राष्ट्रीय प्रौद्योगिकी संस्थान मिजोरम

NATIONAL INSTITUTE OF TECHNOLOGY MIZORAM

(An Institute of National Importance under Ministry of Education, Govt. of India)

Chaltlang, Aizawl, Mizoram – 796012

Course Structure & Syllabus for M. Tech Programme in Microelectronics and VLSI System Design

BATCH: 2023-24 onwards

VIDE **BoS** dated **10.03.2023**, **SENATE SNT 21.12** dated **14.03.2023**

सूक्ष्म कणिका एवं संचार अभियांत्रिकी विभाग

Department of Electronics & Communication Engineering

Classification of Credits Points:

1 Hr Lecture (L) per week	1 Hr Tutorial (T) per week	1 Hr Laboratory (P) per week
1 Credits	1 Credits	0.5 Credit

Semester I				
Course Code	**Course Name**	**Category**	**L-T-P**	**Credit**
ECL 2101	Physics of Semiconductor Devices	DC	3-0-0	3
ECL 2102	Analog VLSI Circuits	DC	3-0-0	3
ECL 2103	Digital VLSI Circuits	DC	3-0-0	3
ECL 2104	Semiconductor Device Modeling	DC	3-0-0	3
ECL 21XX	Elective I	DC	3-0-0	3
ECP 2101	Analog VLSI Circuits Lab	DC	0-0-3	1.5
ECP 2102	Seminar	DC	0-0-2	1
TOTAL CREDITS				**17.5**

Semester II				
Course Code	**Course Name**	**Category**	**L-T-P**	**Credit**
ECL 2201	VLSI Physical Design	DC	3-0-0	3
ECL 2202	IC Technology	DC	3-0-0	3
ECL 22XX	Elective II	DC	3-0-0	3
ECL 22XX	Elective III	DC	3-0-0	3
ECP 2201	Digital VLSI Circuits Lab	DC	0-0-3	1.5
ECP 2202	Device and Process Modeling Lab	DC	0-0-3	1.5
ECP 2203	VLSI System Design Lab	DC	0-0-4	2
ECP 2204	Term Paper	DC	0-0-3	1.5
TOTAL CREDITS				**18.5**

Semester III				
Course Code	**Course Name**	**Category**	**L-T-P**	**Credit**
ECP 2301	Project Phase I	DC	0-0-16	8
TOTAL CREDITS				**8**

Semester IV				
Course Code	**Course Name**	**Category**	**L-T-P**	**Credit**
ECP 2401	Project Phase II	DC	0-0-24	12
TOTAL CREDITS				**12**

SEMESTER WISE CREDIT POINT(s)

Semester	Semester I	Semester II	Semester III	Semester IV	TOTAL
Credits	**17.5**	**18.5**	**8**	**12**	**56**

ELECTIVES

Sl. No.	Course Code	Course Name
1	2X01	Mixed Signal VLSI Design
2	2X02	Low Power VLSI Design
3	2X03	MEMS and Microsystems
4	2X04	VLSI Architecture for DSP
5	2X05	VLSI Testing and Verification
6	2X06	Embedded Systems
7	2X07	RF IC Design
8	2X08	Nanoelectronics
9	2X09	Compound Semiconductors
10	2X10	Semiconductor Optoelectronics: Theory and Design
11	2X11	Nanoscale Semiconductor FET

Syllabus of First Semester

ECL 2101 **Physics of Semiconductor Devices**

L-T-P: 3-0-0 **Credits: 3**

1. Introduction: Review of Semiconductor Devices, Carrier Statistics, Basic Crystal Structure, Valence Bonds, Energy Bands. **10 Lectures**

2. Semiconductors in Equilibrium and Carrier Transport in Semiconductors: Semiconductor Materials, Carrier Concentration, Carrier Drift, Carrier Diffusion, Generation and Recombination Process, Continuity Equation, Thermionic Emission, Tunneling, Ballistic Transport, High Field Effects. **8 Lectures**

3. Physics of Junction Devices: Thermal Equilibrium Condition, Depletion Region, Depletion and Diffusion Capacitances, Current-Voltage Characteristics, Charge Storage and Transient Behavior, Junction Breakdown, Metal Semiconductor Contacts, Optoelectronics devices. **10 Lectures**

4. Physics of Bipolar devices: Transistor Action, Static Characteristics, Frequency Response and Switching, Heterojunction. **6 Lectures**

5. Metal-semiconductor & Fundamentals of MOS and Field effect Devices: MOS Capacitor, MOSFET Fundamentals, MOSFET Scaling, CMOS and BiCMOS, SoI. **6 Lectures**

Text Books:

1. Semiconductor Physics and Devices, 3ed, An Indian Adaptation, S. M. Sze, M. K. Lee, R. S. Dhar, A. Nair, 2021 Wiley India.
2. Semiconductor Devices: Modeling and Technology by A Dasgupta, N. Dasgupta, Prentice Hall of India Private Limited, 2004.
3. Solid State Physics by Neil W. Ashcroft, N. David Mermin, Cengage Learning, 2011.

