M.TECH. EMBEDDED SYSTEMS

Department of Electrical and Electronics Engineering

Almost all Electronics, Electrical and Mechanical systems are now controlled by a controller, which is embedded as a part of the complete system. Such a system is called an Embedded System. Examples are tele-communication systems, chemical-processing plants, transportation systems such as aircrafts and automobiles, bio-medical instruments and home appliances like microwave ovens and washing machines. The characteristics of embedded systems are that they are designed to do some specific tasks often in real time satisfying certain performance requirements. It is achieved through the controllers and software called firmware stored in read only memory of the controller.

The vast majority of control systems built today are embedded, that is, they rely on built-in, special-purpose microcontrollers (digital computers) to close their feedback loops. Some systems may contain large number of controllers. In such settings, controllers often use shared networks to communicate with each other and with large numbers of sensors and actuators scattered throughout the system. The design of embedded controllers and the intricate, automated communication networks that support them raises many new problems- theoretical and practical- about network protocols, compatibility of operating systems, and ways to maximize the effectiveness of the embedded hardware. This course will address many such questions and aspects of embedded and networked control.

CURRICULUM

First Semester

Course Code	Type	Course	L T P	Cr
MA611	FC	Probability and Random Processes	3 0 0	3
ES611	FC	FPGA-Based System Design	3 0 1	4
ES612	FC	Embedded System Programming	3 0 1	4
ES613	FC	Digital Signal Processing	3 0 1	4
ES621	SC	Networked Embedded Systems	3 0 0	3
HU601	HU	Cultural Education*		P/F
			Credits	**18**

*Non credit course

Second Semester

Course Code	Type	Course	L T P	Cr
ES622	SC	Computer Organization and Design Using ARM Processor	3 0 1	4
ES623	SC	Sensor Networks	3 0 1	4
ES624	SC	Real Time Systems	3 0 1	4
ES625	SC	Model Based Design for Embedded System	3 0 0	3
	E	Elective I	3 0 0	3
EN600	HU	Technical Writing *		P/F
			Credits	**18**

*Non credit course

Third Semester

Course Code	Type	Course	L T P	Cr
	E	Elective II	3 0 0	3
	E	Elective III	3 0 0	3
ES626	SC	Embedded System Application Lab	0 0 1	1
ES799	P	Dissertation		8
			Credits	**15**

Fourth Semester

Course Code	Type	Course	L T P	Cr
ES799	P	Dissertation		14
			Credits	**14**

Total Credits: 65

List of Courses

Foundation Core

Course Code	Course	L T P	Cr
MA611	Probability and Random Processes	3 0 0	3
ES611	FPGA-Based System Design	3 0 1	4
ES612	Embedded System Programming	3 0 1	4
ES613	Digital Signal Processing	3 0 1	4

Subject Core

Course Code	Course	L T P	Cr
ES621	Networked Embedded Systems	3 0 0	3
ES622	Computer Organization and Design Using ARM Processor	3 0 1	4
ES623	Sensor Networks	3 0 1	4
ES624	Real Time Systems	3 0 1	4
ES625	Model Based Design for Embedded System	3 0 0	3
ES626	Embedded System Application Lab	0 0 1	1

Electives

Groups of Streams

I. Embedded Applications

Course Code	**Title**	**L-T-P**	**Cr**
ES701	Embedded Systems for Automotive Applications	3-0-0	3
ES702	Advanced Mobile and Wireless Networks	3-0-0	3
ES703	Embedded Systems in Biomedical Applications	3-0-0	3
ES704	Embedded Systems in Robotics	3-0-0	3
RE709	Smart Grid	3-0-0	3

II. Architecture and Programming

Course Code	**Title**	**L-T-P**	**Cr**
ES705	Multi-Core Architectures	3-0-0	3
ES706	Fault Tolerant Systems	3-0-0	3
ES707	GPU Architecture and Programming	2-0-1	3
ES708	Soft Computing	3-0-0	3
ES709	Hardware Software Co-Design	3-0-0	3

III. Controls and Systems

Course Code	**Title**	**L-T-P**	**Cr**
ES710	Cryptography and Network Security	3-0-0	3
ES711	Speech and Language Processing	3-0-0	3
ES712	Advanced Digital Signal Processing and Processors	3-0-0	3
ES713	Modern Control Systems	3-0-0	3
ES714	Object Oriented Analysis and Design	3-0-0	3
ES715	Image and Video Processing	3-0-0	3
ES716	Micro Electro Mechanical Systems	3-0-0	3

Project Work

Course Code	Course	L T P	Cr
ES799	Dissertation		8
ES799	Dissertation		14

MA611 PROBABILITY AND RANDOM PROCESSES 3-0-0-3

Probability and Advanced Statistics: Introduction to probability concepts, Bayesian approach to distributions, two dimensional random variables and joint probability distributions, stochastic independence of random variables, stochastic convergence and limit theorems, stopping rules for simulation experiments, multivariate Probability distributions, variance and co-variance matrices, regression models using matrices, theory of estimation, Bayesian methods of estimation, construction of test statistics, critical region, p value.

Random processes: General concepts, definition, systems with stochastic inputs, power spectrum, discrete-time processes, random walks and other applications, Poisson points and short noise, cyclo-stationary, band limited processes, bi-spectrum, spectrum estimation, ergodicity, Markov chains introduction, transition probabilities, classification of stated, limiting distributions, transient and absorption probabilities.

