

Model Curriculum for Minor Degree Course in Electronics Engineering (VLSI Design and Technology)

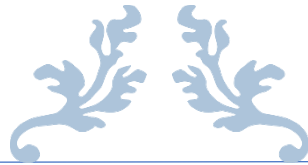
2023



ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

Nelson Mandela Marg, Vasant Kunj, New Delhi 110070

www.aicte-india.org



Minor Degree
in
Electronics Engineering
(VLSI Design and Technology)



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MESSAGE

With a view to enhance the employability skills and impart deep knowledge in emerging areas which are usually not being covered in Undergraduate Degree credit framework, AICTE has come up with the concept of '**Minor Degree**' in emerging areas. The concept of Minor Degree is discussed in the Approval Process Handbook (APH) for the academic session 2020-21 issued by AICTE. Minor Degree will carry 18 to 20 credits in addition to the credits essential for obtaining the Under Graduate Degree in Major Discipline (i.e. 160 credits usually).

Keeping in mind the need of manpower in emerging areas, AICTE with the help of industry-academia experts, has framed the curriculum for Minor Degree in Electronics Engineering (VLSI Design and Technology) to develop teachers, parents and policy makers of tomorrow who will have a humane worldview along with technical skills and strive to ensure value-based living for themselves as well as the society. The degree course will facilitate developing sufficient number of teachers to impart value-based education right from primary to higher education across the country.

Courses have been designed after rigorous brainstorming and considering the inputs from the experts of corresponding domain. I am hopeful that knowledge of this emerging area will help for nurturing students to their full human potential, so they can contribute to the development of an equitable and just society and promote national development.

I gratefully acknowledge the time and efforts of all those who were involved in preparation of this curriculum especially, the contributions of the members of the Working Group: Prof. Siva Rama Krishna and which included, Dr. Saurabh Lodha, Prof. Rajendra Patrikar, Dr. Sushobhan Avasthi, Dr. P.Ramesh and other committee members.

The well timed initiative to have this model curriculum addressing the need by Dr. Abhay Jere, Vice Chairman, Prof. Rajive Kumar, Member Secretary, AICTE is highly appreciated. I also appreciate the continuous effort put in coordinating the complete process of development of this curriculum by members of the Policy and Academic Planning Bureau of AICTE namely, Dr. Ramesh Unnikrishnan, Adviser-II; Dr. Naveen Arora, Assistant Director (P&AP); Dr. Anil Sharma, Assistant Director (P&AP), Mr. Rakesh Kumar Pandit, Young Professional (P&AP); and other office staff of AICTE.

(Prof. T G Sitharam)

Chairman

All India Council for Technical Education

Working Group for this Model Curriculum of Minor Degree in Electronics Engineering (VLSI Design and Technology)

S.No	Name	Designation & Organization
1	Dr. Siva Rama Krishna	Professor Dept. of Electrical Engineering, IIT Hyderabad (Chairman)
2	Dr. Saurabh Lodha	Institute Chair Professor, Dept. of Electrical Engineering, IIT Bombay. Mumbai (Member)
3	Prof. Rajendra Patrikar	Professor, Centre for VLSI and Nano Technology, Visvesvaraya National Institute of Technology, Nagpur, Maharashtra (Member)
4	Dr. Sushobhan Avasthi	Associate Professor, Indian Institute of Science, Bengaluru (Member)
5	Dr. P.Ramesh	Associate Professor, Dept. of Electronics and Communication, Govt. College of Engg Munnar, Idukki, Kerala (Member)

Minor Degree in “Electronics Engineering (VLSI Design and Technology)”

S. No.	Course Code	Course Title	L	T	P	Credit
1	VLSI-01	Electronic Materials, Devices and Circuits	3	0	2	4
2	VLSI -02	Digital System Design	3	0	2	4
3	VLSI -03	Analog Circuits OR Semiconductor Material Synthesis and Characterization	3	0	2	4
4	VLSI -04	1. VLSI Design / 2. VLSI Verification and Testing / 3. Embedded Systems OR 1. Semiconductor Equipment Design and Tech/ 2. Industrial Operation and Planning / 3. Reliability and Yield Engineering	3	0	0	3
5	VLSI -05	Introduction to Microfabrication	3	0	0	3
TOTAL						18

Course Coding Nomenclature:

- VLSI denotes that Minor Degree related to “Electronics Engineering (VLSI Design and Technology)”.
- 01, 02, 03, 04, 05 are course in order they have to be taken, if taken in different semesters.

