M. S. RAMAIAH INSTITUTE OF TECHNOLOGY
BANGALORE
(Autonomous Institute, Affiliated to VTU)

M. Tech
VLSI Design & Embedded Systems

SYLLABUS
(For 2014 – 2016 Batch)

I - IV Semester

Department of Electronics & Communication
### Faculty List

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Name of the Faculty</th>
<th>Qualification</th>
<th>Designation</th>
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<tr>
<td>1.</td>
<td>Dr. S Sethu Selvi</td>
<td>Ph.D</td>
<td>Professor &amp; Head</td>
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<tr>
<td>2.</td>
<td>Prof. C R Raghunath</td>
<td>M.Tech</td>
<td>Professor</td>
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<td>3.</td>
<td>Prof. K. Giridhar</td>
<td>M.Tech</td>
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<td>4.</td>
<td>Prof. M S Srinivas</td>
<td>M.Tech</td>
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<td>5.</td>
<td>Dr. K. Indira</td>
<td>Ph.D</td>
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<td>6.</td>
<td>K. Manikantan</td>
<td>M.E (Ph.D)</td>
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<td>C. Manjunath</td>
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<td>B. Sujatha</td>
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<td>Dr. Maya V Karki</td>
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<td>S. Lakshmi</td>
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<td>V. Anandi</td>
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<td>Dr. T D Senthil Kumar</td>
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<td>Dr. Naga Ravikanth D</td>
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<td>Dr. Raghuram Srinivasan</td>
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<td>H. Mallika</td>
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<td>Sarala S M</td>
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<td>Punya Prabha V</td>
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<td>30.</td>
<td>Suma K V</td>
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<td>31.</td>
<td>Jayashree S</td>
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<td>33.</td>
<td>Ms. Chitra M</td>
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## I Semester M. Tech (VLSI Design & Embedded Systems)

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## III Semester M. Tech (VLSI & Embedded Systems)

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## IV Semester M. Tech (VLSI Design & Embedded Systems)

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L: Lecture, T: Tutorial, P: Practical, S: Self Study
LIST OF ELECTIVES:
The student is required to take **35 credits** from the given list of electives.

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<tr>
<th>SI. No.</th>
<th>Subject Code</th>
<th>Subject</th>
<th>Credits</th>
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ADVANCED MATHEMATICS

Subject Code: MVES11  
Prerequisites: Nil  
Credits: 4:1:0:0

Course Objectives:
- Model given electronic circuit using differential equation.
- Understand different standard distributions.
- Analyze the statistical characteristics of random variables.
- Find the joint density function and analyze the statistical characters of joint pdf.
- Apply arithmetic operations on vectors and matrices including inversion and determinants.
- Apply row reduction method to solve systems of linear equations.
- Analyze basic terminology of Linear Algebra in Euclidean spaces including Linear independence, spanning, basis, rank and null space.
- Employ Eigen values and Eigen vectors to diagonalise a matrix.
- Demonstrate projections and orthogonality among Euclidean vectors including Gram-Schmidt orthonormalization process and orthogonality matrices.

UNIT – I


UNIT – II

Random Variables: Introduction to probability, repeated trails, random variables, distribution and density functions, mean and variance, moments and characteristic functions.
Pairs of Random Variables: Joint distribution and density functions, conditional distributions, covariance and correlation coefficient, conditional mean and conditional variances.

UNIT – III

Solving Linear Equations: Introduction, geometry of linear equations, Gaussian elimination, matrix notation, inverses.
Vector Spaces: Vector spaces and subspaces, linear independence, basis and dimension, linear transformation.

UNIT – IV

Orthogonality: Orthogonal vectors and subspaces, projections, orthogonal bases and Gram – Schmidt orthogonalization. Eigen values, Eigen vectors and diagonalization, Symmetric Matrices and quadratic forms and SVD.

UNIT – V

Graph Theory: Introduction, Isomorphism, connected graphs, disconnected graphs, trees, cut sets, vector spaces of graphs, electrical network analysis by graph theory.

References:
5. Narsingh Deo, “Graph Theory with applications to engineering and computer science”, PHI learning, 2011.

**Course Outcomes:**

2. Apply in various communication applications.
3. Apply linear systems in Economics, business, balancing chemical equations, and determining currents in a network.
4. Apply linear transformation in computer graphics.
5. Apply Eigen values and Eigen vectors in discrete dynamical system describing the population of a city.
6. Solve a system described by differential equations.
7. Solve inconsistent systems using Least square method.
8. Employ least square method to fit data points close to a curve.
9. Apply Quadratic forms in constrained optimization.
CMOS VLSI CIRCUITS

Subject Code: MVES12
Credits: 4:0:1:0
Pre requisites: Semiconductor Physics

Course Objectives:

- Appraise basic principles of MOS devices
- Understand the essence of design rules & scaling in MOS devices
- Discuss the basics of digital CMOS design
- Understand the basic concepts of analog design
- Discuss the clock generation & distribution issues

UNIT-I

MOS Transistor Theory: n MOS / p MOS transistor, threshold voltage equation, body effect, MOS device design equation, sub threshold region, Channel length modulation, mobility variation, Tunneling, punch through, hot electron effect MOS models, small signal AC Characteristics, CMOS inverter, $\beta_n / \beta_p$ ratio, noise margin, static load MOS inverters, differential inverter, transmission gate, tristate inverter, BiCMOS inverter.

UNIT-II

CMOS Process Technology: Semiconductor Technology overview, basic CMOS technology, p well / n well / twin well process. Current CMOS enhancement (oxide isolation, LDD, refractory gate, multilayer inter connect), Circuit elements, resistor, capacitor, interconnects, sheet resistance & standard unit of capacitance concepts delay unit time, inverter delays, driving capacitive loads, RC delay Line, Super Buffers, propagation delays, MOS mask layout, stick diagram, design rules and layout, symbolic diagram, masking, scaling of MOS circuits.

