M.Sc Electronic Science
Course Structure

SEM-I	EL1 UT01	Foundation of Semiconductor Devices
	EL1 UT02	Analog Circuit Design and Analysis
	EL1 UT03	Instrumentation and Measurement Techniques
	EL1 UP01	Practical course -I
	EL1 UP02	Practical course –II
SEM-II	EL2 UT04	Applied Electromagnetics, RF and Microwave
	EL2 UT05	Communication Electronics
	EL2 UT06	Digital System Design using VHDL
	EL2 UP03	Practical course –III
	EL2 UP04	Practical course –IV

EL UT: University Theory: Three courses per semester

EL UP: University Practical: Two courses per semester.

EL1 UT01 : Foundation of Semiconductor Devices

Objectives:

1. To provide an understanding of the characteristics of semiconductor devices
2. To introduce concept device simulators
3. To introduce quantum & statistical mechanics
4. To introduce theory of diode, transistor & FET from semiconductor physics point of view

Unit-1: Theory of solids, quantum and statistical mechanics [10]

Crystal structure of solids: Semiconductor materials, types of solids, basics of crystallography , space lattice atomic bonding, unit cell, Miller indices imperfections and impurities in solids, methods for semiconductor crystal growth

Introduction to Quantum Mechanics: Principles of quantum mechanics, Schrodinger wave equation, Applications of Schrodinger's wave equation for bound state potential problems

Introduction to quantum theory of solids: Allowed & forbidden energy bands, electrical conduction in solids, extensions to three dimensions, density of states, **Statistical mechanics**: Statistical laws, Fermi-Dirac probability function, the distribution function and the Fermi energy

Unit-2: Physics of semiconductors [8]

Semiconductor in equilibrium: Charge carriers in semiconductors, dopant atoms and energy levels, extrinsic semiconductors, **Statistics** of donors and acceptors, charge neutrality, position of Fermi energy level

Carrier transport phenomena: – charge, effective mass, state & carrier distributions ,Carrier drift, carrier diffusion, graded impurity distribution, resistivity ,the Hall effect.

Non-equilibrium excess carriers in semiconductors: Carrier generation and recombination, characteristics of excess carriers, ambipolar transport, quasi-Fermi energy levels, excess carrier lifetime, surface effects

Unit-3: pn junction diode [8]

pn junction electrostatics: Junction terminologies, Poisson's equation, built-in potential, depletion approximation

pn junction diode characteristics: Ideal diode equation, Qualitative and Quantitative analysis, Reverse-bias breakdown, avalanching, zener process, C-V characteristics, Transient response .

Miscellaneous devices : Gunn diode , tunnel diode ,Schottky diodes

Optoelectronic Devices: Photodiodes- p-n and pin, LEDs, Laser diodes

Unit-4 BJT and other junction devices **[10]**

BJT: Terminology, electrostatics and performance parameters, Eber-Moll model, Two port model, hybrid – pi model, device models in spice , Modern BJT structures – polysilicon emitter BJT, Heterojunction bipolar transistor (HBT)

Polyjunction devices : SCR, DIAC , TRIAC .

Unit-5 Unipolar devices **[14]**

FET: JFET and MESFET : Junction terminologies , characteristics , ac response , spice models .

MOSFET: Fundamentals,Electrostatics-, Capacitance- voltage characteristics.

I-V characteristics: Qualitative Theory of Operation, I_D - V_D Relationship, a.c response, spice models.

Modern FET structures: Small Dimension Effects, Select Structure Survey.

Reference Books:

1. Semiconductor Device fundamentals – Robert F. Pierret, Pearson Education (2006)
2. Semiconductor Physics and Devices Basic Principles, Donald A. Neamen Third Edition (2003) TATA McGRAW-HILL EDITION
3. Solid State Electronics Devices: Streetman PHI Fifth Edition
4. Semiconductor Physics: S. M SZE

EL1 UT02: Analog Circuit Design and Analysis

Objectives:

1. To learn the principles and working of discrete circuits
2. To develop skills in analysis and design of analog circuits
3. To familiarize students with various elements of the engineering design process, including formulation of specifications, analysis of alternative solutions, synthesis, decision making, iterations, simulation, & tolerance issues.
4. To form a sound backgrounds to study the internal circuit blocks of IC

Unit 1: Essentials of network analysis [14]

Analogy between Electrical Networks and different physical systems.

