technical literature and reliable information sources. 5. **Interpretation of Data:** Follow appropriate codes of practice and industry standards when analyzing and interpreting experimental data. 6. **Synthesis:** Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations. 7. **Valid Conclusions:** Draw valid conclusions by addressing technical uncertainties through sound reasoning and scientific principles. 8. **Engineering Principles:** Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges. 9. **Modelling Techniques:** Use analytical and modeling techniques to identify, classify, and describe the performance of engineering systems and components. **10. Quantitative Methods:** Employ analytical software and quantitative methods efficiently and accurately.	
PO 5.	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	1. **Create:** Develop engineering solutions using modern tools across various disciplines. 2. **Select:** Identify appropriate prediction and modeling tools for diverse engineering applications. 3. **Apply:** Utilize IT tools in engineering analysis, design, and decision-making.	**4**

	(**Modern Tool Usage).**	4. **Techniques:** Implement simulation tools in different engineering fields.	
PO 6.	Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice (**The Engineer and Society).**	1. **Contextual Knowledge:** Understand the commercial and economic context of engineering processes. 2. **Management Techniques:** Apply management strategies in engineering objectives within this context. 3. **Sustainable Development:** Promote sustainable development through engineering activities. 4. **Legal Awareness:** Recognize relevant legal requirements governing engineering practices, including health, safety, and environmental risks. **5. Professional Ethics:** Uphold high standards of professional and ethical conduct in engineering.	**5**
PO 7.	Understand the impact of the professional Engineering solutions in societal and Environmental contexts, and demonstrate the knowledge of, and need for sustainable development (**Environment and Sustainability).**	1. **Socio-Economic Impact:** Understand the socio-economic effects of engineering solutions on society. 2. **Political Impact:** Recognize the political implications and responsibilities of engineering solutions. 3. **Environmental Impact:** Assess the environmental consequences of engineering practices and solutions. 4. **Sustainability:** Demonstrate the importance of sustainable development in engineering solutions.	**4**
PO 8.	Apply ethical principles and commit to professional ethics and responsibilities and norms of the Engineering practice (**Ethics).**	1. **Ethical Judgement:** Make informed decisions based on ethical principles, using professional codes of ethics to guide actions and evaluate the ethical aspects of practice. 2. **Integrity:** Demonstrate a strong sense of trust and integrity, standing firm in	

		one’s values while acting responsibly and ethically. 3. **Fairness and Equity:** Ensure fair treatment and equity in all professional activities, valuing diversity and respecting others' perspectives. 4. **Professional Responsibility:** Adhere to the norms of engineering practice by committing to high ethical standards and demonstrating ethical behavior in all professional engagements.	**4**
PO9	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings (**Individual and Teamwork).**	1. **Independence:** Work effectively as an individual, taking ownership of tasks and driving progress independently. 2. **Maturity:** Demonstrate maturity by focusing on goal achievement, requiring minimal external motivation. 3. **Self-Direction:** Approach vaguely defined problems with systematic problem-solving skills to find solutions. 4. **Team Collaboration:** Engage in teamwork during various activities, including hands-on labs and multidisciplinary projects. 5. **Adaptability:** Participate in diverse team settings, adjusting to different roles and projects such as mini projects and design tasks. 6. **Project Management:** Understand and apply principles of teamwork and project management to effectively complete assignments and projects. 7. **Peer Evaluation:** Contribute to team dynamics by evaluating and reflecting on individual and group performance. 8. **Building Relationships:** Foster teamwork and lasting relationships, contributing to both academic	**10**

		success and post-graduation professional networks. 9. **Organizational Integration**: Collaborate with individuals across all levels of an organization, demonstrating adaptability and interpersonal skills. **10. Effective Communication:** Develop strong relationships through positive interactions, showcasing an ability to get along with others and work cohesively in teams.	
PO10	Communicate effectively on complex Engineering activities with the Engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions (**Communication).**	**1. Clarity:** Communicate complex engineering concepts clearly and concisely in written reports and design documentation. **2. Grammar and Punctuation:** Ensure high standards of grammar and punctuation in written communication, maintaining professionalism and clarity. **3. References:** Properly reference sources in written communication, ensuring accuracy and academic integrity. **4. Speaking Style:** Deliver oral presentations effectively, with appropriate speaking style to engage the audience and convey technical information clearly. **5. Subject Matter**: Demonstrate a deep understanding of the subject matter, clearly communicating complex ideas during oral discussions and presentations.	**5**
PO11	Demonstrate knowledge and understanding of the Engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multi-disciplinary Environments (**Project**	1. **Scope Definition:** Define the project scope clearly to ensure alignment with objectives and requirements. 2. **Critical Success Factors:** Identify and prioritize critical success factors necessary for project completion and success. 3. **Deliverables:** Ensure the timely delivery of project outputs, meeting	**10**

	Management and Finance).	the predefined objectives and quality standards. 4. **Work Breakdown Structure:** Develop and organize a structured breakdown of tasks and activities to achieve project goals. 5. **Scheduling:** Create and manage schedules to ensure tasks are completed on time and milestones are met. 6. **Budget Management:** Develop and manage project budgets, ensuring that resources are used efficiently and within financial constraints. 7. **Quality Assurance**: Apply quality control measures to ensure that project deliverables meet the required standards. 8. **Human Resources Planning:** Plan and allocate human resources effectively, ensuring the right skills and team dynamics. 9. **Stakeholder Management:** Identify and manage stakeholders, ensuring their needs and expectations are addressed throughout the project. **10. Risk Management:** Develop a risk register and apply strategies to identify, assess, and mitigate project risks.	
PO12	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 (**Life - Long Learning).**	1. **Professional Certificate:** Pursue professional, Academic, Global certifications. 2. **Advanced Education:** Begin and work towards advanced programs to further deepen knowledge. 3. **Continuous Learning:** Stay updated on industry trends and emerging technologies to remain relevant in the field. 4. **Skill Acquisition:** Learn at least 2–3 new significant skills annually to ensure continuous growth and development. 5. **Training Commitment:** Dedicate time for formal training for a standard duration of training each year.	**8**

		6. **Personal Development:** Engage in ongoing self-improvement efforts to enhance both personal and professional growth. 7. **Adaptability:** Be adaptable to technological changes by actively pursuing new learning opportunities and challenges. 8. **Networking:** Build a network with industry peers and professionals to stay informed and grow knowledge through collaboration	

10. Key Competencies for Assessing Program Specific Outcomes:

PSO	NBA statement/Vital features	No. of vital features
PSO1	Analyze and design analog & digital circuits or systems for a given specification and function. Operate, control and protect Computer system. 1. Analyze response of a circuit or system 2. Design of a circuit or system for a given specification 3. Understand and apply circuit or system specifications accurately. 4. Knowledge of analog and digital signal processing techniques.	4
PSO2	Implement functional blocks of hardware-software co-design for signal processing and communication applications. 1. Develop Operational block diagrams 2. Proficiency in the use of software tools for circuit design. 3. Hardware-software integration in analog and digital systems 4. Understanding trade-offs in hardware and software design parameters.	4

11. Program Outcomes and Program Specific outcomes Attained through course modules:

Courses offered in Electronics and Communication Engineering Curriculum (MLRS-R20) and POs/PSOs attained

Through course modules for I, II, III, IV, V, VI, VII and VIII semesters.