Reference Books:

1. Physics of Semiconductor Devices by S. M. Sze and Kwok K. Ng, John Wiley & Sons, 3rd Edition, 2002.
2. Solid State Electronic Devices by Ben G. Streetman and Sanjay Banerjee, Prentice Hall, 6th Edition, 2005.
3. Semiconductor Device Fundamentals by Robert F. Pierret, Addison-Wesley Publishing, 1996
4. Semiconductor Physics and Devices by Donald A. Neamen, Mc GrawHill, 3rd Edition 2003
5. Semiconductor Devices- Basic Principles by Jasprit Singh, John Wiley and Sons Inc., 2001

ECL 2102 **Analog VLSI Circuits**
L-T-P: 3-0-0 **Credits: 3**

1. **Introduction:** Basic MOSFET device, characteristics, second order effects, MOS device model.	**6 Lectures**
2. **Amplifiers:** Low frequency and high frequency operation of single stage amplifier and differential amplifier, **(i) Single stage amplifiers:** common source (CS), source follower, common gate stage, cascade stage with different load; **(ii) Differential Amplifiers:** Basic differential operation, common mode response, Current mirror, differential amplifier with current mirror load.	**7 Lectures**
3. **Noise analysis:** Statistical characteristic of noise, thermal noise, Flicker noise, representation noise in circuits	**3 Lectures**
4. **Operational amplifier:** one stage OPAMP, two stage OPAMP, gain boosting, common mode feedback, slew rate, power supply rejection.	**3 Lectures**
5. **Bandgap references:** Supply independent biasing, temperature independent references, PTAT and CTAT current generation	**4 Lectures**
6. **Switched capacitor circuits:** Sampling switches, switched capacitor amplifier, switched capacitor integrator.	**3 Lectures**
7. **Oscillators:** Feedback and Stability, Ring Oscillator, L-C oscillator, Voltage Control oscillator, phase locked loop, building blocks, locking characteristics and design.	**5 Lectures**
8. **Comparator:** Simple, Switch-based and latch based.	**3 Lectures**
9. **Data Converter:** Characterization of ADC and DAC, ADC and DAC architectures.	**3 Lectures**
10. **Active Filters:** Design of switch capacitor filer, Design of Gm-C filter.	**3 Lectures**

Text Books:
1. Design of Analog CMOS Integrated Circuits by Behzad Razavi, McGraw Hill, 2003
2. CMOS Analog Circuit Design by P.E Allen and Douglas R. Holdberg, Oxford University Press, 2nd edition, 2012.

Reference Books:
1. Analysis and Design of Analog Integrated Circuits by Paul Gray and Robert G Meyer, John Wiley & Sons, 2009
2. Analog Circuit Design by Johan Huijsing Rudy van Plassche and Willy Sansen, Springer Science and Business Media, B.V.

ECL 2103 **Digital VLSI Circuits**

L-T-P: 3-0-0 **Credits: 3**

1. Combinational logic design: Static CMOS design-complementary CMOS-static properties- complementary CMOS design-Power consumption in CMOS logic gates- dynamic or glitching transitions- Design techniques to reduce switching activity- Radioed logic-pass transistor logic- Differential pass transistor logic- Sizing of level restorer-Sizing in pass transistor-Dynamic CMOS design-Basic principles -Domino logic optimization of Domino logic-NPCMOS-logic style selection Designing logic for reduced supply voltages. **10 Lectures**

2. Sequential logic design: Timing metrics for sequential circuit -latches Vs registers-static latches and registers - Bi-stability principle - multiplexer based latches-master slave edge triggered registers- non-ideal clock signals low voltage static latches-static SR flip flop - Dynamic latches and registers-CMOS register - Dual edge registers-True single phase clocked registers-pipelining to optimize sequential circuit latch Vs register based pipelines-non-Bistable sequential circuit-Schmitt trigger-mono stable–Astable sequential circuit - choosing a clocking strategy. **12 Lectures**

3. CMOS subsystem design: Data Path Operations: Addition/Subtraction – Comparators – Zero/One Detectors- Binary Counters- General arrangement of 4-bit Arithmetic Processor, Design of 4-bit shifter, Design of ALU subsystem, Implementing ALU functions with an adder, Carry-look-ahead adders, Multipliers, Serial Parallel multipliers, Pipeline multiplier array, modified Booth's algorithm, Memory elements, control: Finite-State Machines. **12 Lectures**

4. HARDWARE MODELING WITH THE VERILOG HDL: Hardware Encapsulation – The Verilog Module, Descriptive Styles, Structural Connections, Behavioral Description In Verilog, Hierarchical Descriptions of Hardware, Structured (Top Down) Design Methodology, Using Verilog for RTL Synthesis. **6 Lectures**

Text Books:

1. CMOS VLSI Design –A Circuits and Systems Perspective by Neil H Weste, D Harris and Ayan Banerjee, Pearson, 2012.
2. Digital Integrated Circuits- A Design Perspective by J M Rabaey, Prentice Hall, 3rd Edition, 2012.
3. FPGA based systems, Waney Wolf, Pearson, 1st ed, 2005.
4. Sung-Mo Kang, Yusuf Leblebici, "CMOS Digital IC-Analysis and Design", Tata McGraw Hill publication.

Reference Books:

1. M. D. CILETTI, "Modeling, Synthesis and Rapid Prototyping with the Verilog HDL", Prentice-Hall.
2. M. G. ARNOLD, "Verilog Digital – Computer Design", Prentice-Hall.