Laplace transform, transformation of networks in Laplace-domain, time and frequency domain, response of network using Laplace transform, transient and steady state response of networks, formulation of mesh and loop equations in S domain. Impulse response and convolution techniques for LTI networks. Node-voltage analysis of networks. Sinusoidal response of networks using phasors, application to LCR series, and parallel circuits,

Driving point impedance, concept of transfer functions, poles zeros of network functions and their significance, stability criteria for passive and active networks. Parameters of two port networks, impedance parameters, admittance parameters, transmission parameters, hybrid parameters, inter-relationship among parameters.

Filter networks, propagation constant of T and π-network, concept of constant k filters, m-derived filters, s domain transfer functions of second order, LP,HP, BP,BS, notch, all pass filter, resonant filter, Attenuators, equalizers, series and shunt equalizers.

Unit 2. Op-amp fundamentals [8]

Ideal characteristics of Op amp, Basic op-amp configurations, Ideal closed loop characteristics, Ideal op-amp circuit analysis.

Transistor current sources and active loads, use of these in biasing of internal stages of op-amp, Supply independent biasing and temperature independent biasing, Low current biasing, Matching considerations in transistor current sources.

Emitter coupled differential amplifier, source-coupled FET pairs, Device mismatch effects. Frequency response of single and multistage amplifiers

Internal circuit of IC 741, Feedback and its effect on amplifier parameters, Practical considerations and effect of loading. Stability of feedback amplifiers: Relation between gain and bandwidth, instability and Nyquist criterian compensation, slew rate.

Unit 3 . Op-amp circuits and applications [10]

Characteristics of practical op-amps (static and dynamic) i.e. DC and low frequency parameters as well as large signal and transient characteristics.

Inverting and non-inverting amplifiers, Integrators and Differentiators

Instrumentation and bridge amplifiers, Log and antilog amplifiers, Active filters (Butterworth Chebyshev designs first and second orders), Sample and Hold circuits, Precise rectifiers and peak detectors, Comparator Circuits, Voltage references and regulators , need of low power design .

Unit 4 : Special Applications [8]

Low input voltage/current amplifier design, Op-amp parameters of interest for such designs, shielding and guarding techniques, special purpose op-amps. High voltage – high power amplifier design: Use of special high power op-amps, Modifying an amplifiers output capability, output voltage and current boosting

Low power design – Need, Applications, power sources and considerations, Linear Micropower design techniques, discrete linear design example, Micropower op-amps, programmable op-amps, design example, micropower comparators

Unit 5 Data Converters and Applications [10]

Digitization fundamentals, Performance specifications of D-A and A-D converters, D-A conversion techniques, multiplying DAC and its applications, (Weighted resistor and capacitor DAC's, potentiometric DAC's, current and voltage outputs, voltage and current mode segmentation)

Analog/digital conversion techniques: DAC based successive approximation, charge redistribution, pipelined converters, integrating converters, oversampling converters, $\sum$ - Δ converters. Application of DAC's and ADC's

Reference Books:

1. Network Analysis : G.K.Mittal
2. Introduction to Modern Network Synthesis : M.E.Van Valkenberg, John Wiley
3. Microelectronic Circuits: analysis and design: M. Rashid, PWS pub. Co.
4. Pulse Digital & Switching waveforms: Millman Taub
5. Operational Amplifiers: Franko
6. Operational Amplifiers: Clayton
7. Analysis and Design of analog integrated Circuits, Grey and Mayer.
8. Art of Electronics, Horwitz, Hill
9. Electronic Fundamental and Applications, J.D. Ryder
10. Transistor circuit Analysis and Design, Franklin C.Fitchen
11. Electronic Devices and Circuits, Mohammed Ghousi

EL1 UT03 : Instrumentation and Measurement Techniques

Objectives:

1. To understand the application of basic electronics assumptions and circuits.
2. To understand the basic working principle of transducers and actuators and further signal conditioning, data processing circuits.
3. To understand instrumentation required and needed in different disciplines.
4. To understand the correlation of electronics with other disciplines.

Unit-1: Introduction to measurement and measurement systems. [8]

Definition and significance of measurement. Methods of measurement. Instruments and Measurement systems. Classification of Instruments, Elements of Generalized measurement system.