Course Code	Course Title	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
C111	Matrix Algebra & Calculus	√	√	√	√								√	√	√
C112	Applied Physics	√	√		√									√	√
C113	Programming For Problem Solving	√	√	√	√		√						√	√	√
C114	Engineering Workshop	√		√											
C115	English For Skill Enhancement					√	√	√	√	√		√	√		
C116	Elements Of Electronics And Communication Engineering	√	√	√	√	√							√	√	√
C117	Applied Physics Laboratory	√	√		√									√	
C118	Programming For Problem Solving Laboratory	√	√	√		√	√		√		√		√	√	
C119	English Language And Communications Skills Lab						√	√	√	√	√		√	√	
C1110	Environmental Science						√	√	√						
C121	Differential Equations And Vector Calculus	√	√	√	√								√	√	√
C122	Engineering Chemistry	√	√				√	√							
C123	Engineering Drawing Practice	√		√		√	√								
C124	Basic Electrical Engineering	√	√	√	√										
C125	Electronic Devices And Circuits	√	√	√	√								√	√	√
C126	Data Structures Laboratory	√	√	√		√	√		√		√		√	√	

C127	Engineering Chemistry Laboratory	√	√		√										
C128	Basic Electrical Engineering Laboratory	√	√	√	√	√								√	√
C129	Electronic Devices And Circuits Laboratory	√	√	√	√	√							√	√	√
C211	Numerical Methods & Complex Variables	√	√	√	√								√	√	√
C212	Digital System Design	√	√	√	√									√	√
C213	Signals And Systems	√	√	√	√									√	√
C214	Probability Theory And Stochastic Processes	√	√	√	√								√	√	√
C215	Analog And Pulse Circuits	√	√	√	√									√	√
C216	Digital System Design Laboratory	√	√	√	√	√							√	√	√
C217	Basic Simulation Laboratory	√	√		√	√							√	√	√
C218	Analog And Pulse Circuits Lab	√	√	√	√	√								√	√
C219	Gender Sensitization						√		√						
C221	Business Economics And Financial Analysis						√		√	√		√	√		
C222	Electromagnetic Theory And Transmission Lines	√	√	√	√									√	√
C223	Analog And Digital Communication	√	√	√	√									√	√
C224	Linear And Digital IC Applications	√	√	√	√									√	√
C225	Python Programming	√	√	√	√								√	√	

C226	Analog And Digital Communications Lab	√	√	√	√	√							√	√	√
C227	Linear And Digital IC Applications Laboratory	√	√	√	√	√								√	√
C228	Python Programming Laboratory	√	√	√		√	√		√		√		√	√	
C229	Field Based Project	√	√	√	√	√	√	√	√	√	√	√	√	√	√
C311	Constitution Of India						√	√	√			√			
C311	Control Systems	√	√	√	√									√	√
C312	Micro Processors And Micro Controllers	√	√	√			√							√	√
C313	Digital CMOS IC Design	√		√	√	√							√	√	√
C314	Electronic Measurements And Instrumentation	√	√	√	√	√								√	√
C315	Data Base Management Systems	√	√	√								√	√	√	
C316	Advanced English Language Communication Skills Laboratory					√	√		√	√	√		√		
C317	Micro Processors And Micro Controllers Lab	√	√	√	√	√								√	√
C318	Data Base Management Lab	√	√	√		√	√		√		√		√	√	
C319	Intellectual Property Rights						√		√			√	√		
C321	Antennas And Wave Propagation	√	√	√	√								√	√	√
C322	Digital Signal Processing	√	√	√	√								√	√	√

C323	Analog CMOS IC Design	√	√	√	√	√							√	√	√
C324	Digital Image Processing	√	√	√	√								√	√	√
C325	Oops Through Java	√	√	√	√									√	
C326	Digital Signal Processing Laboratory	√	√	√	√	√							√	√	√
C327	Digital CMOS IC Design Laboratory	√	√	√	√	√							√	√	√
C328	Industry Oriented Mini Project / Summer Internship	√	√	√	√	√	√	√	√	√	√	√	√	√	√
C329	Professional Ethics						√	√	√	√			√		
C411	Embedded System Design	√	√										√	√	√
C412	Microwave And Optical Communications	√	√	√	√								√	√	√
C413	Fundamentals Of Management						√		√	√		√	√		
C414	Wireless Communications And Networks	√	√	√		√							√	√	√
C415	Internet Of Things	√	√	√	√		√					√	√	√	√
C416	Microwave Engineering Laboratory	√	√	√	√								√	√	√
C417	Project Stage-I	√	√	√	√	√	√	√	√	√	√	√	√	√	√
C421	Satellite Communications	√	√	√	√	√							√	√	√
C422	Radar Systems	√	√	√	√	√							√	√	√

C423	Test And Testability	√	√	√	√	√							√	√	√
C424	Technical Seminar	√	√	√	√	√	√	√	√	√		√	√	√	√
C425	Project Stage-II	√	√	√	√	√	√	√	√	√	√	√	√	√	√

12. Methods for measuring Learning Outcomes and Valu Addition

There are many different ways to assess student learning. In this section, we present the different types of assessment approaches available and the different frame works to interpret the results.

i) Continuous Internal Evaluation (CIE).
ii) Semester end examination (SEE)
iii) Laboratory and project work
iv) Course exit survey
v) Program exit survey
vi) Alumni survey
vii) Employer survey
viii) Department Advisory Board
ix) Faculty meetings

The above assessment indicators are detailed below.

12.1. Continuous Internal Evaluation (CIE)

Two Continuous Internal Evaluation (CIEs) are conducted for all courses by the department. All students must participate in this evaluation process. These evaluations are critically reviewed by HOD and senior faculty and the essence is communicated to the faculty concerned to analyze, improve and practice so as to improve the performance of the student.

12.2. Semester End Examination (SEE)

The semester end examination is conducted for all the courses in the department. Before the Semester end examinations course reviews are conducted, feedback taken from students and remedial measures will be taken up such that the student gets benefited before going for end exams. The positive and negative comments made by the students about the course are recorded and submitted to the departmental academic council and to the principal for taking necessary actions to better the course for subsequent semesters.

12.3. Laboratory and Project Works

The laboratory work is continuously monitored and assessed to suit the present demands of the industry. Students are advised and guided to do project works giving solutions to research/ industrial problems to the extent possible by the capabilities and limitations of the student. The results of the assessment of the individual projects and laboratory work can easily be conflated in order to provide the students with periodic reviews of their overall progress and to produce terminal marks and grading.