UNIT-III


UNIT-IV

Dynamic CMOS and clocking: Introduction, advantages of CMOS over NMOS, CMOS\SOS technology, CMOS\bulk technology, latch up in bulk CMOS., static CMOS design, Domino CMOS structure and design, Charge sharing, Clocking- clock generation, clock distribution, clocked storage elements

UNIT-V

Circuit Simulation: Introduction to circuit simulation, Spice tutorials, Device models, Device characterization, circuit characterization, Simulation mismatches, Monte carlo simulation

References:

Laboratory Experiments

CMOS VLSI Design Lab (using Cadence EDA Tools)

Laboratory Experiments

CMOS VLSI Circuits Lab (use any of the EDA Tools)

Digital Design ASIC – Digital Design Flow

1. Write Verilog Code for the following circuits and their Test Bench for verification, observe the waveform and synthesize the code with technological library with given constraints. Do the initial timing verification with gate level simulation.
   (i) An inverter
   (ii) A Buffer
   (iii) Transmission Gate
   (iv) Basic/universal gates
   (v) Flip flop -RS, D, JK, MS, T
   (vi) Serial & Parallel adder
   (vii) 4-bit counter (Synchronous & Asynchronous counter)
   (viii) Successive approximation register (SAR)

   An appropriate constraint should be given
   1. Using SPICE how do you measure the power for a digital circuit.
   2. Using a suitable simulator determine the logic propagation delay available in a cycle for a traditional domino pipeline using 500 ps clock cycle. Assume there is zero clock skew.
   3. Simulate the worst-case propagation delay of an 8-bit dynamic NOR gate driving a fanout of 4.
   4. Simulate a pseudo nMOS inverter in which the pMOS transistor is half the width of the nMOS transistor. What are the rising, falling and average logical efforts? What is VoL?
   5. Simulate a static CMOS circuit to compute f = (A+B)(C+D) with least delay.

   Each input can present a maximum of 30 lambda of transistor width. The output must drive a load equivalent to 500 lambda of transistor width. Choose transistor size to achieve least delay and estimate the delay in t.

Digital Inverter Design

Design an Inverter with given specifications, completing the design flow mentioned below:
   a. Draw the schematic and verify the following
      i) DC Analysis
      ii) Transient Analysis
   b. Draw the Layout and verify the DRC, ERC
   c. Check for LVS
   d. Extract RC and back annotate the same and verify the design
   e. Verify & Optimize for Time, Power and Area to the given constraint

Course Outcomes:

1. Appreciate the importance of analog CMOS design
2. Understand the basic blocks of analog designs
3. Build complete analog system using basic building blocks
4. Understand the dynamic CMOS clocking and clock distribution
EMBEDDED SYSTEMS – I

Subject code: MVES13  Credits: 4:1:0:0
Pre requisites: Microcontrollers

Course Objectives:

- Understand embedded systems software and computer design
- Comprehend the architecture of, & understand the operation of parts and be able to apply this knowledge in simple programs.
- Use the addressing modes and instruction set to perform - arithmetic & logic operations, data & control transfer operations, input & output operations.
- Understand the C data types for, & write C programs & assembly language programs using Keil development software.
- Illustrate the various modes of timers, describe serial communication features and program the timers/counters & serial port in assembly & C.
- Understand what occurs on an interrupt and how hardware generated interrupts operate, & write programs using interrupts.
- Interface application circuits like LCD, keyboard, ADC, DAC and stepper motor with the microcontroller & develop application programs.

UNIT – I

MSP430 – 16-bit Microcontroller family: CPU architecture, Instruction set, Interrupt mechanism, Clock system, Memory subsystem, bus –architecture, the assembly language and ‘C’ programming for MSP-430 microcontrollers.

Low Power embedded systems: On-chip peripherals, Examples of applications.

UNIT – II

On-chip peripherals: digital input, output, Liquid crystal display, Watchdog timer, Op-Amp, Timer, Basic Timer, Real Time Clock (RTC),

Mixed signal systems: Comparator, Analog-to-digital conversion- general issues, Successive approximation, Sigma delta, signal conditioning using operational amplifiers and Digital-to- analog conversion.

UNIT - III

Low power features of MSP430: Clock system, low-power modes, Clock request feature, Low-power programming and interrupts.

Communication peripherals: Serial peripheral interface, Inter-integrated circuit bus, Asynchronous serial communication

Applications of MSP430: Thermometer using I²C–Low Power RF circuits; Pulse Width Modulation (PWM) in Power Supplies.

UNIT – IV

32 bit microcontroller: ARM Cortex M0 technical overview, Architecture, ARM Cortex M0 operation modes, Registers & Special Registers, Stack Pointer, Link Register, Program Counter, combined Program Status Register

Instruction set: moving data, memory access, arithmetic & logic operations, shift & rotate, Instruction usage examples.

Memory System: memory map, program memory, boot loading, data memory, Little endian and Big endian support, memory attributes

UNIT – V

Exceptions and interrupts: Exception types, exception priority definition, vector table, Interrupt control & system control, overview of NVIC and Control block features, Interrupt Enable and Clear Enable, Interrupt pending status.
**Simple Application Programming**: Assembly projects, mixed assembly and C projects.

**Introduction to ARM Cortex M3 & M4**: Technical overview, Comparison of features of Cortex M0, M3 & M4.

**References:**

4. Sample Programs for MSP430 downloadable from msp430.com

**Course Outcomes:**

1. Identify the components of microcontroller architecture
2. Develop, simulate and debug assembly language and C programs for time delays, I/O operations, logic and arithmetic operations, data conversion using Keil software development tools.
3. Develop programs using interrupts to: perform a task at regular intervals using counters, to communicate between processors serially, or to provide immediate service to external hardware.
4. Write C programs to interface chip to Interfacing modules to develop single chip solutions for: Displaying the pressed key’s key code on the On-board LCD of the ESA MCB51, rotate the stepper motor, read the ADC output and display it on the on-board LCD and generate waveforms using DAC.
5. Interpret and design hardware and software for simple real-time digital systems microcontroller.
Course Objectives:
- Illustrate the system design methodologies.
- Understand the various methods & capture tools of chip design.
- Analyze the data path subsystems.
- Explain and analyze the array and special purpose subsystems.
- Illustrate the design economics, VLSI testing and verification methods.

UNIT – I


UNIT – II


UNIT – III

Floor Planning and Placement: Floor Planning goals and objectives, Measurement of delay in Floor Planning, Floor Planning Tools, Placement terms and Definitions, Placement goals and objectives, Measurement of Placement goals and objectives, Placement algorithms.

Routing: Goals and objectives, Measurement of interconnect delay, detailed routing goals and objectives, SPF, RSPF and DSPF

UNIT – IV


UNIT – V

Array Subsystem Design: SRAM, Special Purpose RAMs, DRAM, Read Only Memory, Content Addressable Memory, Programmable Logic Arrays.

