UNIVERSITY OF HYDERABAD
SCHOOL OF PHYSICS

M. Tech. (IC Technology)

Objectives of the M. Tech. (ICT) program: The rapid growth of the integrated circuit (IC) industry has led to the emergence of microelectronics process engineering as a new discipline. There is a need to impart quality education at a sufficiently advanced level in this discipline. A few IIT's and other engineering colleges have M. Tech. programs in this area. They are not only far too few, but also tend to be too specialized, focusing either on IC design or on micro-electronic fabrication only. It was therefore felt that there is a need to have a program that covers both these aspects. In addition, numerical simulation techniques are fast emerging as important tools to reduce the efforts and costs involved in fine-tuning the processes and circuits and they form an integral part of the design and development. The M. Tech. (ICT) program is designed to encompass all these aspects, *viz.*, design, simulation and fabrication and all types of IC's. It is expected that, after undergoing this program, the student will acquire both theoretical knowledge and practical skills in these three areas of IC technology and will be able to get into any one of these areas or be a bridge between these three important areas. After teaching six batches it is felt that the following changes in the course structure and syllabi are necessitated by the need to ensure availability of two full semesters for project to conform with norms followed in other premier institutions.

Revised Course Structure – M. Tech. (ICT)

Semester I			**Total No. of Credits : 24**
Course No.	Title of the course	Contact Hours	Credits
IC401	Semiconductor Device Physics and Modeling	4	4
IC402	Integrated Circuit & Nano Fabrication Technology	4	4
IC403	VLSI Design Technology	4	4
IC404	RF/Microwave IC's	4	4
IC405	Semiconductor Processing, Characterization and Simulation Laboratory	6	3
IC406	VLSI Design Tech. Laboratory	6	3
IC407	RF/Microwave IC Laboratory	4	2

Semester II			**Total No. of Credits : 24**
Course No.	Title of the course	Contact Hours	Credits
IC451	Process, Device and Circuit Modeling and Analysis	4	4
IC452	MEMS Theory	2	2
IC453	Advanced Digital Design	4	4
IC454	VLSI Signal Processing	4	4
IC455	Integrated Circuit & Nano Fabrication Technology Laboratory	8	4
IC456	MEMS Laboratory	4	2
IC457	Advanced Digital Design Laboratory	8	4

Semester III			**Total No. of Credits : 24**
Course No.	Title of the course	Contact Hours	Credits
	Project Work + Seminar		24

Semester IV			**Total No. of Credits : 24**
Course No.	Title of the course	Contact Hours	Credits
	Project Work + Dissertation + Viva	Semester	24

IC401 : Semiconductor Device Physics and Modeling

Overview of Semiconductor Physics- Crystal Structure, Concepts of Band structure, Valence and Conduction bands and Electrons and Holes, Density of States, Carrier statistics, Equilibrium carrier concentrations in intrinsic and doped semi-conductors.

Carrier mobility and scattering mechanisms recombination / lifetime due to various mechanisms, determination of carrier mobilities and life times, photoconductivity.

p-n junctions- Band structures across homogeneous junctions, depletion widths and capacitances of abrupt and linearly graded junctions, current flow through p –n junctions, ideal and practical I-V Characteristics, breakdown, heterogeneous junctions

BJTs: current through a BJT, current gain and its dependence on various factors, Ebers-Moll and Gummel-Poon Models

Schottky junctions: Metal Semi-conductor junctions, determination of work-functions and barriers heights, Band structures across junctions, Schottky diode and its I-V Characteristics

Unipolar devices: JFETs, MESFETs, MOS structures, Band Structure, CV curves, Strong inversion condition, MOSFET characteristics, depletion and enhancement structures, short-channel and hot-carrier effects, HEMT, HBT

Books:

Physics of Semi-conductor Devices: S.M. Sze
Semi-conductor Devices – Physics and technology - S. M. Sze

IC402 : Integrated Circuit & Nano Fabrication Technology

- Basic Device structures: BJT, MOSFET, MESFET, capacitors, resistors
- Design rules, self-alignment, device isolation, oxide breakdown and protection
- Process stream/steps: Bipolar, NMOS, CMOS, SOI/SOS, BiMOS etc, ULSI issues

Technology

- Wafer fabrication
- Epitaxy: MBE, CVD
- Lithography
- Ion implantation
- Oxidation
- Thin films deposition- vacuum techniques, sputtering techniques, e-beam and resistive heating evaporation
- Etching: wet etching, RIE, RIBE, etchants
- Packaging- Die-bonding, wire-bonding, flip-chip technology
- Testing and Yield estimation
- Clean room methodologies

If time permits:

- Basic Circuits: Digital-DRAM, SRAM, Flash memory elements, CMOS inverters and multi-input logic gates; analog- amplifiers, comparators and others components of differential amplifiers.

