KONERU LAKSHMAIAH EDUCATION FOUNDATION

(Deemed to be University estd, u/s, 3 of the UGC Act, 1956)

(NAAC Accredited "A++" Grade University)

Green Fields, Guntur District, A.P., India – 522502

Department of Basic Engineering Science - II

I B.Tech. II Semester – CSE / AI & DS / ECE / EEE / CS & IT / IOT

A.Y.2024-25 - EVEN SEMESTER

Digital Design and Computer Architecture (23EC1202)

CO – 1: Combinational Digital Logic Circuits

Session 2: Boolean Algebra

1. Course Description (Description of the subject):

The course on "Digital Design and Computer Architecture" provides a comprehensive exploration of the foundational principles in digital design process and computer organization. Students explore the concepts of combinational and sequential circuits, memory circuits. The curriculum extends to the Basic computer architecture concepts, memory hierarchies, and input/output fundamentals, fostering a deep understanding of computer organization. Through practical projects and simulations, students develop the skills to design and implement digital circuits. Graduates emerge with a robust skill set, ready to embark on careers in hardware design, computer architecture, and related fields, equipped to contribute to the ever-evolving landscape of digital technology.

2. Aim of the Course:

The course aims to equip students with the knowledge and skills related to:

i. Proficiency in designing and optimizing Combinational and Sequential Circuits using Boolean algebra and programmable logic devices with a solid foundation in digital design.

ii. Skill development using hands-on experience in designing digital circuits which includes latches, flip-flops, and counters in combination with memory, registers, and timing and sequence control modules using hardware & modeling tools.

iii. Explore the architecture of modern computers, including the organization and structure of central processing units, memory systems, and input/output interfaces.

iv. Bridge theoretical concepts with real-world applications by examining case studies and examples of digital design and computer architecture in modern computing systems.

Overall, the aim of the course is to prepare the student well-equipped to apply their knowledge to the design and analysis of digital systems and computer architectures, preparing them for careers in areas such as hardware design, computer engineering, and embedded systems development.

3. Instructional Objectives (Course Objectives):

The course objectives for "Digital Design and Computer Architecture" typically include:

i. To Understand and apply foundational concepts in digital design which results in proficiency over designing and analyzing combinational and sequential logic circuits.

ii. To Gain hands-on experience with industry-standard simulation and modeling tools, for verifying and testing digital designs.

iii. To analyze the architecture of a computer system, including the organization and operation of the CPU, memory hierarchy, and input/output subsystems.

iv. To apply digital design and computer architecture principles to solve real-world engineering problems and challenges by reinforcing theoretical knowledge with hands-on experience.

4. Learning Outcomes (Course Outcomes):

i. Able to build the combinational and programmable digital logic circuits using logic gates and optimization methods.

ii. Able to construct the sequential and memory circuits using flip-flops, demonstrating a comprehensive understanding of the principles governing clocked sequential logic.

iii. Able to organize computer architecture and instructions sequence through a grasp of the foundational principles that govern the organization and functioning of a computer system.

iv. Capable of modeling Memory Architecture and I/O Organization modules proficiently.

v. Able to develop and analyze the computer architecture modules using basic combinational, sequential and memory logics.

5. Module Description (CO - 1 Description):

The module covers essential topics in digital electronics, starting with Boolean algebra and progressing to the representation and optimization techniques of digital logic using SOP/POS forms. Students will delve into the design of key components such as adders, subtractors, multiplexers, de-multiplexers, decoders, and encoders. The module introduces the concept of reversible gates, exploring their unique properties. Additionally, students will gain insights into Programmable Logic Devices (PLDs) like PROM, PAL, and PLA, understanding their design principles. The implementation of Complex Programmable Logic Devices (CPLDs) with macrocells and Field-Programmable Gate Arrays (FPGAs) featuring Configurable Logic Blocks (CLBs) and Look-Up Tables (LUTs) will be covered. Practical applications of these digital logic modules in various scenarios will be emphasized, providing students with a comprehensive understanding of digital electronics and its real-world applications.

6. Session Introduction:

Boolean algebra:

Boolean variable is used to represent the voltage level present on a wire or the input/output terminal of a circuit. At any time, it takes either logic 0 or logic 1 and may be designated as (A, B, C) or (X, Y, Z) for three variables.

Boolean Algebra is a means for expressing the relation between inputs and outputs of a logic circuit. It can be used to analyze a logic circuit and express its operation mathematically.

Advantages of Boolean algebra over ordinary Algebra:

- Easy to understand or use as only two binary values are present.
- No fractions, decimals, negative numbers, roots, logarithms, etc.
- Contains only three functions AND, OR and NOT.