Special Purpose Subsystems: Packaging, Power Distribution, I/O, Clock,

References:

Course Outcomes:

1. Use methodologies for designing CMOS system design.
2. Understand the various methods & capture tools of chip design.
3. Understand the operations of various data path subsystems of design.
4. Analyze the architecture and understand the operation of memories and special purpose subsystems.
5. Understand the design economics and various VLSI applications
EMBEDDED SYSTEMS – II

Subject code: MVES22
Prerequisites: Microcontrollers

Credits: 4:0:1:0

Course Objectives:

- Learn the overview of the building blocks of embedded systems including memory types, sensors, actuators, communication interfaces and firmware
- Describe different embedded system components like Reset circuit, Brown out Protection, RTC and WDT
- Understand hardware and software co-design approach for embedded system development
- Explain the EDA process starting from placing wire, bus, port, junction to net list creation and finally PCB layout design.
- Understand operating system basics such as tasks, process, threads and extending it to real time operating system based embedded system
- Employ embedded system development support available such as IDE, cross- compilation, simulators, emulators and boundary scan.

UNIT – I

Typical Embedded System: Core of the Embedded System, Memory, Sensors and Actuators, Communication Interface, Embedded Firmware, Other System Components, Characteristics and Quality Attributes of Embedded Systems

UNIT – II


UNIT – III

Embedded Firmware Design and Development: Embedded Firmware Design Approaches, Embedded Firmware Development Languages

UNIT – IV

Real-Time Operating System (RTOS) based Embedded System Design: Operating System Basics, Types of OS, Tasks, Process and Threads, Multiprocessing and Multitasking, Threads, Processes and Scheduling: Putting them altogether, Task Communication, Device Drivers, How to Choose an RTOS

UNIT – V

The Embedded System Development Environment: The Integrated Development Environment (IDE), Types of Files Generated on Cross- compilation, Disassembler/Decompiler, Simulators, Emulators and Debugging, Target Hardware Debugging, Boundary Scan.

Lab Experiments

1. Use any EDA (Electronic Design Automation) tool to learn the Embedded Hardware Design and for PCB design.
2. Familiarize the different entities for the circuit diagram design.
3. Familiarize with the layout design tool, building blocks, component placement, routings, design rule checking etc.
4. RTOS programming on Linux platform

References:

Course Outcomes:
1. Understand the various crucial aspects of embedded systems such as memory to be used, sensors & actuators available, existing communication protocols and circuits like brownout protection and watchdog timer.
2. Apply computational models in embedded design and use Unified Modeling language for embedded system design.
3. Design a PCB using an EDA tool including creation of part numbers, bill of materials and netlist.
4. Decide on an RTOS by understanding the issues of operating system for real time embedded systems.
5. Know about the development environment for embedded systems including disassembler, simulator and emulator
PHYSICS OF SEMICONDUCTOR DEVICES

Subject code: MVESE01
Prerequisites: Solid State Devices and Circuits

Credits: 4:0:1:0

Course Objectives:
- Introduce to properties of semiconductors
- Discuss basic device technology of a PN junction diode, a junction transistor and JFET.
- Describe the energy band relation at a metal semiconductor contact.
- Interpret MIS diode and its characteristics.
- Introduce IGFET and related field effects.
- Convey the basic concepts about nano electronic devices.

UNIT – I

Physics and properties of semiconductors: Crystal structures, energy bands, carrier concentration at thermal equilibrium, carrier transport phenomena, basic equations for semiconductor device operations.

UNIT – II

Basic device technology: Depletion region and depletion region capacitance, V-I characteristics, Junction breakdown, Transient behavior, Thermal functions, Hetero junctions, effects of high doping, Tunneling process, junction transistor, static characteristics, Junction field effect transistor.

UNIT – III

Metal semiconductor devices: Energy band relation at a metal semiconductor contact.

MIS diodes: Ideal MIS diode, Surface state surface charge and space charge, Effects of metal work function, crystal orientation, temperature, illumination, radiation on a MIS characteristics, Carrier transport in insulating films, FinFETS.

UNIT – IV

IGFET and related field effects: Surface-Space charge region, under non equilibrium condition, Channel conductance, Basic device characteristics, General characteristics, Surface field effects on p-n junction and Metal-semiconductor Devices.

UNIT – V


Physical processes: Modulation doping, quantum hall effect, resonant tunneling, charging effects, ballistic carrier transport, Inter band absorption, intra band absorption, Light emission processes, phonon bottleneck, quantum.

References:

Course Outcomes:
1. Appreciate the properties of semiconductors.
2. Understand the operation of IGFET devices.
3. Recognize the MIS diode characteristics and how it is affected by radiation, illumination etc.
4. Differentiate between quantum wells, quantum wires, and quantum dots.
5. Investigate the quantum confinement in semiconductor nanostructures.
DIGITAL SYSTEM DESIGN USING HDL

Subject Code: MVESE02
Prerequisites: Digital Electronics

Credits: 4:0:1:0

Course Objectives:

- Appraise basic principles of combinational and sequential logic
- Understand the concept of HDL modeling of combinational circuits and sequential data path and control circuits.
- Discuss embedded processor concepts like microcontroller, I/O interfacing and accelerators.
- Appreciate the concept of a design approach based on programmable logic and the power of HDL as a tool for advanced digital design.
- Develop advanced digital design skills.

UNIT – I


UNIT – II

Sequential Basics: Storage elements, Counters, Sequential Data paths and Control, Clocked Synchronous Timing Methodology (VHDL)

UNIT – III

Memories: Concepts, Memory Types, Error Detection and Correction. (VHDL)

UNIT – IV


UNIT – V

Accelerators: Concepts, case study, Verification of accelerators. (VERILOG)

Design Methodology: Design flow, Design optimization

References:


Reading Web Materials:

Laboratory Experiments

Digital design Lab

Course learning objectives:

- Learn to design and model complex combinational and sequential digital circuits using HDL at behavioral, structural, and RTL levels.
- Develop test benches to simulate combinational and sequential circuits.
- Learn how the language infers hardware and to simulate and test that hardware.
- Learn implementation fabrics such as FPGAs and ASIC in digital design.

Laboratory Sessions: Laboratories are scheduled for the design of digital combinational and sequential circuits using HDL and implementation on FPGA using Xilinx platform.

