

GODAVARI INSTITUTE OF ENGINEERING & TECHNOLOGY
 NH-16, CHAITANYA KNOWLEDGE CITY, RAJAHMUNDRY-533296

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SPECIALIZATION: DE & CS
COURSE STRUCTURE-R14

I SEMESTER

S.No	SUBJECT CODE	SUBJECT	Periods per week			C	Scheme of Examination Max.Marks		
			T	P	D		Int.	Ext.	Total
1	14241101	Digital System Design	4	-	-	3	40	60	100
2	14241102	Detection& Estimation Theory	4	-	-	3	40	60	100
3	14241103	Digital Data Communication	4	-	-	3	40	60	100
4	14241104	Advanced Digital Signal processing	4	-	-	3	40	60	100
5	14241161(A) 14241161(B)	Elective I 1. VLSI Technology & Design 2. Transformation Techniques	4	-	-	3	40	60	100
6	14241162(A) 14241162(B)	Elective II 1. Optical communication Technology 2. Statistical Signal Processing	4	-	-	3	40	60	100
7	14241111	Laboratory 1.Design and Simulation lab	-	3	-	2	40	60	100
		TOTAL	24	3	-	20	280	420	700

II-SEMESTER

S.No	SUBJECT CODE	SUBJECT	Periods per week			C	Scheme of Examination Max.Marks		
			T	P	D		Int.	Ext.	Total
1	14241201	Coding Theory & Applications	4	-	-	3	40	60	100
2	14241202	Embedded Real Time Operating Systems	4	-	-	3	40	60	100
3	14241203	Image and Video Processing	4	-	-	3	40	60	100
4	14241204	Wireless Communication and Networks	4	-	-	3	40	60	100
5	14241263(A) 14241263(B)	Elective III 1.CMOS Analog and Digital IC Design 2.Advanced Computer Architecture	4	-	-	3	40	60	100
6	14241264(A) 14241264(B)	Elective IV 1.DSP processor and Architecture 2.EMI/EMC	4	-	-	3	40	60	100
7	14241211	Laboratory Advanced Communication Laboratory	4	3	-	2	40	60	100
		TOTAL	24	3	-	20	280	420	700

T-THEORY P-PRACTICAL D-DRAWING C-CREDITS Int.-INTERNAL Ext.-EXTERNAL

III SEMESTER

S.No	SUBJECT CODE	SUBJECT	Periods per week			C	Scheme of Examination Max.Marks		
			T	P	D		Int.	Ext.	Total
1	14241381	Seminar -I	1	-	-	2	50	-	50
2	14241341	Project work -I	-	-	-	18	-	-	-
		TOTAL	1	-	-	20	50	-	50

T-THEORY P-PRACTICAL D-DRAWING C-CREDITS Int.-INTERNAL Ext.-EXTERNAL

IV SEMESTER

S.No	SUBJECT CODE	SUBJECT	Periods per week			C	Scheme of Examination Max.Marks		
			T	P	D		Int.	Ext.	Total
1	14241481	Seminar -II	1	-	-	2	50	-	50
2	14241441	Project work -II	-	-	-	18	-	-	-
		TOTAL	1	-	-	20	50	-	50

T-THEORY P-PRACTICAL D-DRAWING C-CREDITS Int.-INTERNAL Ext.-EXTERNAL

Elective I

14241161(A) - VLSI Technology & Design

14241161(B) - Transformation Techniques

Elective II

14241162(A) - Optical communication Technology

14241162(B) - Statistical Signal Processing

Elective III

14241263(A) - CMOS Analog and Digital IC Design

14241263(B) - Advanced Computer Architecture

Elective IV

14241264(A) - DSP processor and Architecture

14241264(B) - EMI/EMC

I SEMESTER

I-I	L	P	Credits
	4	-	3
DIGITAL SYSTEM DESIGN			

UNIT-I**Minimization Procedures and CAMP Algorithm:**

Review on minimization of switching functions using tabular methods, k-map, QM algorithm, CAMP-I algorithm, Phase-I: Determination of Adjacencies, DA, CSC, SSMs and EPCs,, CAMP-I algorithm, Phase-II: Passport checking, Determination of SPC, CAMP-II algorithm: Determination of solution cube, Cube based operations, determination of selected cubes are wholly within the given switching function or not, Introduction to cube based algorithms.

UNIT-II**PLA Design, Minimization and Folding Algorithms:**

Introduction to PLDs, basic configurations and advantages of PLDs, PLA-Introduction, Block diagram of PLA, size of PLA, PLA design aspects, PLA minimization algorithm(IISc algorithm), PLA folding algorithm(COMPACT algorithm)-Illustration of algorithms with suitable examples.

UNIT -III**Design of Large Scale Digital Systems:**

Algorithmic state machine charts-Introduction, Derivation of SM Charts, Realization of SM Chart, control implementation, control unit design, data processor design, ROM design, PAL design aspects, digital system design approaches using CPLDs, FPGAs and ASICs.

UNIT-IV**Fault Diagnosis in Combinational Circuits:**

Faults classes and models, fault diagnosis and testing, fault detection test, test generation, testing process, obtaining a minimal complete test set, circuit under test methods- Path sensitization method, Boolean difference method, properties of Boolean differences, Kohavi algorithm, faults in PLAs, DFT schemes, built in self-test.

UNIT-V**Fault Diagnosis in Sequential Circuits:**

Fault detection and location in sequential circuits, circuit test approach, initial state identification, Haming experiments, synchronizing experiments, machine identification, distinguishing experiment, adaptive distinguishing experiments.

TEXT BOOKS:

1. Logic Design Theory-N. N. Biswas, PHI
2. Switching and Finite Automata Theory-Z. Kohavi , 2nd Edition, 2001, TMH
3. Digital system Design using PLDd-Lala

REFERENCE BOOKS

1. Fundamentals of Logic Design – Charles H. Roth, 5th Ed., Cengage Learning.
2. Digital Systems Testing and Testable Design – Miron Abramovici, Melvin A.Breuer and Arthur D. Friedman- John Wiley & Sons Inc

I-I	L	P	Credits
	4	-	3
DETECTION AND ESTIMATION THEORY			

UNIT -I**Random Processes:**

Discrete Linear Models, Markov Sequences and Processes, Point Processes, and Gaussian Processes.