**GENERAL COURSE STRUCTURE
AND
THEME**

GENERAL COURSE STRUCTURE AND THEME

A. Definition of Credit:

1 Hr. Lecture (L) per week	1 Credit
1 Hr. Tutorial (T) per week	1 Credit
2 Hours Practical (P) per week	1 Credit

B. Range of Credits: Minor Degree will carry 18 to 20 credits in addition to the credits essential for obtaining the Under Graduate Degree in Major Discipline (i.e. 161 credits usually).

C. Course code and definition:

Course code	Definitions
L	Lecture
T	Tutorial
P	Practical
C	Credits
XC	Program Core Course

D. Structure of Minor Degree in Universal Human Values (UHV)

S. No.	Course Code	Course Title	L	T	P	Credit
1	VLSI-01	Electronic Materials, Devices and Circuits	3	0	2	4
2	VLSI -02	Digital System Design	3	0	2	4
3	VLSI -03	Analog Circuits OR Semiconductor Material Synthesis and Characterization	3	0	2	4
4	VLSI -04	1. VLSI Design / 2. VLSI Verification and Testing / 3. Embedded Systems OR 1. Semiconductor Equipment Design and Tech/ 2. Industrial Operation and Planning / 3. Reliability and Yield Engineering	3	0	0	3
5	VLSI -05	Introduction to Microfabrication	3	0	0	3
TOTAL						18

Detailed Syllabus

VLSI-01	Electronics Materials , Devices and Circuits	3L:0T:0P	3 credits
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Course Contents:

Types of materials, metals, insulators and semiconductors, Band gap, Miller indices, Crystal Structure of Silicon, Intrinsic Semiconductors, Extrinsic semiconductors, Fermi level, Thermal Equilibrium, Law of mass action, mobility, generation recombination, Transport Equations, Continuity Equations

P-N junction characteristics, I-V characteristics, and small signal switching models; Avalanche breakdown, Zener diode, Schottky diode, Rectifying circuits, Limiting and clamping circuits. MOSFET device structure, current voltage characteristics, DC biasing, small signal analysis, Common Source, Common Gate and Common Collector Configurations, Discrete circuit amplifiers

OPAMP- Ideal Op-AMP, Inverting Configuration, Non inverting configuration, DC imperfections, difference amplifiers, circuits based on Op-amps: Integrators, differentiators, filters, logarithmic amplifiers.

Signal generators, waveform shaping circuits, RC oscillatory circuits, LC and Crystal Oscillators, Bistable multivibrators, monostable multivibrators, Timers, Nonlinear wave forming circuits

Text/Reference Books:

1. A.S.Sedra and K.C. Smith, Microelectronic Circuits
2. G. Streetman, and S. K. Banerjee, —Solid State Electronic Devices, 7th edition, Pearson, 2014.
3. D. Neamen , D. Biswas "Semiconductor Physics and Devices," McGraw-Hill Education
4. S. M. Sze and K. N. Kwok, —Physics of Semiconductor Devices, 3rd edition, John Wiley & Sons, 2006.
5. C.T. Sah, —Fundamentals of solid state electronics, World Scientific Publishing Co. Inc, 1991.

Course outcomes:

At the end of this course students will demonstrate the ability to

1. Categorize materials, explain their properties, explain crystal structure of silicon
2. Elucidate working principles of solid state devices
3. Build discrete amplifiers
4. Build OP-AMP based circuits

VLSI-02	Digital System Design	3L:0T:0P	3 credits
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Course Contents:

Logic Simplification and Combinational Logic Design: Review of Boolean Algebra and De Morgan 's Theorem, SOP & POS forms, Canonical forms, Karnaugh maps up to 6 variables, Binary codes, Code Conversion.