- Lab 1 The use of EDA Tools and Rapid Prototyping with FPGA
- Lab 2 Digital Combinational Circuit Modeling using HDL
- Lab 3 Digital Sequential Circuit Modeling using HDL
- Lab 4 Mini Project on Digital System Design in RTL

Course Outcomes:

1. Use modern electronic design automation software tools for digital systems design including simulation and synthesize of digital systems designs suitable for implementation on programmable device technologies.
2. Design and implement existing SSI and MSI digital circuits with HDL.
3. Apply electronic design automation software to analyze operation and performance of fundamental combinational and sequential circuits
SOC DESIGN AND VERIFICATION

Subject code: MVES03
Pre requisites: CMOS VLSI Circuits

Credits: 4:1:0:0

Course Objectives:

- Understand the System on Chip with its need, evolution, challenges, goals, superiority over system on board & stacked ICs in package.
- Analyze how the SoCs are designed in industrial environment using different design methodologies with the use of intellectual property, the challenges faced with IP integration, design techniques to meet timing closure. VLSI testing & verification
- Discuss the importance of integrating memory components in the SoC and need, selection criteria, types, principle of operation of different memory components (RAM Cache memories with coherency protocols, Flash memories).
- Analyze how the on chip components are interconnected in a SoC.
- Understand problems in using traditional bus based communication architecture and solve the problems imposed by bus based architecture using network on chip.
- Illustrate different techniques’ which is used for power reduction in both logical, memory blocks and architecture of MP SoC.

UNIT – I

Motivation for SoC Design - Review of Moore’s law and CMOS scaling, benefits of system-on-chip integration in terms of cost, power, and performance, Comparison of System-on-Board, System-on-Chip, and System-in-Package, Typical goals in SoC design – cost reduction, power reduction, design effort reduction, performance maximization.

UNIT – II


UNIT – III

Embedded Memories – cache memories, flash memories, embedded DRAM, cache memories, Cache coherence, MESI protocol and Directory-based coherence.

UNIT – IV


UNIT – V

MP SoCs: What, Why, How MP SoCs. Techniques for designing MP SoCs, Performance and flexibility for MP SoCs design
Case study: A Low Power Open Multimedia Application Platform for 3G Wireless
References:

Course Outcomes:
2. Analyze the top-down and bottom-up design flows, timing problems on STA, Latch and flip flop based design. VLSI testing & verification.
3. Analyze high level modeling of cache memories using C.
4. Illustrate the bus architectures of NOCs and routing.
DESIGN OF ANALOG AND MIXED MODE VLSI CIRCUITS

Subject Code: MVESE04 Credits: 4:0:1:0
Prerequisites: Analog and Digital Circuits

Course Objectives:
- Understand the importance of MOS devices, in the field of analog VLSI design.
- Explain the basic operation & design of single stage amplifiers, Band gap references and switched capacitor circuits.
- Provide a quantitative analysis of differential amplifier with different loads.
- Analyze and design simple current mirrors, and cascode current mirrors.
- Analyze frequency response of source follower.
- Analyze and design operational amplifiers, oscillators and PLL.
- Characterize and design different ADCs and DACs
- Identify and analyze the errors in basic D/A and A/D designs.

UNIT – I

Single Stage Amplifier: CS stage with resistance load, diode connected load, current source load, triode load, CS stage with source degeneration, source follower, common-gate stage, cascode stage, folded cascode, choice of device models.

UNIT – II

Frequency Response of CS Stage: General considerations, Miller effect, Association of poles with nodes, Frequency response of common source stage.

Differential Amplifiers and Current Mirrors: Basic differential pair, common mode response, differential pair with MOS loads, Gilbert cell, Basic current mirror, cascode current mirror, Active current mirrors

UNIT – III

Operational Amplifiers: One stage opamp, Two stage opamp, Gain boosting, Common Mode Feedback, Slew rate, PSRR, Noise in opamp

Oscillators and PLL: Ring Oscillators, LC Oscillators, VCO, Mathematical Model of VCO, Simple PLL, Charge pump PLL, Non-ideal effects in PLL, Delay locked loops and applications.

UNIT – IV

Band gap references and switched capacitor circuits: General considerations, supply independent biasing, Temperature independent biasing, PTAT current generation, Constant Gm biasing, sampling switches, switched capacitor amplifiers.

UNIT – V

Data Converter Architecture: DAC and ADC specifications, Qualitative analysis of Resistor string DAC, R-2R Ladder networks, current steering DAC, charge scaling DAC, Cyclic DAC, Pipe line DAC, Flash ADC, Pipeline ADC, Integrating ADC, Successive Approximation ADC

Lab Experiments
All experiments must be implemented using VLSI tools like cadance/synopsis/mentor graphics.

1. Design the MOS transistor circuits for DC & AC small signal parameters, completing the design flow mentioned below:
   a. Draw the schematic and verify the following
(i) DC Analysis  
(ii) AC Analysis  
(iii) Transient Analysis  
b. Draw the Layout and verify the DRC, ERC  
c. Check for LVS.
2. Design a two stage op-amp with given specification using given differential amplifier  
   Common Source and Common Drain amplifier in library and complete the design flow  
   mentioned below:  
a. Draw the schematic and verify the following  
   (i) DC Analysis  
   (ii) AC Analysis  
   (iii) Transient Analysis  
b. Draw the Layout and verify the DRC, ERC  
c. Check for frequency response, slew rate, offset effects and Noise.
3. Design a simple sample and hold circuit and measure the switching times.  
4. Design a PLL and measure all the parameters.  
5. Design a simple ADC/DAC and measure the data conversion time. Assume 95nm  
   technology.  
6. Design 3-8 decoder using MOS technology.

References:
2. Phillip E Allen, Douglas R Holberg, “CMOS Analog Circuit Design”, Oxford University Press,  
   2004  
   PHI Edn, 2005  

Course Outcomes:
1. Employ the concept of MOS devices in various MOS amplifier applications.  
2. Apply the concept of differential amplifiers to construct one stage opamp and two stage  
   opamp  
3. Illustrate the concept of current mirrors and apply the concept for the design of differential  
   amplifiers.  
4. Illustrate the concept of band gap references and switched capacitor circuits.  
5. Understand and appreciate the importance of oscillators and PLLs  
6. Apply the concepts for the design of opamp used in ADC and DAC  
7. Understand different ADCS and DACs and appreciate their importance
LOW POWER VLSI DESIGN

Subject Code: MVESE05
Prerequisites: CMOS VLSI Circuits

Credits: 4:1:0:0

Course Objectives:
- Explain the basic design concepts for low power VLSI circuits in CMOS technology.
- Apply the knowledge in low-power VLSI circuit analysis and simulation.
- Identify the critical parameters that affect the VLSI circuits’ performance.
- Design low-power VLSI circuits by using CMOS processes.