Characteristics of measurement systems: Static characteristics, Noise, Errors in measurement: limiting, relative limiting errors. Types of errors: Gross, Systematic, Environmental errors

Dynamic characteristics: Dynamic Response, linear and non-linear systems 1^{st} and 2^{nd} order systems.

EMI and EMC consideration

Unit-2: Sensors and Transducers [16]

Methods of transduction, Primary sensing elements and transducers, Electrical transducers, Classification and Characteristics: input, transfer, output, Selection criteria for transducers

Motion and Dimensional: Strain gauge, differential, synchros and induction potentiometers, LVDT, Piezoelectric, Ultrasonic transducers.

Force, Torque and Shaft power: Bonded strain gauge, differential transformer, Piezoelectric, variable reluctance/ FM oscillator Digital system.

Pressure and Sound Measurement: Dead weight gauges and manometers, Low pressure measurement: McLeod gauge, Knudsen gauge, Viscosity, Thermal conductivity, Ionization, Sound level meter, microphone, capacitor microphone.

Flow measurement: Pitot-static tube, Yaw tube, Hot wire and hot film Anemometers, Laser Doppler velocitymeter.

Gross Volume Flow Rate: Rotameters, turbine, Ultrasonic flow meter, Electromagnetic flow meters, Direct mass flow meters.

Temperature and Heat measurement transducers: bimetallic thermometers, Liquid in glass thermometers, pressure thermometers, RTD, Thermocouples, optical pyrometers, IR imaginary systems, Heat flux sensing.

Slug type sensors, garden gauge, Smart sensors

Unit-3: Signals and Signal conditioning [10]

Signals and signal analysis, passive active filters, signal analyzers, frequency analysis and the methods of analysis, applications of signal analysis.

Bridge circuits, DC/AC signal conditioning systems, Operational Amplifiers, Instrumentation Amplifier, chopper, chopper stabilized and carrier amplifiers, Integration, Differentiation, Dynamic Compensation, Function generation and Linearization, Use of V-F, F-V, A-D and D-A converters.

Unit-4: Data Transmission and Telemetry. [8]

Method of data transmission , General Telemetry system, Types of Telemetry system : Voltage telemetry, current telemetry system.

Modulation methods, Transmission Channels and Media: Wire line channels, Radio channels Microwave channels.

Telemetry science: Frequency division multiplexing, Time Multiplexing, Telemetry Hardware and applications.

Unit-5: Display and Recording Devices [8]

Introduction, Digital Voltmeters (DVM), CRO, DFM, Galvanometric Recorders, Servo type potentiometric recorders, Magnetic tape recorders, Digital Recorders of memory type, Data Display and Storages, DSO.

Reference Books.

1. Instrumentation: Devices and Systems, 2nd edition,
   Rangan, Sarma, Mani
2. Instrumentation system – Deoublin
3. Instrumentation measurement and analysis,
   B.C. Nakara , K. K. Chaudhary (TMHP)
4. A Course in Electrical And Electronic Measurements And Instrumentation.- A.K.Sawhney
   Dhanpat Rai & Co.
5. Instrumental methods of chemical analysis,
   Chatwal Anand , Himalaya Publishing House , Mumbai.

EL1UP01: Practical Course I

Reference Books:

1. Basic Electronics Text- Lab Manual: By Zbar Malvino Miller TMH
2. Microelectronics Circuits: By Rashid PWS Publication
3. Opamp & Analog integrated circuits: By S. Franko

Group	**No. of Practicals**
A) Analog circuit Design	8
B) PSPICE	4

A) Analog circuit design

1. Design microphone preamplifier for 1000 gain.
2. Design build and test Bootstrap ramp generator for delay triggering.
3. Design, build and test voltage controlled current source/sink using JFET.
4. Design build and test Schmitt trigger for _____ hysteresis and D-A converter using OP-AMP.
5. Design build and test current mirror and doubler.
6. Design build and test Second order butterworth filters (BP and BR)
7. Design build and test waveform generation and shaping circuits using op-amp (quadrature oscillator, Zero Crossing detector)
8. Design build and test V to F & F to V using std. IC
9. Design build and test Instrumentation amplifier
10. Micro-power references and comparators
11. Design build and test Tuned amplifier (IF)
12. Design JFET based preamplifier