UNIT -II**Detection Theory:**

Basic Detection Problem, Maximum A posteriori Decision Rule, Minimum Probability of Error Classifier, Bayes Decision Rule, Multiple-Class Problem (Bayes)- minimum probability error with and without equal a priori probabilities, Neyman-Pearson Classifier, General Calculation of Probability of Error, General Gaussian Problem, Composite Hypotheses

UNIT -III**Linear Minimum Mean-Square Error Filtering:**

Linear Minimum Mean Squared Error Estimators, Nonlinear Minimum Mean Squared Error Estimators. Innovations, Digital Wiener Filters with Stored Data, Real-time Digital Wiener Filters, Kalman Filters.

UNIT -IV**Statistics:**

Measurements, Nonparametric Estimators of Probability Distribution and Density Functions, Point Estimators of Parameters, Measures of the Quality of Estimators, Introduction to Interval Estimates, Distribution of Estimators, Tests of Hypotheses, Simple Linear Regression, Multiple Linear Regression.

UNIT -V**Estimating the Parameters of Random Processes from Data:**

Tests for Stationarity and Ergodicity, Model-free Estimation, Model-based Estimation of Autocorrelation Functions, Power Special Density Functions.

TEXT BOOKS:

1. Random Signals: Detection, Estimation and Data Analysis - K. Sam Shanmugan & A.M. Breipohl, Wiley India Pvt. Ltd, 2011.
2. Random Processes: Filtering, Estimation and Detection - Lonnie C. Ludeman, Wiley India Pvt. Ltd., 2010.

REFERENCE BOOKS:

1. Fundamentals of Statistical Signal Processing: Volume I Estimation Theory– Steven.M.Kay, Prentice Hall, USA, 1998.
2. Fundamentals of Statistical Signal Processing: Volume I Detection Theory– Steven.M.Kay, Prentice Hall, USA, 1998.
3. Introduction to Statistical Signal Processing with Applications - Srinath, Rajasekaran, Viswanathan, 2003, PHI.
4. Statistical Signal Processing: Detection, Estimation and Time Series Analysis – Louis L.Scharf, 1991, Addison Wesley.
5. Detection, Estimation and Modulation Theory: Part – I – Harry L. Van Trees, 2001, John Wiley & Sons, USA.
6. Signal Processing: Discrete Spectral Analysis – Detection & Estimation – Mischa Schwartz, Leonard Shaw, 1975, Mc Graw Hill.

I-I	L	P	Credits
	4	-	3
DIGITAL DATA COMMUNICATION			

UNIT -I**Digital Modulation Schemes:**

BPSK, QPSK, 8PSK, 16PSK, 8QAM, 16QAM, DPSK – Methods, Band Width Efficiency, Carrier Recovery, Clock Recovery.

UNIT -II**Basic Concepts of Data Communications, Interfaces and Modems:**

Data Communication Networks, Protocols and Standards, UART, USB, I2C, I2S, Line Configuration, Topology, Transmission Modes, Digital Data Transmission, DTE-DCE interface, Categories of Networks – TCP/ IP Protocol suite and Comparison with OSI model.

UNIT -III

Error Correction: Types of Errors, Vertical Redundancy Check (VRC), LRC, CRC, Checksum, Error Correction using Hamming code.

Data Link Control: Line Discipline, Flow Control, Error Control.

Data Link Protocols: Asynchronous Protocols, Synchronous Protocols, Character Oriented Protocols, Bit-Oriented Protocol, Link Access Procedures.

UNIT -IV

Multiplexing: Frequency Division Multiplexing (FDM), Time Division Multiplexing (TDM), Multiplexing Application, DSL.

Local Area Networks: Ethernet, Other Ether Networks, Token Bus, Token Ring, FDDI.

Metropolitan Area Networks: IEEE 802.6, SMDS.

Switching: Circuit Switching, Packet Switching, Message Switching.

Networking and Interfacing Devices: Repeaters, Bridges, Routers, Gateway, Other Devices.

UNIT -V**Multiple Access Techniques:**

Random Access, Aloha- Carrier Sense Multiple Access (CSMA)- Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), Controlled Access- Reservation- Polling- Token Passing, Channelization, Frequency- Division Multiple Access (FDMA), Time - Division Multiple Access (TDMA), Code - Division Multiple Access (CDMA), OFDM and OFDMA.

TEXT BOOKS:

1. Data Communication and Computer Networking - B. A. Forouzan, 2nd Ed., 2003, TMH.
2. Advanced Electronic Communication Systems - W. Tomasi, 5th Ed., 2008, PEI.

REFERENCE BOOKS:

1. Data Communications and Computer Networks - Prakash C. Gupta, 2006, PHI.
2. Data and Computer Communications - William Stallings, 8th Ed., 2007, PHI.
3. Data Communication and Tele Processing Systems - T. Housely, 2nd Ed, 2008, BSP.
4. Data Communications and Computer Networks- Brijendra Singh, 2nd Ed., 2005, PHI.

I-I	L	P	Credits
	4	-	3
ADVANCED DITAL SIGNAL PROCESSING			

UNIT -I**Review of DFT, FFT, IIR Filters and FIR Filters:**

Multi Rate Signal Processing: Introduction, Decimation by a factor D, Interpolation by a factor I, Sampling rate conversion by a rational factor I/D, Multistage Implementation of Sampling Rate Conversion, Filter design & Implementation for sampling rate conversion.

UNIT -II**Applications of Multi Rate Signal Processing:**

Design of Phase Shifters, Interfacing of Digital Systems with Different Sampling Rates, Implementation of Narrow Band Low Pass Filters, Implementation of Digital Filter Banks, Sub-band Coding of Speech Signals, Quadrature Mirror Filters, Trans-multiplexers, Over Sampling A/D and D/A Conversion.

UNIT -III

Non-Parametric Methods of Power Spectral Estimation: Estimation of spectra from finite duration observation of signals, Non-parametric Methods: Bartlett, Welch & Blackman-Tukey methods, Comparison of all Non-Parametric methods

UNIT -IV**Implementation of Digital Filters:**

Introduction to filter structures (IIR & FIR), Frequency sampling structures of FIR, Lattice structures, Forward prediction error, Backward prediction error, Reflection coefficients for lattice realization, Implementation of lattice structures for IIR filters, Advantages of lattice structures.

UNIT -V

Parametric Methods of Power Spectrum Estimation: Autocorrelation & Its Properties, Relation between auto correlation & model parameters, AR Models - Yule-Walker & Burg Methods, MA & ARMA models for power spectrum estimation, Finite word length effect in IIR digital filters

– Finite word-length effects in FFT algorithms.