UNIT – I
Power Dissipation in CMOS: Introduction, Need for low power VLSI chips, sources of power consumption, introduction to CMOS inverter power dissipation, low power VLSI design limits.

UNIT – II
Power Optimization: Logical Level Power Optimization: gate reorganization, local restructuring, signal gating, logic encoding, state machine encoding, pre-computation logic. Circuit Level Power Optimization: transistor and gate sizing, equivalent pin ordering, network restructuring and re-organization, special latches and flip-flops.

UNIT – III
Design of Low Power CMOS Circuits: Reducing power consumption in memories: low power techniques for SRAM, circuit techniques for reducing power consumption in adders and multipliers. Special techniques: power reduction and clock networks, CMOS floating gate, low power bus, delay balancing.

UNIT – IV

UNIT – V
Synthesis and Software Design for Low Power: Synthesis for low power: behavioral level transforms, algorithm level transforms for low power, architecture driven voltage scaling, power optimization using operation reduction, operation substitution. Software design for low power: sources of software power dissipation, gate level, architecture level, bus switching activity. Case study: Multi-core processor architecture such as ARM, AMD.

References:
Course Outcomes:

1. Investigate low power design techniques.
2. Classify the mechanisms of power dissipation in CMOS integrated circuits
3. Model power dissipation and use optimization methods on various levels
4. Apply in practice technology-level, circuit-level, and system-level power optimization techniques.
5. Analyze and design low-power VLSI circuits using different circuit technologies and design levels
AUTOMOTIVE ELECTRONICS

Subject Code: MVESE06
Prerequisites: Digital Measurements, Communication

Credits: 4:1:0:0

Course objectives:

- Learn the concepts of automotive fundamentals and air/fuel systems
- Know the use of sensors and actuators
- Understand the working principle of exhaust after-treatment systems, electronic engine control systems and electronic ignition control systems
- Study the concepts of vehicle motion control, antilock braking, electronic steering control and electronically controlled suspension
- Understand automotive diagnostics and future automotive electronic systems

UNIT – I


UNIT – II


Actuators: Fuel Metering Actuator, Fuel Injector, Ignition Actuator

UNIT – III


Electronic Engine Control: Engine parameters, variables, Engine Performance terms, Electronic Fuel Control System, Electronic Ignition control, Idle speed control, EGR Control


UNIT – IV

Vehicle Motion Control: Cruise Control, Chassis, Power Brakes, Antilock Brake System (ABS), Electronic Steering Control, Power Steering, Traction Control, Electronically controlled suspension

Automotive Instrumentation: Sampling, Measurement and Signal Conversion of various parameters

UNIT – V


References:

Course Outcomes:
1. Explain the automotive fundamentals and air/fuel systems
2. Select sensors and actuators for different applications
3. Describe the working principle of exhaust after-treatment systems, electronic engine control systems and electronic ignition control systems
4. Understand the working principle of vehicle motion control systems, antilock braking systems, electronic steering control systems and electronically controlled suspension systems
5. Understand automotive diagnostics and future automotive electronic systems
CMOS RF Circuits and MEMS

Subject Code: MVESE07
Pre-requisites: RF Fundamentals, CMOS Circuits

Credits: 4:0:1:0

Course Objectives:
- Understand the fundamental concepts of RF circuits
- Analyze and design RF transceiver and receivers at architectural, circuits and device level.
- Analyze and design analog and digital modulation of RF circuits.
- Analyze the behavior of BJT and MOSFET at RF frequencies and model the transistors at SPICE model.
- Understand the advantages and limitations of RF-MEMS technology
- Understand the working principles of the state-of-the-art RF-MEMS devices
- Evaluate the merits and drawbacks of an RF-MEMS design
- Complete a design of an RF-MEMS device or circuit with the help of CAD packages

UNIT – I

Introduction to RF Design and Wireless Technology: Design and Applications, Complexity and Choice of Technology. Basic concepts in RF design: Nonlinearly and Time Variance, Intersymbol interference, random processes and noise. Sensitivity and dynamic range, conversion of gains and distortion

UNIT – II

RF Modulation: Analog and digital modulation of RF circuits, Comparison of various techniques for power efficiency, Coherent and non-coherent detection, Mobile RF communication and basics of Multiple Access techniques, Receiver and Transmitter architectures, direct conversion and two-step transmitters, RF Testing: RF testing for heterodyne, Homodyne, Image reject, Direct IF and sub sampled receivers.

UNIT – III

BJT and MOSFET Behavior at RF Frequencies: BJT and MOSFET behavior at RF frequencies, modeling of the transistors and SPICE model, Noise performance and limitations of devices, integrated parasitic elements at high frequencies and their monolithic implementation.

UNIT – IV

RF MEMS Switches and micro-relays: Switch Parameters, Basics of Switching, Switches for RF and microwave Applications, Actuation mechanisms, micro relays and micro actuators, Dynamics of Switch operation, RF Design. MEMS Inductors and capacitors: Effect of inductor layout, reduction of stray capacitance of planar inductors, approaches for improving quality factor, Modeling and design issues of planar inductors. MEMS capacitor: gap tuning and area tuning and dielectric tunable capacitors.

UNIT – V

Micromachined RF Filters and Phase shifters: RF Filters, Modeling of Mechanical Filters, Micromachanical Filters, Micromachined Filters for Millimeter Wave frequencies. Micromachined Phase Shifters, Types and Limitations, MEMS and Ferroelectric Phase shifters, Applications. Micromachined antennas: Design, Fabrication and Measurements.

