Course Structure & Syllabus for M. Tech Programme in Microelectronics and VLSI System Design
BATCH : 2019-20 onwards

सूक्ष्म कणिका एवं संचार अभियांत्रिकी विभाग
Department of Electronics & Communication Engineering
**Classification of Credits Points:**

<table>
<thead>
<tr>
<th>1 Hr Lecture (L) per week</th>
<th>1 Hr Tutorial (T) per week</th>
<th>1 Hr Laboratory (P) per week</th>
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<tr>
<td>2 Credits</td>
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**Semester I**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Category</th>
<th>L-T-P</th>
<th>Credit</th>
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<tbody>
<tr>
<td>ECL 2101</td>
<td>Physics of Semiconductor Devices</td>
<td>DC</td>
<td>3-0-0</td>
<td>6</td>
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<tr>
<td>ECL 2102</td>
<td>Analog VLSI Circuits</td>
<td>DC</td>
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<td>ECL 21XX</td>
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<td>Semiconductor Device Modeling</td>
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<tr>
<td>ECP 2101</td>
<td>Analog VLSI Circuits Lab</td>
<td>DC</td>
<td>0-0-3</td>
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<td>ECP 2102</td>
<td>Seminar</td>
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**TOTAL CREDITS** 35

**Semester II**

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<tr>
<td>ECL 2201</td>
<td>VLSI Physical Design</td>
<td>DC</td>
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<td>ECL 2202</td>
<td>IC Technology</td>
<td>DC</td>
<td>3-0-0</td>
<td>6</td>
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<td>VLSI Testing and Verification</td>
<td>DC</td>
<td>3-0-0</td>
<td>6</td>
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<tr>
<td>ECL 22XX</td>
<td>Elective II</td>
<td>DC</td>
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<td>DC</td>
<td>0-0-3</td>
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<tr>
<td>ECP 2202</td>
<td>Device and Process Modeling Lab</td>
<td>DC</td>
<td>0-0-3</td>
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<td>ECP 2203</td>
<td>VLSI System Design Lab</td>
<td>DC</td>
<td>0-0-4</td>
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<td>ECP 2204</td>
<td>Term Paper</td>
<td>DC</td>
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**TOTAL CREDITS** 37

**Semester III**

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<td>ECP 2301</td>
<td>Project Phase I</td>
<td>DC</td>
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**TOTAL CREDITS** 16

**Semester IV**

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<td>ECP 2401</td>
<td>Project Phase II</td>
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**TOTAL CREDITS** 24

**SEMESTER WISE CREDIT POINT(s)**

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<th>Semester II</th>
<th>Semester III</th>
<th>Semester IV</th>
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<td>35</td>
<td>37</td>
<td>16</td>
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### ELECTIVES

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<tr>
<th>Sl. No.</th>
<th>Course Code</th>
<th>Course Name</th>
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<tbody>
<tr>
<td>1</td>
<td>21XX/22XX</td>
<td>Mixed Signal VLSI Design</td>
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<tr>
<td>2</td>
<td>21XX/22XX</td>
<td>Low Power VLSI Design</td>
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<tr>
<td>3</td>
<td>21XX/22XX</td>
<td>MEMS and Microsystems</td>
</tr>
<tr>
<td>4</td>
<td>21XX/22XX</td>
<td>VLSI Architecture for DSP</td>
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<tr>
<td>5</td>
<td>21XX/22XX</td>
<td>Embedded Systems</td>
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<tr>
<td>6</td>
<td>21XX/22XX</td>
<td>RF IC Design</td>
</tr>
<tr>
<td>7</td>
<td>21XX/22XX</td>
<td>Nano-and-Molecular Electronics</td>
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**Syllabus of First Semester**

**ECL 2101  
Physics of Semiconductor Devices**

*L-T-P: 3-0-0  
Credits: 6*

   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:**

**Reference Books:**
ECL 2102  
**Analog VLSI Circuits**  
L-T-P: 3-0-0  
Credits: 6

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:**  

**Reference Books:**  
2. Analog Circuit Design by Johan Huijsing Rudy van Plassche and Willy Sansen, Springer Science and Business Media, B.V.
ECL 2104  
Digital VLSI Circuits  
L-T-P: 3-0-0  
Credits: 6

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-Dynamic CMOS design-Basic principles-Domino logic optimization of Domino logic-NPCOMOS-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-Register based pipelines-non-Bistable sequential circuit-Schmitt trigger-monostable-Astable sequential circuit-choosing a clocking strategy.  