MSI devices like Comparators, Multiplexers, Encoder, Decoder, Driver & Multiplexed Display, Half and Full Adders, Subtractors, Serial and Parallel Adders, BCD Adder, Barrel shifter and ALU.

Sequential Logic Design: Building blocks like S-R, JK and Master-Slave JK FF, Edge triggered FF, Ripple and Synchronous counters, Shift registers, Finite state machines, Design of synchronous FSM, Algorithmic State Machines charts. Designing synchronous circuits like Pulse train generator, Pseudo Random Binary Sequence generator, Clock generation

Logic Families and Semiconductor Memories: TTL NAND gate, Specifications, Noise margin, Propagation delay, fan-in, fan-out, Tristate TTL, ECL, CMOS families and their interfacing, Memory elements, Concept of Programmable logic devices like FPGA. Logic implementation using Programmable Devices.

VLSI Design flow: Design entry: Schematic, FSM & HDL, different modeling styles in VHDL, Data types and objects, Dataflow, Behavioral and Structural Modeling, Synthesis and Simulation

VHDL constructs and codes for combinational and sequential circuits.

NPTEL Course (if any): <https://nptel.ac.in/courses/117106086>

Text/Reference Books:

1. M.Morris Mano and Michel.D.Ciletti, Digital Design with an introduction to HDL, VHDL and Verilog, Sixth edition Pearson education
2. R. Anand, Digital System Design Using VHDL, Khanna Book Publishing Company.
3. R. Anand, Digital Electronics, Khanna Book Publishing Company.
4. R.P. Jain, –Modern digital Electronics, Tata McGraw Hill, 4th edition, 2009.
5. Douglas Perry, –VHDL, Tata McGraw Hill, 4th edition, 2002.
6. W.H. Gothmann, –Digital Electronics- An introduction to theory and practice, PHI, 2nd edition ,2006.
7. D.V. Hall, –Digital Circuits and Systems, Tata McGraw Hill, 1989
8. Charles Roth, –Digital System Design using VHDL, Tata McGraw Hill 2nd edition 2012.

Course outcomes:

At the end of this course students will demonstrate the ability to

1. Design and analyze combinational logic circuits
2. Design & analyze modular combinational circuits with MUX/DEMUX, Decoder, Encoder

3. Design & analyze synchronous sequential logic circuits
4. Use HDL & appropriate EDA tools for digital logic design and simulation

VLSI-03	Analog circuits	3L:0T:0P	3 credits
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Course Contents:

Diode Circuits, Amplifier models: Voltage amplifier, current amplifier, trans-conductance amplifier and trans-resistance amplifier. Biasing schemes for BJT and FET amplifiers, bias stability, various frequency transistor models, estimation of voltage gain, input resistance, output resistance etc., design procedure for particular specifications, low frequency analysis of multistage amplifiers.

High frequency transistor models, frequency response of single stage and multistage amplifiers, cascode amplifier. Various classes of operation (Class A, B, AB, C etc.), their power efficiency and linearity issues. Feedback topologies: Voltage series, current series, voltage shunt, current shunt, effect of feedback on gain, bandwidth etc., calculation with practical circuits, concept of stability, gain margin and phase margin.

Oscillators: Review of the basic concept, Barkhausen criterion, RC oscillators (phase shift, Wien bridge etc.), LC oscillators (Hartley, Colpitt, Clapp etc.), non-sinusoidal oscillators. Current mirror: Basic topology and its variants, V-I characteristics, output resistance and minimum sustainable voltage (V_{ON}), maximum usable load. Differential amplifier: Basic structure and principle of operation, calculation of differential gain, common mode gain, CMRR and ICMR. OP-AMP design: design of differential amplifier for a given specification, design of gain stages and output stages, compensation.

OP-AMP applications: review of inverting and non-inverting amplifiers, integrator and differentiator, summing amplifier, precision rectifier, Schmitt trigger and its applications. Active filters: Low pass, high pass, band pass and band stop, design guidelines.

Digital-to-analog converters (DAC): Weighted resistor, R-2R ladder, resistor string etc. Analog-to-digital converters (ADC): Single slope, dual slope, successive approximation, flash etc. Switched capacitor circuits: Basic concept, practical configurations, application in amplifier, integrator, ADC etc.