12.4. Course Exit Surveys

Students are encouraged to fill-out a brief survey on the fulfillment of course objectives. The data is reviewed by the concerned course faculty and the results are kept open for the entire faculty. Based on this, alterations or changes to the course objectives are undertaken by thorough discussions in faculty and meetings.

12.5. Programme Exit Survey

The Program Exit Questionnaire is to be completed by all students leaving the institution. The questionnaire is designed to gather information from students regarding program educational objectives, overall program experiences, career choices, and any suggestions or comments for program improvement. The opinions expressed in the exit interview forms are reviewed by the Department Advisory Committee (DAC) for potential implementation.

12.6. Alumni Survey

The survey gathers insights from former students of the department regarding their employment status, further education, perceptions of institutional emphasis, estimated gains in knowledge and skills, undergraduate involvement, and continued engagement with Marri Laxman Reddy Institute of Technology and Management. This survey is conducted every three years, and the collected data is analyzed for continuous improvement.

12.7. Employer Survey

The main purpose of this employer questionnaire is to know employers' views about the skills they require of employees compared to the skills actually possessed by them. The purpose is also to identify gaps in technical and vocational skills, determine the need for required training practices to fill these gaps, and establish criteria for hiring new employees. These employer surveys are reviewed by the College Academic Council (CAC) to modify the present curriculum to suit the requirements of the employer.

12.8. Department Advisory Board (DAB)

The Departmental Advisory Board (DAB) plays an important role in the development of the department. The department-level Advisory Board is established to provide guidance and direction for the qualitative growth of the department. The board interacts and maintains liaison with key stakeholders.

The DAB will monitor the progress of the program and develop or recommend new or revised goals and objectives for the program. Additionally, the DAB will review and analyse the gaps between the curriculum and industry requirements, providing necessary feedback or advice to improve the curriculum

12.9. Faculty Meetings

The DAB meets bi-annually for every academic year to review the strategic planning and modification of PEOs. Faculty meetings are conducted at least once in fortnight for ensuring the implementation of DAB's suggestions and guidelines. All these proceedings are recorded and kept for the availability of all faculties.

13. CO-Assessment processes and tools

Course outcomes are evaluated based on two approaches namely direct and indirect assessment methods. The direct assessment methods are based on the Continuous Internal Evaluation (CIE)and Semester End Examination (SEE)whereas the indirect assessment methods are based on the course end survey and program exit survey provided by the students, Alumni and Employer.

The weightage in CO attainment of Direct and Indirect assessments are illustrated in Table.

Assessment Method	Assessment Tool	Weightage in CO attainment
Direct Assessment	Continuous Internal Evaluation (CIE)	8 0%
	Semester End Examination	
Indirect Assessment	Course End Survey	20%

13.1. Direct Assessment:

Direct assessment methods are based on the student's knowledge and performance in various assessments and examinations. These assessment methods provide evidence that a student has command over a specific course, content, or skill. Additionally, they demonstrate that the student's work exhibits specific qualities such as creativity, analysis, or synthesis.

The various direct assessment tools used to assess the impact of the delivery of course content is listed in the table.

- Continuous internal examination, semester end examinations, Assignment (includesassignment,5 minutes videos, seminars etc.) are used for CO calculation.
- The attainment values are calculated for individual courses and are formulated and summed for assessing the PO s.

- Performance in Assignment is indicative of the student's communication skills.

S No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core / Elective	Midterm Examination	Twice in a semester	30	Answer script
		Comprehensive Assessment Tools (CAT) and PPT	Twice in a semester	10	Video / Quiz / Assignment
		Semester End Examination	Once in a semester	60	Answer script
2	Laboratory	Observation and Result	Once in a week	10	Work sheets
		Record	Once in a week	05	Work sheets
		Viva	Once in a week	05	Work sheets
		Internal laboratory assessment	Once in a semester	20	Answer script
		Semester End Examination	Once in a semester	60	Answer script
3	Project stage-I	Project Review	Twice in a semester	40	Presentation
		Semester End Examination	Once in a semester	60	Project Report
4	Project stage-I	Project Review	Twice in a semester	40	Presentation
		Semester End Examination	Once in a semester	60	Project Report
5	Industry oriented Mini Project	Project Review	Once in a semester	100	Project Report
6	Technical Seminar	Semester End Examination	Twice in a semester	100	Seminar Report
7	Mandatory courses	Midterm Examination	Twice in a semester	100	Answer script

13.2. Indirect Assessment:

Course End Survey-In this survey, questionnaires are prepared based on the level of understanding of the course and the questions are mapped to Course Outcomes. The tools and processes used in indirect assessment are shown in Table.

TABLE 15: Tools used in Indirect assessment

Tools	Process	Frequency
Course end survey	• Taken for every course at the end of the semester • Gives an overall view that helps to assess the extent of coverage/ compliance of COs • Helps the faculty to improve up on the various teaching methodologies	Once in a semester

Direct Tools: (Measurable in terms of marks and w.r.t.CO) Assessment done by faculty at department level.

Indirect Tools: (Non measurable (surveys) in terms of marks and w.r.t.CO) Assessment done at institute level.

14. PO/PSO-Assessment tools and Processes

The institute has the following methods for assessing the attainment of POs/PSOs.

1. Direct method
2. Indirect method

The attainment levels of course outcomes help in computing the PO/PSO based upon the mapping done.

TABLE 16: Attainment of PO / PSOs

	Assessment	Tools	Weight
POs/PSOs Attainment	Direct Assessment	CO attainment of courses	80%
	Indirect Assessment	Student exit survey	20%
		Alumni survey	
		Employer survey	

The CO values of both theory and laboratory courses, with appropriate weightage as per CO-PO mapping, as per the Program Articulation Matrix, are considered for the calculation of direct attainment of PO/PSOs.

14.1 PO Direct Attainment is calculated using the following rubric:

PO Direct Attainment = (Strength of CO-PO) * CO attainment / Sum of CO-PO strength.
The below figure represents the evaluation process of POs/PSOs attainment through course outcome attainment.

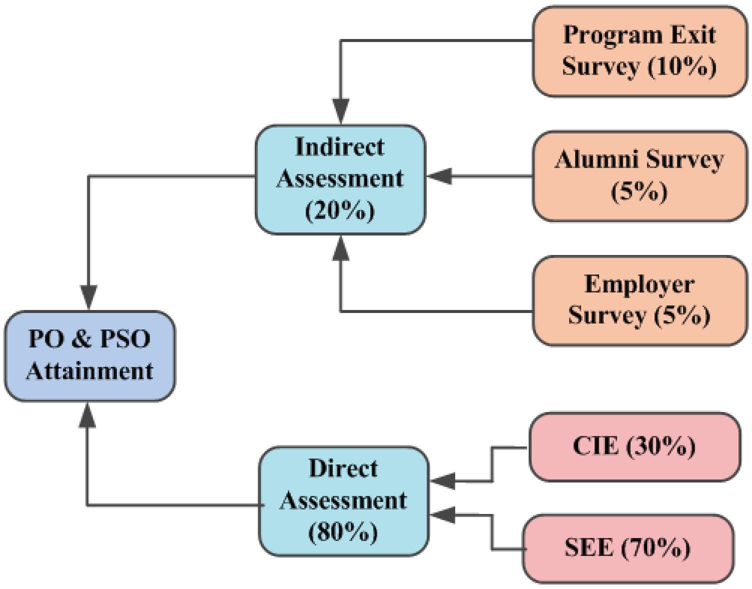


FIGURE 4: Evaluation process of POs / PSOs attainment

15. Course Description:

The "Course Description" provides general information regarding the topics and content addressed in the course. A sample course description is given in Annexure – A for reference.