Books:

Science and engineering of microelectronics by Stephen Campbell
VLSI Technology S.M.Sze (Ed.)
VLSI Design Techniques for Analog and Digital Circuits
R. L. Geiger, P.E. Allen, and N. R. Strader

IC403 **:** VLSI Design Technology

Introduction to Digital Design methodology, Fundamentals of combinational logic and sequential logic design , Introduction to VLSI Design, VLSI Design flow (ASIC and FPGA implementation) , Levels of abstraction and the complexity of design, Challenges of VLSI design: power, timing, area, noise, testability, reliability and yield ; EDA tools - Introduction to Computer-aided Design tools for digital systems.

Full- and semi-custom CMOS logic design, PAL, PLA and FPGA logic architectures

Logic design with Verilog, Logic design with behavioral models for combinational and sequential logic, Functional simulation, Modeling a Test-bench , Synthesis of combinational and sequential logic , Functional and Timing Simulation. programmable logic and storage devices.

Basics of digital IC building blocks [6.hrs]

Recommended Books:

1. Design of VLSI Circuits E. Horbst and C. Muller
2. Introduction to Digital Logic Design J.P. Hayes.
3. Digital VLSI Design with Verilog - A Textbook from Silicon Valley Technical Institute: by John Williams
4. Digital Design and Implementation with Field Programmable Devices, J.Navabi
5. VHDL Programming by Examples by D.L. Perry
6. VHDL : Analysis and Modeling of Digital Systems by J. Navabi
7. Advanced Digital Design With The Verilog HDL by CILETTI MICHAEL D
8. *Digital* Integrated circuit Design by John M. *Rabey*

IC404 : RF / Microwave ICs

Part I : Review of basic concepts: Introduction to MICs, MMICs and RF ICs

Review of transmission line analysis: transmission line equations; reflection coefficient, standing waves and impedance. Transmission line open & short sections as circuit elements; transmission line resonators.

Smith chart and admittance chart. Review of network analysis for RF and microwave circuits : S- Parameters, ABCD- Parameters, Z and Y - Parameters.

Planar transmission lines - Modes of a microstripline, stripline, coplanar waveguide and other planar transmission lines. Substrates for transmission lines – dielectrics, semiconductors.

Parasitics in high frequency circuits -

Part II: Passive Circuit Design for RF ICs.

Impedance matching circuits: L-section impedance matching, stubs for impedance matching, impedance matching by quarter wave transformers, multisection transformers.

Circuit elements and discontinuities: Lumped elements, planar transmission line sections as circuit elements, equivalent network model for microstrip discontinuities. DC returns and blocks, bias injection circuits.

Filters using transmission line sections, Kuroda's Identities, Richard's transformation.

Power dividers and directional couplers: Design of coupled striplines or microstrip lines, Even and odd modes, a quarter-wave coupled line section, multiple section directional couplers. T-junction power divider, Wilkinson Power divider.

Part III: EDA tools for RF IC Design.
Numerical Techniques for the analysis and design of RF/Microwave structures, circuit theory based CAD, field theory based CAD, nonlinear RF and Microwave circuit analysis. Introduction to available EDA tools. Design examples using EDA tools.

Part IV: Active circuit design for RF/Microwave ICs.
Active devices for RF/Microwave ICs.
Design of amplifiers, phase shifters, switches, mixers and oscillators. Implementation in MIC, MMIC and RFIC. Layout optimization.

Usage of EDA tools in active circuit design and simulation. Examples.
Mini projects on circuit design and simulation (both active and passive ICs) using EDA tools.

Text Books:

David M. Pozar, "Microwave Engineering," 2nd Edition, John Wiley 1998, ISBN 0-471-17096-8.
Peter A. Rizzi, "Microwave Engineering – Passive Circuits", PHI, ISBN 81-203-1461-1

Reference Books:

K. C. Gupta, Ramesh Garg, Inder Bahl, and Prakash Bhartia, "Microstrip Lines and Slotlines," Artech House, 2nd edition, 1996, ISBN: 089006766X.

T. C. Edwards and M. B. Steer, "Foundations of Interconnect and Microstrip Design," John Wiley & Sons, 3rd edition, 2001, ISBN: 0471607010.

Mike Golio (Ed.), The RF and Microwave Handbook, CRC Press.

Novel technologies for microwave and millimeter-wave applications, Jean-Fu Kiang, Kluwer Academic Publishers.

RFIC and MMIC design and technology, I.D. Robertson and S.Lucyszyn, IEE Circuits, Devices and Systems Series 13.