TEXT BOOKS

1. Digital Signal Processing: Principles, Algorithms & Applications - J.G.Proakis & D. G. Manolakis, 4th Ed., PHI.
2. Discrete Time Signal Processing - Alan V Oppenheim & R. W Schaffer, PHI.
3. DSP – A Practical Approach – Emmanuel C. Ifeacher, Barrie. W. Jervis, 2 Ed., Pearson Education.

REFERENCE BOOKS:

1. Modern Spectral Estimation: Theory & Application – S. M .Kay, 1988, PHI.
2. Multi Rate Systems and Filter Banks – P.P.Vaidyanathan – Pearson Education.
3. Digital Signal Processing – S.Salivahanan, A.Vallavaraj, C.Gnanapriya, 2000,TMH
4. Digital Spectral Analysis – Jr. Marple

I-I	L	P	Credits
	4	-	3
	ELECTIVE -I TRANSFORMATION TECHNIQUES		

UNIT -I

Fourier Analysis: Fourier series, Examples, Fourier Transform, Properties of Fourier Transform, Examples of Fourier transform, sampling theorem, Partial sum and Gibbs phenomenon, Fourier analysis of Discrete time Signals, Discrete Fourier Transform.

Time – Frequency Analysis: Window function, Short Time Fourier Transform, Discrete Short Time Fourier Transform, Continuous wavelet transform, Discrete wavelet transform, wavelet series, Interpretations of the Time-Frequency plot.

UNIT -II

Transforms: Walsh, Hadamard, Haar and Slant Transforms, DCT, DST, KLT, Singular value Decomposition – definition, properties and applications

UNIT -III

Continuous Wavelet Transform (CWT): Short comings of STFT, Need for wavelets, Wavelet Basis- Concept of Scale and its relation with frequency, Continuous time wavelet Transform Equation- Series Expansion using Wavelets- CWT- Tiling of time scale plane for CWT. Important Wavelets: Haar, Mexican Hat, Meyer, Shannon, Daubechies.

UNIT -IV

Multi Rate Analysis and DWT: Need for Scaling function – Multi Resolution Analysis, Two-Channel Filter Banks, Perfect Reconstruction Condition, Relationship between Filter Banks and Wavelet Basis, DWT, Structure of DWT Filter Banks, Daubechies Wavelet Function, Applications of DWT.

UNIT -V

Wavelet Packets and Lifting: Wavelet Packet Transform, Wavelet packet algorithms, Thresholding-Hard thresholding, Soft thresholding, Multidimensional Wavelets, Bi-orthogonal basis- B-Splines,
Multidimensional Wavelets, Bi-orthogonal basis- B-Splines.

TEXT BOOKS:

1. A Wavelet Tour of Signal Processing theory and applications - Raghuvir M.Rao and Ajit S. Bopardikar, Pearson Edu, Asia, New Delhi, 2003.
2. K.P.Soman and K.I Ramachandran, “ Insight into Wavelets – from theory to practice” PHI, Second edition,2008

REFERENCE BOOKS:

1. Fundamentals of Wavelets- Theory, Algorithms and Applications - Jaideva C Goswami, Andrew K Chan, John Wiley & Sons, Inc, Singapore, 1999.
2. Jaideva C.Goswami and Andrew K.Chan, “ Fundamentals of Wavelets” Wiley publishers, 2006
3. A Wavelet Tour of Signal Processing-Stephen G. Mallat, Academic Press, 2 Ed
4. Digital Image Processing – S.Jayaraman, S.Esakkirajan, T.Veera Kumar – TMH,2009

I-I	L	P	Credits
	4	-	3
ELECTIVE -I VLSI TECHNOLOGY & DESIGN			

UNIT-I

VLSI Technology: Fundamentals and applications, IC production process, semiconductor processes, design rules and process parameters, layout techniques and process parameters.

VLSI Design: Electronic design automation concept, ASIC and FPGA design flows, SOC designs, design technologies: combinational design techniques, sequential design techniques, state machine logic design techniques and design issues.

UNIT-II

CMOS VLSI Design: MOS Technology and fabrication process of pMOS, nMOS, CMOS and BiCMOS technologies, comparison of different processes.

Building Blocks of a VLSI circuit: Computer architecture, memory architectures, communication interfaces, mixed signal interfaces.

VLSI Design Issues: Design process, design for testability, technology options, power calculations, package selection, clock mechanisms, mixed signal design.

UNIT-III

Basic electrical properties of MOS and BiCMOS circuits, MOS and BiCMOS circuit design processes, Basic circuit concepts, scaling of MOS circuits-qualitative and quantitative analysis with proper illustrations and necessary derivations of expressions.

UNIT-IV

Subsystem Design and Layout: Some architectural issues, switch logic, gate logic, examples of structured design (combinational logic), some clocked sequential circuits, other system considerations.

Subsystem Design Processes: Some general considerations and an illustration of design processes, design of an ALU subsystem.

UNIT-V

Floor Planning: Introduction, Floor planning methods, off-chip connections.

Architecture Design: Introduction, Register-Transfer design, high-level synthesis, architectures for low power, architecture testing.

Chip Design: Introduction and design methodologies.

TEXT BOOKS:

1. Essentials of VLSI Circuits and Systems, K. Eshraghian, Douglas A. Pucknell, Sholeh Eshraghian, 2005, PHI Publications.
2. Modern VLSI Design-Wayne Wolf, 3rd Ed., 1997, Pearson Education.
3. VLSI Design-Dr.K.V.K.K.Prasad, Kattula Shyamala, Kogent Learning Solutions Inc., 2012.

REFERENCE BOOKS:

1. VLSI Design Technologies for Analog and Digital Circuits, Randall L.Geiger, Phillip E.Allen, Noel R.Strader, TMH Publications, 2010.
2. Introduction to VLSI Systems: A Logic, Circuit and System Perspective-Ming-BO Lin, CRC Press, 2011.
3. Principles of CMOS VLSI Design-N.H.E Weste, K. Eshraghian, 2nd Edition, Addison Wesley.

I-I	L	P	Credits
	4	-	3
ELECTIVE -II STATISTICAL SIGNAL PROCESSING			

UNIT- I

Signal models and characterization: Types and properties of statistical models for signals and how they relate to signal processing, Common second-order methods of characterizing signals including autocorrelation, partial correlation, cross-correlation, power spectral density and cross-power spectral density.