ECL 2104 Semiconductor Device Modeling
L-T-P: 3-0-0 Credits: 3

1. Introduction: Semiconductor, Junctions and Overview **2 Lectures**

2. Two terminal MOS Structure: Introduction, Flat band voltage, Potential Balance and charge balance, Effect of gate body voltage on surface condition, Accumulation and depletion, Inversion, CV Characteristics. **6 Lectures**

3. Three terminal MOS Structure: Introduction, Contacting the Inversion layer, The body effect, Regions of inversion, VCB control. **6 Lectures**

4. Four terminal MOS Structure: Introduction, Transistor region of operation, Complete all region model, Simplified all region models, Model based on Quasi-Fermi Potential, Regions of inversion in term of terminal voltages, strong inversion, weak inversion, moderate inversion, source referenced vs body referenced modeling, effective mobility, temperature effects. **10 Lectures**

5. Small Dimension Effects: Introduction, carrier velocity saturation, channel length modulation, charge sharing, drain induced barrier lowering, punch through, hot carrier effects, polysilicon depletion, quantum mechanical effects, DC gate current, junction leakage: band to band tunneling and GIDL, leakage currents. **8 Lectures**

6. Large signal modeling: Introduction, quasi static operation, terminal currents in quasi static operation, transit time under DC conditions, limitations of Quasi static model, non-quasi static modeling, extrinsic parasitic. **6 Lectures**

7. Small signal modeling: Introduction, low frequency small signal model, medium frequency small signal model, noise, all region models. **6 Lectures**

8. High frequency small signal models: Introduction, quasi-static model, y-parameter models, non quasi static models, high frequency noise. **4 Lectures**

Text Books:

1. Operation and modeling of the MOS transistor by Yannis Tsividis, Oxford University Press, 2011.

Reference Books:

1. Charge-Based MOS Transistor Modeling: The EKV Model for Low-Power and RF IC Design by Christian C. Enz, Eric A. Vittoz, Wiley, 2006.
2. Fundamental of Modern VLSI devices by Yuan Taur and Tak H. Ning, Cambridge University press, 2nd Edition, 1998.

ECL 21XX	**Elective I**	
L-T-P: 3-0-0		**Credits: 3**
As per syllabus of chosen elective from list of electives.		

ECP 2101	**Analog VLSI Circuits Lab**	
L-T-P: 0-0-3		**Credits: 1.5**
As per syllabus of ECL 2102.		

ECP 2102	**Seminar**	
L-T-P: 0-0-2		**Credits: 1**
As allotted by the department.		

Syllabus of Second Semester

ECL 2201 VLSI Physical Design

L-T-P: 3-0-0 Credits: 3

1. Introduction: VLSI Design Cycle, Physical Design Cycle, Design Styles, System Packaging Styles, Algorithmic complexity and optimization problems	**4 Lectures**
2. Partitioning: Problem formulation, Classification of Partitioning algorithms, Kernighan-Lin Algorithm, Simulated Annealing.	**4 Lectures**
3. Floor planning: Problem formulation, Classification of floor planning algorithms, Constraint based floor planning, Rectangular dualization.	**4 Lectures**
4. Pin Assignment: Problem formulation, Classification of pin assignment algorithms, General and channel pin assignments.	**5 Lectures**
5. Placement: Problem formulation, Classification of placement algorithms, Partitioning based placement algorithms.	**5 Lectures**
6. Global Routing and Detailed Routing: Global Routing: Problem formulation, Classification of global routing algorithms, Maze routing algorithms; Detailed Routing: Problem formulation, Classification of routing algorithms, Single layer routing algorithms.	**5 Lectures**
7. Physical Design Automation of FPGAs: FPGA Technologies, Physical Design cycle for FPGAs, Partitioning, Routing: Routing Algorithm for the Non-Segmented model, Routing Algorithms for the Segmented Model; Physical Design Automation of MCMs: Introduction to MCM Technologies, MCM Physical Design Cycle.	**7 Lectures**
8. Chip Input and Output Circuits: ESD Protection, Input Circuits, Output Circuits and noise, On-chip clock Generation and Distribution, Latch-up and its prevention.	**4 Lectures**
9. On Chip PDN Design: Noise and Decap Placement.	**2 Lectures**

Text Books:

1. Algorithms for VLSI Physical Design Automation by Naveed Shervani, Springer International Edition, 3rd Edition, 2005.
2. VLSI Physical Design Automation Theory and Practice by Sadiq M Sait, Habib Youssef, World Scientific.
3. FPGA based systems design, Waney Wolf, Pearson, 1st ed, 2005

Reference Books:

1. Algorithms for VLSI Design Automation, S. H. Gerez, 1999, Wiley student Edition, John Wiley and Sons (Asia) Pvt. Ltd.
2. VLSI Physical Design Automation by Sung Kyu Lim, Springer International Edition.

ECL 2202 **IC Technology**
L-T-P: 3-0-0 **Credits: 3**

1. Introduction: Integrated Circuits and Planar Process, IC Families, CMOS Process Flow. **2 Lectures**

2. Crystal Growth and Wafer Fabrication: Crystal Structure, Defects in Crystals, Raw materials and Purification, Czochralski and Float-Zone Crystal Growth Methods, Wafer Preparation and Specification, Measurement Methods. **6 Lectures**

3. Lithography: Light Sources, Wafer Exposure Systems, Photoresists, Mask Engineering, Measurement of Mask Features and Defects, Resist Patterns and Etched Features. **4 Lectures**

4. Oxidation: Basic Concepts, Wet and Dry methods, Measurement Methods: Physical, Electrical and Optical, Models and Simulation: Linear and Parabolic, Growth Kinetics, Effect of Temperature, Pressure and Crystal Orientation. **2 Lectures**