The "Course Description" contains the following contents:

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Content Delivery / Instructional Methodologies
- Evaluation Methodology
- Course Objectives
- Course Outcomes
- Program Outcomes
- Program Specific Outcomes
- How Program Outcomes are Assessed
- How Program Specific Outcomes are Assessed
- Mapping of each CO with PO(s), PSO(s)
- Justification for CO–PO/PSO Mapping - Direct
- Total Count of Key Competencies for CO–PO/PSO Mapping
- Percentage of Key Competencies for CO–PO/PSO
- Course Articulation Matrix (PO/PSO Mapping)
- Assessment Methodology - Direct
- Assessment Methodology - Indirect
- Syllabus
- List of Textbooks / References / Websites

15.1 Course Description:

MARRI LAXMAN REDDY
INSTITUTE OF TECHNOLOGY AND MANAGEMENT
(AN AUTONOMOUS INSTITUTION)
(Approved by AICTE, New Delhi & Affiliated to JNTUH, Hyderabad)
Accredited by NBA and NAAC with 'A' Grade & Recognized Under Section2(f) & 12(B)of the UGC act,1956

DIGITAL CMOS IC DESIGN

1	Department	ELECTRONICS & COMMUNICATION ENGINEERING							
2	Course Name	DIGITAL CMOS IC DESIGN							
3	Course Code	2250430							
4	Year/Semester	III/I							
5	Regulation	MLRS-R22							
6	Structure of the course	Theory				Practical			
		Lecture	Tutorials	Practical	Credit	L	T	P	C
		3	1	0	4	0	0	0	0
7	Type of course	BS	HS	ES	PC	PE	OE	PS	MC
		×	×	×	✓	×	×	×	×
8	Course Offered	Odd Semester		✓	Even Semester				×
9	Total lecture, tutorial and practical hours for this course Offered (16 weeks of teaching per semester)								
	Lectures: 48 Hours	Tutorials: 0 hours		Practical: 0 hours					
10	Course Coordinator	Ms. Pranali Surkar							
11	Date Approved by BOS								
12	Course Webpage	www.mlritm.ac.in/							
13	Prerequisites/ Co-requisites	Level	Course Code	Semester	Prerequisites				
		-	2210501	I	Programming for Problem Solving				
			2230423	III	Digital System Design				

14. Course Overview:

CMOS is one of the most popular technologies in the computer chip design industry and it is broadly used today to form integrated circuits (IC's) in numerous and varied applications. Digital integrated circuits have become an essential component in modern electronic devices. One type of digital integrated circuit that has gained popularity in recent years is the complementary metal-oxide-semiconductor (CMOS) technology. CMOS digital integrated circuits are used to create digital logic gates, which are the building blocks of digital circuits. CMOS technology is widely used in the design of microprocessors, memory chips, and other digital circuits due to its low power consumption, high noise immunity, and high integration density. CMOS circuits are also highly reliable and have a long lifespan, making them ideal for use in critical applications.

15. Course Objectives:

The students will try to learn:

- Different steps involved in the fabrication of ICs
- Static and dynamic behavior of CMOS logic circuits
- The process to design the logic circuits with Verilog HDL with its modelling concepts
- The modelling concepts to design CMOS logic circuits
- Basic programmable logic devices and testing of CMOS circuits

16. Course Outcomes:

After successful completion of the course, students should be able to:

CO1	Acquire knowledge of CMOS fabrication, MOS devices, VLSI design flow, and circuit scaling for efficient digital design.
CO2	Implement CMOS inverter and logic circuits with focus on performance, power, and timing characteristics.
CO3	Use top-down and bottom-up HDL design methodology in designing building blocks of CMOS logic circuits.
CO4	Demonstrate Verilog modeling for designing and simulating digital circuits with timing and control.
CO5	Design digital circuits using PLDs and apply CMOS testing techniques for reliability and manufacturability.

17. Course Learning Outcome (CLOs):

Sno	Topic Name	CLO No	Course Learning Outcome	Course Outcome	Blooms Level
1.	Introduction to IC Technology	CLO 1	Understand the Evolution of IC Technology	CO1	Understand

2.	Issues in Digital Integrated Circuit Design	CLO 3	Understand the impact of process variations on circuit performance.	CO1	Understand
3.	Quality Metrics of a Digital Design	CLO 4	Define key quality metrics for digital designs	CO1	Understand
4.	MOS, PMOS, NMOS	CLO 5	Analyze the advantages and disadvantages of each technology.	CO1	Analyze
5.	CMOS, BiCMOS	CLO 6	Evaluate the impact of technology choices on circuit performance.	CO1	Evaluate
6.	VLSI Circuit Design Processes: VLSI Design Flow	CLO 7	Analyze and Design Digital Circuits Using VLSI Technique	CO1	Analyze
7.	MOS Layers, Stick Diagrams	CLO 8	Create stick diagrams for digital circuits.	CO1	Create
8.	Transistors Layout Diagrams for NMOS and CMOS Inverters and Gates	CLO 10	Create layout diagrams for digital circuits.	CO1	Create
9.	Scaling of MOS circuits	CLO 11	Understand the scaling of MOS circuits and its impact on performance and power.	CO1	Understand
10.	The CMOS Inverter: Static CMOS Inverter	CLO 12	Understand the Structure and analyze the VTC of a CMOS inverter to determine its noise margins and gain.	CO2	Understand, Analyze
11.	Static Behavior, Dynamic Behavior	CLO 13	Analyze the factors affecting static and dynamic power dissipation.	CO2	Analyze
12.	Power, Energy, and Energy-Delay	CLO 14	Define energy and energy-delay product as performance metrics.	CO2	Understand
13.	Designing Logic Circuits in CMOS	CLO 15	Design Static CMOS and Dynamic CMOS	CO2	Create
14.	Timing Metrics of Sequential Circuits	CLO 16	Analyze the Timing Metrics of Sequential Circuits	CO2	Analyze
15.	Static and Dynamic Latches and Registers	CLO 17	Understand the structure and operation of static latches and registers	CO2	Understand
16.	Pipelining	CLO 19	Understand the concept of pipelining and its benefits	CO2	Understand