NPTEL course: <https://nptel.ac.in/courses/108106084>

Text/Reference Books:

1. A.V.N. Tilak, Design of Analog Circuits, Khanna Publishing House, 2022.
2. A.S. Sedra and K.C. Smith, Microelectronic Circuits, sixth edition, Oxford University Press
3. J.V. Wait, L.P. Huelsman and GA Korn, Introduction to Operational Amplifier theory and applications, McGraw Hill, 1992.
4. J. Millman and A. Grabel, Microelectronics, 2nd edition, McGraw Hill, 1988.
5. P. Horowitz and W. Hill, The Art of Electronics, 2nd edition, Cambridge

University Press, 1989.

6. Paul R. Gray and Robert G.Meyer, Analysis and Design of Analog Integrated Circuits, John Wiley, 3rd Edition

Course Outcomes:

At the end of this course students will demonstrate the ability to

1. Understand the characteristics of diodes and transistors
2. Design and analyze various rectifier and amplifier circuits
3. Design sinusoidal and non-sinusoidal oscillators
4. Understand the functioning of OP-AMP and design OP-AMP based circuits
5. Design ADC and DAC

VLSI-03	Semiconductor materials synthesis and characterization	3L:0T:0P	3 credits
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Course Contents:

Principles of extraction, pyrometallurgical processes, material and heat balance of processes, thermodynamics of processes; introduction to laws, thermodynamic equilibrium, thermochemistry, Ellingham diagram. Process kinetics; introduction to chemical kinetics and rate processes, heterogeneous kinetics, kinetics of liquid-liquid reactions, concepts of reactor design. Structure & properties of molten liquids.

Production of metallurgical grade (MG) Si: Carbothermic reduction, principle, operation and practice of sub-merged arc furnace, energy and process calculation, refining & impurities control in molten MG Si. Production of electronic grade (EG) Si: Concept of fluidized bed reactor, Siemens Process. Crystal Growth: Crystal growth processes (Bridgman and its variants, Czochralski), heat and species transfer during non-steady and steady state plane-front growth, interface instability and effect of convection on interface stability

XRD (Bulk and thin film), Microscopy (Optical, SEM, TEM, SPM), UV-Visible spectroscopy, Photoluminescence, Raman spectroscopy

Text/Reference Books:

1. Principles of Extractive Metallurgy, Terkel Rosenqvist, McGraw-Hill Book Company, 1973
2. Stoichiometry and Thermodynamics of Metallurgical Processes: Y K Rao, Cambridge University Press, 2009
3. Handbook of Extractive Metallurgy: Fathi Habashi; Wiley-VCH, 1997
4. Solar-Grade Silicon: Refining and Recycling: L Zhang et al, CRC Press, 2013
5. Scheel and Capper: Crystal Growth Technology: From Fundamentals and Simulation to Large-scale Production, John Wiley & Sons, 2008
6. Nakajima and Usami: Crystal Growth of Si for Solar Cell, Springer, 2009

Course Outcome:

1. Understand the Silicon extraction and purification process
2. Understand Crystallography of Si and various methods of growth
3. Understand key methods of physicochemical, morphological and analytical characterization techniques

VLSI-04	VLSI Design	3L:0T:0P	3 credits
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Course Contents:

Overview of VLSI Design: Historical perspective, overview of VLSI design methodologies, VLSI design flow, design hierarchy, concepts of regularity, modularity, and locality, VLSI design styles, design quality, packaging technology, CAD technology.

MOS Transistor Theory: Introduction to The metal oxide semiconductor (MOS) structure, Long-channel I-V characteristics, C-V characteristics, non-linear I-V effects, DC transfer characteristics.

Introduction to ASIC and SoC, Overview of ASIC flow, functional verification, RTL-GATE level synthesis, synthesis optimization techniques, pre-layout timing verification, static timing analysis, floor-planning, placement and routing, extraction, post layout timing verification, extraction.