5. Memory testing: Permanent, intermittent and pattern-sensitive faults; test generation. **5 Lectures**

6. Ion Implantation: Role of Crystal Structure, High-Energy Implants, Ultralow Energy Implants, Ion Beam Heating, Measurement Methods, Models: Nuclear Stopping, Electronic Stopping, Damage and annealing. **2 Lectures**

7. Deposition: Manufacturing Methods, CVD, APCVD, LPCVD, PECVD, PVD, Epitaxial Silicon, MBE, MOCVD, Polycrystalline Silicon, dielectrics and metals, Measurement and models. **6 Lectures**

8. Etching: Wet, Plasma Etching, Etching of Various Films, Measurement and Models. **4 Lectures**

9. Back-end technology: Contacts, Interconnects and Vias, Silicide Gates and Source/Drain Regions, IMD Deposition and Planarization, Chemical-Mechanical Polishing, Electro-migration, Measurement methods and methods. **6 Lectures**

10. Wafer Processing, Process Variation and DFM. **3 Lectures**

Text Books:
1. Silicon VLSI Technology by James Plummer, M. Deal and P.Griffin, Prentice Hall Electronics and VLSI series, 2009.
2. Semiconductor Devices: Basic Principles, Wiley Student edition, Paperback, 2007, Jasprit Singh.
3. VLSI Technology, by S M Sze, McGraw-Hill, 1988.

Reference Books:
1. The Science and Engineering of Microelectronics, by Stephen Campbell, Oxford University Press, 1996.
2. VLSI Fabrication Principles by Sorab K Ghandhi, John Wiley and Sons, 2nd Edition, 1994.
3. Microchip Fabrication by Peter van Zant, MicraGraw Hill, Sixth edition, 2013

ECL 22XX	**Elective II**	
L-T-P: 3-0-0		**Credits: 3**
As per syllabus of chosen elective from list of electives.		

ECL 22XX	**Elective III**	
L-T-P: 3-0-0		**Credits: 3**
As per syllabus of chosen elective from list of electives.		

ECP 2201	**Digital VLSI Circuits Lab**	
L-T-P: 0-0-3		**Credits: 1.5**
As per syllabus.		

ECP 2202	**Device and Process Modeling Lab**	
L-T-P: 0-0-3		**Credits: 1.5**
As per syllabus.		

ECP 2203	**VLSI System Design Lab**	
L-T-P: 0-0-4		**Credits: 2**
Areas to be considered: Analog Design: OPAMP, ADC, Ring VCO, LC VCO Digital Design & FPGA: DFT, FFT, ALU, Memory Tools: Analog: Cadence & Synopsis Digital: Synopsis & Xilinx For Analog & Digital Design (except FPGA), the students should perform schematic level design, process corner simulation and temperature variation simulation, layout and post layout simulation. For FPGA Design: Simulation, RTL Synthesis and FPGA Hardware Implementation.		

ECP 2204	**Term Paper**	
L-T-P: 0-0-3		**Credits: 1.5**
As allotted by the department.		

Third Semester

ECP 2301	**Project Phase I**	
L-T-P: 0-0-16		**Credits: 8**

Fourth Semester

ECP 2401	**Project Phase II**	
L-T-P: 0-0-24		**Credits: 12**

Syllabus of Electives

ECL 2X01 **Mixed Signal VLSI Design**
L-T-P: 3-0-0 **Credits: 3**

1. Introduction: Signals, Filters and Tools: Sinusoidal Signals, Comb Filters, Representing Signals, Sampling and Aliasing. **4 Lectures**

2. Filters: Continuous-time filters, Discrete-time filters, Analog and discrete-time signal processing, Analog integrated continuous-time and discrete-time (switched-capacitor) filters. **6 Lectures**

3. Digital Converters: Basics of Analog to digital converters (ADC), Basics of Digital to analog converters (DAC), DACs, Successive approximation ADCs, Dual slope ADCs, High-speed ADCs: flash ADC, pipeline ADC and related architectures, High-resolution ADCs: delta-sigma converters. **8 Lectures**

4. Phase locked loops: Phase Detector Voltage Controller Oscillator, Loop Filter: XOR DPLL, PFD DPLL, System Concerns: Clock Recovery from NRZ Data, Delay-Locked Loops. **6 Lectures**

5. VLSI Layout: Chip Layout: Regularity, Standard Cell Examples, Power and Ground Considerations, Layout Steps by Dean Moriarty: Planning and Stick Diagrams, Device Placement, Polish, Standard cells Versus Full-Custom Layout. **8 Lectures**

6. Interconnects: Basics, application, RC delay and its model. **6 Lectures**

Text Books:
1. CMOS mixed-signal circuit design by R. Jacob Baker, Wiley India, IEEE press, 2008.

Reference Books:
1. Design of analog CMOS integrated circuits by Behzad Razavi, McGraw-Hill, 2003.
2. CMOS circuit design, layout and simulation by R. Jacob Baker, Revised second edition, IEEE press, 2008.
3. CMOS Integrated ADCs and DACs by Rudy V. dePlassche, Springer (Indian edition), 2005.
4. Electronic Filter Design Handbook by Arthur B. Williams, McGraw-Hill, 1981.
5. Design of analog filters by R. Schauman, Prentice-Hall 1990.

