

Chapter 1 : Number Systems and Logic Gates

1-1 to 1-50

Syllabus : Review of number systems, Logic gates.

1.1	Introduction	1-2
1.1.1	Signals	1-2
1.1.2	Types of Signals	1-2
1.1.3	Analog Signals	1-2
1.1.4	Digital Signals	1-2
1.1.5	Sources of Digital Signal	1-2
1.1.6	Advantages of Digital Signals	1-2
1.2	System or Circuit	1-3
1.2.1	Analog Systems	1-3
1.2.2	Digital Systems	1-3
1.3	Number Systems	1-4
1.3.1	Important Definitions	1-4
1.3.2	Various Numbering Systems	1-4
1.3.3	The Decimal Number System	1-4
1.3.4	Characteristics of a Decimal System	1-4
1.4	The Binary System	1-5
1.4.1	Binary Number Formats	1-5
1.4.2	Advantages of Binary	1-6
1.4.3	Disadvantages of the Binary System	1-6
1.5	Conversion of Number Systems	1-6
1.6	Conversions Related to Binary and Decimal	1-6
1.6.1	Conversion from Binary to Decimal	1-6
1.6.2	Conversion from Decimal to Binary	1-7
1.7	Octal and Binary Coded Octal	1-8
1.7.1	Applications of Octal Numbers	1-9
1.7.2	Binary Coded Octal (BCO)	1-9
1.8	Conversions Related to Octal System	1-9
1.8.1	Conversion from Octal to Decimal	1-9
1.8.2	Decimal to Octal Conversion	1-10
1.8.3	Binary to Octal Conversion	1-10
1.8.4	Octal to Binary Conversion	1-11
1.9	The Hexadecimal Code	1-11

1.10	Conversions Related to Hexadecimal Numbers	1-12
1.10.1	Hex to Decimal Conversion	1-12
1.10.2	Conversion from Decimal to Hex System	1-12
1.10.3	Binary to Hex Conversion	1-13
1.10.4	Hex to Binary Conversion	1-13
1.10.5	Octal to Hex Conversion	1-13
1.10.6	Hex to Octal Conversion	1-14
1.11	Counting in a General Radix (Base) r	1-15
1.11.1	Solved Examples on Number Systems ...	1-15
1.12	Arithmetic In Number Systems.....	1-21
1.12.1	Binary Addition	1-21
1.12.2	Rules of Binary Addition	1-21
1.12.3	Binary Subtraction	1-21
1.12.4	Subtraction and Borrow	1-22
1.12.5	Octal Addition	1-22
1.12.6	Subtraction of Octal Numbers	1-22
1.12.7	Hex Addition	1-23
1.12.8	Hex Subtraction	1-23
1.13	1's and 2's Complements of a Binary Number	1-24
1.13.1	1's Complement	1-24
1.13.2	2's Complement	1-24
1.14	Binary Subtraction using 1's and 2's Complements	1-25
1.14.1	Subtraction using 1's Complement	1-25
1.14.2	Binary Subtraction using 2's Complement Method	1-26
1.15	Binary Codes	1-27
1.15.1	Advantages of Binary Codes	1-27
1.15.2	Applications of Binary Codes	1-27
1.15.3	Classification of Codes	1-27
1.15.4	Weighted Binary Codes	1-27
1.15.5	Non Weighted Codes	1-28
1.15.6	Reflective Codes	1-28
1.15.7	Sequential Codes	1-28
1.15.8	Alphanumeric Codes	1-28