IC405: Semiconductor Processing, Characterization and Simulation Laboratory

1. Device characterization using Device Analyser
2. Hall Effect and conductivity
3. Optical Band gap estimation
4. Process Simulation-
5. Device Simulation-
6. Circuit Simulation-

IC406 : VLSI Design Technology Laboratory

1. Familiarization with Verilog in designing and simulation using simple examples (multiplexer, registers etc.,) (2 lab classes).
2. Behavioral level design simulation using Verilog (ALU, CPU, PIC etc.,) (3 Lab classes).
3. Structural level design and simulation using Verilog (Counter, ALU etc.,) (3 Lab classes).
4. Test-bench generation in VerilogL for few circuits (ALU, CPU etc.,) (3 Lab classes).
5. Experiments with FPGA synthesizer including timing verification. (3 Lab classes).
6. Synthesis for implementation on FPGA for given examples (3 Lab classes).
7. Digital design in FPGA and verification using chipscope pro (3 Lab classes)
8. Mini project (3 Lab classes)

IC407 : RF/ Microwave IC Lab.

1. Introduction to EDA Tools.
2. Familiarization of EDA tools for RF/ Microwave IC design and simulation.
3. Usage of Models and Libraries for EDA tools.
4. Design Examples (both active and passive devices).
5. Circuit Simulation and Fullwave simulation of Layouts.
6. Design and simulation of active and passive microwave integrated circuits using EDA tools.
    - The list of passive circuits includes: Dividers, Filters, Couplers, Tees, Circulators etc
    - The list of active circuits includes : Amplifiers, oscillators, switches, phase shifters, mixers etc
7. Fabrication and characterization of at least one of the above devices.
8. Design example of an RFIC.

IC451: Process , Device and Circuit Modeling and Analysis

Process Simulation – Overview of basic FET ad BJT process flows, physical models and simulation techniques for unit process such as etching, thermal oxidation, diffusion, ion implantation and process integration.

Device Modeling - Overview of basic device structures (BJT, FET and MOSFETs), basic concepts of Carrier transport; drift-diffusion, hydrodynamic, energy balance. Numerical methods, meshing (fixed & adaptive), numerical solutions, common methods (Newton, Gummel etc.), DC & AC simulation, transient simulation, mixed device and compact model based techniques, Monte Carlo,

DC electrical simulation; Id-Vgs, Id-Vds, extraction of key electrical parameters, e.g., Vt, gm, ft, Gate current; thermionic current, Fowler Nordheim tunneling, direct tunnel current, damage, interface states, trap assisted tunneling, lattice heating, thermal properties of device, thermal boundaries, Metal & dielectic modeling, parasitic resistance & capacitance, RC delays. Future trends in TCAD, 3-D modeling,

Circuit Simulation –Nodal equations, Linear Equation Solution, Gaussian elimination and LU factorization, Linear dc and transient analysis, Sparse matrix behavior, Sensitivity analysis, Nonlinear Equation Solution, Transient Simulation, Convergence, Timing simulation

Richard C. Jaeger, Introduction to Microelectronic Fabrication
S.A. Campbell, The Science and Engineering of Microelectronic Fabrication
J.S. Yuan, J.J. Liou, Semiconductor Device Physics and Simulation
S Selberherr, Analysis and Simulation of Semiconductor Devices
K Lee, M Shur, T Fjeldly, T Ytterdal, Semiconductor Device Modeling for VLSI.
C.M. Snowden, semiconductor Device Modeling.
W. J. McCalla, Fundamentals of Computer-Aided Circuit Simulation
T. L. Pillage, R. A. Rohrer, and C. Visweswariah, Electronic Circuit & System Simulation Methods
A. E. Ruehli, Circuit Analysis, Simulation and Design

IC452 : MEMS Technology Theory

Introduction

- An overview of micro-electromechanical devices and technologies
- Physics in microscopic world, scaling issues
- MEMS in Electrical technology
- Applications : RF MEMS, Optical MEMS, Lab on a Chip, MEMS based Sensors

Micromachining technologies

- Basics of micro-fabrication technologies
- Bulk micromachining
- Surface micromachining
- Materials encountered in micromachining processes and their properties
- Silicon in micromachining
- Process steps involved in micromachining
- Etching for micromachining
- Packaging and related issues

Introduction to Micro-system Design

- Modeling Strategies.
- CAD for micromachining
- Introduction to ANSYS.

Case Study

- RF MEMS Switch

Textbooks

1. MEMS & Microsystems, Design and Manufacturing, Tai- Ran Hsu, TMH.
2. RF MEMS: Theory, Design, and Technology, Gabriel M. Rebeiz, Wiley-Interscience.

