M.TECH. EMBEDDED SYSTEMS
Department of Electrical and Electronics Engineering

Almost all Electronics, Electrical and Mechanical systems are now controlled by acontroller, 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
16MA610	FC	Probability and Random Processes	3 0 0	3
16ES602	FC	FPGA-Based System Design	3 0 1	4
16ES603	FC	Embedded System Programming	3 0 1	4
16ES604	FC	Signal and Image Processing	3 0 1	4
16ES611	SC	Distributed Embedded Systems	3 0 0	3
16HU601	HU	Cultural Education*		P/F
Credits **18**				

*Non-credit course

Second Semester

Course Code	Type	Course	L T P	Cr
16ES612	SC	Embedded Processor Architecture and Design	3 0 1	4
16ES613	SC	Sensor Networks	3 0 1	4
16ES614	SC	Real Time Systems	3 0 1	4
16ES615	SC	Model Based Design for Embedded System	3 0 0	3
	E	Elective - I	3 0 0	3
16EN600	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
16ES616	SC	Embedded System Application Lab	0 0 1	1
16ES798	P	Dissertation		8
Credits **15**				

Fourth Semester

Course Code	Type	Course	L T P	Cr
16ES799	P	Dissertation		14
			Credits	**14**

Total Credits: 65

List of Courses

Foundation Core

Course Code	Course	L T P	Cr
16MA610	Probability and Random Processes	3 0 0	3
16ES602	FPGA-Based System Design	3 0 1	4
16ES603	Embedded System Programming	3 0 1	4
16ES604	Signal and Image Processing	3 0 1	4

Subject Core

Course Code	Course	L T P	Cr
16ES611	Distributed Embedded Systems	3 0 0	3
16ES612	Embedded Processor Architecture and Design	3 0 1	4
16ES613	Sensor Networks	3 0 1	4
16ES614	Real Time Systems	3 0 1	4
16ES615	Model Based Design for Embedded System	3 0 0	3
16ES616	Embedded System Application Lab	0 0 1	1

Electives
Groups of Streams

I. Embedded Applications

Course Code	Course	L T P	Cr
16ES701	Embedded Systems for Automotive Applications	3 0 0	3
16ES702	Advanced Mobile and Wireless Networks	3 0 0	3
16ES703	Embedded Systems in Biomedical Applications	3 0 0	3
16ES704	Embedded Systems in Robotics	3 0 0	3
16ES705	Embedded Systems in Smart Grid	3 0 0	3
16ES706	Design for Internet of Things	3 0 0	3

II. Architecture and Programming

Course Code	Course	L T P	Cr
16ES707	Multi-Core Architectures	3 0 0	3
16ES708	Fault Tolerant Systems	3 0 0	3
16ES709	GPU Architecture and Programming	2 0 1	3

16ES710	Soft Computing	3 0 0	3
16ES711	Hardware Software Co-Design	3 0 0	3
16ES712	Object Oriented Programming	3 0 0	3
16ES713	Machine Learning	3 0 0	3

III. Controls and Systems

Course Code	Course	L T P	Cr
16ES714	Cryptography and Network Security	3 0 0	3
16ES715	Speech and Language Processing	3 0 0	3
16ES716	Advanced Digital Signal Processing and Processors	3 0 0	3
16ES717	Modern Control Systems	3 0 0	3
16ES718	Object Oriented Analysis and Design	3 0 0	3
16ES719	Video Processing	3 0 0	3

Project Work

Course Code	Course	L T P	Cr
16ES798	Dissertation		8
16ES799	Dissertation		14

16MA610 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 UnnikrishnaPillai, "*Probability, Random Variables and Stochastic Processes,*" Fourth Edition, McGraw Hill, 2002.

16ES602 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 modelling - Creating Combinational and Synchronous Logic – Designing FIFO - Test Benches - State Machine Designs - Design Examples - Memory Controller – Mealy State Machines - Design Considerations - General principles of circuit synthesis - Synthesis and Design Implementation - Synthesis and Fitting CPLDs, FPGAs- 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. Analysis & Synthesis of asynchronous digital circuits, State Reduction, State Assignment, Hazards, Testing of digital circuits.