1.15.9	Error Detecting and Correcting Codes ...1-28	1.26.2	Multiple Input EX-OR Gate1-41
1.16	Binary Coded Decimal (BCD) Code1-29	1.26.3	The EX-NOR Gate1-42
1.16.1	Conversion from Decimal to BCD1-29	1.26.4	Multiple Input EX-NOR Gate.....1-42
1.16.2	Comparison with Binary1-29	1.27	Universal Gates1-43
1.16.3	Packed BCD1-30	1.27.1	The NAND Gate1-43
1.16.4	Advantages of BCD Codes1-30	1.27.2	Multiple Input NAND Gate1-43
1.16.5	Disadvantages1-30	1.27.3	The NOR Gate1-44
1.17	BCD Arithmetic1-30	1.27.4	Multiple Input NOR Gate1-44
1.17.1	BCD Addition1-31	1.27.5	Using NAND and NOR Gates for Inverters1-44
1.18	Non – weighted Codes1-32	1.27.6	Practical Value of NAND and NOR Gates (Universal Gates)1-45
1.18.1	Excess – 3 Code1-32	1.27.7	TTL and CMOS Logic Gate ICs1-45
1.18.2	Gray Code1-33	1.28	ANSI / IEEE Standard 91-1984 Logic Symbols1-45
1.18.3	Gray-to-Binary Conversion1-33	1.29	Solved University Examples (New Syllabus)1-49
1.18.4	Binary to Gray Conversion1-34	1.30	University Questions and Answers1-49
1.19	The Use of Binary in Digital Systems1-35	1.31	University Questions and Answers (New Syllabus).....1-50
1.19.1	Integrated Circuits for Digital Systems ...1-35		• Review Questions1-46
1.19.2	Scale of Integration1-35		• MCQs with Answers1-46
1.20	Binary Logic1-35	<hr/>	
1.20.1	Logical Operations1-36	Chapter 2 : Boolean Algebra 2-1 to 2-76	
1.21	Logic Gates1-36	Syllabus : Boolean algebra : Postulates and theorems, SOP and POS forms, Canonical forms, Logic minimization using Karnaugh map and tabulation methods upto 6 variables, Realizing logic functions using gates.	
1.21.1	Classification of Logic Gates1-37	2.1	Introduction2-2
1.21.2	Symbols and Truth Tables of Basic Gates1-37	2.2	Axiomatic Definition of Boolean Algebra2-3
1.22	Types of Logic1-37	2.2.1	Boolean Postulates and Laws2-3
1.22.1	Positive Logic1-38	2.2.2	Differences between Boolean and Ordinary Algebra2-4
1.22.2	Negative Logic1-38	2.3	Two Valued Boolean Algebra2-4
1.22.3	Mixed Logic1-38	2.4	Basic Theorems and Properties of Boolean Algebra2-5
1.22.4	Function Table and Its Relation with Truth Table1-39	2.4.1	Duality2-5
1.23	NOT Gate or Inverter1-39	2.4.2	Basic Theorems2-6
1.24	AND Gate1-40	2.4.2.1	The AND Relations2-6
1.24.1	Multiple Input AND Gates1-40	2.4.2.2	The OR Relations2-6
1.25	The OR Gate1-40	2.4.2.3	Inversion Law2-6
1.25.1	Multiple Input OR Gate1-41		
1.26	Special Type of Gates or Derived Gates1-41		
1.26.1	The EX-OR Gate1-41		



2.4.2.4	Other Important Relations	2-7	2.8.9	To Write Standard SOP Expression for a Given Truth Table	2-29
2.4.3	De-Morgan's Theorems	2-7	2.8.10	Conversion from SOP to POS and Vice Versa	2-30
2.4.4	Operator Precedence	2-8	2.9	Methods to Simplify the Boolean Functions	2-31
2.5	Boolean Expression and Boolean Function	2-9	2.9.1	Algebraic Simplification	2-31
2.5.1	Truth Table Formation	2-9	2.9.2	Disadvantages of Algebraic Method of Simplification	2-32
2.5.2	Examples on Reducing the Boolean Expression	2-9	2.10	Karnaugh-Map Simplification (The Map Method)	2-33
2.5.3	Complement of a Function	2-11	2.10.1	K-map Structure	2-33
2.6	Realization of Switching Functions	2-13	2.10.2	K-map Boxes and Associated Product Terms	2-34
2.6.1	To Draw a Logic Circuit from Boolean Equation	2-13	2.10.3	Alternative Way to Label the K-map	2-34
2.6.2	To Write a Boolean Expression for a Logic Circuit	2-15	2.10.4	Truth Table to K-map	2-34
2.6.3	NAND Gate as Universal Gate	2-15	2.10.5	Representation of Standard SOP Form on K-map	2-35
2.6.4	NOR Gate as Universal Gate	2-17	2.11	Simplification of Boolean Expressions using K-map	2-36
2.6.5	Realizing the Logic Circuits using Only NAND or NOR Gates	2-19	2.11.1	How does Simplification Take Place ?	2-36
2.6.6	Dependency Notation	2-21	2.11.2	Way of Grouping (Pairs, Quads and Octets)	2-36
2.6.7	Assertion Levels	2-22	2.11.3	Grouping Two Adjacent One's (Pairs)	2-37
2.6.8	Polarized Mnemonics	2-23	2.11.4	Grouping Four Adjacent Ones (Quad)	2-38
2.7	System or Circuit	2-23	2.11.5	Grouping Eight Adjacent Ones (Octet)	2-39
2.7.1	Digital Systems	2-23	2.11.6	Summary of Rules Followed for K-Map Simplification	2-40
2.7.2	Types of Digital Circuits	2-24	2.12	Minimization of SOP Expressions (K - Map Simplification)	2-40
2.7.3	Combinational Circuit Design	2-24	2.12.1	Elimination of a Redundant Group	2-42
2.8	SOP and POS Forms	2-25	2.12.2	Minimization of Logic Functions not Specified in Standard SOP Form	2-43
2.8.1	Sum-of-Products (SOP) Form	2-25	2.12.3	Don't Care Conditions	2-44
2.8.2	Product of the Sums Form (POS)	2-25	2.12.4	Disadvantages of K-Map Technique	2-45
2.8.3	Standard or Canonical SOP and POS Forms	2-25	2.13	Five and Six Variable K-maps	2-50
2.8.4	Conversion of a Logic Expression to Standard SOP or POS Form	2-26	2.13.1	Five Variable K-maps	2-50
2.8.5	Concepts of Minterm and Maxterm	2-28	2.13.2	Six Variable K-Map	2-54
2.8.6	Representation of Logical Expressions using Minterms and Maxterms	2-29	2.14	Product of Sum (POS) Simplification	2-55
2.8.7	Writing SOP and POS Forms for a Given Truth Table	2-29	2.14.1	K-map Representation of POS Form	2-55
2.8.8	To Write Standard SOP Expression for a Given Truth Table	2-29			