Reference Books

1. Fundamentals of Micro-fabrication, Marc Madou, CRC Press, ISBN 0-8493-9451-1
2. Introduction to Micro-electromechanical Microwave Systems, H.J. De Los Santos, Artech House.
3. Micro-system Technology W.Menz, J. Mohr, O.Paul, Wiley-VCH.

IC453 : Advanced Digital Design

High level synthesis, Design and synthesis of data path controller, Post synthesis design tasks, Circuit Partition using KL algorithm , simulated annealing algorithm, Floor planning using Simulated annealing algorithm, force direct method,

Placement and routing: Place and route techniques and tools. Block place and routing. Physical design verification.

Embedded Processors architecture : RISC, super scalar, and VLIW architectures, ARM and SHARC Processor, Embedded bus architectures: Bus architectures and transactions, Serial interconnects, Networked embedded systems: Bus protocols, I2C bus and CAN bus;

H/W and S/W co-design; embedded multiprocessor; DSP Algorithm Design: A/D conversion and finite precision analysis,

Introduction to Design for test, Introduction to System on chip.

Recommended Books:

9. Introduction to Digital Systems. M. Eregovac, T. Lang and J.H. Moreno.
10. VHDL analysis and Modeling of Digital Systems. Z. Navabi
11. The Art of Digital Design. F.P. Processor and D.E. Winkel
12. **Advanced Digital Design With The Verilog Hdl by CILETTI MICHAEL D**
13. A VHDL Synthesis Primer J. Bhasker
14. Digital Systems Design Using VHDL C.H. Roth
15. W. Wolf, *Computers as Components : Principles of Embedded Computer System Design*, Second Edition, Elsevier/MK, 2005
16. F. Vahid and T. Givargis, *Embedded System Design: A Unified Hardware/Software Introduction*, Wiley, 2002
17. VLSI Physical Design Automation: Theory and Practice Sadiq M. Sait and Habib Youssef

IC454 : VLSI Signal processing

DSP Algorithm Design – DSP Representation (Data-flow, Control-flow, Signal-flow graphs and block diagrams), fixed point DSP design, filter structures, system modeling and performance indicators.

Circuit and Architecture Design – Hardware design of real and complex multiplication and addition. Fast Digital Filtering algorithms. Retiming, Pipelining, Harvard and modified Harvard architectures, Block Processing, Folding, Distributed Arithmetic Architectures. Systolic architecture design, VLSI performance indicators (area, power and speed), structural modeling in VHDL.

DSP Module Synthesis – High performance arithmetic unit architecture, bit-parallel, bit-serial, digital serial, carry-save architectures, redundant number systems, scaling and round off noise, DSP Implementation of FPGA.

Multimedia processor architecture

Books recommended:

1. K.K. Parhi – VLSI Digital Signal Processing Systems – Design and Implementation
2. U. Meyer-Baese – Digital Signal Processing with Field Programmable Gate Arrays

IC455 : IC & Nano Fabrication Technology Laboratory

1. Layout Design, Use of design rules, layout design of 1 CMOS circuit
2. Processing introduction: Wafer scribing/cleaving, wafer cleaning, spin-coating, lift-off
3. GaAs processing and lithography: Process steps for GaAs (implanted/multilayer wafer) to pattern for for carrier concentration, mobility measurements and optionally FET.
4. Thin film deposition by sputtering, evaporation and spin coating
4. If time permits, testing.

IC456 : MEMS Technology Laboratory

1. **Introduction**
   - CAD tools for MEMS design and simulation.
   - Familiarization of ANSYS: modeling, material attributes, meshing and elements, choice of solvers, loads and load steps, post processing.
   - Coupled field simulation.
   - 3D structure drawing in ANSYS
   - Design Examples.

2. **Specific cases**
   - Simulation of a cantilever structure – Model, Harmonic and Transient analysis.
   - Cantilever based chemical sensor design – by mass sensing route.
   - Cantilever based RF switch
   - Membrane based RF switch
   - Membrane based piezoresistive pressure sensor
   - Interdigitated structure based MEMS devices
   - Optical micromirror
   - Any other examples suggested by the instructer.

3. **Mini project**: Design and simulation of MEMS based sensors and presentation of the results.

IC457 : Advanced Digital Design Laboratory

1. Design and synthesis of pipelined adder. (1 classe)
2. Design and synthesis of FIFO, memory elements. (3 classes)
3. Familiarity with ASIC tool (2 classes)
4. Synthesis of binary counter for ASIC (2 classes)
5. Floor planning, Placement and routing for ASIC/ FPGA (6 classes)
6. System On chip implementation of digital system using Xilinx EDK (6 classes)
7. Design and synthesis of FIR filter (one week)

Mini-project (4 weeks).