TEXT BOOKS / REFERENCES:

1. Douglas C. Montgomery and George C. Runger, "*Applied Statistics and Probability for Engineers*", Third Edition, John Wiley and Sons Inc., 2003.
2. Ronald E.Walpole, Raymond H Myres, Sharon L Myres and Kying Ye, "*Probability for Engineers and Scientists*", Seventh Edition, Pearson Education, Asia, 2002.
3. A. Papoulis and Unnikrishna Pillai, "*Probability, Random Variables and Stochastic Processes*", Fourth Edition, McGraw Hill, 2002.

ES611 FPGA-BASED SYSTEM DESIGN 3-0-1-4

HDL – Role of HDL - HDL for Design Synthesis - Design Flow – Programmable logic: Simple PLDs, CPLDs ,FPGA HDL - A Simple Design – HDL elements - Data flow – behavioural – structural modeling - Creating Combinational and Synchronous Logic - Designing FIFO - Test Benches - State Machine Designs - Design Examples - Memory Controller - Mealy State Machines - Design Considerations - Hierarchy in Large Designs - Functions and Procedures – Subprograms.

General principles of circuit synthesis - Synthesis and Design Implementation - Synthesis and Fitting CPLDs, FPGAs- Resource Sharing - Creating Test Benches – Implementation technology – PLD's, Custom Chips, Standard Cell and Gate arrays – FPGA Architectures – SRAM based FPGAs – Permanently programmed FPGAs – Circuit design of FPGA fabrics – Architecture of FPGA fabrics – Logic Implementation of FPGAs - Physical design for FPGAs.

TEXT BOOKS / REFERENCES

1. Stephen Brown and Zvonko Vranesic, "*Fundamental of Digital Logic with VHDL Design*", Second Edition, McGraw Hill, 2000.
2. Douglas L Perry, "*VHDL Programming by Example*", Fourth Edition, Tata McGraw Hill, 2002.
3. Wayne Wolf, "*FPGA-Based System Design*", Prentice Hall India Pvt. Ltd., 2004.
4. Samir Palnitkar, "*Verilog HDL, A Guide to Digital Design and Synthesis*", Second Edition, Pearson Education, 2003.
5. T. R. Padmanabhan and B. Bala Tripura Sundari, "*Design Through Verilog HDL*", Wiley-Blackwell, 2003.

ES612 EMBEDDED SYSTEM PROGRAMMING 3-0-1-4

C – Data types, Operators and Expressions, Control Flow, Arrays and pointers, Storage Class, Structure and union, Functions, Stacks and Queues, linked lists – singly linked list, doubly linked list – implementation of stacks and queues using arrays and linked lists. Embedded C – Introduction to Embedded Systems, Embedded C- Programming & Examples, Compiling, Linking, Downloading & Debugging, Interrupts & Exceptions, RTOS. Software Process Models - Software Specification, UML use cases, class diagrams, Finite State Machines– Architecture Styles - Software Design – Design qualities –Structure chart, UML diagrams for design - Testing and verification – Software Estimation – Software Configuration Management.
Use LINUX platform for Lab.

TEXT BOOKS / REFERENCES:

1. Behrouz A. Forouzan and Richard F. Gilberg "*Computer Science: Structured Programming Approach Using C*", Course Technology Inc., 2007.
2. David E Simon, "*An Embedded Software Primer*", Pearson Education Asia, 2005.
3. Kirk Zurellm, "*C Programming for Embedded Systems*", Elsevier, 2000.
4. Sommerville I, "*Software Engineering Concepts*", Seventh Edition, Tata McGraw-Hill, 1999.
5. Carlo Ghezzi, "*Fundamentals of Software Engineering*" Second Edition, Prentice Hall, 2003.

ES613 DIGITAL SIGNAL PROCESSING 3-0-1-4

Spectrum Analysis: Review of Frequency and time domain analysis - Sampling and aliasing, Discrete Fourier Transforms – properties - Fast Fourier Transform – overlap Add and Save Method - Digital Filters - IIR Filters – Impulse Invariant Technique - Bilinear transformation. IIR filter structure - FIR filters – Windowing method - FIR filter structure - Random Processes – Auto correlation expression - Wiener Filters. Study of MAC unit and FPGA implementation through MATLAB.

TEXT BOOKS / REFERENCES:

1. Proakis J. G and Manolakis D. G., "*Digital Signal Processing: Principles, Algorithms, and Applications*", Fourth Edition, Prentice Hall, 2007.
2. Ifeachor E. C and Jervis B. W, "*Digital Signal Processing: A Practical Approach*", Second Edition, Addison Wesley, 2002.
3. Mitra S. K, "*Digital Signal Processing, A Computer-Based Approach*", Third Edition, McGraw Hill, 2005.
4. Steven W Smith, "*The Scientist and Engineer's Guide to DSP*", Newnes, 1997.

ES621 NETWORKED EMBEDDED SYSTEMS 3-0-0-3

Networked Embedded systems, Characteristics of Real-time systems, Functional, Temporal and Dependability requirements, Distributed computing-System architecture, CNI, Communication system, Composability, Scalability, Extensibility, Complexity, Distributed and Centralized architecture, Time and Order, Clock, Clock drift, Time measurements, Dense and Sparse time, External and Internal clock synchronization, Time gateways, Modeling distributed real-time systems-Assumption coverage, Structure of a node, Fault tolerant unit, Real time communication, Requirements of real time communication system, Flow control-Explicit and Implicit, Thrashing, Protocol mechanisms protocol performance, OSI reference model, CAN Bus architecture, USB Architecture, Embedded Ethernet, Embedded TCP/IP, Embedded Internet.