2.14.2	Representation of Standard POS Form on K-map2-55	3.4	Magnitude Comparators3-17
2.14.3	Simplification of Standard POS Form using K-map2-56	3.4.1	1-Bit Number Comparator3-17
2.15	Quine Mc-Cluskey Minimization Technique (Tabular Method)2-59	3.4.2	A 2-bit Comparator3-18
2.15.1	Important Definitions2-59	3.5	Combinational Logic with MSI Circuits3-19
2.16	Map Entered Variables (MEV) or Variable Entered Map (VEM)2-66	3.6	Multiplexer (Data Selector)3-20
2.17	Realizing Logic Functions With Gates2-71	3.6.1	IEEE/IEC Symbol of Multiplexer3-20
2.17.1	Gates2-71	3.6.2	Necessity of Multiplexers3-21
2.17.2	The EX-OR and EX-NOR Gates in Function Realization2-72	3.6.3	Advantages of Multiplexers3-21
2.18	Solved University Examples (New Syllabus)2-77	3.7	Types of Multiplexers3-21
2.19	University Questions and Answers (New Syllabus).....2-77	3.7.1	2 : 1 Multiplexer3-21
	• Review Questions 2-73	3.7.2	A 4 : 1 Multiplexer3-22
	• MCQs with Answers 2-74	3.7.3	8 : 1 Multiplexer3-22
		3.7.4	16 : 1 MUX3-23
		3.7.5	Applications of a Multiplexer3-23
Chapter 3 : Combinational Logic Circuit Design		3.8	Multiplexer Tree3-24
3-1 to 3-63		3.9	Correspondence between K-map and MUX3-25
Syllabus : Half adder, Full adder, BCD adder, Code converters, Magnitude comparator, Multiplexers and decoders, MSI digital circuit design problems.		3.10	Combinational Logic Design with Multiplexers3-25
3.1	Introduction to Combinational Circuits..... 3-2	3.10.1	Use of 8 : 1 MUX to Realize a 4 Variable Function3-26
3.1.1	Analysis of a Combinational Circuit 3-2	3.10.2	Implementation of a Logical Expression in the Non-standard Form3-28
3.1.2	Combinational Design Examples 3-3	3.10.3	Implementation of Boolean Expression with Don't Care Conditions3-29
3.1.3	A Combinational Function Generator 3-8	3.10.4	VEM and MUX Implementation3-29
3.2	Adders 3-8	3.10.5	Input Gates and MUX Realization3-32
3.2.1	Half Adder 3-8	3.10.6	Use of Dual Multiplexer3-32
3.2.2	Half Adder using Only NAND Gates 3-9	3.10.7	Implementing a Standard POS Expression using Multiplexer3-33
3.2.3	Full Adder3-10	3.11	Demultiplexers3-34
3.2.4	Full Adder using Half Adders3-11	3.11.1	Demultiplexer Principle3-34
3.2.5	Applications of Full Adder3-11	3.11.2	Types of Demultiplexers3-35
3.3	Code Converters 3-11	3.11.3	Comparison of Multiplexer and Demultiplexer3-37
3.3.1	BCD to Excess 3 Converter 3-11	3.11.4	Use of DEMUX in Combinational Logic Design3-37
3.3.2	BCD to Gray Code Converter3-13	3.12	Decoder3-38
3.3.3	Binary to Gray Code Converter3-13		
3.3.4	Gray to BCD Converter3-15		