B) PSpice

1. D.C. circuit simulation using Pspice
2. Frequency response Filters: All types
3. Examples of transient and AC analysis: Rectifiers, Clamper
4. Opamp /BJT/FET macro model
5. Differential amplifier
6. Frequency response and transfer characteristics of multistage RC coupled amplifier
7. TTL inverter

EL1UP02 : Practical Course II

Reference Books:

1. Semiconductor Physics & Devices By D. Neamen TMH
2. Pspice By Rashid

Group	**No. of Practicals**
A) Principles of semiconductor devices using C / C++ / MATLAB	4
B) Instrumentation	8

A) Principles of semiconductor using C/C++/MATLAB

1. Evaluation of drift – diffusion equation.
2. Determination & visualization of fermi level
3. Characterization of semiconductor material (temperature dependent conductivity)
4. Determination of diffusion coefficient and plotting of excess carrier distribution
5. Determination of electron/hole mobility of semiconductor material using Hall effect.
6. Determination of terminal currents in BJT by solving differential equation in base region
7. Optical conductivity Vs lambda
8. Solution of partial differential equation

B) Instrumentation

1. Design build and test A.C. to rms converter
2. Displacement measurement using test LVDT
3. Temperature measurement using PT 100
4. Temperature measurement using thermocouple
5. Study of DPM
6. Frequency measurement.
7. Telemetry
8. Ultrasonic switch
9. RPM measurement
10. Optical position encoder

EL2UT04 : Applied Electromagnetics, RF and Microwave

Objectives:

1. To introduce to students the concepts of Electromagnetics and Electromagnetics as relevant to electronics.
2. To understand the use of the theory of transmission lines & wave guide.
3. To be able to analyze various parameters of antenna & antenna systems.
4. To study various applications of Electromagnetics.

Unit-1: Electromagnetic waves [6]

Revision: Maxwell equations, wave prorogation in conducting and non conducting media, reflection and refraction of polarised electromagnetic waves at an interference of non-conducting media, EM frequency spectrum, electromagnetic sources and detectors

Unit-2: Principles of transport of electromagnetic energy [12]

Transmission Lines: Different types of transmission lines, two wire transmission line, lumped and distributed parameters, transmission line equations for voltages and currents using circuit theory and field theory, characteristic impedance, propagation constants, attenuation and phase constants, phase velocity, reflection and transmission coefficient, SWR, line impedance, normalized impedance and admittance, Numerical exercises using circuit and Phasor theory, Smith chart-construction and applications, single stub and double stub matching, shielding of transmission lines.

Microstripline – Introduction to striplines, characteristic impedance, effective dielectric constant, dielectric ohmic and radiation losses in microstripline, Q-factor of microstripline, different types of microstriplines such as parallel, coplanar, shielded striplines

Waveguides – concept of cut-off frequency, guide impedance, phase velocity, guide wavelength for TE and TM modes, Applications to TE mode in rectangular waveguide, power losses in a rectangular waveguide, circular waveguide, optical fiber- Principal of operation and construction.

Unit-3: Electromagnetic radiation [14]

Potentials of electromagnetic fields, gauge transformations, Lorentz gauge and Coulomb gauge condition, Retarded potential, radiation from oscillating dipoles, concept of near zone and radiation zone, radiation resistance , Role of Antenna in exciting different TE, TM modes in wave guides.

Antenna parameters- Gain, directivity, power, aperture, different types, radiation pattern and application areas of antennas

Basic antennas, small loop, short dipoles and slot antennas, Reflector antennas – open out two conductor antenna, conical and horn antennas

Aperture antennas – parabolic dish antennas, dielectric lens antennas

End fire antenna – yagi-uda and axial mode helix antennas, stripline feed antennas

Microstrip antennas.

Unit-4: Applications of Electromagnetics in Electronic system. [6]

Electromagnetic effects in high speed digital systems e.g. reset signal on a PC card, CD player on air plane interface with the navigation system, ECL technology on a fiber-glass circuit board, EMI/EMC, shielding, Global positioning satellite

Unit-5: RF, microwave devices and applications [12]

Applications of RF: heating, plasma etching, sputter deposition, EMI shielding

Microwave frequencies and frequency bands for different applications, Absorption of microwave by atmospheric constituents, microwave system, generation of microwaves, microwave transistors and tunnel diodes, microwave FETs, MESFET and MOSFETs, Gunn effect diode, IMPATT diode, magnetron oscillator, Reflex Klystron Oscillator, monolithic microwave integrated circuits, microwave waveguides and resonant cavities and components, passive microwave devices -Terminator, variable short circuits, rotary, cut-off, nonreciprocal and ferrite attenuators, Faraday rotation, directional coupler, microwave guide junction , circulators, Application of microwaves **–**microwave oven, long distance communication.