Lab Experiments

1. Design of RF MEMS switch.
2. Design of RF MEMS capacitor
3. Design RF MEMS Inductor
4. Design of RF MEMS filter
5. Design of RF MEMS phase shifter

References:

Course Outcomes:
1. Learn and utilize accurate RF CMOS transistor and passive models
2. Understand various parasitic effects due to layout and substrate
3. Understand the tradeoffs in circuit architectures and how they translate to RF systems parameters like noise figure, IIP3 and phase noise.
4. Analyze the impact of CMOS technology scaling on various circuit blocks.
5. Design RF MEMS switches
6. Design RF MEMS inductors and capacitors
7. Design and analyze the operation of RF MEMS filters and phase shifter.
8. Describe various fabrication techniques involved in all RF MEMs components.
ASIC DESIGN

Subject code: MVESE08 Credits: 4:0:1:0
Prerequisites: Digital Electronics, HDL

Course Objectives:
- Be productive members of an industrial ASIC design team
- Implement projects involving digital circuits using ASIC techniques and synthesis
- Provide an understanding of ASIC life cycle
- Develop team work skills
- Learn to enjoy the learning and designing process
- Discuss full custom, Semicustom design using ASIC flow
- Understand the concept of ASIC construction, floor planning, placement and routing

UNIT – I

Introduction: Full custom with ASIC, Semicustom ASICs, standard cell based ASIC, Gate array based ASIC, channeled gate array, channel less gate array, structured gate array, Programmable logic device, FPGA Design Flow, ASIC cell libraries

UNIT – II

Data Logic Cells: Data path elements, Adders, Multiplier, Arithmetic operator, I/O Cell, Cell compilers

ASIC Library Design: Logical effort, practicing delay, logical area and logical efficiency, logical paths, multi stage cells, optimum delay, optimum no. of stages, library cell design

UNIT – III

Low Level Design Entry: Schematic entry, Hierarchical design, The cell library, Names, Schematic, Icons & symbols, Nets, Schematic entry for ASICs, Connections, vectored instances and buses, Edit in place attributes, Netlist, screener, Back annotation

UNIT – IV

Programmable ASIC: Programmable ASIC logic cell, ASIC I/O cell.

A Brief Introduction to Low Level Design Language: an introduction to EDIF, PLA Tools, an introduction to CFI design representation, Half gate ASIC, Introduction to synthesis and simulation.

UNIT – V

ASIC Construction Floor Planning and Placement and Routing: Physical Design, CAD Tools, System Partitioning, Estimating ASIC Size, Partitioning methods, Floor Planning Tools, I/O and power planning, clock planning, Placement algorithms, iterative placement improvement, Time driven placement methods, Physical Design flow global routing, local routing, Detail routing, Special routing, circuit extraction and DRC

References:

**Course Outcomes:**

1. Practice and demonstrate critical thinking
2. Understand the requirements and translate them to high level design language
3. Understand the capabilities and limitations of CMOS logic and adjust designs to best use CMOS ASIC Technologies
4. Demonstrate common ASIC team rules and articulate the purpose of such rules
5. Demonstrate an ability to use industry synthesis tools to achieve desired project objectives
6. Demonstrate an understanding of module interfaces, pipelining, design for test, test pattern generation
7. Modify designs to achieve performance objectives.
8. Perform an ASIC design from requirements to timing verification.
VLSI DESIGN VERIFICATION

Subject code: MVESE09
Prerequisites: HDL, VLSI Design and Circuits

Credits: 4:1:0:0

Course Objectives:

- Understand design verification and its importance.
- Identify different linting tools and its function.
- Explain code coverage and functional coverage.
- Convey the basic concepts of static timing analysis.
- Describe the role of verification plan and different levels of verification.
- Explain SoC integration problem and formal verification.

UNIT I

Importance of Design Verification: Verification, Test bench, Importance of verification, Reconvergence model, Formal verification, Equivalence checking, Model checking, Functional verification. Functional verification approaches: Black box verification, white box verification, grey box verification. Testing versus verification: scan based testing, design for verification, Verification reuse, cost of verification.

UNIT II


UNIT III

The verification plan: The role of verification plan: specifying the verification plan, defining the first success. Levels of verification: unit level verification, reusable components verification, ASIC and FPGA verification, system level verification, board level verification, verifying strategies, verifying responses, From specification to features: component level feature, system level features, Error types to look for?, prioritize, design for verification. Directed test bench approaches group into test cases, from test cases to test benches, measuring progress. Coverage driven random based approach: Measuring progress, from features to functional coverage, from features to test bench, from features to generators, directed test cases.

Static Timing Verification: Concept of static timing analysis, Cross talk and noise, Limitations of STA. slew of a waveform, Skew between the signals, Timing arcs and innateness, Min and Max timing paths, clock domains, operating conditions, critical path analysis, false paths, Timing models.

UNIT IV

Behavioral HDLS: Behavioral VS RTL thinking, Contrasting the approaches, maintainable robust code, optimizing, Structure of behavioral code, Data abstraction, HDL parallel engine, portability issues.

Stimulus and response: Simple stimulus, Verifying the output, Self-checking test benches, Complex stimulus, Complex response, Predicting the output.
UNIT V

**Architecting test benches:** Reusable verification components, Verilog implementation, VHDL implementation, Autonomous generation and monitoring, Input and output paths, Verifying configurable designs.

**Simulation management:** Behavioral models, performance of a test bench, Managing simulations, SDF back annotation, Regression.

**References:**


**Course Outcomes:**

1. Appreciate the importance of verification in VLSI design.
2. Understand and use linting tools.
3. Appreciate code coverage and function coverage.
4. Differentiate between different levels of verification.
5. Assess the importance of static timing analysis.
6. Perform physical design verification in their design.
7. Investigate SoC integration problem and formal verification methods.
ADVANCED DIGITAL SIGNAL PROCESSING

Subject code: MVESE10
Prerequisites: Digital Signal Processing

Credits: 4:1:0:0

Course Objectives:
- Review the basics of Discrete Fourier Transform and design of Digital Filters
- Explain decimation and interpolation by factor D and I
- Describe sampling rate conversion and multistage implementation of sampling rate conversion
- Understand sampling rate conversion of bandpass signals
- Explain sampling rate conversion by an arbitrary factor
- Appreciate applications of multirate signal processing and adaptive filtering

UNIT – I

Introduction to Discrete Fourier Transform: Signals, Systems and Signal processing, Classification of signals, concept of Frequency in continuous-time and discrete-time signals, Analog to Digital and Digital to Analog conversion, Frequency domain sampling: Discrete Fourier Transform, Properties of DFT, Linear Filtering methods based on DFT.

UNIT – II

Digital Filter Implementation: Elementary Operations, State space realization of Digital Filters, Robust implementation of Digital Filters: Lattice implementation of FIR and IIR filters, Robust implementation of equiripple FIR filters.

UNIT – III

Multirate Digital Signal Processing: Introduction, Decimation by a factor D, Interpolation by a factor I, Sampling rate conversion by a rational factor I/D, Filter design and implementation for sampling rate conversion: Direct form FIR Filter structures, Polyphase Filter Structures, Time variant Filter structures, Multistage implementation of sampling rate conversion.