3.12.1	2 to 4 Line Decoder	3-39	3.19.4	A Four Bit Parity Checker using EX-OR Gates	3-58
3.12.2	Demultiplexer as Decoder	3-39	3.20	MSI Digital Circuit Design Problems	3-58
3.12.3	3 to 8 Line Decoder	3-39	3.21	Solved University Examples (New Syllabus)	3-62
3.12.4	1 : 8 DEMUX Operated as 3:8 Decoder	3-40	3.22	University Questions and Answers	3-63
3.12.5	IC 74138 (3 : 8 Decoder)	3-40	3.23	University Questions and Answers (New Syllabus).....	3-63
3.13	Combinational Logic Design Using Decoders	3-41		• Review Questions	3-60
3.13.1	BCD to Decimal Decoder.....	3-43		• MCQs with Answers	3-61
3.13.2	Advantage of Decoder Realization	3-43	<hr/>		
3.13.3	Comparison of Realization using Gates, MUX and Decoder	3-43	Chapter 4 : Flip Flops 4-1 to 4-43		
3.13.4	Expanding Decoding	3-44	Syllabus : Sequential logic circuit design : Flip-flops-SR, JK, T, D and Master slave Flip flops.		
3.13.5	4 Line to 16 Line Decoder using 3 : 8 Decoder	3-45	4.1	Introduction	4-2
3.13.6	Multifunction Realization using MUX and Decoder	3-47	4.1.1	Clock Signal	4-2
3.14	Standard Logic Functions with MSI Circuits	3-50	4.1.2	Comparison of Combinational and Sequential Circuits	4-3
3.15	Encoders	3-50	4.2	Latches and Flip-flops	4-3
3.15.1	Types of Encoders	3-50	4.2.1	1-Bit Memory Cell (Basic Bistable Element)	4-3
3.16	Priority Encoder	3-50	4.2.2	The Bistable Multivibrator	4-4
3.16.1	Priority Encoders in the IC Form	3-51	4.2.3	Latch	4-4
3.16.2	Decimal to BCD Encoder	3-51	4.3	Flip Flops / Latches with Active High or Active Low inputs	4-4
3.16.3	Octal to Binary Encoder	3-52	4.3.1	FF / Latches with Active High Inputs	4-5
3.17	A 4-Bit Magnitude Comparator (IC 7485)	3-53	4.3.2	Flip Flop / Latches with Active Low Inputs	4-5
3.18	Seven Segment LED Display	3-54	4.3.3	S-R Latch using NOR Gates	4-5
3.18.1	Types of Seven Segment Displays	3-55	4.3.4	NAND Latch [S-R Latch using NAND Gates]	4-7
3.18.2	Common Anode Display	3-55	4.4	Triggering Methods	4-9
3.18.3	Common Cathode Display	3-55	4.4.1	Concept of Level Triggering	4-9
3.18.4	Use of a Decoder for Driving the Seven Segment Display	3-55	4.4.2	Types of Level Triggered Flip-flops	4-9
3.18.5	Driving a Common Cathode Seven Segment Display	3-56	4.4.3	Concept of Edge Triggering	4-9
3.19	Parity Generators / Checkers	3-56	4.4.4	Types of Edge Triggered Flip Flops	4-10
3.19.1	Parity Generator	3-57	4.5	Gated Latches (Level Triggered SR Flip Flop)	4-10
3.19.2	Parity Checker	3-57	4.5.1	Types of Level Triggered (Clocked) Flip Flops	4-10
3.19.3	Use of EX-OR Gate as a Parity Checker	3-58	4.6	The Gated S-R Latch (Clocked S-R Flip Flop)	4-10



4.6.1	Negative Level Triggered SR Flip Flop	4-11	4.14.1	S-R Flip-Flop with Preset and Clear Inputs	4-25
4.6.2	Disadvantage of S-R latch	4-12	4.14.2	JK Flip Flop with Preset and Clear Inputs	4-26
4.6.3	Application of S-R latch	4-12	4.14.3	Applications of JK Flip Flop	4-26
4.7	Gated D Latch (Clocked D Flip Flop)	4-12	4.15	The Schmitt Trigger	4-26
4.8	Gated JK Latch (Level Triggered JK Flip Flop)	4-13	4.16	Flip Flop Applications	4-27
4.8.1	Race Around Condition in JK Latch	4-14	4.16.1	Frequency Division and Clock Generation	4-27
4.8.2	Difference between Latch and Flip-flop	4-14	4.16.2	Clock System with Delayed Clock Signal	4-28
4.8.3	Pulse Narrowing Circuits for Edge Triggered Flip Flops	4-15	4.16.3	A Two Phase Clock Circuit	4-29
4.8.4	A Differentiator Circuit	4-15	4.17	Other Applications of Flip Flops	4-29
4.8.5	Pulse Narrowing Circuit for IC Flip Flops	4-15	4.17.1	Application of SR Latch for Elimination of Keyboard Debounce	4-29
4.9	Edge Triggered SR Flip Flops	4-16	4.18	Excitation Table of Flip-Flop	4-30
4.9.1	Positive Edge Triggered S-R Flip Flop	4-16	4.18.1	Excitation Table of SR Flip Flops	4-30
4.9.2	Negative Edge Triggered S - R Flip Flop	4-17	4.18.2	Excitation Table of D Flip Flop	4-31
4.10	Edge Triggered D Flip Flop	4-17	4.18.3	Excitation Table of JK Flip Flop	4-31
4.10.1	Positive Edge Triggered D Flip Flop	4-17	4.18.4	Excitation Table of T Flip Flop	4-32
4.10.2	Negative Edge Triggered D Flip Flop	4-18	4.19	Conversion of Flip Flops	4-32
4.10.3	Applications of D Flipflop	4-19	4.19.1	Conversion from S-R Flip Flop to D Flip Flop	4-32
4.11	Edge Triggered J-K Flip Flop	4-19	4.19.2	SR Flip Flop to T Flip Flop	4-33
4.11.1	Positive Edge Triggered JK Flip Flop	4-19	4.19.3	SR Flip Flop to JK Flip Flop	4-33
4.11.2	Characteristic Equation of JK Flip Flop	4-20	4.19.4	T Flip Flop to D Flip Flop Conversion	4-34
4.11.3	How does an Edge Triggered JK FF Avoid Race Around Condition ?.....	4-21	4.19.5	JK Flip Flop to D Flip Flop Conversion	4-34
4.11.4	Negative Edge Triggered JK Flip-Flop	4-21	4.19.6	D FF to SR FF Conversion	4-34
4.12	Toggle Flip Flop (T Flip Flop)	4-21	4.20	Analysis of Clocked Sequential Circuits	4-35
4.12.1	Positive Edge Triggered T-FF	4-21	4.20.1	State Table	4-35
4.12.2	Negative Edge Triggered T Flip Flop	4-22	4.20.2	State Diagram	4-35
4.12.3	Application of T F/F	4-23	4.20.3	State Equation	4-36
4.13	Master Slave (MS) JK Flip Flop	4-23	4.21	Design Procedure for Clocked Sequential Circuits	4-38
4.13.1	Master Slave FF Timing Chart	4-25	4.22	Solved University Examples (New Syllabus)	4-41
4.14	Preset and Clear Inputs	4-25	4.23	University Questions and Answers	4-42
			4.24	University Questions and Answers (New Syllabus)..	4-43