TEXT BOOKS / REFERENCES:

1. H Kopetz, "*Real Time Systems: Design Principles for Distributed Embedded Applications*", Kluwer, 1997.
2. Gregory J. Pottie and William J. Kaiser, "*Principles of Embedded Networked Systems Design*", Cambridge University Press, 2005.
3. Jan Axelson, "*Embedded Ethernet and Internet Complete: Designing and Programming Small Devices for Networking*", Lakeview Research LLC, 2003.
4. Richard Zurawski, "*Networked Embedded Systems*", CRC Press, 2009.
5. Fred Eady, "*Networking and Internetworking with Microcontrollers*", Newnes, 2004.

ES622 COMPUTER ORGANIZATION AND DESIGN USING ARM PROCESSOR

3-0-1-4

An Introduction to Embedded processors – RISC versus CISC – CPU Performance Metrics – Benchmark – Arithmetic for computers – RISC processor design: Single cycle and Pipelined data path design for MIPS Processor – Pipeline Hazards. Memory system design –Memory Management Unit - Cache – Virtual Memory.

ARM7 Architecture - ARM Instruction Set - Thumb Instruction Set - Interrupts and Exception Handling - AMBA bus system – NXP LPC 24xx Microcontroller –Architecture – Peripherals – Application development using Keil IDE - ARM advanced CPU Cores (ARM9, ARM11 and CORTEX). ARM Programming using Linux.

TEXT BOOKS / REFERENCES:

1. David A. Patterson and John L.Hennessy, "*Computer Organization and Design – The Hardware/Software Interface*", ARM Edition, Morgan Kaufmann Publisher, 2010.
2. Steve Furber, "*ARM System-on-Chip Architecture*", Second Edition**,** Addison Wesley Trade Computer Publications, 2000.
3. Andrew Sloss, Dominic Symes and Chris Wright, "*ARM System Developer's Guide*", Morgan Kaufmann Publisher, 2004.
4. Vincent P Heuring, Harry F Jordan and T.G.Venkatesh, "*Computer Systems Design and Architecture*", Second Edition, Pearson Education Inc., 2008.
5. NXP LPC 24xx datasheet. (*www.nxp.com*)

ES623 SENSOR NETWORKS 3-0-1-4

Introduction: Applications, challenges, comparison with other technologies, Hardware components. Network architecture: Sensor network scenarios, optimization goals, design principles, Physical Layer: Wireless channel and communication fundamentals.
MAC protocols: Fundamentals of (wireless) MAC protocols, Low duty cycle protocols and wakeup concepts, Contention-based protocols, Schedule-based protocols, The IEEE 802.15.4 MAC protocol. Naming and Addressing: Fundamentals, Address and name management in wireless sensor networks, Assignment of MAC addresses. Link-layer protocols: fundamentals, framing Topology control: Motivation and basic ideas, Flat network topologies, Hierarchical networks by dominating sets, Hierarchical networks by clustering, Combining hierarchical topologies and power control, Adaptive node activity.
Routing protocols: The many faces of forwarding and routing, Gossiping and agent-based unicast forwarding, Energy-efficient unicast, Broadcast and multicast, Geographic routing, Mobile nodes. Transport layer: The transport layer and QoS in wireless sensor networks, Coverage and deployment, Reliable data transport, Block delivery, Congestion control and rate control. Data-centric and content-based networking: Data-centric routing, Data aggregation, Data-centric storage. Case Study: Landslide detection.

TEXT BOOKS / REFERENCES:

1. Holger Karl and Andreas Willig, "*Protocols and Architectures for Wireless Sensor Networks*", John Wiley and Sons Ltd., 2005.
2. Feng Zhao and Leonidas J. Guibas, "*Wireless Sensor Networks: An Information Processing Approach*", Morgan Kaufmann, 2004.
3. C S Raghavendra, KM Shivalingam and T Zanti, "*Wireless Sensor Networks*", Springer, New York, 2004.

ES624 REAL TIME SYSTEMS 3-0-1-4

Introduction to real-time systems, clock synchronization – RTOS basics-architecture, RTOS Vs GPOS, RTOS Kernel, Kernel services, task attributes and components- task management, task states and transition, time services, interrupt handling, interrupt latency, memory management, input-output handling, task communication and synchronization, task assignment and scheduling- scheduling algorithms, RM, DM and EDF, schedulability, response time analysis, preemption-context switching, blocking, deadlock, priority inversion problem- PIP, PCP, response time analysis with blocking, real-time database, fault tolerant techniques, case studies in real-time operating systems. RT Linux.

TEXT BOOKS / REFERENCES:

1. Jane W.S. Liu, "*Real -Time Systems*", Pearson Education, 2000.
2. Krishna and Shin, "*Real Time Systems*", Addison Wesley, 2001.
3. Phillip A. Laplante, "*Real-Time System Design and Analysis*", Third Edition, Prentice Hall of India, 2004.
4. Christopher Hallinan, "*Embedded Linux Primer: A Practical Real-World Approach*", Prentice Hall, 2006.
5. P. Raghavan, Amol Lad and Sriram Neelakandan, "*Embedded Linux System Design and Development*", CRC Press, 2005.