ECL 2X02 **Low Power VLSI Design**
L-T-P: 3-0-0 **Credits: 3**

1. Introduction: Low power and its applications; Algorithmic, Architectural, Gate and Physical Level power reduction approaches. **6 Lectures**

2. Sources of Power Dissipation: Dynamic Power Dissipation: Short Circuit Power, Switching Power, Glitching Power; Static Power Dissipation, Degrees of Freedom. **8 Lectures**

3. Supply Voltage Scaling Approaches: Device feature size scaling, Multi-Vdd Circuits, Voltage scaling using high-level transformations, Dynamic voltage scaling, Power Management. **8 Lectures**

4. Switched Capacitance Minimization Approaches: Hardware Software Tradeoff, Bus Encoding Two's complement verses Sign Magnitude, Clock Gating. **8 Lectures**

5. Leakage Power minimization Approaches: Variable-threshold-voltage CMOS (VTCMOS) approach, multi-threshold-voltage CMOS (MTCMOS) approach, Power gating, Transistor stacking, Dual-Vt assignment approach (DTCMOS). **6 Lectures**

6. Low Power Design Examples: Memory, Arithmetic circuits. **4 Lectures**

Text Books:

1. Low Power VLSI CMOS Circuit Design, by A. Bellamour, and M. I. Elmasry, Springer Science + Business Media, 2012.
2. Low Power Design Essentials (Integrated Circuits and Systems), by Jan Rabaey, Springer, 2009.

Reference Books:

1. Principles of CMOS VLSI Design, by Neil H. E. Weste and K. Eshraghian, Addison Wesley (Indian reprint).
2. CMOS Digital Integrated Circuits, by Sung Mo Kang, Yusuf Leblebici,Tata McGraw Hill.
3. Low Power Digital CMOS Design, by Anantha P. Chandrakasan and Robert W. Brodersen, Kluwer Academic Publishers, 1995.
4. Low Power CMOS VLSI circuit design by Kaushik Roy, Sharat C. Prasad, John Willy & Sons, 2009.

ECL 2X03 **MEMS and Microsystems**
L-T-P: 3-0-0 **Credits: 3**

1. Scaling Laws, Why MEMS?	**2 Lectures**
2. Micro-fabrication Techniques: Bulk micro machining, surface micro machining and LIGA processes	**6 Lectures**
3. MEMS based inertial sensors: Accelerometer; piezo-resistive and capacitive.	**6 Lectures**
4. MEMS based gyro and tilt sensors	**2 Lectures**
5. MEMS based pressure sensor: Type Pressure Monitoring System	**2 Lectures**
6. Electrostatic actuation: study of electrostatically actuated micro-machined cantilever beam: Free natural mode of vibration, resonance analysis, static voltage response, pull-in and pull-out phenomenon. Dynamic response to time varying electrostatic actuation	**4 Lectures**
7. RF MEMS: RF switch, MEMS based inductor and capacitors, MEMS based varactors and resonators.	**6 Lectures**
8. Optical MEMS: MEMS based mirrors, MEMS based optical switch	**2 Lectures**
9. Microfluidic and Bio MEMS: advantages of MEMS based fluidic system.	**1 Lectures**
10. Micro pump and Micro valve, Micro nozzle and thrusters, micro needle, micro cantilever-based bio sensors, lab on a chip**.**	**6 Lectures**
11. MEMS based interfacing electronics: variable gain instrumentation amplifier and wireless integrated micro sensors.	**4 Lectures**

Text Books:

1. Analysis and design principles of MEMS devices by M.-H. Bao.
2. Microsystem Design by Stephen D. Senturia, Kluwer Academic Publishers, 2001.
3. Micro and Smart system by G. K. Ananthasuresh, K.J. Vinoy, S. Gopalakrishnan, K. N. Bhat, V. K. Aatre, Wiley, 2012.
4. Fundamentals of Microfabrication techniques, Marc Madou, CRC Press

ECL 2X04 **VLSI Testing and Verification**
L-T-P: 3-0-0 **Credits: 3**

1. Physical faults and their modeling: Automatic test pattern generation. Fault equivalence and dominance; fault collapsing, permanent and transient faults.	**8 Lectures**
2. Fault simulation: Parallel, deductive and concurrent techniques; critical path tracing.	**3 Lectures**
3. Test generation for combinational circuits: Boolean difference, D-algorithm, PODEM, Exhaustive, random and weighted test pattern generation; aliasing and its effect on fault coverage.	**6 Lectures**
4. PLA testing: Cross-point fault model, test generation, easily testable designs.	**4 Lectures**
5. Diffusion: Dopant Solid Solubility, Fick's Law, Predeposition and drive-in, Gaussian Solution near a Surface, Measurement Methods: SIMS, Spreading Resistance, Sheet Resistance, Capacitance Voltage.	**4 Lectures**
6. Test pattern generation for sequential circuits: Ad-hoc and structured techniques; scan path and LSSD, boundary scan.	**4 Lectures**
7. Design for testability, Built-in self-test techniques, System-on-chip (SoC) testing. Low-power testing. Delay fault testing. Iddq testing.	**4 Lectures**
8. Design verification techniques based on simulation, analytical and formal approaches. Functional verification. Timing verification. Formal verification.	**4 Lectures**
9. Basics of equivalence checking and model checking. Hardware emulation	**3 Lectures**

Text Books:

1. Design of analog CMOS integrated circuits by Behzad Razavi, McGraw-Hill, 2003.
2. CMOS circuit design, layout and simulation by R. Jacob Baker, Revised second edition, IEEE press, 2008.
3. CMOS Integrated ADCs and DACs by Rudy V. dePlassche, Springer (Indian edition), 2005.
4. A roadmap for formal property verification, Pallab Das Gupta, Springer, 1st ed, 2006 with NPTEL lectures.
5. Essentials of electronic testing for digital, memory and mixed signal VLSI circuits, M L Bushnell and V D Agarwal, Springer, 1st ed, 2002