- **Review Questions** 4-39
- **MCQs with Answers**..... 4-40

Chapter 5 : Counters **5-1 to 5-30**

Syllabus : Ripple and synchronous counters.

5.1	Introduction	5-2
5.1.1	Types of Counters	5-2
5.1.2	Classification of Counters	5-2
5.2	Asynchronous/Ripple Up Counters	5-2
5.2.1	3 Bit Asynchronous Up Counter	5-4
5.2.2	4 Bit Asynchronous up Counter	5-4
5.2.3	State Diagram of a Counter	5-6
5.3	Asynchronous Down Counters	5-6
5.3.1	3- Bit Asynchronous Down Counter	5-6
5.4	UP / DOWN Counters	5-8
5.4.1	UP/DOWN Ripple Counters	5-8
5.4.2	3-bit and 4-bit Up Down Ripple Counters	5-8
5.5	Modulus of the Counter (MOD-N Counter)	5-10
5.5.1	Frequency Division Taking Place in Asynchronous Counters	5-13
5.5.2	Decade (BCD) Ripple Counter	5-14
5.6	Disadvantages of Ripple Counters	5-15
5.7	Synchronous Counters	5-15
5.7.1	2-Bit Synchronous up Counter	5-15
5.7.2	3-Bit Synchronous Binary up Counter	5-16
5.7.3	Design of the 3 Bit Synchronous Counter	5-17
5.7.4	Four Bit Synchronous Up Counter	5-19
5.8	Modulo – N Synchronous Counters	5-20
5.8.1	Synchronous Decade Counter	5-20
5.9	UP / DOWN Synchronous Counter	5-27
5.9.1	3-bit Up/Down Synchronous Counter	5-27
5.9.2	Advantages of Synchronous Counter	5-27
5.9.3	Comparison of Synchronous and Asynchronous Counters	5-28
5.9.4	Typical Counter ICs	5-28

5.10	Applications of Counters	5-28
5.11	Solved University Examples	5-30
5.12	Solved University Examples (New Syllabus)	5-30
5.13	University Questions and Answers	5-30
5.14	University Questions and Answers (New Syllabus).....	5-30
	• Review Questions	5-28
	• MCQs with Answers	5-29

Chapter 6 : Shift Registers **6-1 to 6-22**

Syllabus : Shift registers.

6.1	Introduction	6-2
6.2	Data Formats	6-2
6.3	Classification of Registers	6-2
6.4	Buffer Registers	6-2
6.5	Shift Registers	6-3
6.5.1	Serial Input Serial Output (Shift Left Mode)	6-4
6.5.2	Serial In Serial Out (Shift Right Mode)	6-5
6.5.3	Applications of Serial Operation	6-6
6.6	Serial In Parallel Out (SIPO)	6-7
6.7	Parallel In Serial Out Mode (PISO)	6-7
6.8	Parallel In Parallel Out (PIPO)	6-8
6.9	Bidirectional Shift Register	6-8
6.9.1	A 3-bit Bidirectional Register using the JK Flip Flops	6-9
6.10	Universal Shift Register	6-9
6.10.1	Universal Shift Register using Multiplexers and D-flip flops	6-10
6.11	Applications of Shift Registers	6-11
6.11.1	Serial to Parallel Converter	6-11
6.11.2	Parallel to Serial Converter	6-11
6.11.3	Ring Counter	6-12
6.11.4	Johnson's Counter (Twisted / Switch Tail Ring Counter)	6-13
6.11.5	Johnson's Counter using D Flip-flops	6-14
6.11.6	Sequence Generator	6-14
6.12	Serial Data Transmission using Registers	6-16

6.12.1 Practical Serial Transmission System6-16

6.12.2 Timing Problems6-16

6.12.3 Common Formats6-16

6.12.4 Conversion of NRZ to RZ6-17

6.12.5 Generation of Gated Clocked Signal6-17

6.12.6 Clock Pulses for Serial Data Transmission6-18

6.12.7 Gated Clock Pulse Generator using Counter6-18

6.12.8 Clock Pulses for Serial Data Reception6-19

6.13 Solved Examples6-19

6.14 University Questions and Answers (New Syllabus).....6-22

- **Review Questions** 6-21
- **MCQs with Answers**..... 6-22

Chapter 7 : Introduction to Finite State Machines

7-1 to 7-18

Syllabus : Introduction to Finite State Machines (FSM) : The need for state machines, The state machine, Basic concepts in state machine analysis.