17.	Overview of Verilog HDL	CLO 20	Understand the Evolution of CAD Tools in VLSI Design	CO3	Understand
18.	Typical HDL-based design flow	CLO 22	Understand and Apply the HDL-based design flow to design simple digital circuits.	CO3	Apply
19.	Hierarchical Modeling Concepts	CLO 24	Apply top-down and bottom-up design methodologies to design digital systems	CO3	Apply
20.	Parts of a simulation	CLO 26	Explain the purpose of design blocks and stimulus blocks.	CO3	Understand
21.	Lexical conventions	CLO 27	Use Verilog's lexical conventions to create readable and maintainable designs	CO3	Apply
22.	Data types	CLO 28	Use appropriate data types in Verilog designs	CO3	Apply
23.	System tasks, Compiler directives	CLO 29	Utilize system tasks and functions to perform specific operations	CO3	Apply
24.	Module definition	CLO 30	Explain how to create hierarchical designs using modules	CO3	Understand
25.	Port declaration, connecting ports	CLO 31	Explain the process of connecting ports between modules.	CO3	Understand
26.	Hierarchical name referencing.	CLO 32	Apply hierarchical naming conventions to reference modules and their components	CO3	Apply
27.	Gate-Level Modeling	CLO 33	Model simple logic circuits using Verilog gate-level primitives	CO4	Create
28.	Dataflow Modeling	CLO 34	Develop efficient and optimized Verilog dataflow models	CO4	Create
29.	Behavioral Modeling	CLO 35	Design and implement complex digital systems using Verilog behavioral modeling.	CO4	Create
30.	Programmable Logic Devices	CLO 36	Understand the Basics of Programmable Logic Devices	CO5	Understand
31.	CMOS Testing	CLO 37	Implement Design Strategies for Test	CO5	Implement

18. Employability Skills:

Example: Communication skills / Programming skills / Project based skills **/**
For a course focused on **Digital CMOS IC Design**, the following **Employability Skills** are essential for students to effectively enter and succeed in the workforce. These skills encompass both technical competencies and soft skills, providing a well-rounded foundation for careers in the semiconductor and electronics industries.

19. Content Delivery / Instructional Methodologies:

✓	Power Point Presentation	✓	Chalk & Talk	✓	Assignments	✓	MOOC
✓	ALP	✓	Seminars	**x**	Mini Project	**x**	Videos

20. Evaluation Methodology:

The performance of a student in a course will be evaluated for 100 marks each, with 40 marks allotted for CIE (Continuous Internal Evaluation) and 60 marks for SEE (Semester End-Examination). In CIE, for theory subjects, during a semester, there shall be two mid-term examinations. Each Mid-Term examination consists of two parts i) **Part – A** for 10 marks, ii) **Part – B** for 20 marks with a total duration of 2 hours as follows:

Mid Term Examination for 30 marks:

a. Part - A: Objective / quiz / short answer type paper for 10 marks.
b. Part - B: Descriptive paper for 20 marks.

The average of two midterm examinations shall be taken as the final marks for mid term examinations.

The semester end examinations (SEE), will be conducted for 60 marks consisting of two parts viz. i) **Part- A** for 10 marks, ii) **Part - B** for 50 marks.

a. Part-A is a compulsory question which consists of ten sub-questions from all units carrying equal marks.

b. Part-B consists of five questions (numbered from 2 to 6) carrying 10 marks each. Each of these questions is from each unit and may contain sub-questions. For each question there will be an "either" "or" choice, which means that there will be two questions from each unit and the student should answer either of the two questions.

c. The duration of Semester End Examination is 3 hours.

Table 1: Outline for Continues Internal Evaluation (CIE-I and CIE-II) and SEE

Activities	CIE-I	CIE-II	Average of CIE	SEE	Total Marks
Continues Internal Evaluation (CIE)	20 Marks	20 Marks			Average of CIE + SEE
Objective / quiz / short answer Questions	10 Marks	10 Marks			
Assignment	5 Marks	5 Marks			
Viva-Voce / PPT / Poster Presentation / Case Study	5 Marks	5 Marks			
Total Marks	**40 Marks**	**40 Marks**	**40 Marks**	**60 Marks**	**100 Marks**

21. Course content - Number of modules: Five:

MODULE 1	**Introduction to IC Technology:** A Historical Perspective, Issues in Digital Integrated Circuit Design, Quality Metrics of a Digital Design, MOS, PMOS, NMOS, CMOS, BiCMOS. VLSI Circuit Design Processes: VLSI Design Flow, MOS Layers, Stick Diagrams, Design Rules and Layout, Transistors Layout Diagrams for NMOS and CMOS Inverters and Gates, Scaling of MOS circuits.	No. of Lectures: 14
MODULE 2	**The CMOS Inverter:** Static CMOS Inverter, Static Behavior, Dynamic Behavior, Power, Energy, and Energy-Delay. Designing Logic Circuits in CMOS: Static CMOS Design, Dynamic CMOS Design, Timing Metrics for Sequential Circuits, Static Latches and Registers, Dynamic Latches and Registers, Pipelining.	No. of Lectures: 10
MODULE 3	**Overview of Verilog HDL:** Evolution of CAD, emergence of HDLs, typical HDL-based design flow, why Verilog HDL trends in HDLs. **Hierarchical Modeling Concepts:** Top-down and bottom-up design methodology, differences between modules and module instances, parts of a simulation, design block, stimulus block, Lexical conventions, data types, system tasks, compiler directives, Module definition, port declaration, connecting ports, hierarchical name referencing.	No. of Lectures: 8
MODULE 4	**Gate-Level Modeling:** Modeling using basic Verilog gate primitives, description of and/or and buf/not type gates, rise,	No. of Lectures: 9

	fall and turn-off delays, min, max, and typical delays. **Dataflow Modeling:** Continuous assignments, delay specification, expressions, operators, operands, operator types. **Behavioral Modeling:** Structured procedures, initial and always, blocking and nonblocking statements, delay control, generate statement, event control, conditional statements, multiway branching, loops, sequential and parallel blocks	
MODULE 5	**Programmable Logic Devices:** Design Approach PLA, PAL, Standard Cells, FPGAs, CPLDs. CMOS **Testing:** CMOS TESTING, Test Principles, Design Strategies for Test, Chip Level Test Techniques.	No. of Lectures: 7

TEXTBOOKS:

1. Jan M Rabaey, "Digital Integrated Circuit: A Design Perspective", PHI; 2nd Edition, 2016

2. S. Palnitkar, Verilog HDL: A Guide Digital Design and Synthesis, Pearson, 2nd Edition, 2003

REFERENCE BOOKS:

1. Kamran Eshraghian, Eshraghian Dougles and A. Pucknell, "Essentials of VLSI Circuits and Systems",PHI, 2nd Edition 2009
2. Neil H. E. Weste, David Harris, Ayan Banerjee, "CMOS VLSI DESIGN-A circuits and Systems Perspective", 4th Edition, Pearson, 2nd Edition 2015
3. Wayne Wolf, "Modern VLSI Design", Pearson Education, 4th Edition 2015