CMOS Process Technology: Fabrication process flow- basic steps, the CMOS n-Well process, layout design rules, stick diagram, full-custom mask layout design

MOS Inverter (Static Characteristics): Resistive-load inverter, inverter with n-type 16 MOSFET load, CMOS inverter

MOS Inverters (Switching Characteristics and Interconnects effects): Delay-time definitions, calculation of delay times, logical efforts, inverter design with delay constraints, estimation of interconnect parasitics, calculation of interconnect delay, Bus vs. Network-onChip (NoC), switching power dissipation of CMOS inverters.

Combination CMOS Logic Circuits: MOS logic circuits with depletion nMOS loads, CMOS logic circuits, complex logic circuits, CMOS transmission gates (pass gates), ratioed, dynamic and pass transistor logic circuits.

Sequential MOS logic circuits: Behaviour of bi-stable elements, SR latch circuits, clocked latch and flip-flop circuits, CMOS D-latch and edge-triggered flip-flop. Timing path, Setup time and hold time static, example of setup and hold time static, setup and hold slack, clock skew and jitter, Clock, reset and power distributions.

Semiconductor Memories: Memory Design, SRAM, DRAM structure and implementations

Recent Trends in VLSI Design & its research issues in industry: System case studies. Design automation of VLSI Systems: basic concepts. Deep Sub-micron Technologies: Some Design Issues

Text/Reference Books:

1. N. H. E. Weste and C. Harris, “Principles of CMOS VLSI Design: A System Perspective, 3rd Edition, Pearson Education 2007.
2. J. Rabaey, A. Chandrakasan and B. Nikolic, Digital Integrated Circuits: A Design Perspective, 2nd Edition, Prentice Hall 2004.

Course Outcomes:

At the end of this course students will demonstrate the ability to

1. provide an overview of the digital IC design techniques
2. Understand the characteristics of CMOS inverter.
3. Analyze the static and dynamic characteristics of CMOS circuits
4. Design and implementation of combinational and sequential circuits
5. Evaluate the performance of CMOS circuits

VLSI-04	VLSI Verification and Testing	3L:0T:0P	3 credits
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Course Contents:

Physical faults and their modeling. Fault equivalence and dominance; fault collapsing, Fault simulation: parallel, deductive and concurrent techniques; critical path tracing.

Test generation for combinational circuits: Boolean difference, D-algorithm, Podem, random etc. Exhaustive, random and weighted test pattern generation; aliasing and its effect on fault coverage.

PLA testing: cross-point fault model, test generation, easily testable designs.

Memory testing: permanent, intermittent and pattern-sensitive faults; test generation.

Delay faults and hazards; test pattern generation techniques, ATPG and its different types

Test pattern generation for sequential circuits: ad-hoc and structures techniques scan path and LSSD, boundary scan

Built-in self-test techniques: LBIST and MBIST. Verification: logic level (combinational and sequential circuits), RTL-level (data path and control path). Verification of embedded systems. Use of formal techniques: decision diagrams, logic-based approaches.

ASIC/IP Verification, direct and random testing, Error detection and correction codes.

Text/Reference Books:

1. Essentials of Electronic Testing, M. L. Bushnell and V. D. Agrawal, 3rd Kluwer Academic Publishers 2002
2. Delay Fault Testing for VLSI Circuits, A. Krstic and K-T Cheng, 3rd Kluwer Academic Publishers. 2003
3. Testing of Digital Systems, N. K. Jha and S. Gupta, 2nd, Cambridge University Press. 2003
4. Digital Systems Testing and Testable Design, M. Abramovici, M. A. Breuer and A. D. Friedman, 3rd, Wiley-IEEE Press. 1994
5. Fault Tolerant and Fault Testable P. K. Lala, 4th, Hardware Design, Prentice-Hall. 198

Course Outcomes:

1. Extend knowledge of the requirement of fault modeling in VLSI circuits.
2. Generate test vectors to test a circuit efficiently covering maximum faults.
3. Demonstrate the concept of Memory testing techniques
4. Discuss about Built-in-Self Test and its application in modern digital design
5. Use modern tools for testing and verification.