References:

1. Electromagnetic with Applications: by Kraus and Fleiseh, McGrawHill 5-Ed, 1999
2. Fundamentals of Applied Electromagnetic: by Fawwaz and Ulaby, PHI 2001, Electromagnetic by J.D. Kraus 4th Edition McGrawHill 1992
3. Electromagnetic by B.B. Laud
4. Microwave devices and circuits: by Samuel Y. Liao, PHI 3rd Edition, 2002
5. Engineering Electromagnetic: By William H. Hayt McGrawHill
6. Electromagnetic Theory and wave propagations: By S.N. Gosh, Narosa Publishing House.1998.

EL2 UT05 : Communication Electronics

Objectives:

1. To study different circuits used in communication.
2. To study different transmission & reception systems
3. To study basic & advanced concepts in digital communication.

Unit 1. Signals and systems [06]

Forms and classification of telecommunication signals, Sinusoidal signals, Frequency content of signals, time and frequency domain representations, Fourier Transforms, Continuous and discrete time signals, sampling, sampling theorem, quantization and coding of quantized signals, practical limitations in sampling and reconstruction, information theory, data compression. Transmission media, noise and their types.

Unit 2. Analog communication circuit analysis [08]

Circuit analysis of AM generator and receiver, Super-heterodyne receiver, SSB generator, balanced modulators, filters, transmitters, SSB receiver, FM: Generator and receiver.

Unit 3 RF and mixed signal design [08]

Theory and and design of tuned amplifiers, cascode tuned amplifier, multistage tuned amplifier: synchronous stagger tunning, instability of tuned amplifiers and compensation (neutralization) techniques.

RF and wide band integrated circuit amplifiers

Unit 4. Baseband Digital Communication [10]

Block diagram of Pulse modulation, Block diagram of pulse code modulation, digital signal encoding formats, Algorithms for code error detection and correction, delta modulation, Adaptive Delta Modulation, line codes, TDM, data compression.

Unit 5.Data Communication [10]

Block diagram of Data Communication,(DTE, DCE, data link protocol), SDLC, HDLC, XMODM protocols, ASK, FSK, PSK, QAM, telephone modems, cable modems and DSL, computer modem connection.

Unit 6. Communication Technologies [08]

Local Loop, PSTN, ISDN, digital exchanges, satellite communication and VSAT, Wireless communication technologies: spread spectrum techniques, OFDM, Cellular phones, 3G wireless, IP telephony, Bluetooth, IrDA, CDMA

Reference Books

1. Modern Electronic Communications – Gray M. Miller Jeffrey Beasley, PHI, 2003.
2. Electronic Communication systems – Roy Blaks, Thomson –Delmar 2002.
3. Electronic Communication – robber t J .Schoenbeck , UBS 2002.
4. Electronic Communication–Taub,Schilling,1993 McGraw Hill
5. Electronic Communication – Carlson Published 2002 McGraw-Hill
6. Electronic communication systems, Kennedy,TMH
7. Electronic communication, Roody, Coolean, Prentis Hall

EL2 UT06 : Digital System Design using VHDL

Objectives:

1. To Understand sequential & combinational logic design techniques
2. To introduce VHDL
3. To learn various digital circuits using VHDL
4. To learn PLD, CPLD, FPGA & their application

Unit-1. Introduction of VHDL [10]

VHDL- description of digital circuits, design flow, program structure, variables, signals and constants, arrays, operators, functions, procedures, packages and libraries.

VHDL models for a logic gates, compilation and simulation of VHDL code.

Tools used for hardware testing of digital circuits developed with VHDL.

Unit-2. Combinational Logic Design [12]

Discrete logic design using standard MSI IC's : Design procedure, representation of logic function, and simplification of logic functions, use of K-maps, design examples- arithmetic circuits (Adder, subtractors), code converters, multiplexers, demultiplexers, and decoders, encoders. study and applications – Multi-bit adder circuit, parity generator/checker, multiple word data bussing, time multiplexer, function generator, data multiplexing, priority encoders, key board encoders, magnitude comparator, parallel adder, look ahead carry generator, binary multiplier.