ES625 MODEL BASED DESIGN FOR EMBEDDED SYSTEM 3-0-0-3

Introduction - Applications - The Design Process - Modeling Dynamic Behaviors - Continuous Dynamics - Newtonian Mechanics - Actor Models - Properties of Systems - Feedback Control - Discrete Dynamics - Discrete Systems - The Notion of State - Finite-State Machines - Extended State Machines – Non determinism -Behaviors and Traces - Hybrid Systems - Modal Models - Classes of Hybrid Systems - Composition of State Machines - Concurrent Composition - Hierarchical State Machines - Concurrent Models of Computation - Structure of Models - Synchronous-Reactive Models - Dataflow Models of Computation -Timed Models of Computation - Introduction to Embedded Systems - Design of Embedded Systems - Parallelism - Memory Architectures - Memory Models - Input and Output -Sequential Software in a Concurrent World - Scheduling - Multiprocessor Scheduling - Analysis and Verification - Invariants and Temporal Logic - Equivalence and Refinement - Models as Specifications - Type Equivalence and Refinement - Language Equivalence and Containment - Abstraction in Model Checking - Quantitative Analysis - Programs as Graphs - Basics of Execution Time Analysis.

TEXT BOOKS / REFERENCES:

1. Edward Ashford Lee and Sanjit Arunkumarr Seshia, "*Introduction to Embedded Systems: A Cyber-Physical Systems Approach*", http://LeeSeshia.org, 2011.
2. Marwedel P, "*Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems*", Second Edition, Springer, 2011.
3. *http://www.cis.upenn.edu/~alur.*

ES626 EMBEDDED SYSTEM APPLICATION LAB 0-0-1-1

Each student in consultation with the faculty in-charge will select a topic related to embedded systems and applications and implement it in the lab.

EN600 TECHNICAL WRITING P/F

Technical terms- Definitions- extended definitions- grammar checks- error detection- punctuation- spelling and number rules - tone and style- pre-writing techniques - Online and offline library resources- citing references – plagiarism - Graphical representation - documentation styles- instruction manuals- information brochures- research papers, proposals – reports (dissertation, project reports etc.) - Oral presentations.

TEXTBOOKS/REFERENCES:

1. Hirish, Herbert L. "*Essential Communication Strategies for Scientists, Engineers and Technology Professionals*". Second Edition. New York: IEEE press, 2002.
2. Anderson, Paul V. "*Technical Communication: A Reader-Centred Approach*". VI Edition. Cengage Learning India Pvt. Ltd., New Delhi, Reprint, 2010.
3. Strunk, William Jr. and White, E.B. "*The Elements of Style*" New York. Alliyan and Bacon, 1999.

ES701 EMBEDDED SYSTEMS FOR AUTOMOTIVE APPLICATIONS 3-0-0-3

Automotive Fundamentals – Vehicle functional domains and requirements – The systems approach to control and automotive instrumentation – Sensors and actuators in various vehicle domains. Systems in Power train Electronics: Engine Management Systems: Spark Ignition, Petrol/ Diesel Injection Systems, Transmission Systems. Systems in Chassis control: ABS, ESP, TCS, Active Suspension Systems, Cruise control and adaptive cruise control systems – Drive-by-wire systems. Body electronic systems: Power Generation/ Storage, starting motor systems, Vehicle wiring systems, HVAC, Automotive alarm systems, Vehicle immobilization & deactivation, Driver information systems, Parking systems, Central locking system – electric windows – Occupants and driver safety systems: Seat belt lighteners and air-bags – Diagnostics systems. Embedded automotive protocols: CAN, LIN, FlexRay, MOST, TTP/A, TTP/C and TTCAN - AUTOSAR standard and its applications – OSEK/VDX Open Systems in Automotive Networks.

TEXT BOOKS / REFERENCES:

1. William B. Ribbens, "*Understanding Automotive Electronics*", Sixth Edition, Society of Automotive Engineers Inc., 2003.
2. V. A. W. Hillier and David R. Rogers, "*Hillier's Fundamentals of Motor Vehicle Technology on Chassis and Body Electronics*", Fifth Edition, Nelson Thrones, 2007.
3. V A W Hillier, Peter Coombes, David R Rogers and Alma Hillier, "*Hillier's Fundamentals of Motor Vehicle Technology on Power Train Electronics*", Fifth Edition, Nelson Thrones, 2007.
4. Joseph Lemieux, "*Programming in the OSEK/VDX Environment*", CMP Books, USA, 2001.
5. Tom Denton, "*Automobile Electrical and Electronic Systems*", Third Edition, Elsevier Butterworth-Heinemann, 2004.

ES702 ADVANCED MOBILE AND WIRELESS NETWORKS 3-0-0-3

Overview of Wireless Systems, TeleTraffic Engineering-Service level, Usage, Measurement Units, Types, B Formulas, Overview of Digital Communication and Transmission, Multiple Access Techniques, Architecture of Wireless Wide-Area Network, Mobility Management, Mobile Network and Transport Layer- TCP/IP Suite for Wireless Networks, Mobile IP, SIP, Wide Area Wireless Network Service- GSM,3G, UMTS, QoS Mangament, HSDPA, FOMA, CDMA, Wireless Application Protocol, Bluetooth - Protocol stack, Link Types, Security, Error Correction, Topology, Applications, WiMax, 4G Systems, Software Defined Radio, Cognitive Radio.

TEXT BOOKS / REFERENCES:

1. Vijay K Garg, "*Wireless Communications and Networking*", Morgan Kaufmann, 2007.
2. Adreas F Molisch, "*Wireless Communications*", Second Edition, Wiley, 2011.
3. William Lee, "*Wireless and Cellular Telecommunications*", Third Edition, McGraw Hill, 2005.
4. Martin Sauter, "*Beyond 3G - Bringing Networks, Terminals and the Web Together: LTE, WiMAX, IMS, 4G Devices and the Mobile Web 2.0*", Wiley, 2009.

5. Eldad Perahia, "*Next Generation Wireless LANs: Throughput, Robustness, and Reliability in 802.11n*", Cambridge University Press, 2008.