UNIT- II

Spectral estimation: Nonparametric methods for estimation of power spectral density, autocorrelation, cross-correlation, transfer functions, and coherence from finite signal samples.

UNIT- III

Review of signal processing: A review on random processes, A review on filtering random processes, Examples.

Statistical parameter estimation: Maximum likelihood estimation, maximum a posteriori estimation, Cramer-Rao bound.

UNIT -IV

Eigen structure based frequency estimation: Pisarenko, MUSIC, ESPRIT their application sensor array direction finding.

Spectrum estimation: Moving average (MA), Auto Regressive (AR), Auto Regressive Moving Average (ARMA), Various non-parametric approaches.

UNIT -V

Wiener filtering: The finite impulse case, causal and non-causal infinite impulse responses cases, Least mean squares adaptation, recursive least squares adaptation, Kalman filtering.

TEXT BOOKS:

1. Steven M.Kay, fundamentals of statistical signal processing: estimation Theory, Prentice-Hall, 1993.
2. Monsoon H. Hayes, Statistical digital signal processing and modeling, USA, Wiley, 1996.

REFERENCE BOOKS:

1. Dimitris G. Manolakis, Vinay K. Ingle, and Stephen M. Kogon, Statistical and adaptive signal processing, Artech House, Inc, 2005, ISBN 1580536107

I-I	L	P	Credits
	4	-	3
	ELECTIVE -II OPTICAL COMMUNICATION AND TECHNOLOGY		

UNIT -I

Signal propagation in Optical Fibers: Geometrical Optics approach and Wave Theory approach, Loss and Bandwidth, Chromatic Dispersion, Non Linear effects- Stimulated Brillouin and Stimulated Raman Scattering, Propagation in a Non-Linear Medium, Self-Phase Modulation and Cross Phase Modulation, Four Wave Mixing, Principle of Solitons.

UNIT -II

Fiber Optic Components for Communication & Networking: Couplers, Isolators and Circulators, Multiplexers, Bragg Gratings, Fabry-Perot Filters, Mach Zender Interferometers, Arrayed Waveguide Grating, Tunable Filters, High Channel Count Multiplexer Architectures, Optical Amplifiers, Direct and External Modulation Transmitters, Pump Sources for Amplifiers, Optical Switches and Wavelength Converters.

UNIT -III

Modulation and Demodulation: Signal formats for Modulation, Subcarrier Modulation and Multiplexing, Optical Modulations – Duobinary, Single Side Band and Multilevel Schemes, Ideal and Practical receivers for Demodulation, Bit Error Rates, Timing Recovery and Equalization, Reed-Solomon Codes for Error Detection and Correction.

UNIT -IV

Transmission System Engineering: System Model, Power Penalty in Transmitter and Receiver, Optical Amplifiers, Crosstalk and Reduction of Crosstalk, Cascaded Filters, Dispersion Limitations and Compensation Techniques.

UNIT -V

Fiber Non-linearities and System Design Considerations: Limitation in High Speed and WDM Systems due to Non-linearities in Fibers, Wavelength Stabilization against Temperature Variations, Overall System Design considerations – Fiber Dispersion, Modulation, Non-Linear Effects, Wavelengths, All Optical Networks.

TEXT BOOKS:

1. Optical Networks: A Practical Perspective - Rajiv Ramaswami and Kumar N. Sivarajan, 2nd Ed., 2004, Elsevier Morgan Kaufmann Publishers (An Imprint of Elsevier).
2. Optical Fiber Communications – Gerd Keiser, 3rd Ed., 2000, McGraw Hill.

REFERENCE BOOKS:

1. Optical Fiber Communications: Principles and Practice – John.M.Senior, 2nd Ed., 2000, PE.
2. Fiber Optics Communication – Harold Kolimbris, 2nd Ed., 2004, PEI
3. Optical Networks: Third Generation Transport Systems – Uyless Black, 2nd Ed., 2009, PEI
4. Optical Fiber Communications – Govind Agarwal, 2nd Ed., 2004, TMH.
5. Optical Fiber Communications and Its Applications – S.C.Gupta, 2004, PHI.

I-I	L	P	Credits
	-	2	2
DESIGN AND SIMULATION LABORATORY			

PART-A VLSI Lab (Front-end environment)

- The students are required to design the logic circuit to perform the following experiments using necessary simulator (Xilinx ISE Simulator/ Mentor Graphics Questa Simulator) to verify the logical /functional operation and to perform the analysis with appropriate synthesizer (Xilinx ISE Synthesizer/Mentor Graphics Precision RTL) and then verify the implemented logic with different hardware modules/kits (CPLD/ FPGA kits).
- The students are required to acquire the knowledge in both the Platforms (Xilinx and Mentor graphics) by perform at least FOUR experiments on each Platform.

List of Experiments:

1. Realization of Logic gates.
2. Parity Encoder.
3. Random Counter.
4. Synchronous RAM.
5. ALU.
6. UART Model.
7. Traffic Light Controller using Sequential Logic circuits
8. Finite State Machine (FSM) based logic circuit.

PART-B: VLSI Lab (Back-end Environment)

- The students are required to design and implement the Layout of the following experiments of any THREE using CMOS 130nm Technology with Mentor Graphics Tool.

List of Experiments:

1. Inverter Characteristics.
2. Full Adder.
3. RS-Latch, D-Latch and Clock Divider.
4. Synchronous Counter and Asynchronous Counter.
5. Digital-to-Analog-Converter.
6. Analog-to-Digital Converter.

LAB REQUIREMENTS FOR PART-A & PART-B:

Software: Xilinx ISE Suite 13.2 Version, Mentor Graphics-Questa Simulator, Mentor Graphics-Precision RTL, Mentor Graphics Back End/Tanner Software tool.

Hardware: Personal Computer with necessary peripherals, configuration and operating System and relevant VLSI (CPLD/FPGA) hardware Kits.

PART-C: Embedded Systems Laboratory

- The Students are required to write the programs using C-Language according to the Experiment requirements using RTOS Library Functions and macros ARM-926 developer kits.
- The following experiments are required to develop the algorithms, flow diagrams, source code and perform the compilation, execution and implement the same using necessary hardware kits for verification. The programs developed for the implementation should be at the level of an embedded system design.
- The students are required to perform at least THREE experiments.