Design examples using VHDL- multiplexer, simple floating point arithmetic, encoders and decoders.

Unit-3.Sequential logic design and circuits [10]

Discrete logic design using standard MSI IC's : Asynchronous sequential circuit design, use of excitation equations, excitation tables, transition tables, state tables, output table and flow graph, practical design example, sequential logic design, Finite state machine (FSM) design and practical design examples.

Design examples using VHDL - Traffic light control, washing machine control, parking controller, coffee vending machine.

Unit-4.Process and control Logic design [8]

Processor organization, bus organization, scratch pad memory, interregistor transfers, study of ALU and its design using VHDL

PLA and its application. PLD's, CMOS PLD circuits, device programming and testing, GAL 16V8A.

Unit-5.Memory, CPLD's, and FPGA's [10]

ROM – Types, data storage principle, control inputs and timings, applications.

RAM – Types (static, dynamic, NVRAM), RAM control inputs and timings, RAM cell design using VHDL.

CPLD- function block architecture, input/output block.

FPGA- functional block architecture, input/output block.

References:

1. Digital design –Principles practices by Wakerly
2. Digital System Design with VHDL – Mark Zwolinski
3. Digital systems design using VHDL-Roth.
4. Digital systems –Principles and applications by Tocci
5. Digital logic and computer design-Morris Mano

EL2UP 03 : Practical Course III

Reference Books:

1. Digital Design : Principles & Practices by John F. Wakerly PHI Pub. 3rd Ed.
2. Digital System Design using VHDL by Charles Roth (PWS Pub. Co.)

Group	**No. of Practicals**
A) Digital Practicals	4
B) VHDL based Practicals	8

A) Digital circuit design

1. Frequency Counter using CMOS IC's (Battery Operated)
2. 3 digit combinational lock design
3. Design and implementation of logic level converters (CMOS to TTL and TTL to CMOS)
4. Keyboard encoder
5. Practical based on state machine (Vending Machine, Washing Machine)
6. Stepper Motor Control (Sequence Generator)
7. Adder using look ahead carry
8. Function Generator using EPROM and DAC
9. Digital Thermometer

A) VHDL based practicals

1. Practical Based on VHDL Programming (Combinational Logic)
    a. Parity Generator and checker
    b. Hamming Code Generator
    c. Manchester code Generator
2. Designing of 4 $\times$ 2 bit Multiplier using VHDL
3. Practical Based on VHDL Programming (Sequential)
    a. 8 bit binary counter
    b. Universal shift register
4. Four bit ALU design using VHDL
5. Design of Simple Memory (RAM) model using VHDL.
6. Keyboard Scanning (Counter Method) using VHDL
7. Designing of Traffic light Controller using VHDL.
8. Implementation of 8 bit multiplexer on FPGA Board.
9. Designing of Digital logic for RPM Measurement using VHDL.
10. Code Converter (BCD to seven Segment)
11. Design of Modulo-7 Counter using FSM Model

EL2UP04 : Practical Course - II

Group	No. of Practicals
A) Electromagnetics	6
B) Communication	6

A) Electromagnetics

1. To plot Equipotential contours and field lines for given charge distribution.
2. Design of an electromagnetic lift
3. To determine crosstalk parameters of microstrip lines
4. Use of Smith chart for transmission line pattern.
5. Use of MATLAB for potential distribution in a region bound by two conductors.
6. Use of MATLAB for directivity pattern for simple antenna.
7. Study of waveguide component for directional couplers, H-T plane inverters , power reflectors
8. Measurement of primary secondary coupling factor in case of transformer with spacing and adjustable core
9. Study of parallel strip structure supported by an insulated plane for
   a) characteristic impedance b) frequency response

B) Communication

1. Design of AM transmitter and receiver
2. Design of FM transmitter and receiver
3. Delta modulation
4. Design PCM encoder and decoder system
5. Design of ASK /FSK transmitter and receiver
6. Time division Multiplexing
7. Telemetry Applications
8. Study of Antenna parameters (Any two)
9. Design of Yagi uda Antenna
10. Varacter diode characteristics and its application in FM