7.1 The Need for State Machines 7-2

7.1.1 Advantages of State Machine Approach 7-2

7.1.2 Disadvantages of FSM 7-2

7.2 The State Machine 7-2

7.2.1 The State Machine Definition 7-2

7.2.2 General Model of Sequential Machine 7-2

7.3 Classification of State Machines 7-3

7.3.1 Classification on the Basis of Clock 7-3

7.3.2 Comparison of Synchronous and Asynchronous System 7-3

7.3.3 Classification of State Machines Based on Model Type 7-3

7.3.4 Moore Machine 7-4

7.3.5 Mealy Machine7-4

7.3.6 Comparison of Moore and Mealy Models7-5

7.3.7 The State Machine as Sequential Controller7-6

7.4 Basic Concepts in State Machines7-6

7.4.1 State Machine Notations7-6

7.4.2 Present States, Next State7-6

7.4.3 Excitation Table of Flip-Flop7-6

7.4.4 Flip Flop as State Machine7-6

7.5 Analysis of a State Machine7-6

7.5.1 Flip Flop Input Output Equations7-7

7.5.2 Analysis Procedure7-7

7.5.3 Analysis with D Flip Flops7-7

7.5.4 Analysis Using JK Flip-Flops7-9

7.5.5 Analysis using T Flip Flops7-10

7.6 State Diagrams7-11

7.7 Solved Examples on Analysis of State Machines ..7-12

7.8 University Questions and Answers (New Syllabus)..7-18

- **Review Questions**.....7-17
- **MCQs with Answers**.....7-17

Chapter 8 : Synchronous State Machine Design

8-1 to 8-50

Syllabus : Sequential counters, State changes referenced to clock, Number of state flip-flops, Input forming logic, Output forming logic, Generation of a state diagram from a timing chart, Redundant states, General state machine architecture, Concept of asynchronous state machine and comparison to synchronous state machine.

8.1 Introduction8-2

8.2 Sequential Counters8-2

8.2.1 Design of Clocked Synchronous State Machine using State Diagram8-2

8.2.2 Lock Out Condition in a Counter8-2



8.2.3	Bush Diagram for Sequence Counter	8-6	8.13.2	Total State	8-46
8.3	State Changes Referenced to Clock	8-11	8.13.3	Advantages of Asynchronous Machines	8-46
8.4	Number of State Flip-flops	8-13	8.13.4	Disadvantages	8-47
8.5	Input Forming Logic (IFL)	8-13	8.13.5	Applications	8-47
8.5.1	IFL using Gates	8-13	8.14	Modes of Asynchronous Sequential Machines	8-47
8.5.2	Design using Unused States	8-13	8.15	Fundamental Mode Asynchronous Circuits	8-47
8.5.3	State Assignment	8-15	8.15.1	Pulse Mode Asynchronous Circuits	8-48
8.6	Construction of State Diagram	8-17	8.16	Solved University Examples	8-48
8.6.1	IFL Design for Sequence Detector	8-20		• Review Questions	8-49
8.6.2	IFL using Direct Addressed Multiplexers	8-24		• MCQs with Answers	8-49
8.7	Output Forming Logic (OFL)	8-27	<hr/>		
8.7.1	Unconditional and Conditional Outputs	8-28	Chapter 9 : Logic Families 9-1 to 9-30		
8.7.2	State Assignment for Minimization of OFL	8-28	Syllabus : Specifications, Noise margin, Propagation delay, Fan-in, Fan-out, Transistor-Transistor Logic (TTL), Emitter Coupled Logic (ECL), CMOS logic, TTL and CMOS gates, Introduction to basics of FINFET.		
8.7.3	The Output Glitch Problem	8-29	9.1	Logic Families.....	9-2
8.7.3.1	Glitches Due to Flip-Flop Unequal Switching Speeds	8-30	9.2	Classification of Logic Families	9-2
8.7.3.2	Glitches Due to Conditional Outputs	8-30	9.3	Characteristics of Digital ICs	9-3
8.7.3.3	Clock Suppression to Avoid Glitches	8-31	9.3.1	Voltage and Current Parameters	9-3
8.7.3.4	Clock Suppression Method for Unconditional Output	8-31	9.3.2	Fan-in and Fan-out	9-4
8.7.3.5	Output Holding Register to Avoid Glitches	8-32	9.3.3	Noise Margin	9-4
8.8	OFL Design Examples	8-33	9.3.4	Propagation Delay (Speed of Operation)	9-5
8.9	Generation of State Diagram from a Timing Diagram	8-33	9.3.5	Power Dissipation	9-6
8.10	Redundant State	8-34	9.3.6	Operating Temperature	9-6
8.10.1	State Reduction	8-34	9.3.7	Figure of Merit (Speed Power Product SPP)	9-6
8.10.2	Example on State Reduction (Redundancy States)	8-35	9.3.8	Invalid Voltage Levels	9-6
8.11	General State Machine Architecture	8-39	9.3.9	Current Sourcing and Current Sinking	9-6
8.11.1	Solved Examples	8-40	9.4	Transistor-Transistor Logic (TTL)	9-7
8.12	Asynchronous Sequential Circuits	8-45	9.4.1	The Multiple Emitter Transistor	9-7
8.13	Block Diagram of an Asynchronous Circuit	8-45	9.4.2	Two Input TTL-NAND Gate (Totem Pole Output)	9-7
8.13.1	Stable System	8-46	9.4.3	Totem-pole (Active Pull up) Output Stage	9-9