UNIT – IV

Sampling Rate Conversion and Applications: Sampling rate conversion of Bandpass signals: Decimation and interpolation by Frequency conversion, Modulation-Free method for Decimation and Interpolation, Sampling rate conversion by an arbitrary factor: First order approximation, second order approximation


UNIT – V


Laboratory Experiments:
Implementation in MATLAB
1. Response of an LTI system to i) impulse input ii) step input III) exponential input.
2. Design of Equiripple FIR Filter
3. Effect of time domain aliasing
4. Downsampling, upsampling and resampling
5. Anti-aliasing Filter, interpolation and decimation.
6. Multirate filter bank implementation
7. LMS and RLS algorithm

References:

Course Outcomes:
1. Apply DFT in filtering of long data sequences.
2. Design and implement digital filters on a DSP
3. Apply up sampling, down sampling and sampling rate conversion techniques in audio signal processing, data compression in subband coding and implementation of high performance filtering operations.
4. Apply adaptive filters in system identification, signal modeling, spectrum estimation, noise cancellation and adaptive equalization.
MICRO AND SMART SYSTEMS TECHNOLOGY

Subject Code: MVESE11
Prerequisites: CMOS VLSI Circuits

Credits: 4:0:1:0

Course Objectives:
- Learn about typical applications of microsystems
- Understand scaling laws.
- Understand the principles of microsensors and microactuators.
- Understand the various principles of operations of mems transducers.
- Learn basic mechanical concepts and Analyze coupled domain aspects.
- Learn basic electrostatics and its applications in MEMS sensors and actuators.
- Familiarize oneself with atleast one MEMS CAD tool.
- Learn about ways to fabricate a MEMS device and Understand the packaging needs for a MEMS device.

UNIT – I

Introduction: Introduction to micro systems, smart materials, structures and systems. Micro and smart devices and systems: transduction principles – electrostatic sensing and actuation, thermal sensing and actuation, piezo resistive sensor, piezoelectric sensing and actuation and magnetic actuation, scaling effects.

UNIT – II

Micro Fabrication And Micro Manufacturing: Introduction, Fabrication Processes, Thin Film Deposition, Lithography, Etching, Si Micro Machining, Surface And Bulk Micromachining, Thick Film Processing And Specialized Materials

UNIT – III

Modeling: Mechanical concepts – stress and strain, flexural beam bending analysis under simple loading conditions, analysis of beams under simple loading, torsional deflections, residual stresses and stress gradient, resonant frequency and quality factor, introduction to coupled domain concepts

UNIT – IV

Electronics, Control, Integration, Packaging And Cad Tools For Smart And Micro Systems: Semiconductor Devices, Electronic Amplifiers, Signal Conditioning, Control Theory For Smart Systems, Integration And Packaging, Cad Tools – Intellisuite, Comsol And Matlab Based Simulations Of Mems Devices

UNIT – V

Applications: Case studies – silicon capacitive accelerometer, piezo-resistive pressure sensor, blood analyzer, conductometric gas sensor, silicon micro-mirror arrays, piezo-electric based inkjet print head, electrostatic comb-drive and magnetic micro relay, portable clinical analyzer, active noise control in a helicopter cabin.

Lab Experiments
- BEL pressure sensor
- Active vibration control
- CAD tools (comsol and intellisuite)

References:

Course outcomes:
1. Know the significance and analyze scaling laws.
2. Describe the operation of various practical MEMS systems.
3. Analyze the mechanical aspects of a MEMS system.
4. Analyze the electrical and electronics aspects of MEMS system.
5. Describe various fabrication and packaging techniques for MEMS devices.
IMAGE AND VIDEO PROCESSING

Subject Code: MVESE12
Prerequisites: Digital Signal Processing

Credits: 4:0:1:0

Course Objectives:
- Review the basics of two dimensional signal processing
- Interpret two dimensional sampling theory, quantization and convolution
- Distinguish between different image enhancement algorithms
- Appraise 2-D filtering and image restoration
- Study different feature extraction and pattern classification methods
- Illustrate basics of digital video

UNIT – I


UNIT – II


UNIT – III

Image Enhancement: Point operations, Histogram modeling, spatial operations, Transform operations, Multi-spectral image enhancement, false color and Pseudo-color, Color Image enhancement.

UNIT – IV


UNIT – V

Image Analysis, Computer Vision and Video Processing: Spatial feature extraction, Transform features, Edge detection, Boundary Extraction, Boundary representation, Region representation, Moment representation, Structure, Shape features, Texture, Scene matching & detection, Image segmentation, Classification Techniques. Representation of Digital Video – Analog and digital video, Models for time-varying images, time-space sampling, conversion between sampling structures.

Laboratory Experiments:
Implementation in MATLAB
1. Image Sampling and Quantization.
2. Contrast enhancement, Histogram equalization, Histogram specification, Edge detection
4. Reading, displaying and processing video
5. Background subtraction, motion detection
6. Content based image retrieval, Object classification and tracking
References:

Course Outcomes:
1. Analyze the effect of sampling and quantization on an N x N image
2. Apply and compare various image enhancement techniques on an image
3. Design a face recognition system using K-L transform
4. Develop motion detection based security monitoring system
5. Employ K means algorithm to segment a given image
6. Implement a character recognition system
VLSI DESIGN AUTOMATION

Subject Code: MVESE13
Prerequisites: Digital Logic

Credits: 4:1:0:0

Course objectives:

- Understand the concepts of Physical Design Process such as partitioning; Floor planning, Placement and Routing.
- Discuss the concepts of design optimization algorithms and their application to physical design automation.
- Appreciate the latest design techniques as practiced in the industry for design layout optimization.
- Understand the concepts of simulation and synthesis in VLSI Design Automation
- Formulate CAD design problems using algorithmic methods

UNIT – I


VLSI Automation Algorithms:

Partitioning: Problem formulation, classification of partitioning algorithms, Group migration algorithms, simulated annealing & evolution, other partitioning algorithms.

UNIT – II

Placement, Floor Planning & Pin Assignment: Problem formulation, simulation base placement algorithms, other placement algorithms, constraint based floor planning, floor planning algorithms for mixed block & cell design. General & channel pin assignment

UNIT – III

Global Routing: Problem formulation, classification of global routing algorithms, Maze routing algorithm, line probe algorithm, Steiner Tree based algorithms.

UNIT – IV

Detailed Routing: Problem formulation, classification of routing algorithms, single layer routing algorithms, two layer channel routing algorithms, three layer channel routing algorithms, and switchbox routing algorithms.
Compaction: problem formulation, one-dimensional compaction.