ES703 EMBEDDED SYSTEMS IN BIOMEDICAL APPLICATIONS 3-0-0-3

Overview of biomedical devices – Origin of bio potentials – bio potential electrodes – bio potential amplifiers, System Theory for Physiological Signals: Filters, Modeling – Embedded systems in Patient monitoring: ECG, EEG, EMG, Blood pressure, respiration, pulse oxymeters, diagnostic devices. Embedded systems in patient assistive devices - cardiac pacemakers, defibrillators ventilators, heart lung machine, hemo dialysis unit pumps – insulin pumps, infusion pumps, syringe pumps, dialysis equipments. Applications of embedded systems in surgical devices- endoscopy/laparoscopy, medical robots, anesthesia machine, surgical table, haptics augmented reality in minimally invasive surgery, lithotripsy, drug delivery systems, therapeutic application of laser. Embedded system applications in Medical Imaging systems, Therapeutic and prosthetic devices, Tele Medical system, Micro Fluidics and Lab-on-a-chip devices, Clinical Laboratory equipments.

TEXT BOOKS / REFERENCES:

1. Anthony Y. K. Chan, "*Biomedical Device Technology: Principles and Design*", Charles C Thomas Pub. Ltd., 2008.
2. John G. webster, "*Medical Instrumentation - Application and Design*", Fourth Edition, John Wiley and Sons, 2010.
3. Subhas Chandra Mukhopadhyay and Aime Lay-Ekuakille, "*Advances in Biomedical Sensing, Measurements, Instrumentation and Systems*", Springer, 2010.
4. Gail Baura, "*A Biosystems Approach to Industrial Patient Monitoring and Diagnostic Devices*", Morgan & Claypool Publishers, 2008.
5. Aime Lay-Ekuakille and Subhas Chandra Mukhopadhyay, "*Wearable and Autonomous Biomedical Devices and Systems for Smart Environment - Issues and Characterization*", Springer, 2010.

ES704 EMBEDDED SYSTEMS IN ROBOTICS 3-0-0-3

Robots and Controllers - Embedded Controllers, Interfaces, Operating System. Sensors - Sensor Categories, Binary Sensor, Analog versus Digital Sensors, Shaft Encoder; A/D Converter, Position Sensitive Device; Compass, Gyroscope, Accelerometer, Inclinometer, Digital Camera. Actuators - DC Motors, H-Bridge, Pulse Width Modulation, Stepper Motors, Servos. Control - On-Off Control, PID Control, Velocity Control and Position Control, Multiple Motors – Driving Straight, V-Omega Interface.

Industrial Robots - Evolution of robotics, Robot anatomy, Design and control issues, Manipulation and Control. Direct Kinematic Model –Denavit-Hartenberg Notation, Kinematic Relationship between adjacent links, Manipulator Transformation Matrix; Inverse Kinematic Model – Manipulator Workspace, Solvability, Solution techniques, Closed form solution. Industrial Robot Applications - Material Handling, Process, Assembly, Inspection; Non-Industrial Applications. Computer vision for Robotics. Mobile Robots and applications. Autonomous robots and Underwater Vehicles, Evolution of Walking Gaits.

TEXT BOOKS / REFERENCES:

1. Thomas Bräunl, "*Embedded Robotics: Mobile Robot Design and Applications with Embedded Systems*", Third Edition, Springer-Verlag Berlin Heidelberg, 2006.
2. R.K.Mittal and I.J.Nagrath, "*Robotics and Control*", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2003.
3. John J. Craig, "*Introduction to Robotics: Mechanics and Control*", Third Edition, Addison-Wesley, 2005.
4. K.S. Fu, R.C. Gonzalez and C.S.G. Lee, "*Robotics: Control, Sensing, Vision, and Intelligence*", McGraw-Hill, New York, 1987.
5. Sara Morgan, "*Programming Microsoft Robotics Studio*", WP Publishers, 2008.

RE709 SMART GRID 3-0-0-3

Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid. Today's grid versus smart grid. Present development & International policies in Smart Grid. Smart Grid – Overview and stakeholders. Performance analysis tools for smart grid, Stability analysis tools for smart grid.

Smart Grid Technologies: Communication Technologies for Smart Grid, Interoperability and connectivity, Layered Architecture and Protocols, Standards for Information Exchange. Information Security in smart grid - Encryption and decryption, Authentication, Digital Signatures, Cyber Security standards. Smart Meters, Demand response. Distribution Side automation and Transmission side automation – WAMS. Power electronics in Smart grid.

Renewable Energy and Storage Technologies – Distributed generation and storage. Solar, Wind, Pumped Hydro, PHEVs. Market Model for smart grid. Regulation and standardization of smart grid.

TEXT BOOKS / REFERENCES:

1. James Momoh, "*Smart Grid: Fundamentals of Design and Analysis*", Wiley-IEEE Press, March 2012.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu and Akihiko Yokoyama, "*Smart Grid:Technology and Applications",* Wiley, February 2012.
3. Nouredine Hadjsaïd and Jean-Claude Sabonnadière, "*Smart Grids*", Wiley-ISTE, May 2012.
4. Ali Keyhani and Muhammad Marwali, "*Smart Power Grids 2011*", Springer, 2011.

ES705 MULTI-CORE ARCHITECTURES 3-0-0-3

Review of Computer Design - Basics of Pipelining - Hazards, Measuring performance - Instruction level parallelism - Branch prediction techniques - Static & Dynamic scheduling – Speculation - Limits of ILP. Thread-level parallelism, Multi-issue and Multi-core processors - Shared and Distributed memory Multiprocessor Architectures - Transaction Memory issues - Memory hierarchy design - Cache coherence, Memory wall problem - Advanced Cache Memory design - Virtual Memory, Storage Systems - Ware-house Scale Computers - Power optimization

in multi-core systems - Multi-core architectures for embedded systems - Programming environments for multi-core.