9.4.4	Unconnected Inputs	9-9	9.15.5	Comparison of Totem-pole and Open Collector Outputs	9-24
9.4.5	Clamping Diodes	9-10	9.15.6	Open Drain Outputs (CMOS)	9-24
9.5	Wired AND Connection	9-10	9.15.7	Application of Open Drain Inverter	9-24
9.6	TTL NOR Gate	9-11	9.15.8	Wired Logic (CMOS)	9-25
9.7	Standard TTL Characteristics	9-12	9.16	Tristate Output Devices	9-25
9.8	Advantages and Disadvantages of TTL	9-13	9.16.1	Tristate (Three state) TTL Devices	9-25
9.9	Emitter Coupled Logic (ECL)	9-13	9.16.2	Advantages of Tristate	9-26
9.9.1	ECL 2-input OR/NOR Gate	9-13	9.16.3	Tristate Buffers	9-26
9.9.2	ECL Characteristics	9-14	9.16.4	Applications of Tristate Buffers (Bus Organization)	9-26
9.9.3	Advantages and Disadvantages of ECL Family 9-15		9.16.5	A TRI-STATE Inverter	9-27
9.10	MOS - Logic Family	9-15	9.16.6	Tristate Logic Output (CMOS)	9-27
9.11	CMOS Logic	9-15	9.17	Logic Compatibility	9-28
9.11.1	CMOS Inverter	9-15	9.18	Comparison of TTL, CMOS and ECL	9-28
9.11.2	CMOS NOR Gate	9-16	9.19	University Questions and Answers	9-30
9.11.3	CMOS NAND Gate	9-17	9.20	University Questions and Answers (New Syllabus).....	9-30
9.11.4	CMOS Series	9-19		• Review Questions	9-29
9.12	CMOS Characteristics	9-19		• MCQs with Answers	9-29
9.13	Advantages and Drawbacks of CMOS	9-19	<hr/>		
9.14	TTL Circuits	9-19	Chapter 10 : Programmable Logic Devices		
9.14.1	Schottky TTL (74 S Series)	9-19	10-1 to 10-30		
9.14.2	Low Power Schottky TTL (LS – TTL)	9-20	<hr/>		
9.14.3	High Speed TTL (74 H series)	9-20	Syllabus : Introduction to Programmable Logic Devices, Read-Only Memory, Programmable Logic Arrays (PLA), Programmable Array Logic (PAL), Combinational PLD Based State Machines, State Machines on a Chip.		
9.14.4	Low Power TTL (L-TTL)	9-20	10.1	Introduction to PLDs.....	10-2
9.14.5	Fast (F) TTL (74 F Series)	9-21	10.1.1	Advantages of PLDs	10-2
9.14.6	Advanced Schottky TTL, 74 AS Series (AS – TTL)	9-21	10.1.2	Disadvantages of PLDs	10-2
9.14.7	Advanced Low Power Schottky TTL 74 ALS Series	9-21	10.1.3	Types of PLDs	10-2
9.14.8	Available Gates	9-21	10.2	ROM (Read Only Memory) used as PLD	10-2
9.15	Open Collector / Drain Gates	9-22	10.2.1	Types of ROMs	10-3
9.15.1	Open Collector TTL ICs	9-22	10.2.2	Internal Logic of a ROM	10-5
9.15.2	Disadvantages of Open Collector Output	9-22	10.2.3	Implementation of a Combinational Circuit (Generating the Boolean Function)	10-7
9.15.3	Advantage	9-23	10.2.4	Advantages of ROM as PLD	10-9
9.15.4	Wired ANDing	9-23			