TEXT BOOKS / REFERENCES

1. Stephen Brown and ZvonkoVranesic, "*Fundamental of Digital Logic with VHDL Design*", Third Edition, McGraw Hill, 2012.
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. Michael John Sebastian Smith, "*Application-Specific Integrated Circuits*", Pearson Education, 1997.

16ES603 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, Software Process Models - Software Specification, Architecture Styles - Software Design –Design qualities–Testing and verification–Software Estimation. Use LINUX platform for Lab.

TEXT BOOKS / REFERENCES:

1. Behrouz A. Forouzan and Richard F. Gilberg, "*Computer Science: Structured Programming Approach Using C*", Third Edition, Course Technology Inc., 2006.
2. Carlo Ghezzi, "Fundamentals of Software Engineering" Second Edition, PHI Learning, 2009.
3. Sommerville I, "*Software Engineering Concepts*", Tenth Edition, Pearson Education, 2015.
4. David E Simon, "*An Embedded Software Primer*", Pearson Education Asia, 2005.
5. Kirk Zurellm, "*C Programming for Embedded Systems*", CRC Press, 2000.

16ES604 SIGNAL AND IMAGE PROCESSING 3-0-1-4

Signal Processing: Review of Frequency and time domain analysis –Sampling, Convolution-Discrete Fourier Transforms, Fast Fourier Transform–Digital Filters-IIR Filters–Bilinear transformation. IIR filter structure-FIR filters–Windowing method-FIR filter structure.

Image Processing: Elements of Visual Perception- Image Sensing and Acquisition-Simple Image Formation- Image Sampling and Quantisation—Image Quality-Introduction to colour image- 2D Convolution, 2D FIR Filters- Spatial filtering.

TEXT BOOKS / REFERENCES:

1. Mitra S. K, "*Digital Signal Processing, A Computer-Based Approach*", Third Edition, McGraw Hill, 2005.
2. Ifeachor E. C and Jervis B. W, "*Digital Signal Processing: A Practical Approach*", Second Edition, Addison Wesley, 2002.
3. Steven W Smith, "*The Scientist and Engineer's Guide to DSP*", Newnes, 2002.
4. Rafael C. Gonzalez and Richard E. Woods, "*Digital Image Processing", Third* Edition, Prentice Hall, 2008.
5. Milan Sonka, Vaclav Hlavac and Roger Boyle, "*Image Processing, Analysis, and Machine Vision*",CL Engineering,2007.

16ES611 DISTRIBUTED EMBEDDED SYSTEMS 3-0-0-3

Distributed 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, Modelling 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*",Second Edition, Kluwer, 2011.
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 ProgrammingSmall 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.

16HU601 CULTURAL EDUCATION P/F

Students will undergo self-awareness / personality development and yoga training classes. They will also experience learning form ancient Indian culture.

16ES612 EMBEDDED PROCESSOR ARCHITECTURE AND DESIGN 3-0-1-4

An introduction to Embedded Processors – RISC verses CISC- CPU Performance Metrics- Benchmark- Integer and Floating Point data representation - RISC processor design: ARM Architecture – Programming Model, Pipelined data path design - Pipeline Hazards, Addressing Modes, ARM Instruction set - Thumb Instruction Set- Floating Point data processing, Interrupts & Exception Handling- ARM Programming , DSP Extensions, Mixed C and Assembly programming, AMBA bus system Peripherals, SoC design using ARM core, Debug support, Memory system design- Cache Memory, Memory Management unit - Virtual Memory. ARM advanced CPU cores, Applications development using Keil IDE.

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*", Pearson India, 2015.
3. Andrew Sloss, Dominic Symes and Chris Wright, "*ARM System Developer's Guide:* Designing and Optimizing System Software", First Edition, Morgan Kaufumann Publisher, 2011.
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).