TEXT BOOKS / REFERENCES:

1. J.L. Hennessy and D.A. Patterson, "*Computer Architecture: A Quantitative Approach*", Fifth Edition, Morgan Kaufmann, 2011.
2. Georgios Kornaros, "*Multi-core Embedded Systems*", CRC Press, Taylor and Francis Group, 2010.
3. J.P. Shen and M.H. Lipasti, "*Modern Processor Design: Fundamentals of Super-Scalar Processors*", McGraw Hill, 2005.
4. David Culler, J.P. Singh and Anoop Gupta, "*Parallel Computer Architecture: A Hardware/Software Approach*", Morgan Kaufmann, 1998.
5. Dezso Sima, Terence Fountain and Peter Kacsuk, "*Advanced Computer Architectures*", Pearson, 1998.

ES706 FAULT TOLERANT SYSTEMS 3-0-0-3

Hardware fault tolerance, software fault tolerance, information redundancy, check pointing, fault tolerant networks, reconfiguration-based fault tolerance, and simulation techniques. Students will gain familiarity with the core and contemporary literature in the area for dependable computing.
Dependability concepts: Dependable system, techniques for achieving dependability, dependability measure, fault, error, failure, and classification of faults and failures. Fault Tolerance Strategies: Fault detection, masking, containment, location, reconfiguration, and recovery. Fault Tolerant Design Techniques: Hardware redundancy, software redundancy, time redundancy and information redundancy.
Dependable communication: Dependable channels, survivable networks, fault-tolerant routing. Fault recovery, Stable storage and RAID architectures, and Data replication and resiliency. Tolerance in Distributed System: Byzantine General Problem, consensus protocols, check pointing Fault Tolerance interconnection networks: Analysis of fault tolerant hardware and software architectures. Case studies of fault tolerant multiprocessor and distributed systems.

TEXT BOOKS / REFERENCES:

1. Israel Koren and C. Mani. Krishna, "*Fault Tolerant Systems"*, Elsevier.2007
2. P. Jalote, "*Fault Tolerance in Distributed Systems*" Prentice-Hall Inc. 1994,
3. D. K. Pradhan, *"Fault-Tolerant Computing, Theory and Techniques*", Prentice-Hall, 1998,
4. Los Alamitos, CA, "*Fault-Tolerant Computing, Theory and Techniques*", IEEE Computer Society Press, 1996.
5. Barry W. Johnson, "*Design and Analysis of Fault-Tolerant Digital System*", Addison, 1989

ES707 GPU ARCHITECUTRE AND PROGRAMMING 2-0-1-3

Introduction to Parallel Programming - Introduction to OpenCL - OpenCL Device Architectures - Basic OpenCL – examples - Understanding OpenCL - Concurrency and Execution Model - Dissecting a CPU/GPU - OpenCL Implementation - OpenCL case study: Convolution, Video

Processing, Histogram and Mixed Particle Simulation - OpenCL Extensions - OpenCL Profiling and Debugging - WebCL

TEXT BOOKS / REFERENCES:

1. Benedict R Gaster, Lee Howes, David, R. Kaeli, Perhaad Mistry and Dana Schaa, "*Heterogeneous Computing with OpenCL*", Second Edition, Elsevier, 2012.
2. Aaftab Munshi, Benedict Gaster, Timothy G. Mattson, James Fung and Dan Ginsburg, "*OpenCL Programming Guide*", Addison-Wesley Professional, 2011.
3. Ryoji Tsuchiyama, Takashi Nakamura, Takuro Iizuka and Akihiro Asahara, "*The OpenCL Programming Book ",* Fixstars Corporation, 2010.
4. Matthew Scarpio, "*OpenCL in Action: How to Accelerate Graphics and Computations*", Manning Publications, 2011.

ES708 SOFT COMPUTING 3-0-0-3

Fuzzy Logic (FL) – Membership Functions – Fuzzifications and Defuzzifications – Fuzzy Relations – TSK Fuzzy Modeling – Neural Networks (NN) – Supervised and Unsupervised Learning – Hopfield – RBF Networks – Principal Component Analysis – PNN – Kohonen Self Organizing Networks – Learning Vector Quantization – Hebbian Learning – Adaptive Resonance Theory – Genetic Algorithms (GA) – Standard GA – Schema Theory – Building Block Hypothesis – Chaos and Fractals – One Dimensional Logistic Equation – Hurst Exponent – Fractal Dimension – Non Linear Time Series Analysis – Lyapunov Exponent – Correlation Dimension – Rough Set Theory – Feature Extraction – Dimensionality Reduction – Discernability – Matrix – Introduction to Support Vector Machines – Classification and Regression – Typical Applications Integrating Various Soft Computing Tools.

TEXT BOOKS / REFERENCES:

1. Timothy Ross, "*Fuzzy Logic with Engineering Applications*", Second Edition, John Wiley and Sons, 2004.
2. Simon Haykin, "*Neural Networks and Learning Machines*", Third Edition, Pearson Education, 2009.
3. K.F. Man, K.S. Tang and S. Kwong, "*Genetic Algorithms: Concepts and Applications*", IEEE Transactions on Industrial Electronics, Vol-3, 1996.
4. Thomas S.Parker and Leon O Chua, "*CHAOS: A Tutorial for Engineers*", IEEE Proceedings, Vol-75, No.8, 1987.
5. Jan Komorowski, Lech Polkowski and Andrzej Skowron, "*Rough Sets: A Tutorial*", http://Folli.Loria.Fr/Cds/1999/Library/Pdf/Skowron.Pdf

ES709 HARDWARE SOFTWARE CO-DESIGN 3-0-0-3

Introduction to system level design, Models of computation for Embedded Systems, Architectural selection, Partitioning, scheduling and communication, Simulation, synthesis and verification, Implementation case studies, Performance Analysis and Optimization, Retargetable code generation, FPGAs.