12 Lectures


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:**  

**Reference Books:**  
ECL 2105  
Semiconductor Device Modeling
L-T-P: 3-0-0  
Credits: 6

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

   6 Lectures

   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:**  

**Reference Books:**  

ECP 2101  
Analog VLSI Circuits Lab
L-T-P: 0-0-3  
Credits: 3
As per syllabus.
Syllabus of Second Semester

ECL 2201  VLSI Physical Design  Credits: 6
L-T-P: 3-0-0

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

   - 5 Lectures

   - 7 Lectures

   - 4 Lectures

9. **On Chip PDN Design:** Noise and Decap Placement.
   - 2 Lectures

**Text Books:**
3. FPGA based systems design, Waney Wolf, Pearson, 1st ed, 2005

**Reference Books:**
M.Tech Programme in Microelectronics & VLSI System Design: Course Structure & Syllabus

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

Credits: 6

   2 Lectures

   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

   2 Lectures

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

   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

   4 Lectures

   6 Lectures

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

**Text Books:**


**Reference Books:**

**VLSI Testing and Verification**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>ECL 2203</td>
<td>VLSI Testing and Verification</td>
<td>6</td>
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</table>

**Course Structure**

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:**

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

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

ECP 2203  
VLSI System Design Lab  
L-T-P: 0-0-3  
Credits: 3  
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.

Third Semester

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

Fourth Semester

ECP 2401  
Project Phase II  
L-T-P: 0-0-24  
Credits: 24
# Syllabus of Electives

**ECL 21XX/22XX**  
**Mixed Signal VLSI Design**  
**L-T-P:** 3-0-0  
**Credits:** 6

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**

   **8 Lectures**

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

**Text Books:**

**Reference Books:**
M.Tech Programme in Microelectronics & VLSI System Design: Course Structure & Syllabus

ECL 21XX/22XX

Low Power VLSI Design

L-T-P: 3-0-0

Credits: 6

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

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

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

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

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. **Low Power Design Examples:** Memory, Arithmetic circuits.

Text Books:

Reference Books:
ECL 21XX/22XX  
MEMS and Microsystems  
L-T-P: 3-0-0  
Credits: 6

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 Lecture

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.
4. Fundamentals of Microfabrication techniques, Marc Madou, CRC Press
### M.Tech Programme in Microelectronics & VLSI System Design: Course Structure & Syllabus

#### ECL 21XX/22XX

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<thead>
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<td><strong>VLSI Architecture for DSP</strong></td>
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<tr>
<td><strong>L-T-P</strong>: 3-0-0</td>
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1. **Introduction**: Introduction to DSP systems, DSP application demand and scaled CMOS technologies, representation of DSP algorithms, DFT and FFT.  
   - **Lectures**: 3

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

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

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

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

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

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

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

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.  
   - **Lectures**: 4

**Text Books:**


**Reference Books:**

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

**Reference Books:**
ECL 21XX/22XX  RF IC Design  Credits: 6
L-T-P: 3-0-0

1. **Introduction to RF and Wireless Technology**: Complexity, design and applications. Choice of Technology.  
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. **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. **Radio Frequency Synthesizers**: PLLS, design of integer-N RF frequency synthesizer and frequency dividers.  
7. **Design issues in integrated RF filters**: Some discussion on available CAD tools for RF VLSI designs; Prerequisite: (Analog VLSI Design).  
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

**Text Books:**
3. Power Amplifier by Cripp

**Reference Books:**
ECL 21XX/22XX  
Nano-and-Molecular Electronics  

L-T-P: 3-0-0  

Credits: 6

1. **Introduction:** Nanotechnology and Nanoelectronics; Moore’s Law; Review of Semiconductor Electronics: Maxwell’s Equation, Poisson Equation, Continuity Equations, carrier concentration, Carrier Transport, Drift and diffusion; basics of molecular electronics.

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 postulates; Pauli-exclusion principle; Quantum dots, wires, and wells; Transport in quantum structures; Optoelectronic property.

3. **Nanoelectronic Devices:** Overview of MOS and MOSFET; CMOS Scaling and shrink down approaches; FINFET; Tunnel FET; Junctionless Transistor; Single electron transistors; Nanowire MOSFET, GAA FET.

4. **Molecular Electronics:** Need of molecular electronics and atoms-up approach; Strategies of electronic development; Molecular bonding and hybridization; Molecules as electronic devices; Carbon molecules & electronics; Pentacene; Transport in molecular electronics; Graphene devices; Carbon nanotube electronics; CNT FET.

**Text Books:**

**Reference Books:**