Boolean algebra is an algebraic structure defined on a set of elements B together with two binary operators + and · provided the following postulates are satisfied:

1. a) Closure with respect to the operator +.

   b) Closure with respect to the operator ·.

2. a) An identity element with respect to +, designated by 0: $x + 0 = 0 + x = x$.

   b) An identity element with respect to ·, designated by 1: $x \cdot 1 = 1 \cdot x = x$.

3. a) Commutative with respect to +: $x + y = y + x$.

   b) Commutative with respect to ·: $x \cdot y = y \cdot x$.

4. a) · is distributive over +: $x \cdot (y + z) = (x \cdot y) + (x \cdot z)$.

   b) + is distributive over ·: $x + (y \cdot z) = (x + y) \cdot (x + z)$.

5. For every element $x \in B$, there exists an element $x' \in B$ (complement of x) such that $x + x' = 1$ and $x \cdot x' = 0$.

Boolean Laws & Theorems:

Duality Principle:

It states that every algebraic expression deducible from the postulates of Boolean algebra remains valid if the operators and identity elements are interchanged. If the dual of an algebraic expression is desired, OR and AND operators are interchanged and 1's are replaced by 0's and 0's by 1's.

1. a) $x + 0 = x$ b) $x \cdot 1 = x$

2. a) $x + x' = 1$ b) $x \cdot x' = 0$

3. a) $x + x = x$ b) $x \cdot x = x$

4. a) $x + 1 = 1$ b) $x \cdot 0 = 0$

5. Absorption Theorem: a) $x + xy = x$ b) $x(x + y) = x$

6. DeMorgan's Theorem:

a) $\overline{AB} = \bar{A} + \bar{B}$

A	**B**	**A . B**	$\overline{AB}$	$\bar{A}$	$\bar{B}$	$\bar{A}+\bar{B}$
0	0	0	1	1	1	1
0	1	0	1	1	0	1
1	0	0	1	0	1	1
1	1	1	0	0	0	0

$b)\ \overline{A + B} = \bar{A}\ \bar{B}$

A	B	A + B	$\overline{A + B}$	$\bar{A}$	$\bar{B}$	$\bar{A} . \bar{B}$
0	0	0	1	1	1	1
0	1	1	0	1	0	0
1	0	1	0	0	1	0
1	1	1	0	0	0	0

Examples on Simplification using Boolean Laws & Theorems:

The Boolean functions can be simplified by using appropriate Boolean laws and theorems.

Simplify the following functions using Boolean laws and theorems:

1. $F = ABCD + ABC'D' + ABCD' + ABC'D + ABCDE + ABC'D'E' + ABC'DE$

Sol: $F = ABCD + ABC'D' + ABCD' + ABC'D + ABCDE + ABC'D'E' + ABC'DE$

$= ABC(D + D') + ABC'(D + D') + ABDE(C + C') + ABC'D'E'$

$= AB(C + C') + ABDE + ABC'D'E' = AB(1 + DE + C'D'E') = AB$

2. $F = xy + x'z + yz$

Sol: $F = xy + x'z + yz$

$= xy + x'z + yz(x + x') = xy(1 + z) + x'z(1 + y) = xy + x'z$

3. $F = ABC + A'B'C + A'BC + ABC' + A'B'C'$

Sol: $F = ABC + A'B'C + A'BC + ABC' + A'B'C'$

$= BC + A'B' + ABC' = B(C + AC') + A'B' = AB + BC + A'B'$

7. Terminal Questions:

1. Apply De Morgan's theorems to simplify the expression: $\overline{(\overline{\overline{\overline{A}}}+\overline{\overline{B}})}.\overline{(\overline{\overline{\overline{C}}}+\overline{\overline{D}})}$
2. Simplify the expression $F = \bar{A}.(A+B) + A.\bar{B}$ using Boolean identities.
3. Reduce A (A + B) to the least number of terms.
4. Simplify the expression F=A B ' D+A B' D' & $F = \bar{A}.(A+B) + A.\bar{B}$
5. Simplify the following expressions using boolean laws.

$F = A.B + A.(C.D + C.\bar{D})$ $F = A.B.C + \bar{A} + A.C.\bar{B}$

8. References books:

- Computer System Architecture by M. Moris Mano
- Fundamentals of Digital Logic with Verilog HDL by Stephen Brown and ZvonkoVranesic

9. Sites and Web links:

- https://www.javatpoint.com/boolean-algebra-in-digital-electronics
- https://www.geeksforgeeks.org/basics-of-boolean-algebra-in-digital-electronics/