TEXT BOOKS / REFERENCES:

1. D Gajski, F Valhid, S Narayan and J Gong, "*Specification and Design of Embedded Systems*", Prentice Hall PTR, 1994.
2. Jorgen Staunstrup and Wayne Wolf, "*Hardware / Software Co-Design: Principle and Practice*", Kluwer Academic, 1997.
3. Ti - Yen Yen and Wayne Wolf, "*Hardware-Software Co-Synthesis of Distributed Embedded Systems*", Kluwer, Reprint 2010.
4. Peter Marwedel, "*Embedded System Design*", Kluwer Academic Publishers, 2003.
5. Joris van den Hurk and Jochen A.G. Jess, "*System Level Hardware/Software Co-Design: An Industrial Approach*", Springer, 1997.

ES710 CRYPTOGRAPHY AND NETWORK SECURITY 3-0-0-3

Classical Encryption Techniques – Symmetric Cipher Model – Steganography – AES Cipher - Symmetric Cipher – Multiple Encryption and triple DES – Blocks Cipher – stream Cipher – Confidentiality using symmetric encryption – Placement of encryption function – random number generation – Introduction to number theory – Cryptosystems – message authentication and Hash functions – requirements – functions – course – Hash and MAC algorithms – secure Hash algorithms – Digital signatures and authentication protocols – standard – authentication applications – Electronic mail security - S/MIME-IP security – overview- architecture – web security - socket layer and transport layer security – Intruders – Detection – Malicious software – viruses and related threats – counter measures – firewalls – design principles – trusted systems.

TEXT BOOKS / REFERENCES:

1. William Stallings, "*Cryptography and Network Security – Principles and Practices*", Fourth Edition, Prentice Hall, 2003.
2. Douglas R Stinson, "*Cryptography: Theory and Practice*", Third Edition, Chapman and Hall/CRC, 2005.

ES711 SPEECH AND LANGUAGE PROCESSING 3-0-0-3

Introduction to Linguistics – natural language and formal language – regular expressions and finite state automata – words and their parts – morphology – parsing – word tokenization – pronunciation and spelling – N grams and language models – Transliteration – Transliteration using sequence labeling – Part of speech tagging – POS tagging using SVM – chunking – shallow parsing – context free grammars – Parsing using context free grammars – probabilistic and lexicalized parsing, CFG parser – Parsing techniques – structured output learning – generalized linear classifiers in NLP.

TEXT BOOKS / REFERENCES:

1. Daniel Jurafsky and James H Martin, "*Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition*", Second Edition, Prentice Hall, 2008.
2. Christopher D. Manning and Hinrich Schutze, "*Foundations of Statistical Natural Language Processing*", MIT press, 1999.

3. Sandra Kubler, Ryan McDonald and Joakim Nivre, "*Dependency Parsing Synthesis Lecturers on Human Language Technologies*", Morgan and Claypool Publishers, 2009.

ES712 ADVANCED DIGITAL SIGNAL PROCESSING AND PROCESSORS 3-0-0-3

Multirate Digital Signal Processing - Decimation, Interpolation, Cascade Equivalents, Fractional Sampling Rate Alteration, Applications- acquisition of high quality data, high resolution spectral analysis and design and analysis of narrowband digital filtering.
Basic building blocks of a typical DSP Processor – Hardware Multiplier – Barrel Shifter – MAC unit – Modified Harvard architecture – Special Addressing Modes-Pipelining. Floating point number representation and arithmetic - Architecture of TMS320C67xx DSP - Instruction set – Addressing modes – Peripherals - Assembly language and C programming – Integrated Development Environment - Code Composer Studio.
Digital Signal Processing implementation using TMS320C67xx DSP for digital filters - Levinson Durbin Algorithm - Embedded Target for TMS320C67xx DSP Platform using MATLAB - Simulink. Application development using MATLAB – Simulink - Real-Time Workshop and hardware.

TEXT BOOKS / REFERENCES:

1. Vaidyanathan P. P, "*Multirate Systems and Filter Banks*", Prentice Hall, 1993.
2. Dahnoun N, "*Digital Signal Processing Implementation: Using the TMS320C6000 DSP Platform*", Prentice Hall, 2000.
3. Andy Bateman and Iain Paterson-Stephens, "*The DSP Handbook, Algorithms, Applications and Design Techniques*", Prentice-Hall, 2002.
4. Rulph Chassaing, "*DSP Applications Using C and the TMS320C6x DSK*", John Wiley & Sons, 2002.
5. B Venkataramani and M Bhaskar, "*Digital Signal Processors: Architecture, Programming and Applications*", Tata McGraw Hill, 2002.