VLSI-04	Embedded Systems	3L:0T:0P	3 credits
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Course Contents:

Introduction to Embedded systems: Motivation based on applications of embedded systems, Basics of Embedded systems, functional block

Modeling of Embedded system: Mathematical modeling of physical systems to fit into embedded systems, Continuous Dynamics, Discrete Dynamics, Hybrid Systems, actor models, Composition of State Machines

Microcontrollers, Sensors, Actuators, Basics of Microcontrollers, 8951, Arduino microcontroller development board, I/Os, Sensors, Actuators

Interfacing between analog and digital blocks, signal conditioning, digital signal processing. sub-system interfacing, interfacing with external systems, user interfacing. Design tradeoffs due to process compatibility, thermal considerations, etc., Software aspects of embedded systems: real time programming languages and operating systems for embedded systems.

Text/Reference Books:

1. J.W. Valvano, "Embedded Microcomputer System: Real Time Interfacing", Brooks/Cole, 2000.
2. Jack Ganssle, "The Art of Designing Embedded Systems", Newness, 1999.
3. V.K. Madiseti, "VLSI Digital Signal Processing", IEEE Press (NY, USA), 1995.
4. David Simon, "An Embedded Software Primer", Addison Wesley, 2000.
5. K.J. Ayala, "The 8051 Microcontroller: Architecture, Programming, and

Applications", Penram Intl, 1996.

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Suggest design approach using advanced controllers to real-life situations.
2. Design interfacing of the systems with other data handling / processing systems.
3. Appreciate engineering constraints like energy dissipation, data exchange speeds etc.

VLSI-04	Semiconductor Equipment Design and Technology	3L:0T:0P	3 credits
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Course Contents:

Fundamentals of vacuum technology- nomenclature and definition, pressure regions, gas properties and laws, molecular processes and kinetic theory, gas flow calculations, technology of vacuum pumps- throughput, pumping speed, forevacuum and high vacuum pumping, pump system design, diaphragm pumps, vacuum blowers, diffusion pumps, cryogenic pumps, turbomolecular pumps, pumps for ultra-high vacuum, vacuum measurements, types of gauges, mass analysis and spectrometry, mass flow control and measurement, vacuum valves, flanges and components, vacuum feedthroughs, vacuum seals, vacuum leak detectors, vacuum chambers and viewports, outgassing, vacuum applications such as sputtering, plasma etching, CVD, epitaxy, electron spectroscopies

Plasma Science and Technology

Plasma physics- Motion of individual electrons and ions in electric and magnetic fields- Single, collisionless, particles in DC and AC electric fields, Particle orbits in magnetic fields, Space charge and collective effects, Debye shielding, Plasma oscillations and plasma frequency, Plasma shielding and plasma sheaths, Response to DC, RF and microwave fields, Plasma potential, Characteristic electron and ion transit times

Introduction to Plasma Reactors- Chamber pump systems, load locks, mass flow control, hazardous gas handling, effluent control, Pressure gauges / control (Piranhi, thermocouple, ionization, baratron, convectron) Wafer chucks (Clamps/Electrostatic chucks)

RF and microwave power sources and coupling- Power sources, matching networks, feedthroughs and coupling

RF Capacitively and Inductively coupled plasmas- Spatial variations of plasma potential, electric field, charge density and energy, optical emission, Sheaths at powered, grounded and floating surfaces, parameters, models, matching networks, Ion bombardment - energy / time / frequency/ power dependencies

Applications in processes- etching, deposition, sputtering, ashing

Text/Reference Books:

1. V.V. Rao, T.B. Ghosh, K.L. Chopra,, Vacuum Science and Technology, Allied Publishers Ltd., New Delhi
2. Handbook of Vacuum Science and Technology- Dorothy M. Hoffman, Bawa Singh, John H. Thomas, III, Academic Press
3. Handbook of Vacuum Technology: Karl Jousten, Wiley
4. Plasma Etching: Fundamentals and Applications: 7 (Series on Semiconductor Science and Technology)- M. Sugawara, OUP Oxford
5. Plasma Etching in Semiconductor Fabrication- Russ Morgan, Elsevier
6. Fundamentals of Plasma Physics- J. A. Bittencourt, Springer India
7. Plasma Physics and Engineering- Alexander Fridman, Lawrence Kennedy, CRC Press