List of Experiments: (using ARM-926 with PERFECT RTOS)

1. Register a new command in CLI.
2. Create a new Task.
3. Interrupt handling.
4. Allocate resource using semaphores.
5. Share resource using MUTEX.
6. Avoid deadlock using BANKER'S algorithm.

Lab Requirements for PART-C:**Software:**

- (i) Eclipse IDE for C and C++ (YAGARTO Eclipse IDE), Perfect RTOS Library
- (ii) LINUX Environment for the compilation using Eclipse IDE & Java with latest version.

Hardware:

- (i) The development kits of ARM-926 Developer Kits Boards.
- (ii) Serial Cables, Network Cables and recommended power supply for the board.

I-II	L	P	Credits
	4	-	3
CODING THEORY AND APPLICATIONS			

UNIT-I

Coding for Reliable Digital Transmission and Storage: Mathematical model of Information, A Logarithmic Measure of Information, Average and Mutual Information and Entropy, Types of Errors, Error Control Strategies.

Linear Block Codes: Introduction to Linear Block Codes, Syndrome and Error Detection, Minimum Distance of a Block code, Error-Detecting and Error-correcting Capabilities of a Block code, Standard array and Syndrome Decoding, Probability of an undetected error for Linear Codes over a BSC, Hamming Codes. Applications of Block codes for Error control in data storage system

UNIT -II

Cyclic Codes: Description, Generator and Parity-check Matrices, Encoding, Syndrome Computation and Error Detection, Decoding, Cyclic Hamming Codes, Shortened cyclic codes, Error-trapping decoding for cyclic codes, Majority logic decoding for cyclic codes.

UNIT -III

Convolutional Codes: Encoding of Convolutional Codes, Structural and Distance Properties, maximum likelihood decoding, Sequential decoding, Majority- logic decoding of Convolution codes. Application of Viterbi Decoding and Sequential Decoding, Applications of Convolutional codes in ARQ system.

UNIT -IV

Burst –Error-Correcting Codes: Decoding of Single-Burst error Correcting Cyclic codes, Single-Burst-Error-Correcting Cyclic codes, Burst-Error-Correcting Convolutional Codes, Bounds on Burst Error-Correcting Capability, Interleaved Cyclic and Convolutional Codes, Phased-Burst –Error-Correcting Cyclic and Convolutional codes.

UNIT -V

BCH – Codes: BCH code- Definition, Minimum distance and BCH Bounds, Decoding Procedure for BCH Codes- Syndrome Computation and Iterative Algorithms, Error Location Polynomials and Numbers for single and double error correction

TEXT BOOKS:

1. Error Control Coding- Fundamentals and Applications –Shu Lin, Daniel J.Costello,Jr, Prentice Hall, Inc.
2. Error Correcting Coding Theory-Man Young Rhee- 1989, McGraw-Hill Publishing.

REFERENCE BOOKS:

1. Digital Communications-Fundamental and Application - Bernard Sklar, PE.
2. Digital Communications- John G. Proakis, 5th Ed., 2008, TMH.
3. Introduction to Error Control Codes-Salvatore Gravano-oxford
4. Error Correction Coding – Mathematical Methods and Algorithms – Todd K.Moon, 2006, Wiley India.
5. Information Theory, Coding and Cryptography – Ranjan Bose, 2nd Ed, 2009, TMH.

I-II	L	P	Credits
	4	-	3
EMBEDDED REAL TIME OPERATING SYSTEMS			

UNIT-I

Introduction OS Services, Process Management, Timer Functions, Event Functions, Memory Management, Device, File and IO Systems Management, Interrupt Routines in RTOS Environment and Handling of Interrupt Source Calls, Real-Time Operating Systems, Basic Design Using an RTOS, RTOS Task Scheduling Models, Interrupt Latency and Response of the Tasks as Performance Metrics, OS Security Issues.

UNIT-II

RTOS Programming Basic Functions and Types of RTOS for Embedded Systems, RTOS mCOS-II, RTOS Vx Works, Programming concepts of above RTOS with relevant Examples, Programming concepts of RTOS Windows CE, RTOS OSEK, RTOS Linux 2.6.x and RTOS RT Linux.

UNIT-III

Program Modeling – Case Studies Case study of embedded system design and coding for an Automatic Chocolate Vending Machine (ACVM) Using Mucos RTOS, case study of digital camera hardware and software architecture, case study of coding for sending application layer byte streams on a TCP/IP Network Using RTOS Vx Works, Case Study of Embedded System for an Adaptive Cruise Control (ACC) System in Car, Case Study of Embedded System for a Smart Card, Case Study of Embedded System of Mobile Phone Software for Key Inputs.

UNIT-IV

Target Image Creation & Programming in Linux Off-The-Shelf Operating Systems, Operating System Software, Target Image Creation for Window XP Embedded, Porting RTOS on a Micro Controller based Development Board. Overview and programming concepts of Unix/Linux Programming, Shell Programming, System Programming.

UNIT-V

Programming in RT Linux Overview of RT Linux, Core RT Linux API, Program to display a message periodically, semaphore management, Mutex, Management, Case Study of Appliance Control by RT Linux System.

TEXT BOOKS:

1. Dr. K.V.K.K. Prasad: "Embedded/Real-Time Systems" Dream Tech Publications, Black pad book.
2. Rajkamal: "Embedded Systems-Architecture, Programming and Design", Tata McGraw Hill Publications, Second Edition, 2008.

REFERENCES:

1. Labrosse, "Embedding system building blocks ", CMP publishers.
2. Rob Williams," Real time Systems Development", Butterworth Heinemann Publications.

I-II	L	P	Credits
	4	-	3
IMAGE AND VIDEO PROCESSING			

UNIT -I**Fundamentals of Image Processing and Image Transforms:**

Introduction, Image sampling, Quantization, Resolution, Image file formats, Elements of image processing system, Applications of Digital image processing

Introduction, Need for transform, image transforms, Fourier transform, 2 D Discrete Fourier transform and its transforms, Importance of phase, Walsh transform, Hadamard transform, Haar transform, slant transform Discrete cosine transform, KL transform, singular value decomposition, Radon transform, comparison of different image transforms.

UNIT -II

Image Enhancement: Spatial domain methods: Histogram processing, Fundamentals of Spatial filtering, Smoothing spatial filters, Sharpening spatial filters.