ES713 MODERN CONTROL SYSTEMS 3-0-0-3

State Variable Analysis and Design: Introduction, concept of state, state variables and state model, state modeling of linear systems, linearization of state equations. State Space representation using physical variables, Phase variables and Canonical variables. Derivation of transfer function from state model, diagonalization, Eigen values, Eigen vectors, generalized Eigen vectors. Solution of state equation, state transition matrix and its properties, computation using Laplace transformation, power series method, Cayley-Hamilton method, concept of controllability and observability, methods of determining the same.
Pole Placement Techniques: Stability improvements by state feedback, necessary and sufficient conditions for arbitrary pole placement, state regulator design, and design of state observer, Controllers- P, PI, PID. Non-linear systems: Introduction, behavior of non-linear system, common physical non linearity-saturation, friction, backlash, dead zone, relay, multi- variable non-linearity. Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories. Liapunov stability criteria, Liapunov functions, direct method

of Liapunov and the linear system, Hurwitz criterion and Liapunov's direct method, construction of Liapunov functions for nonlinear system.

TEXT BOOKS/ REFERENCES:

1. Ogata, "*Modern Control Engineering*". Fifth Edition, Prentice Hall, 2009.
2. Franklin and Powell, "*Feedback Control of Dynamics Systems*". Fourth Edition, Prentice Hall, 2002.
3. Joseph DiStefano III, Allen J. Stubberud and Ivan J. Williams "*Feedback and Control Systems*". Schaum's outline Series, Mcgraw-Hill, 1967.
4. David G. Luenberger, "*Introduction to Dynamic Systems : Theory, Models, and Applications*", Wiley, 1979.
5. Richard C. Dorf and Robert H. Bishop, "*Modern Control Systems*", Eleventh Edition Prentice Hall, Pears Education, 2008.

ES714 OBJECT ORIENTED ANALYSIS AND DESIGN 3-0-0-3

Object – Oriented Analysis and Design: Iterative Development, Case Studies, Inception, Understanding Evolution of Requirements, Use Cases, Identifying Other Requirements, Domain Models, System Sequence Diagrams, Logical Architecture and UML Package Diagrams, Object Design, Interaction Diagrams, Class Diagrams, Objects and Responsibilities, Object Design Examples, Mapping Designs to Code, Test Driven Development and Refactoring, UML Tools, GRASP : More Object Design, GoF Patterns, Activity Diagrams and Modeling, State Machine Diagrams and Modeling, Relating Use Cases, Domain Model Refinement, Architectural Analysis.

TEXT BOOKS / REFERENCES:

1. Craig Larman, "*Applying UML and Patterns: An Introduction to Object-Oriented Analysis*", Third Edition, Pearson Education, 2004.
2. Brown D. W, "*An Introduction to Object-Oriented Analysis: Objects and UML in Plain English*", Second Edition, John Wiley & Sons, 2002.
3. Mark Priestley, "*Practical Object Oriented Design with UML*", Second Edition, Tata McGraw Hill, 2005.
4. Michael Bleha and James Rambaugh, "*Object-Oriented Modelling and Design with UML*", Second Edition, Pearson, 2005.
5. Bernd Bruegge and Allen H. Dutoit, "*Object-Oriented Software Engineering: Using UML, Patterns and Java*", Third Edition, Prentice Hall, 2000.

ES715 IMAGE AND VIDEO PROCESSING 3-0-0-3

Two-Dimensional Signals – Sampling in Two-Dimensions – Two-Dimensional Systems and Z Transforms – 2-D Discrete Transforms – Two-Dimensional Filter Design – Introductory Image Processing – Image Estimation and Restoration – Digital Image Compression – Three dimensional Signals and Systems – Properties of 3D Fourier Transform – 3-D Filters – 3-D Sampling Theorem – Digital Video Processing – Digital Video Compression – Video Transmission over Networks.

TEXT BOOKS / REFERENCES:

1. John W Woods, "*Multidimensional Signal, Image and Video Processing and Coding*", Elsevier, 2006.
2. Alan C Bovik, "*The Essential Guide to Image Processing*", Academic Press, 2009.
3. Rafael C. Gonzalez and Richard E. Woods, "*Digital Image Processing*", Third Edition, Pearson Education, 2008.
4. I. Pitas, "*Digital Image Processing - Algorithms and Application*", Prentice Hall, 1993.

ES716 MICRO ELECTRO MECHANICAL SYSTEMS 3-0-0-3

Introduction to MEMS, Fabrication methods - Silicon and polymeric MEMS fabrication, MEMS and Smart materials systems - Microsensors and Microactuators for embedded systems, Fabrication, Integration and Packaging of Smart Microsystems, MEMS based sensors and devices for satellite communication, space technology, medical and aerospace Applications, Wireless technology, Embedding Microsensors, System-on-a-chip (SoC) concepts, Wearable and Implantable devices - Design of highly miniaturized, unobtrusive and secure wearable systems.

TEXT BOOKS / REFERENCES:

1. Julian W. Gardner, Vijay K. Varadan and Osama O. Awadelkarim, "*Microsensors, MEMS and Smart Devices*", Wiley, 2001.
2. A.R. Jha, "*MEMS and NanoTechnology-Based Sensors and Devices for Communications, Medical and Aerospace Applications*", CRC Press, 2008.
3. Vijay K. Varadan, K. J. Vinoy and S. Gopalakrishnan, "*Smart Material Systems and MEMS: Design and Development Methodologies*", Wiley, 2006.
4. Richard Zurawsky, "*Embedded Systems Handbook*", CRC Press, 2006.
5. Steven S. Saliterman, "*Fundamentals of BioMEMS and Medical Microdevices*", SPIE Press, 2006.

ES799 DISSERTATION 8

Each student should select and work on a topic related to his/her field of specialization during summer of second semester under the supervision of a faculty member. By the end of the third semester he/she must prepare a report in the approved format and present it.

ES799 DISSERTATION 14

During fourth semester each student should work further on the topic of the minor project or a new topic under the supervision of a faculty member. By the end of fourth semester the student has to prepare a report in the approved format and present it.