Course Outcome:

1. Understand Basics of Vacuum Technology
2. Understand Basics of Plasma Technology
3. Ability to analyze vacuum and plasma based semiconductor equipment

VLSI-04	Industrial Operation and Planning	3L:0T:0P	3 credits
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Course Objectives:

1. One of the most critical areas for success in any business enterprise is how Production and Operations are managed.
2. To study the statistics, economics, finance, organizational behaviour and strategy into a consolidated production and operation related decisions.
3. To discuss the role of location strategy and the criteria for location decisions.
4. To define quality and explain quality management, including TQM and its tools.

Course Content:

UNIT-I: Process Planning and Process Engineering: Process Planning: Introduction, Function, Pre-requisites and steps in process planning, Factors affecting process planning, Make or buy decision, plant capacity and machine capacity. Process Engineering: Preliminary Part Print Analysis: Introduction, Establishing the General Characteristics of work piece, determining the principal Process, Functional surfaces of the work piece, Nature of the work to be Performed, Finishing and identifying operations. Dimensional Analysis: Introduction, types of dimensions, measuring the Geometry of form, Baselines, Direction of specific dimensions. Tolerance Analysis: Causes of work piece variation, Terms used in work piece dimensions, Tolerance stacks. Work piece Control: Introduction, Equilibrium Theories, Concept of location, Geometric Control, Dimensional control, Mechanical control.

UNIT-II: Production Forecasting: Introduction of production forecasting, The strategic role of forecasting in supply chain, Time frame, Demand behavior, Forecasting methods- Qualitative and Quantitative, Forecast accuracy.

Scheduling:

Introduction, Objectives in scheduling, Loading, Sequencing, Monitoring, Advanced Planning and Scheduling Systems, Theory of Constraints, Employee scheduling.

UNIT-III: Break-Even Analysis: Introduction, Break-even analysis charts, Breakeven analysis for process, plant and equipment selection.

Aggregate Operations Planning: Aggregate production planning, adjusting capacity to meet the demand, Demand management, Hierarchical and collaborative planning, Aggregate planning for services.

UNIT-IV: Assembly Line Balancing: Assembly lines, Assembly line balancing, splitting tasks, Flexible and U-shaped line layouts, Mixed model line balancing, Current thoughts on assembly lines, Computerized assembly line balancing.

UNIT-V: Material Management: Introduction, Importance and objectives, Purchasing and Stores: policies and procedures, Vendor development, selection, analysis and rating.

Reference Books:

1. Production and Operations Management – K.Aswathappa, K.Shridhara Bhat, Himalaya Publishing House, 2014.
2. Production and Operations Management – Shailendra Kale, McGraw Hill Educations(India) Private Limited,2013.
3. Production and Operations Management – R.Paneerselvam, PHI Learning Private Limited, 2013.
4. Operations Management – Joseph Monk, TMH Publishers, New Delhi, 2004.
5. Modern Production /Operations Management – Buffa Elwood S, John Wiley Publishers, Singapore, 2002.
6. Industrial Engineering and Management, S.C. Sharma & T.R. Banga, Khanna Book Publishing Company, 2022.

Course outcomes:

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

CO1	Define operations management and explain its relationship to productivity. And also understand tools and techniques.
CO2	Describe the importance of forecasting and explain the effective application of the different forecasting approaches and methods.
CO3	Explain layout strategy and how operations managers determine facility arrangements and size.
CO4	Describe how operations managers achieve a reasonable work environment and set expectations related to employee productivity.
CO5	Understand make-or-buy decisions, and the selection and integration of suppliers. And how much to order and when to order.