Frequency domain methods: Basics of filtering in frequency domain, image smoothing, image sharpening, Selective filtering.

Image Restoration: Introduction to Image restoration, Image degradation, Types of image blur, Classification of image restoration techniques, Image restoration model, Linear and Nonlinear image restoration techniques, Blind deconvolution

UNIT -III

Image Segmentation: Introduction to image segmentation, Point, Line and Edge Detection, Region based segmentation., Classification of segmentation techniques, Region approach to image segmentation, clustering techniques, Image segmentation based on thresholding, Edge based segmentation, Edge detection and linking, Hough transform, Active contour

Image Compression: Introduction, Need for image compression, Redundancy in images, Classification of redundancy in images, image compression scheme, Classification of image compression schemes, Fundamentals of information theory, Run length coding, Shannon – Fano coding, Huffman coding, Arithmetic coding, Predictive coding, Transformed based compression, Image compression standard, Wavelet-based image compression, JPEG Standards

UNIT -IV

Basic Steps of Video Processing: Analog Video, Digital Video. Time-Varying Image Formation models: Three-Dimensional Motion Models, Geometric Image Formation, Photometric Image Formation, Sampling of Video signals, Filtering operations.

UNIT -V

2-D Motion Estimation: Optical flow, General Methodologies, Pixel Based Motion Estimation, Block- Matching Algorithm, Mesh based Motion Estimation, Global Motion Estimation, Region based Motion Estimation, Multi resolution motion estimation, Waveform based coding, Block based transform coding, Predictive coding, Application of motion estimation in Video coding.

TEXT BOOKS:

1. Digital Image Processing – Gonzaleze and Woods, 3rd Ed., Pearson.
2. Video Processing and Communication – Yao Wang, Joem Ostermann and Ya-quin Zhang. 1st Ed., PH Int.
3. S.Jayaraman, S.Esakkirajan and T.VeeraKumar, ‘Digital Image processing, Tata Mc Graw Hill publishers, 2009.

REFERENCE BOOKS:

1. Digital Image Processing and Analysis-Human and Computer Vision Application with CVIP Tools – Scotte Umbaugh, 2nd Ed, CRC Press, 2011.
2. Digital Video Processing – M. Tekalp, Prentice Hall International.
3. Digital Image Processing – S.Jayaraman, S.Esakkirajan, T.Veera Kumar – TMH, 200911
4. Multidimentional Signal, Image and Video Processing and Coding – John Woods, 2nd Ed, Elsevier.
5. Digital Image Processing with MATLAB and Labview – Vipula Singh, Elsevier. Video Demystified – A Hand Book for the Digital Engineer– Keith Jack, 5th Ed., Elsevier

I-II	L	P	Credits
	4	-	3
WIRELESS COMMUNICATIONS AND NETWORKS			

UNIT -I

The Cellular Concept-System Design Fundamentals: Introduction, Frequency Reuse, Channel Assignment Strategies, Handoff Strategies-Prioritizing Handoffs, Practical Handoff Considerations, Interference and system capacity – Co channel Interference and system capacity, Channel planning for Wireless Systems, Adjacent Channel interference , Power Control for Reducing interference, Trunking and Grade of Service, Improving Coverage & Capacity in Cellular Systems- Cell Splitting, Sectoring .

UNIT -II

Mobile Radio Propagation: Large-Scale Path Loss: Introduction to Radio Wave Propagation, Free Space Propagation Model, Relating Power to Electric Field, The Three Basic Propagation Mechanisms, Reflection-Reflection from Dielectrics, Brewster Angle, Reflection from perfect conductors, Ground Reflection (Two-Ray) Model, Diffraction-Fresnel Zone Geometry, Knife-edge Diffraction Model, Multiple knife-edge Diffraction, Scattering, Outdoor Propagation Models- Longley-Ryce Model, Okumura Model, Hata Model, PCS Extension to Indoor Propagation Models-Partition losses (Same Floor), Partition losses between Floors, Log-distance path loss model, Ericsson Multiple Breakpoint Model, Attenuation Factor Model, Signal penetration into buildings, Ray Tracing and Site Specific Modeling.

UNIT -III

Mobile Radio Propagation: Small –Scale Fading and Multipath Small Scale Multipath propagation-Factors influencing small scale fading, Doppler shift, Impulse Response Model of a multipath channel-Relationship between Bandwidth and Received power, Small-Scale Multipath Measurements-Direct RF Pulse System, Spread Spectrum Sliding Correlator Channel Sounding, Frequency Domain Channels Sounding, Parameters of Mobile Multipath Channels-Time Dispersion Parameters, Coherence Bandwidth, Doppler Spread and Coherence Time, Types of Small-Scale Fading-Fading effects Due to Multipath Time Delay Spread, Flat fading, Frequency selective fading, Fading effects Due to Doppler Spread-Fast fading, slow fading, Statistical Models for multipath Fading Channels-Clarke's model for flat fading, spectral shape due to Doppler spread in Clarke's model, Simulation of Clarke and Gans Fading Model, Level crossing and fading statistics, Two-ray Rayleigh Fading Model

UNIT -IV

Equalization and Diversity Introduction, Fundamentals of Equalization, Training A Generic Adaptive Equalizer, Equalizers in a communication Receiver, Linear Equalizers, Non-linear Equalization-Decision Feedback Equalization (DFE), Maximum Likelihood Sequence Estimation (MLSE) Equalizer, Algorithms for adaptive equalization-Zero Forcing Algorithm, Least Mean Square Algorithm, Recursive least squares algorithm. Diversity Techniques-Derivation of selection Diversity improvement, Derivation of Maximal Ratio Combining improvement, Practical Space Diversity Consideration-Selection Diversity, Feedback or Scanning Diversity, Maximal Ratio Combining, Equal Gain Combining, Polarization Diversity, Frequency Diversity, Time Diversity, RAKE Receiver.

UNIT -V

Wireless Networks Introduction to wireless Networks, Advantages and disadvantages of Wireless Local Area Networks, WLAN Topologies, WLAN Standard IEEE 802.11, IEEE 802.11 Medium Access Control, Comparision of IEEE 802.11 a,b,g and n standards, IEEE 802.16 and its enhancements, Wireless PANs, Hiper Lan, WLL.

TEXT BOOKS:

1. Wireless Communications, Principles, Practice – Theodore, S. Rappaport, 2nd Ed., 2002, PHI.
2. Wireless Communications-Andrea Goldsmith, 2005 Cambridge University Press.
3. Mobile Cellular Communication – Gottapu Sasibhushana Rao, Pearson Education, 2012.