10.2.5	Disadvantages of ROM as PLD	10-9	11.1.3	Advantages of HDL	11-3
10.3	Programmable Logic Array (PLA)	10-11	11.1.4	Characteristics / Features of HDL	11-3
10.3.1	The Programming Procedure for PLA	10-13	11.2	Introduction to Verilog HDL	11-4
10.3.2	Application Areas of PLA	10-13	11.2.1	Features of Verilog HDL	11-4
10.3.3	Designing of Combinational Circuit using PLA	10-13	11.2.2	Structure of Verilog HDL Module	11-4
10.4	Programmable Array Logic (PAL)	10-18	11.2.3	Important Points to Remember While Designing any Module using Verilog HDL	11-4
10.4.1	Solved Examples on PAL	10-19	11.3	Synthesis in Digital Design	11-5
10.5	Comparison of PROM, PLA and PAL	10-23	11.3.1	Simulation	11-5
10.6	Combinational PLD-Based State Machines	10-23	11.4	Logic Value System	11-6
10.7	State Machines On a Chip	10-25	11.5	Data Types and Objects in Verilog	11-6
10.7.1	Registered PALs	10-25	11.5.1	Net Data Types	11-6
10.7.2	Configurable PAL	10-25	11.5.2	Variable Data Types	11-7
10.7.3	Generic Array Logic Devices (GAL)	10-26	11.6	Constants	11-7
10.8	Field Programmable Gate Array (FPGA)	10-26	11.7	Parameters	11-8
10.8.1	Basic Architecture of FPGA	10-26	11.8	Constructs in Verilog HDL	11-8
10.8.2	Xilinx XC 4000 FPGA Family	10-27	11.9	Operators in Verilog HDL	11-8
10.8.3	Tools for Creating State Machines on Chip	10-28	11.10	Statements in Verilog HDL	11-9
10.9	Comparisons	10-28	11.10.1	Concurrent Statements	11-9
10.9.1	Comparison of RAM and ROM	10-28	11.10.2	Procedural / Sequential Statements	11-10
10.10	University Questions and Answers	10-30	11.10.3	Procedural Assignment Statement	11-10
10.11	University Questions and Answers (New Syllabus).....	10-30	11.10.4	if-else Statement	11-10
	• Review Questions	10-28	11.10.5	Case Statement	11-11
	• MCQs with Answers	10-29	11.10.6	While Loop Statement	11-11
<hr/>			11.10.7	For Loop Statement	11-11
<hr/>			11.10.8	Functions and Tasks	11-11
Chapter 11 : Introduction to Verilog HDL 11-1 to 11-24			11.11	Module Instantiation Statements	11-11
Syllabus : VLSI design flow : Design entry : Schematic, FSM and HDL, Different modeling styles in verilog : Behavioral and structural modeling, Data types and objects, Synthesis and simulation verilog constructs and codes for combinational and sequential circuits.			11.12	Modeling Styles in Verilog HDL	11-12
11.1	Introduction	11-2	11.12.1	Structural / Gate Level Modeling	11-12
11.1.1	VLSI Design Flow	11-2	11.12.2	Dataflow Modeling	11-13
11.1.2	Introduction to Hardware Description Language (HDL)	11-3	11.12.3	Behavioral Modeling of Logic Circuits using Continuous Assignment	11-13
			11.12.4	Behavioral Modeling of Logic Circuits using Always Block	11-13
			11.13	Verilog HDL Implementation of Logic Gates	11-14



11.14 Verilog HDL Implementation of Combinational Circuits 11-14	11.15.3 Verilog HDL Implementation of D Flip-flop11-20
11.14.1 Verilog HDL Implementation of Half Adder 11-14	11.15.4 Verilog HDL Implementation of JK Flip flop11-21
11.14.2 Verilog HDL Implementation of Full Adder 11-14	11.15.5 Verilog HDL Implementation of T Flip flop11-21
11.14.3 Verilog HDL Implementation of 24 Bit Adder 11-15	11.15.6 Verilog HDL Implementation of Shift Register (SISO)11-21
11.14.4 Verilog HDL Implementation of Full Subtractor 11-15	11.15.7 Verilog HDL Implementation of Shift Register (SIPO)11-22
11.14.5 Verilog HDL Implementation of 2 to 1 Multiplexer 11-15	11.15.8 Verilog HDL Implementation of Modulo 8 Up Counter11-22
11.14.6 Verilog HDL Implementation of 4 to 1 Multiplexer 11-16	11.15.9 Verilog HDL Implementation of 2-bit Up Counter using JK Flip flop11-22
11.14.7 Verilog HDL Implementation of 1 to 2 Demultiplexer 11-16	11.15.10 Verilog HDL Implementation of Johnson's Counter JK Flip flop11-22
11.14.8 Verilog HDL Implementation of 1 : 4 De-multiplexer 11-17	11.16 University Questions and Answers (New Syllabus)11-24
11.14.9 Verilog HDL Implementation of 4:2 Encoder 11-18	• Review Questions11-23
11.14.10 Verilog HDL Implementation of 2 : 4 Decoder (Behavioral Modeling) 11-18	• MCQs with Answers11-23
11.14.11 Verilog HDL Implementation of 3:8 Decoder 11-19	• Appendix-A : Binary Subtractors and BCD Arithmetic A-1 to A-12
11.15 Verilog HDL Implementation of Sequential Circuits 11-20	• Appendix-B : Fin Field Effect Transistor (FinFET)B-1 to B-4
11.15.1 Verilog HDL Implementation of D Latch 11-20	• Appendix-C : Data ConvertersC-1 to C-3
11.15.2 Verilog HDL Implementation of SR Latch 11-20	• Solved University Question Paper of Dec. / Winter 2020 Q-1 to Q-5