ELECTRONIC RESOURCES:

1. https://archive.nptel.ac.in/courses/108/107/108107129/
2. https://www.youtube.com/playlist?list=PLHO2NKv71TvsSqYwVvUCZwNkY-jUyUHdS
3. https://nptel.ac.in/courses/108107129
4. https://www.studocu.com/in/document/vellore-institute-of-technology/vlsi-design/verilog-hdl-samir-palnitkar-part-1/9770258
5. https://www.youtube.com/watch?v=vHLBO05TeyU&t=1s
6. https://www.chipverify.com/verilog/verilog-gate-level-modeling
7. https://www.asic-world.com/verilog/gate3.html
8. https://archive.nptel.ac.in/courses/117/108/117108040/

22. COURSE PLAN:

S. No.	Topics to be covered	Cos	Reference
1.	Discussion on Outcome Based Education, CO, POs and PSOs	-	-
2.	A Historical Perspective, Issues in Digital Integrated Circuit Design	CO1	T1: 1.1, 1.2
3.	Quality Metrics of a Digital Design	CO1	T1: 1.3
4.	MOS structure, NMOS fabrication	CO1	T1: 2.2
5.	PMOS fabrication process, CMOS fabrication process	CO1	T1: 2.2
6.	CMOS fabrication process: N WELL and Twin Tub	CO1	T1: 2 .2.4
7.	BiCMOS Technology and BiCMOS inverter operation	CO1	T1: 2
8.	VLSI Circuit Design Processes	CO1	T1: 2
9.	MOS Layers, Stick Diagrams	CO1	R2: 1.5.5
10.	Design Rules and Layout	CO1	T1: 2.3 R2: 1.5.3
11.	Layout design	CO1	R2: 1.5.4
12.	Transistors Layout Diagrams for NMOS and CMOS Inverters	CO1	R2: 1.5.4
13.	Transistors Layout Diagrams for Gates	CO1	R2: 1.5.4
14.	Scaling of MOS circuits	CO1	R2: 7.4
15.	The CMOS Inverter, Static CMOS Inverter	CO2	T1: 5.2
16.	VTC characteristics of CMOS Inverter	CO2	T1: 5.2
17.	Static Behavior of CMOS Inverter	CO2	T1: 5.3
18.	Dynamic Behavior of CMOS Inverter	CO2	T1: 5.4
19.	Power, Energy, and Energy-Delay	CO2	T1: 5.5
20.	Designing Logic Circuits in CMOS	CO2	T1: 6.2, 6.3
21.	Timing Metrics for Sequential Circuits	CO2	T1: 7.1.1
22.	Static Latches and Registers	CO2	T1: 7.2
23.	Dynamic Latches and Registers	CO2	T1: 7.3
24.	Pipelining	CO2	T1: 7.5
25.	Evolution of CAD, Emergence of HDLs	CO3	T2: 1.1, 1.2
26.	Typical HDL-based design flow, Why Verilog HDL trends in HDLs	CO3	T2: 1.3, 1.5
27.	Hierarchical Modeling Concepts, Differences between modules and module instances	CO3	T2: 2.1, 2.3, 2.4

28.	Parts of a simulation, Design block, stimulus block	CO3	T2: 2.5, 2.6.1
29.	Lexical Conventions, Data types, system tasks	CO3	T2: 3.1, 3.2,3.3
30.	Compiler directives, Module definition	CO3	T2: 3.3.2, 4.1
31.	Port declaration, Connecting ports	CO3	T2: 4.2.2, 4.2.4
32.	Hierarchical name referencing	CO3	T2: 4.3
33.	Gate-Level Modeling: Modeling using basic Verilog gate primitives	CO4	T2: 5, 5.1
34.	Description of and/or and buf/not type gates	CO4	T: 5.1.1, 5.1.2
35.	Rise, fall and turn-off delays, min, max, and typical delays	CO4	T2: 5.2.1
36.	Dataflow Modeling: Continuous assignments, Learn Delay specification, expressions	CO4	T2: 6, 6.1, 6.2
37.	Operators, operands, operator types.	CO4	T2: 6.3
38.	Behavioral Modeling: Structured procedures, initial and always	CO4	T2: 7, 7.1
39.	Blocking and nonblocking statements, Delay control, generate statement	CO4	T2: 7.2, 7.3
40.	Event control, conditional statements, multiway branching	CO4	T2: 7.3.2, 7.4
41.	Understand loops, sequential and parallel blocks	CO4	T2: 7.6, 7.7
42.	Design Approach - PLA, PAL	CO5	R2:12.7
43.	Standard Cells , FPGAs	CO5	R2:14.3.2.2
44.	Understand about CPLDs	CO5	R2:14.3.2.2
45.	CMOS Testing	CO5	R2:15
46.	Test Principles	CO5	R2:15.5
47.	Design Strategies for Test	CO5	R2:15.6
48.	Chip Level Test Techniques	CO5	R2:15.7

23. PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES:

PO 1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and engg. specialization to the solution of complex engineering problems.
PO 2: Problem analysis: Identify, formulate, research literature, and analyze engineering problems to arrive at substantiated conclusions using first principles of mathematics, natural, and engineering sciences.
PO 3: Design/development of solutions: Design solutions for complex engineering problems and design system components, processes to meet the specifications with consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4: 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.
PO 5: 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.
PO 6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO 7: 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.
PO 8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO 9: Individual and team work: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.
PO 10: 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.
PO 11: 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.
PO 12: 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.
Program Specific Outcomes
PSO 1: Analyze and design analog & digital circuits or systems for a given specification and function.
PSO 2: Implement functional blocks of hardware-software co-designs for signal processing and communication applications.

24. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes		Strength	Proficiency Assessed by
PO1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and engg. specialization to the solution of complex engineering problems.	3	CIE/ PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce
PO3	Design/development of solutions: Design solutions for complex engineering problems and design system components, processes to meet the specifications with consideration for the public health and safety, and the cultural, societal, and environmental considerations.	3	CIE/ PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce
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.	3	CIE/ PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce
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.	3	CIE/ PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce
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.	3	

25. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Outcomes		Strength	Proficiency Assessed by
PSO1	Analyze and design analog & digital circuits or systems for a given specification and function.	3	CIE/ PPT/ SEE/ Objective / quiz / Assignments/ Viva-Voce
PSO2	Implement functional blocks of hardware-software co-designs for signal processing and communication applications.	3	CIE/ PPT/ SEE/ Objective / quiz / Assignments/ Viva-Voce

3 = High; 2 = Medium; 1 = Low

26. MAPPING OF EACH CO WITH PO(s), PSO(s):

Course Outcomes	PROGRAM OUTCOMES												PSOs	
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	✓	-	✓	✓	-	-	-	-	-	-	-	✓	✓	✓
CO2	✓	-	✓	✓	-	-	-	-	-	-	-	✓	✓	✓
CO3	✓	-	✓	✓	✓	-	-	-	-	-	-	✓	✓	✓
CO4	✓	-	✓	✓	✓	-	-	-	-	-	-	✓	✓	✓
CO5	✓	-	✓	✓	✓	-	-	-	-	-	-	✓	✓	✓