REFERENCE BOOKS:

- 1 . Principles of Wireless Networks – Kaveh Pah Laven and P. Krishna Murthy, 2002, PE
2. Wireless Digital Communications – Kamilo Feher, 1999, PHI.
3. Wireless Communication and Networking – William Stallings, 2003, PHI.
4. Communication – Upen Dalal, Oxford Univ. Press Wireless Communications and Networking – Vijay K. Gary, Elsevier

I-II	L	P	Credits
	4	-	3
	(ELECTIVE-III) CMOS ANALOG AND DIGITAL IC DESIGN		

UNIT-I

MOS Devices and Modeling The MOS Transistor, Passive Components-Capacitor & Resistor, Integrated circuit Layout, CMOS Device Modeling - Simple MOS Large-Signal Model, Other Model Parameters, Small-Signal Model for the MOS Transistor, Computer Simulation Models, Sub-threshold MOS Model.

MOS Design Pseudo NMOS Logic – Inverter, Inverter threshold voltage, Output high voltage, Output Low voltage, Gain at gate threshold voltage, Transient response, Rise time, Fall time, Pseudo NMOS logic gates, Transistor equivalency, CMOS Inverter logic.

UNIT-II

Combinational MOS Logic Circuits: MOS logic circuits with NMOS loads, Primitive CMOS logic gates – NOR & NAND gate, Complex Logic circuits design – Realizing Boolean expressions using NMOS gates and CMOS gates , AOI and OIA gates, CMOS full adder, CMOS transmission gates, Designing with Transmission gates.

Sequential MOS Logic Circuits Behaviour of bistable elements, SR Latch, Clocked latch and flip flop circuits, CMOS D latch and edge triggered flip-flop.

UNIT -III

Dynamic Logic Circuits Basic principle, Voltage Bootstrapping, Synchronous dynamic pass transistor circuits, Dynamic CMOS transmission gate logic, High performance Dynamic CMOS circuits.

Semiconductor Memories Types, RAM array organization, DRAM – Types, Operation, Leakage currents in DRAM cell and refresh operation, SRAM operation Leakage currents in SRAM cells, Flash Memory-NOR flash and NAND flash.

UNIT -IV

Analog CMOS Sub-Circuits MOS Switch, MOS Diode, MOS Active Resistor, Current Sinks and Sources, Current Mirrors-Current mirror with Beta Helper, Degeneration, Cascode current Mirror and Wilson Current Mirror, Current and Voltage References, Band gap Reference.

UNIT-V

CMOS Amplifiers Inverters, Differential Amplifiers, Cascode Amplifiers, Current Amplifiers, Output Amplifiers, High Gain Amplifiers Architectures.

CMOS Operational Amplifiers Design of CMOS Op Amps, Compensation of Op Amps, Design of Two-Stage Op Amps, Power-Supply Rejection Ratio of Two-Stage Op Amps, Cascode Op Amps, Measurement Techniques of OP Amp.

TEXT BOOKS:

1. Digital Integrated Circuit Design – Ken Martin, Oxford University Press, 2011.
2. CMOS Digital Integrated Circuits Analysis and Design – Sung-Mo Kang, Yusuf Leblebici, TMH, 3rd Ed., 2011.
3. CMOS Analog Circuit Design - Philip E. Allen and Douglas R. Holberg, Oxford University Press, International Second Edition/Indian Edition, 2010.
4. Analysis and Design of Analog Integrated Circuits- Paul R. Gray, Paul J. Hurst, S. Lewis and R. G. Meyer, Wiley India, Fifth Edition, 2010.

REFERENCE BOOKS:

1. Analog Integrated Circuit Design- David A. Johns, Ken Martin, Wiley Student Edn, 2013.
2. Design of Analog CMOS Integrated Circuits- Behzad Razavi, TMH Edition.
3. CMOS: Circuit Design, Layout and Simulation- Baker, Li and Boyce, PHI.
4. Digital Integrated Circuits – A Design Perspective, Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, 2nd Ed., PHI.

I-II	L	P	Credits
	4	-	3
(ELECTIVE-III) ADVANCED COMPUTER ARCHITECTURE			

UNIT - I

Fundamentals of Computer Design: Fundamentals of Computer design, Changing faces of computing and task of computer designer, Technology trends, Cost price and their trends, Measuring and reporting performance, Quantitative principles of computer design, Amdahl's law.

Instruction set principles and examples- Introduction, Classifying instruction set- Memory addressing- type and size of operands, Operations in the instruction set.

UNIT -II

Pipelines: Introduction, Basic RISC instruction set, Simple implementation of RISC instruction set, Classic five stage pipe lined RISC processor, Basic performance issues in pipelining, Pipeline hazards, Reducing pipeline branch penalties.

Memory Hierarchy Design: Introduction, Review of ABC of cache, Cache performance, Reducing cache miss penalty, Virtual memory.

UNIT -III

Instruction Level Parallelism the Hardware Approach: Instruction-Level parallelism, Dynamic scheduling, Dynamic scheduling using Tomasulo's approach, Branch prediction, high performance instruction delivery- hardware based speculation.

ILP Software Approach Basic compiler level techniques, Static branch prediction, VLIW approach, Exploiting ILP, Parallelism at compile time, Cross cutting issues -Hardware verses Software.

UNIT -IV

Multi Processors and Thread Level Parallelism: Multi Processors and Thread level Parallelism- Introduction, Characteristics of application domain, Systematic shared memory architecture, Distributed shared – memory architecture, Synchronization.

UNIT -V

Inter Connection and Networks: Introduction, Interconnection network media, Practical issues in interconnecting networks, Examples of inter connection, Cluster, Designing of clusters.

Intel Architecture: Intel IA-64 ILP in embedded and mobile markets Fallacies and pit falls.

TEXT BOOKS:

1. John L. Hennessy, David A. Patterson - Computer Architecture: A Quantitative Approach, 3rd Edition, An Imprint of Elsevier.

REFERENCE BOOKS:

1. John P. Shen and Miikko H. Lipasti - Modern Processor Design : Fundamentals of Super Scalar Processors
2. Computer Architecture and Parallel Processing - Kai Hwang, Faye A. Briggs., MC Graw Hill.
3. Advanced Computer Architecture - A Design Space Approach - Dezso Sima, Terence Fountain, Peter Kacsuk , Pearson Ed.