VLSI-04	Reliability and Yield Engineering	3L:0T:0P	3 credits
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Course Content:

IC Manufacturing defects, defect mechanisms, defect classifications. defect monitoring, yield estimation, Process control and defect monitoring in manufacturing, optical/SEM detection of defects Parametric yield, use of circuit simulation for estimation. Monte Carlo simulations for analysis, robust circuit design

Functional yield, Inductive fault analysis the concept of the critical area, Layout design for optimum yield

Yield models: Poisson Model, Murphy model, Gamma model

Definitions of reliability, bath tub curve failure modes, mechanisms, Basic concepts –

Reliability functions, Relationship between these functions Exponential failure

density and distribution functions Measures of reliability – MTTF, MTTR, MTBF

Introduction to mathematical methods for reliability: Failure rates, Normal distribution function, Exponential, Weibull and Lognormal distributions for reliability modeling. Physics of failure based models for: Mass transport-induced failures (electromigration and stress voiding),

Electronic charge-induced failures (Dielectric breakdown, Hot carrier effects, Electrical over-stress and Electrostatic discharge), Environmental damage (moisture ingress, corrosion, radiation damage), packaging, stresses induced because of packaging.

Learning Resources:

Text Books:

1. M.P. Poonia & S.C. Sharma, Total Quality Management, Khanna Book Publishing, 2019.
2. Jose Pineda de Gyvez (Editor), Dhiraj Pradhan (Editor), Integrated Circuit Manufacturability: The Art of Process and Design Integration, Wiley-IEEE Press, 1998,
3. M. Ohring, Reliability and Failure of Electronic Materials and Devices, First Edition, Academic Press, 1998.
4. J.W. McPherson, Reliability Physics and Engineering, Second Edition, Springer, 2013.

Course Outcomes: At the end of the course, the students will be able to

1. Understand the concepts of yield and reliability
2. Understand the mathematical models of calculation of yield and reliability
3. Appreciate the role of defect monitoring in the manufacturing process
4. Estimate the process yield and reliability of the chip.

VLSI-05	Introduction to Microfabrication	3L:0T:0P	3 credits
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Course Contents:

Introduction: History of IC's; Operation & Models for Devices of Interest: CMOS and MEMS. Electronic Materials: Crystal Structures, Defects in Crystals, Si, Poly Si, Si Crystal Growth. Clean room and Wafer Cleaning: Definition, Need of Clean Room, RCA cleaning of Si.

Oxidation: Dry and Wet Oxidation, Kinetics of Oxidation, Oxidation Rate Constants, Dopant Redistribution, Oxide Charges, Device Isolation, LOCOS, Oxidation System

Lithography: Overview of Lithography, Radiation Sources, Masks, Photoresist, Components of Photoresist Optical Aligners, Resolution, Depth of Focus, Advanced Lithography: E-beam Lithography, X-ray Lithography, Ion Beam Lithography.

Diffusion: Pre-Deposition and Drive-in Diffusion Modeling, Dose, 2-Step Diffusions, Successive Diffusion, Lateral Diffusion, Series Resistance, Junction Depth, Irvin's Curves, Diffusion System. Ion Implantation: Problems in Thermal Diffusion, Advantages of Ion Implantation, Applications in ICs, Ion Implantation System, Mask, Energy Loss Mechanisms, Depth Profile, Range & Straggle, Lateral Straggle, Dose, Junction Depth, Ion Implantation Damage, Post Implantation Annealing, Ion Channeling, Multi Energy Implantation

Thin Film Deposition: Physical Vapor Deposition: Thermal evaporation, Resistive Evaporation, Electron beam evaporation, Laser ablation, Sputtering Chemical Vapor Deposition: Advantages and disadvantages of Chemical Vapor deposition (CVD) techniques over PVD techniques, reaction types, Boundaries and Flow, Different kinds of CVD techniques: APCVD, LPCVD, Metalorganic CVD (MOCVD), Plasma Enhanced CVD etc.

Etching: Anisotropy, Selectivity, Wet Etching, Plasma Etching, Reactive Ion Etching.

Overview of Interconnects, Contacts, Metal gate/Poly Gate, Metallization, Problems in Aluminum Metal contacts, Al spike, Electromigration, Metal Silicides, Multi-Level Metallization, Planarization, Inter Metal Dielectric

Text/Reference Books:

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

Course Objectives:

At the end of this course students will demonstrate the ability to

1. Elucidate the CMOS process flow
2. Analyze various critical processing steps in microfabrication
3. Appreciate the advanced methods involved in IC fabrication.
4. Analyze the advancements in CMOS process fabrication with scaling in technology.



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