Reference Books:

1. VLSI Physical Design Automation Theory and Practice by Sadiq M Sait, Habib Youssef, World Scientific.

ECL 2X05 **VLSI Architecture for DSP**
L-T-P: 3-0-0 **Credits: 3**

1. Introduction: Introduction to DSP systems, DSP application demand and scaled CMOS technologies, representation of DSP algorithms, DFT and FFT. **3 Lectures**

2. Iteration bound: Introduction, data flow graph representations, loop bound and iteration bound, algorithms for computing iteration bound. **4 Lectures**

3. Pipelining and parallel processing: Introduction, pipelining of FIR digital filters, parallel processing, pipelining and parallel processing for low power. **5 Lectures**

4. Retiming: Introduction, properties, solving systems of inequalities, retiming techniques. **6 Lectures**

5. Unfolding: Introduction, algorithm for unfolding, properties, critical path, unfolding and retiming, applications. **6 Lectures**

6. Folding: Introduction, folding transformation, register minimization techniques, register minimization in folded architectures. **6 Lectures**

7. Systolic Architecture Design: Introduction, systolic array design methodology, FIR systolic arrays, scheduling vector, matrix multiplication and 2D systolic array design. **4 Lectures**

8. Bit level arithmetic architectures: Introduction, parallel multipliers, bit serial multipliers, bit serial filter design and implementation, canonic signed digit arithmetic, distributed arithmetic. **4 Lectures**

9. Redundant Arithmetic: Introduction, Redundant number representation, carry free radix-2 additions and subtractions, hybrid radix-4 addition, radix-2 hybrid redundant multiplication architecture, data format conversion. **4 Lectures**

Text Books:

1. VLSI digital signal processing systems by K K Parhi, John Wiley & Sons, 1999.

Reference Books:

1. DSP with FPGA by U. Meyer-Baese, Springer, 2004.

ECL 2X06 **Embedded Systems**

L-T-P: 3-0-0 **Credits: 3**

1. Introduction: Features, Design metrics, Design flow.	**2 Lectures**
2. ARM Microcontroller: ARM Instruction set architecture, ARM pipeline, THUMB instructions, Exceptions in ARM.	**5 Lectures**
3. Digital Signal Processors: Architecture, Data access features, Computation features, Accuracy, C6000 family of DSP.	**4 Lectures**
4. Field Programmable Gate Arrays: Field programmable devices, Programmability, Logic block variations, Design flow, Modern FPGAs, Concept of soft and hard IP.	**5 Lectures**
5. Interfacing: Requirements, SPI, IIC, RS232-C family, USB, IrDA, CAN, Bluetooth, PCI	**7 Lectures**
6. Real-time System Design: Task classification, Periodicity, Task scheduling, Scheduling algorithms, Resource sharing, Commercial RTOS.	**8 Lectures**
7. Hardware-Software Codesign: Introduction to specification, partitioning and co-simulation.	**5 Lectures**
8. Case studies: Example embedded system design, such as digital camera etc.	**4 Lectures**

Text Books:

1. Embedded System Design, by S. Chattopadhyay, 2nd Edition, 2014.
2. Embedded System Design: A Unified Hardware/Software Introduction, 2002.

Reference Books:

1. Embedded System Design, P. Marwedel, 2003.

ECL 2X07 **RF IC Design**
L-T-P: 3-0-0 **Credits: 3**

1. Introduction to RF and Wireless Technology: Complexity, design and applications. Choice of Technology. **2 Lectures**

2. Basic concepts in RF Design: Nonlinearly and Time Variance, inter-symbol Interference, random processes and Noise. Definitions of sensitivity and dynamic range, conversion Gains and Distortion. **4 Lectures**

3. Analog and Digital Modulation for RF circuits: Comparison of various techniques for power efficiency. Coherent and Non coherent defection. Mobile RF Communication systems and basics of Multiple Access techniques. Receiver and Transmitter Architectures and Testing heterodyne, Homodyne, Image-reject, Direct-IF and sub-sampled receivers. Direct Conversion and two steps transmitters. BJT and MOSFET behavior at RF frequencies Modeling of the transistors and SPICE models. Noise performance and limitation of devices. Integrated Parasitic elements at high frequencies and their monolithic implementation. **10 Lectures**

4. Basic blocks in RF systems and their VLSI implementation: Low Noise Amplifiers design in various technologies, Design of Mixers at GHz frequency range. Various Mixers, their working and implementations. **6 Lectures**

5. Oscillators: Basic topologies VCO and definition of phase noise. Noise-Power trade-off. Resonator-less VCO design. Quadrature and single-sideband generators. **6 Lectures**

6. Radio Frequency Synthesizers: PLLS, design of integer-N RF frequency synthesizer and frequency dividers. **5 Lectures**

7. Design issues in integrated RF filters: Some discussion on available CAD tools for RF VLSI designs; Prerequisite: (Analog VLSI Design). **4 Lectures**

8. RF power amplifier and linearization techniques: Classification of power amplifiers, design of class AB and class E amplifier, various techniques of linearization in cartesian mode **3 Lectures**

Text Books:

1. RF Microelectronics by B Razavi, Prentice-Hall PTR, 1998.
2. The Design of CMOS Radio-Frequency Integrated Circuits, by T H Lee, Press, 1998.
3. Power Amplifier by Cripp

Reference Books:

1. CMOS Circuit Design, Layout and Simulation, by R J Baker, H W Li, and D.E. Boyce, Prentice-Hall, 1998.
2. Mixed Analog and Digital VLSI Devices and Technology by Y P Tsividis, McGraw Hill, 1996.