I-II	L	P	Credits
	4	-	3
(ELECTIVE -IV) DSP PROCESSORS AND ARCHITECTURES			

UNIT - I

Introduction to Digital Signal Processing: Introduction, A Digital signal-processing system, The sampling process, Discrete time sequences. Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT), Linear time-invariant systems, Digital filters, Decimation and interpolation.

Computational Accuracy in DSP Implementations: Number formats for signals and coefficients in DSP systems, Dynamic Range and Precision, Sources of error in DSP implementations, A/D Conversion errors, DSP Computational errors, D/A Conversion Errors, Compensating filter.

UNIT -II

Architectures for Programmable DSP Devices: Basic Architectural features, DSP Computational Building Blocks, Bus Architecture and Memory, Data Addressing Capabilities, Address Generation UNIT, Programmability and Program Execution, Speed Issues, Features for External interfacing.

UNIT -III

Programmable Digital Signal Processors: Commercial Digital signal-processing Devices, Data Addressing modes of TMS320C54XX DSPs, Data Addressing modes of TMS320C54XX Processors, Memory space of TMS320C54XX Processors, Program Control, TMS320C54XX instructions and Programming, On-Chip Peripherals, Interrupts of TMS320C54XX processors, Pipeline operation of TMS320C54XX Processors.

UNIT -IV

Analog Devices Family of DSP Devices: Analog Devices Family of DSP Devices – ALU and MAC block diagram, Shifter Instruction, Base Architecture of ADSP 2100, ADSP-2181 high performance Processor. Introduction to Blackfin Processor - The Blackfin Processor, Introduction to Micro Signal Architecture, Overview of Hardware Processing Units and Register files, Address Arithmetic Unit, Control Unit, Bus Architecture and Memory, Basic Peripherals.

UNIT -V

Interfacing Memory and I/O Peripherals to Programmable DSP Devices: Memory space organization, External bus interfacing signals, Memory interface, Parallel I/O interface, Programmed I/O, Interrupts and I/O, Direct memory access (DMA).

TEXT BOOKS:

1. Digital Signal Processing – Avtar Singh and S. Srinivasan, Thomson Publications, 2004.
2. A Practical Approach to Digital Signal Processing - K Padmanabhan, R. Vijayarajeswaran, Ananthi. S, New Age International, 2006/2009
3. Embedded Signal Processing with the Micro Signal Architecture Publisher: Woon-Seng Gan, Sen M. Kuo, Wiley-IEEE Press, 2007

REFERENCE BOOKS:

1. Digital Signal Processors, Architecture, Programming and Applications – B. Venkataramani and M. Bhaskar, 2002, TMH.
2. Digital Signal Processing – Jonatham Stein, 2005, John Wiley.
3. DSP Processor Fundamentals, Architectures & Features – Lapsley et al. 2000, S. Chand & Co.
4. Digital Signal Processing Applications Using the ADSP-2100 Family by The Applications Engineering Staff of Analog Devices, DSP Division, Edited by Amy Mar, PHI

I-II	L	P	Credits
	4	-	3
	(ELECTIVE -IV) ELECTROMAGNETIC INTERFERENCE AND ELECTROMAGNETIC COMPATIBILITY (EMI / EMC)		

UNIT – I**Introduction, Natural and Nuclear Sources of EMI / EMC:**

Electromagnetic environment, History, Concepts, Practical experiences and concerns, frequency spectrum conservations, An overview of EMI / EMC, Natural and Nuclear sources of EMI.

UNIT -II**EMI from Apparatus, Circuits and Open Area Test Sites:**

Electromagnetic emissions, Noise from relays and switches, Non-linearities in circuits, passive intermodulation, Cross talk in transmission lines, Transients in power supply lines, Electromagnetic interference (EMI), Open area test sites and measurements.

UNIT -III:**Radiated and Conducted Interference Measurements and ESD:**

Anechoic chamber, TEM cell, GH TEM Cell, Characterization of conduction currents / voltages, Conducted EM noise on power lines, Conducted EMI from equipment, Immunity to conducted EMI detectors and measurements, ESD, Electrical fast transients / bursts, Electrical surges.

UNIT -IV:

Grounding, Shielding, Bonding and EMI filters: Principles and types of grounding, Shielding and bonding, Characterization of filters, Power lines filter design.

UNIT -V:

Cables, Connectors, Components and EMC Standards: EMI suppression cables, EMC connectors, EMC gaskets, Isolation transformers, optoisolators, National / International EMC standards.

TEXT BOOKS:

1. Engineering Electromagnetic Compatibility - Dr. V.P. Kodali, IEEE Publication, Printed in India by S. Chand & Co. Ltd., New Delhi, 2000.
2. Electromagnetic Interference and Compatibility IMPACT series, IIT – Delhi, Modules 1 – 9.

REFERENCE BOOKS:

1. Introduction to Electromagnetic Compatibility - Ny, John Wiley, 1992, by C.R. Pal.

I-II	L	P	Credits
		3	2
ADVANCED COMMUNICATION LAB			

NOTE:

Minimum of 10 Experiments have to be conducted

All Experiments may be Simulated using MATLAB and to be verified using related training kits.

- a. Measurement of Bit Error Rate using Binary Data
- b. Verification of minimum distance in Hamming code
- c. Determination of output of Convolutional Encoder for a given sequence
- d. Determination of output of Convolutional Decoder for a given sequence
- e. Efficiency of DS Spread- Spectrum Technique
- f. Simulation of Frequency Hopping (FH) system
- g. Effect of Sampling and Quantization of Digital Image
- h. Verification of Various Transforms (FT / DCT/ Walsh / Hadamard) on a given Image (Finding Transform and Inverse Transform)
- i. Point, Line and Edge detection techniques using derivative operators.
- j. Implementation of FIR filter using DSP Trainer Kit (C-Code/ Assembly code)
- k. Implementation of IIR filter using DSP Trainer Kit (C-Code/ Assembly code)
- l. Determination of Losses in Optical Fiber
- m. Observing the Waveforms at various test points of a mobile phone using Mobile Phone Trainer
- n. Study of Direct Sequence Spread Spectrum Modulation & Demodulation using CDMA-DSS-BER Trainer
- o. Study of ISDN Training System with Protocol Analyzer
- p. Characteristics of LASER Diode.