26. JUSTIFICATIONS FOR CO – PO / PSO MAPPING - DIRECT:

Course Outcomes	PO'S/ PSO'S	Justification for mapping (Students will be able to)	No. of Key Competencies
CO1	PO1	1. Application of scientific principles and methodologies. 2. Integration of knowledge from various engineering disciplines. 3. Application of specialized engineering knowledge in complex engineering problems.	3
	PO3	11. Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. 12. Understand customer and user needs while considering factors such as aesthetics. 13. Ensure fitness for purpose across production, operation, maintenance, and disposal. 14. Manage the design process and evaluate outcomes for safety and risk assessment. 15. Understand the commercial and economic context of engineering processes. 16. Apply management techniques to achieve engineering objectives in a broader context. 17. Promote sustainable development through engineering activities.	7
	PO4	1. Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data.	6

		3. Address complex problems in various engineering contexts, including operations, management, and technology development. 4. Follow appropriate codes of practice and industry standards when analyzing and interpreting experimental data. 5. Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations. 6. Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges.	
	PO12	1. Begin work on advanced degree. 2. Personal continuing education efforts 3. Ongoing learning – stays up with industry trends/ new technology 4. Continued personal development	4
	PSO1	1. Analyze response of a circuit or system 2. Design of a circuit or system for a given specification 3. Understand and apply circuit or system specifications accurately.	3
	PSO2	1. Develop Operational block diagrams	1
CO2	PO1	1. Application of scientific principles and methodologies. 2. Integration of knowledge from various engineering disciplines. 3. Application of specialized engineering knowledge in complex engineering problems.	3
	PO3	1. Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. 2. Understand customer and user needs while considering factors such as aesthetics. 3. Ensure fitness for purpose across production, operation, maintenance, and disposal. 4. Manage the design process and evaluate outcomes for safety and risk assessment.	4
	PO4	1. Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. Address complex problems in various engineering contexts, including operations, management, and technology development.	4

		3. Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations. 4. Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges.	
	PO12	1. Pursue professional, Academic, Global certifications. 2. Begin and work towards advanced programs to further deepen knowledge in engineering and related areas. 3. Stay updated on industry trends and emerging technologies to remain relevant in the field. 4. Learn at least 2–3 new significant skills annually to ensure continuous growth and development.	4
	PSO1	1. Analyze response of a circuit or system 2. Design of a circuit or system for a given specification 3. Understand and apply circuit or system specifications accurately.	3
	PSO2	1. Develop Operational block diagrams	1
CO3	PO1	1. Application of scientific principles and methodologies. 2. Integration of knowledge from various engineering disciplines. 3. Application of specialized engineering knowledge in complex engineering problems.	3
	PO3	1. Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. 2. Understand customer and user needs while considering factors such as aesthetics. 3. Ensure fitness for purpose across production, operation, maintenance, and disposal. 4. Manage the design process and evaluate outcomes for safety and risk assessment.	4
	PO4	1. Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. Address complex problems in various engineering contexts, including operations, management, and technology development. 3. Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations.	4

		4. Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges.	
	PO5	1. Develop engineering solutions using modern tools across various disciplines. 2. Identify appropriate prediction and modeling tools for diverse engineering applications. 3. Utilize IT tools in engineering analysis, design, and decision-making. 4. Implement simulation tools in different engineering fields.	`4
	PO12	1. Pursue professional, Academic, Global certifications. 2. Begin and work towards advanced programs to further deepen knowledge in engineering and related areas. 3. Stay updated on industry trends and emerging technologies to remain relevant in the field. 4. Learn at least 2–3 new significant skills annually to ensure continuous growth and development.	4
	PSO1	1. Design of a circuit or system for a given specification 2. Understand and apply circuit or system specifications accurately.	2
	PSO2	1. Develop Operational block diagrams 2. Proficiency in the use of software tools for circuit design. 3. Hardware-software integration in analog and digital systems 4. Understanding trade-offs in hardware and software design parameters.	4
CO4	PO1	1. Application of scientific principles and methodologies. 2. Integration of knowledge from various engineering disciplines. 3. Application of specialized engineering knowledge in complex engineering problems.	3
	PO3	1. Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. 2. Understand customer and user needs while considering factors such as aesthetics. 3. Ensure fitness for purpose across production, operation, maintenance, and disposal. 4. Manage the design process and evaluate	7

		outcomes for safety and risk assessment. 5. Understand the commercial and economic context of engineering processes. 6. Apply management techniques to achieve engineering objectives in a broader context. 7. Promote sustainable development through engineering activities.	
	PO4	1. Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data. 3. Address complex problems in various engineering contexts, including operations, management, and technology development. 4. Follow appropriate codes of practice and industry standards when analyzing and interpreting experimental data. 5. Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations. 6. Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges.	6
	PO5	1. Develop engineering solutions using modern tools across various disciplines. 2. Identify appropriate prediction and modeling tools for diverse engineering applications. 3. Utilize IT tools in engineering analysis, design, and decision-making. 4. Implement simulation tools in different engineering fields.	4
	PO12	1. Pursue professional, Academic, Global certifications. 2. Begin and work towards advanced programs to further deepen knowledge in engineering and related areas. 3. Stay updated on industry trends and emerging technologies to remain relevant in the field. 4. Learn at least 2–3 new significant skills annually to ensure continuous growth and development.	4
	PSO1	1. Design of a circuit or system for a given specification	2

		2. Understand and apply circuit or system specifications accurately.	
	PSO2	1. Develop Operational block diagrams 2. Proficiency in the use of software tools for circuit design. 3. Hardware-software integration in analog and digital systems 4. Understanding trade-offs in hardware and software design parameters.	4
CO5	PO1	1. Application of scientific principles and methodologies. 2. Integration of knowledge from various engineering disciplines. 3. Application of specialized engineering knowledge in complex engineering problems.	3
	PO3	1. Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. 2. Understand customer and user needs while considering factors such as aesthetics. 3. Ensure fitness for purpose across production, operation, maintenance, and disposal. 4. Manage the design process and evaluate outcomes for safety and risk assessment.	3
	PO4	1. Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively. 2. Address complex problems in various engineering contexts, including operations, management, and technology development. 3. Follow appropriate codes of practice and industry standards when analyzing and interpreting experimental data. 4. Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations. 5. Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges.	5
	PO5	1. Develop engineering solutions using modern tools across various disciplines. 2. Identify appropriate prediction and modeling tools for diverse engineering applications. 3. Utilize IT tools in engineering analysis, design, and decision-making. 4. Implement simulation tools in different	`4

		engineering fields.	
	PO12	1. Pursue professional, Academic, Global certifications. 2. Begin and work towards advanced programs to further deepen knowledge in engineering and related areas. 3. Stay updated on industry trends and emerging technologies to remain relevant in the field. 4. Learn at least 2–3 new significant skills annually to ensure continuous growth and development.	4
	PSO1	1. Design of a circuit or system for a given specification 2. Understand and apply circuit or system specifications accurately.	2
	PSO2	1. Develop Operational block diagrams 2. Proficiency in the use of software tools for circuit design. 3. Hardware-software integration in analog and digital systems 4. Understanding trade-offs in hardware and software design parameters.	4