ECL 2X08 **Nanoelectronics**
L-T-P: 3-0-0 **Credits: 3**

1. Introduction: Nanotechnology and Nanoelectronics, Top-down and Bottom-up approach, Moore's Law, Review of Semiconductor Electronics, Maxwell's Equation, Poisson Equation, Continuity Equations, carrier concentration, Carrier Transport, Drift, diffusion, density of states. **3 Lectures**

2. Basics of Quantum Mechanics: Photoelectric effect, wave nature of particles and wave-particle duality, Compton Effect, Uncertainty Principle, Schrodinger's equations and its applications, wave function and its duality and postulates. Infinite well, finite well, triangular well, potential barrier, tunnelling probability, step-potential function. Atomic orbital, Pauli-exclusion principle, optical device principle, Quantum dots, wires, and wells, Ballistic Transport. **14 Lectures**

3. Nanoelectronic Devices: CMOS scaling: advantages and limitations. Nanoscale MOSFETs, FINFETs, Vertical MOSFETs, system integration limits (interconnect issues etc.), Tunneling Transistors, Single electron transistors, spintronics, and Junctionless Transistor. **13 Lectures**

4. Emerging Nano Devices: SOI MOSFET and FinFET; strained Si FET; Heterostructure on Insulator System; HOI MOSFET, DGFET, FinFET, NanoFET; CGAA, triangular GAA, rectangular GAA, strained channel GAA; strained channel array FinFET and GAA. **12 Lectures**

Text Books:
1. S. M. Sze, M. K. Lee, R. S. Dhar, A. Nair, Semiconductor Physics And Devices, 3ed, An Indian Adaptation, Wiley India, 2021.
2. C.P. Poole Jr. and F.J. Owens, Introduction to Nanotechnology, Wiley, 2003.
3. D.A. Neamen, Semiconductor Physics & Devices, TMH, 2003.
4. G.W. Hanson, Fundamentals of Nanoelectronics, Pearson, 2009.

Reference Books:
1. C. Kittel, Introduction to solid state physics, Wiley, New York, 1976.
2. K. Iniewski, Nanoelectronics: nanowires, molecular electronics, and nanodevices, Mc Graw Hill, New York, 2011.
3. K. Sienicki, Molecular Electronics and Molecular Electronic Devices, CRC Press, 1994.
4. J.H. Davies, The Physics of Low-Dimensional Semiconductors, Cambridge University Press, 1998.
5. R.F. Pierrett, Semiconductor Device Fundamentals, Pearson, 2006.
6. B.G. Streetman and S. Banerjee, Solid State Electronic Devices, Pearson, 2008.

ECL 2X09 **Compound Semiconductors**
L-T-P: 3-0-0 **Credits: 3**

1. Introduction: Basics of Quantum Mechanics, Expectation Value, Density of states. Electron and Phonons in Cryatals, Heterostructure, Quantum Well and Low dimensional system, Tunnelling Transport, Schrödinger Equation in Electric and Magnetic field, Scattering, 2DEG. **4 Lectures**

2. Material properties: Merits of III–V binary and ternary compound semiconductors (GaAs, InP, InGaAs, AlGaAs, SiC, GaN etc.), different SiC structures, SiGe and SiC for high speed devices compared to Si based devices, dopants and electrical properties such as carrier mobility, velocity versus electric field characteristics of these materials, electric field characteristics of materials and device processing techniques, Band diagrams, homo and hetro junctions, electrostatic calculations, Band gap engineering, doping, Material and device process technique with these III-V and IV – IV semiconductors. **16 Lectures**

3. Metal semiconductor contacts and Metal Insulator Semiconductor and MOS devices: Native oxides of Compound semiconductors for MOS devices and interface state density. Metal semiconductor contacts, Schottky barrier diode, MESFETs: Pinch off voltage and threshold voltage of MESFETs. D.C. characteristics and analysis of drain current. Velocity overshoot effects and related advantages of GaAs, InP and GaN based devices for high-speed operation. Sub threshold characteristics, short channel effects and performance of scaled down devices. **9 Lectures**

4. High Electron Mobility Transistors (HEMT): Hetero-junction devices. Modulation Doped FET(MODFET) for high electron mobility realization. Principle of operation and unique features of HEMT, InGaAs/InP HEMT, Pseudomorphic and Metamorphic HEMT, Hetero junction Bipolar transistors (HBTs): Principle of operation for high-speed applications. GaAs and InP HBT device and surface passivation for stable high gain high frequency performance. SiGe HBTs and concept of strained layer devices; High Frequency resonant –tunneling devices, Resonant-tunneling hot electron transistors **13 Lectures**

Text Books:

1. C.Y. Chang, F. Kai, GaAs High-Speed Devices: Physics, Technology and Circuit Applications, Wiley & Sons.
2. Gandhi S K, VLSI Fabrication Principles: Silicon and Gallium Arsenide, John Wiley & Sons (2013).
3. Sandip Tiwari, Compound Semiconductor Device Physics, Academic Press (1991), ISBN 0- 12-691740-X.
4. S.M. Sze, High Speed Semiconductor Devices, Wiley (1990) ISBN 0-471-62307-5
5. Griffiths, David J. Introduction to Quantum Mechanics. Pearson Prentice Hall, 2004. ISBN: 9780131118928.