UNIT – V

Logic Synthesis & Verification: Introduction to combinational logic synthesis, Binary Decision Diagram, Hardware models for High-level synthesis.

References:


Course Outcomes:

1. Analyze physical design problems including partitioning, floor planning, placement and routing of VLSI circuits.
2. Employ appropriate algorithms for particular criteria like performance, memory usage, and appearance.
3. Decompose large mapping problem into pieces, including logic optimization, covering, scheduling, retiming, assignment, partitioning, placement, routing.
4. Write C++ programs for VLSI design automation problem.
5. Implement design automation algorithms
SYNTHESIS AND OPTIMIZATION OF DIGITAL CIRCUITS

Subject Code: MVESE14 Credits: 4:0:0:1
Prerequisites: Digital Electronics

Course Objectives:

- Understand the concept of Microelectronic design styles, semiconductor technologies and computer aided synthesis and optimization.
- Apply graph theory concepts to digital circuit optimization and Boolean algebra
- Simulate and synthesize the HDL model of digital circuits for functionality
- Apply the concept of Heuristic minimization for two level combinational logic optimization
- Understand the concept of multiple level circuits and optimization with respect to delay and area
- Understand the concept of sequential circuit optimization using network models
- Understand the concept of library binding, FPGA and rule based library binding and testing

UNIT – I


UNIT – II

Hardware Modeling: Hardware Modeling Languages, distinctive features, structural hardware language, Behavioral hardware language, HDLs used in synthesis, abstract models, structures logic networks, state diagrams, data flow and sequencing graphs, compilation and optimization techniques.

UNIT – III

Two level combinational logic optimization: Logic optimization, principles, operation on two level logic covers, algorithms for logic minimization, symbolic minimization and encoding problems, minimization of Boolean relations.

UNIT – IV

Multiple level combinational optimizations: Models and transformations for combinational networks, algebraic model, Synthesis of testable network, algorithm for delay evaluation and optimization, rule based system for logic optimization.
Sequential circuit optimization: Sequential circuit optimization using state based models, sequential circuit optimization using network models.

UNIT – V

Schedule Algorithms: A model for scheduling problems, Scheduling with resource and without resource constraints, Scheduling algorithms for extended sequencing models, Scheduling Pipe lined circuits.
Cell library binding: Problem formulation and analysis, algorithms for library binding, specific problems and algorithms for library binding (lookup table FPGAs and Antifuse based FPGAs), rule based library binding.
References:

Course Outcomes:
1. Understand and appreciate the fast-growing area of design automation.
2. Employ the knowledge of data structures and algorithms in modern logic synthesis tools
3. Write verilog and VHDL code for simulation and synthesis
4. Employ optimization techniques to minimize two level circuits
5. Employ optimization techniques to minimize multiple level circuits
6. Analyze and synthesize sequential circuits
7. Apply discrete mathematical problem solving techniques to areas with highly practical application
8. Apply algorithms for library binding to optimize the circuit with respect to speed and area
9. Employ the knowledge of testing for digital systems
RF AND MICROWAVE CIRCUIT DESIGN

Subject Code: MVESE15
Prerequisites: Microwave Circuits and Devices
Credits: 4:1:0:0

Course Objectives:
- Familiarize with RF and microwaves easily and effectively
- Understand the RF and microwave concepts and their applications
- Characterize of two-port networks at RF and microwaves using S-parameters
- Design simple RF and microwave integrated circuits

UNIT – I


UNIT – II

The Smith Chart: Derivation of Smith Chart, Description of two types of Smith Charts, Smith Chart's Circular Scales, Smith Chart's Radial Scales, Normalized Impedance – Admittance (ZY) Smith Chart.


UNIT – III


Gain Considerations in Amplifiers: Power gain concepts, Unilateral Transistor, Mismatch Factor, Input and Output VSWR, Maximum Gain Design, Constant Gain Circles, Unilateral Figure of Merit, Bilateral Case

Noise Considerations in Active Networks: Importance of Noise, Noise Definition, Sources of Noise, Thermal Noise Analysis, Noise Model of a Noisy Resistor, Equivalent Noise Temperature, Definition of Noise Figure, Noise Figure of Cascaded Networks, Constant Noise Figure Circles.
UNIT - IV

RF/Microwave Amplifiers – Small-Signal Design: Types of Amplifiers, Small-Signal Amplifiers, Design of different types of Amplifiers, Multistage Small-Signal Amplifier Design.

RF/Microwave Amplifiers – Large-Signal Design: High-Power Amplifiers, Large-Signal Amplifier Design, Microwave Power Combining/Dividing Techniques, Signal Distortion due to Intermodulation Products, Multistage Amplifiers: Large-Signal Design.

RF/Microwave Oscillator Design: Oscillator versus Amplifier Design, Oscillation Conditions, Design of Transistor Oscillators, Generator-Tuning Networks.

RF/Microwave Frequency Conversion – Rectifier and Detector Design: Small-Signal Analysis of a Diode, Diode Applications in Detector Circuits, Detector Losses, Effect of Matching Network on the Voltage Sensitivity, Detector Design.

UNIT – V

RF/Microwave Frequency Conversion – Mixer Design: Mixer types, Conversion Loss for SSB Mixers, SSB versus DSB Mixers: Conversion Loss and Noise Figure, One-Diode (or Single-Ended) Mixers, Two-Diode Mixers, Four Diode Mixers, Eight-Diode Mixers.

RF/Microwave Control Circuit Design: PN Junction Devices, Switch Configurations, Phase Shifters, Digital Phase Shifters, Semiconductor Phase Shifters, PIN Diode Attenuators.

RF/Microwave Integrated Circuit Design: Microwave Integrated Circuits, MIC Materials, Types of MICs, Hybrid versus Monolithic MICs, Chip Mathematics

References:

Course Outcomes:
1. Understand RF and microwave active circuit concepts such as amplifiers and oscillators and apply them in the design of frequency converters, matching networks, distributed and lumped element circuit applications.
2. Become familiar with the use of the Smith Chart to simplify analysis of complex design problems
3. Understand the concepts of control Circuits in RF and microwave systems, Linear and Non-linear small-signal and large-signal amplifier design as well as RF/Microwave oscillator design
4. Analyze RF and Microwave Integrated Circuits with reference to Frequency Conversion, Rectifier and Detector, Circulators, Gyrators and Isolators.
5. Understand the novel use of live math in RF/Microwave circuit analysis and design.