27. TOTAL COUNT OF KEY COMPETENCIES FOR CO – (PO, PSO) MAPPING:

Course Outcomes	**PROGRAM OUTCOMES**												**PSOs**	
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
	3	10	10	11	1	5	3	3	12	5	12	8	4	5
CO1	3	-	7	6	-	-	-	-	-	-	-	4	3	1
CO2	3	-	4	4	-	-	-	-	-	-	-	4	3	1
CO3	3	-	4	4	4	-	-	-	-	-	-	4	2	4
CO4	3	-	7	6	4	-	-	-	-	-	-	4	2	4
CO5	3	-	4	5	4	-	-	-	-	-	-	4	2	4

28. PERCENTAGE OF KEY COMPETENCIES FOR CO – (PO/ PSO):

Course Outcomes	**PROGRAM OUTCOMES**												**PSOs**	
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	75	-	70	60	-	-	-	-	-	-	-	50	75	25

CO2	75	-	40	40	-	-	-	-	-	-	-	50	75	25
CO3	75	-	40	40	100	-	-	-	-	-	-	50	50	100
CO4	75	-	70	60	100	-	-	-	-	-	-	50	50	100
CO5	75	-	40	50	100	-	-	-	-	-	-	50	50	100

29. COURSE ARTICULATION MATRIX (PO – PSO MAPPING):

CO'S and PO'S, CO'S and PSO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

0 - 0≤ C≤ 5% – No correlation, 2 - 40 % <C < 60% –Moderate

1-5 <C≤ 40% – Low/ Slight 3 - 60% ≤ C < 100% – Substantial /High

Course Outcomes	PROGRAM OUTCOMES												PSOs	
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	3	-	3	3	-	-	-	-	-	-	-	2	3	1
CO2	3	-	1	1	-	-	-	-	-	-	-	2	3	1
CO3	3	-	1	1	3	-	-	-	-	-	-	2	2	3
CO4	3	-	3	3	3	-	-	-	-	-	-	2	2	3
CO5	3	-	1	2	3	-	-	-	-	-	-	2	2	3
Total	**15**	-	**9**	**10**	**9**	-	-	-	-	-	-	**10**	**12**	**11**
Average	**3**	-	**1.8**	**2**	**3**	-	-	-	-	-	-	**2**	**2.4**	**2.2**

30. ASSESSMENT METHODOLOGY DIRECT:

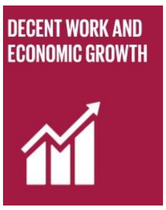
CIE Exams	✓	SEE	✓	Seminars	-
Objective / quiz	✓	Viva-Voce / PPT	✓	MOOCS	-
Assignments	✓	Project	-		

31. ASSESSMENT METHODOLOGY INDIRECT:

✓	Course End Survey (CES)

32. RELEVANCE TO SUSTAINABILITY GOALS:

Digital CMOS IC design plays a significant role in achieving several UN Sustainable Development Goals (SDGs).

x	1		
✓	2		**Zero hunger:** Digital CMOS ICs are foundational in developing sensors and IoT devices used in precision agriculture. CMOS technology is integral to the design of autonomous drones and robots that can monitor crop health, apply fertilizers, and perform pest control. These technologies enhance farming efficiency, reduce manual labor, and ensure better resource management.
✓	3		**Good Health and well-being:** Digital CMOS technology is essential in designing medical sensors that monitor vital signs, such as heart rate, blood pressure, and glucose levels. These devices enable continuous health monitoring, allowing for early detection of health issues and timely interventions.
✓	4		**Quality Education:** Digital CMOS technology is foundational in creating smart devices like tablets and e-readers that provide access to a wealth of educational resources, including e-books, online courses, and interactive learning materials.
x	5		
✓	6		**Clean water and Sanitation:** Digital CMOS IC Design significantly contributes to achieving the Clean Water and Sanitation goal by enabling innovative technologies that enhance water quality monitoring, treatment processes, and sanitation systems.
✓	7		**Affordable and clean Energy:** Digital CMOS IC Design significantly contributes to achieving the Affordable and Clean Energy goal by enabling innovative technologies that promote renewable energy adoption, enhance energy efficiency, and optimize energy management
x	8		**Decent work and Economic growth:** Digital CMOS IC Design plays a significant role in achieving the Decent Work and Economic Growth goal by fostering innovation, creating jobs, and enhancing productivity across various sectors. By leveraging these technologies, we can support sustainable economic growth, improve working conditions, and create decent employment opportunities for all.

✓	9	INDUSTRY, INNOVATION AND INFRASTRUCTURE	**Industry Innovation and Infrastructure:** Digital CMOS IC Design significantly contributes to achieving the Industry, Innovation, and Infrastructure goal by driving technological advancements, promoting sustainable industrial practices, and enhancing infrastructure development.
x	10	REDUCED INEQUALITIES	
✓	11	SUSTAINABLE CITIES AND COMMUNITIES	**Sustainable Cities and Communities:** CMOS technology is integral to the development of IoT devices, which can improve efficiency in energy consumption, agriculture, and smart cities. Digital CMOS ICs are essential for smart grid technologies and renewable energy systems, enabling better management and utilization of renewable resources. Efficient energy management systems facilitate the transition to sustainable energy sources.
✓	12	RESPONSIBLE CONSUMPTION AND PRODUCTION	**Responsible Consumption and Production**: Digital CMOS IC Design plays a vital role in achieving the Responsible Consumption and Production goal by promoting efficiency, reducing waste, and supporting sustainable product development
✓	13	CLIMATE ACTION	**Climate Action**: Digital CMOS IC Design significantly contributes to achieving the Climate Action goal by promoting energy efficiency, facilitating renewable energy adoption, and supporting climate monitoring and research
✓	14	LIFE BELOW WATER	**Life below water:** Digital CMOS ICs are integral to the development of underwater sensors and autonomous vehicles that monitor water quality, temperature, salinity, and other critical parameters affecting marine ecosystems
✓	15	LIFE ON LAND	**Life on Land:** Digital CMOS ICs are used in satellite imaging and remote sensing devices that monitor land use changes, deforestation, and habitat loss. This data is crucial for tracking biodiversity and understanding the impacts of human activity on ecosystems.
x	16	PEACE, JUSTICE AND STRONG INSTITUTIONS	

x	17	PARTNERSHIPS FOR THE GOALS	

Course Coordinator **HOD**

Mr. Rupa Kumar Dhanavath

Assistant Professor