Reference Books:

1. David K. Ferry, Ed., Gallium Arsenide Technology, Howard W. Sams & Co., 1985
2. Avishay Katz, Indium Phosphide and Related materials: Processing, Technology and Devices, Artech House, 1992.
3. Ralph E. Williams, Modern GaAs Processing Methods, Artech (1990), ISBN 0-89006-343-5.

ECL 2X10 Semiconductor Optoelectronics: Theory and Design
L-T-P: 3-0-0 **Credits: 3**

1. Background: carrier distributions, pn junctions, carrier injection **2 Lectures**

2. Photodetectors: absorption in bulk semiconductors, displacement currents, gain-bandwidth limits **3 Lectures**

3. Modulators: absorption in quantum wells, quantum confined Stark effect **4 Lectures**

4. Optical amplifiers: population inversion and gain, non-radiative recombination, coupled electron-photon rate equations, gain saturation, optical confinement **5 Lectures**

5. Lasers: Fabry-Perot resonators, lasing threshold **3 Lectures**

6. Heterostructure materials: optical and electrical properties of alloys, heterostructure band alignment **3 Lectures**

7. Distributed feedback (DFB) and surface emitting laser resonators: T-matrix formalism and coupled mode theory, grating based resonators **4 Lectures**

8. Tunable optics: chirp in semiconductor media, electro-optic effects **3 Lectures**

9. Modulation: small-signal and large signal analysis **3 Lectures**

10. Noise in optoelectronic devices: Langevin theory, shot noise limits, relative intensity noise (RIN) of lasers **3 Lectures**

11. Systems: WDM system design, noise and power budget for fiber optic systems **3 Lectures**

Text Books:

1. Diode Lasers and Photonic Integrated Circuits, Coldren, and Corzine, 1st ed. New York, NY: Wiley-Interscience, October 16, 1995. ISBN: 0471118753.
2. Physics of Optoelectronic Devices, Chuang, S. L, New York, NY: Wiley-Interscience, September 8, 1995. ISBN: 0471109398.
3. Optoelectronics – An Introduction to materials and devices; Jasprit Singh, McGraw-Hill, 1996
4. Semiconductor optoelectronic devices; P. Bhattacharya, Prentice Hall India, 2006.
5. Optoelectronics - Advanced Materials and Devices; Pyshkin and Ballato, InTech, 2013

Reference Books:

1. Introduction to Organic Electronic and Optoelectronic Materials and Devices; Sun and Dalton, CRC Press, 2008.
2. Principles of Electronic Materials and Devices; Kasap; McGraw-Hill, 2005.
3. Fiber Optics and Optoelectronics, R. P. Khare, Oxford, 2004.

ECL 2X11 Physics of Nanoscale FET

L-T-P: 3-0-0 **Credits: 3**

1. Fundamental Concepts: Density of states, 3D, 2D, 1D; carrier densities; ballistic transport: quantum, semi-classical; band-to-band tunneling; MOSFET and Moore's law, Koomey's law; short channel and narrow width effects; Natori's theory, degenerate, nondegenerate and general condition statistics, quantum capacitance. **Lectures: 08**

2. SOI Nano MOSFET: Short channel effects; Single gate, double gate, triple gate and surround gate (GAA) structures; classical and quantum physical effects in multi-gate SOI MOSFET; Multigate FET technology: active areas of Fin, mobility and strain engineering. **Lectures: 10**

3. Multigate Nano FET Physics: Double gate MOS system; impact of carrier confinement and quasi-ballistic transport; oxide thickness, and electron tunnelling; Mobility: phonon limited, interface scattering, Coulomb scattering, temperature dependence, strained double gate SOI. **Lectures: 10**

4. Nanowire FET: Silicon nanowire FET, IV characteristics; electron transport, surface roughness; Bandstructure of carbon nanotubes: graphene, nanotubes, Fermi points; Carbon nanotube FETs. **Lectures: 08**

5. Strain Engineering Nano FET: Strain engineered hetero-FET; Engineered substrates: virtual substrate, strained SOI; Substrate-induced Strained-Si; Double and tri-layered strain HOI system, Strain effect and thickness calculation, threshold voltage, Mobility, thickness and temperature dependence; Characterization of Strained-Si Hetero-FETs. **Lectures: 06**

Text Books:

1. M. Lundstrom, and J. Guo, Nanoscale Transport: Device Physics, Modelling and Simulation, Springer, 2005.
2. Sze, S. M., Lee, M. K., Dhar, R. S., and Nair, A. R., "Semiconductor Physics and Devices and Indian Adaptation", 3rd Ed., Wiley. 2021.
3. J. P. Colinge, FinFETs and Other Multi-Gate Transistors, Springer, 2009.

Reference Books:

1. C. Kittel, Introduction to solid state physics, Wiley, New York, 1976.
2. G.W. Hanson, Fundamentals of Nanoelectronics, Pearson, 2009.
3. Semiconductor Opto Electronic Devices, Pallab Bhattacharya, 2nd Edition, Prentice Hall of India Pvt., Ltd, 2004.
4. Y. Taur and T. Ning, Fundamentals of Modern VLSI Devices, Cambridge Univ. Press, 1998.
5. B. G. Streetman and Sanjay Banerjee, Solid State Electronic Devices, Pearson, 2008