16ES613 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. Link-layer protocols: fundamentals, Error Control, framing and link management. Routing protocols: 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. Naming and Addressing: Fundamentals, Address and name management in wireless sensor networks, Assignment of MAC addresses. Localization and Positioning: Possible approaches, Single-hop localization, Positioning in multi-hop environment. Time Synchronization: Relevance and protocols. Topology Management and power control.Case Studies.

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.
4. Jun Zheng, and Abbas Jamalipour, "Wireless *Sensor Networks - A Networking Perspective*", John Wiley and Sons Inc., 2009.
5. Anna Hac, "*Wireless Sensor Network Designs*", John Wiley and Sons Ltd., 2003.

16ES614 REAL TIME SYSTEMS 3-0-1-4

Introduction to real-time systems, clock synchronization – RTOS basics-architecture, RTOS VsGPOS, RTOS Kernel, Kernel services, task attributes and components- task management, taskstates and transition, time services, interrupt handling, interrupt latency, memory management,input-output handling, task communication and synchronization, task assignment andscheduling- 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, fault tolerant techniques, case studiesin real-time operating systems. RT Linux.

TEXT BOOKS / REFERENCES:

1. Jane W.S. Liu, "*Real -Time Systems*", First Edition, Pearson Education, 2002.
2. Giorgio Buttazzo, "*Hard Real-time Computing Systems: Predictable Scheduling Algorithms and Applications*", Third Edition, Springer, 2011.
2. Krishna and Shin, "*Real Time Systems*", Addison Wesley, 2010.
3. Phillip A. Laplante, "*Real-Time System Design and Analysis*", Third Edition, Prentice Hall ofIndia, 2004.
4. Christopher Hallinan, "*Embedded Linux Primer: A Practical Real-World Approach*", Prentice Hall, 2006.
5. P. Raghavan, Amol Lad and SriramNeelakandan, "*Embedded Linux System Design and Development*", CRC Press, 2005.

16ES615 MODEL BASED DESIGN FOR EMBEDDED SYSTEM 3-0-0-3

Introduction - Applications - The Design Process - Modelling Dynamic Behaviours – 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 -Behaviours 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: ACyber-Physical Systems Approach*", http://LeeSeshia.org, 2011.
2. Marwedel P, "*Embedded System Design - Embedded Systems Foundations of Cyber-PhysicalSystems*", Second Edition, Springer, 2011.
3. *http://www.cis.upenn.edu/~alur.*

16ES616 EMBEDDED SYSTEM APPLICATION LAB 0-0-1-1

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

16EN600 TECHNICAL WRITING P/F

Technical terms- Definitions- extended definitions- grammar checks- error detectionpunctuation-spelling and number rules - tone and style- pre-writing techniques - Online andoffline 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*". Sixth 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.

16ES701 EMBEDDED SYSTEMS FOR AUTOMOTIVE APPLICATIONS 3-0-0-3

Automotive Fundamentals – Vehicle functional domains and requirements – The systemsapproach to control and automotive instrumentation – Sensors and actuators in various vehicledomains. 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-bywiresystems. 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 – electricwindows – Occupants and driver safety systems: Seat belt lighteners and air-bags – DiagnosticsSystems. Embedded automotive protocols: CAN, LIN, FlexRay,

MOST, TTP/A, TTP/C andTTCAN - AUTOSAR standard and its applications – OSEK/VDX Open Systems in AutomotiveNetworks.

TEXT BOOKS / REFERENCES:

1. William B. Ribbens, "*Understanding Automotive Electronics*", Sixth Edition, Society ofAutomotive Engineers Inc., 2003.
2. V. A. W. Hillier and David R. Rogers, "*Hillier's Fundamentals of Motor Vehicle Technologyon Chassis and Body Electronics*", Fifth Edition, Nelson Thrones, 2007.
3. V A W Hillier, Peter Coombes, David R Rogers and Alma Hillier, "*Hillier's Fundamentalsof 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.

16ES702 ADVANCED MOBILE AND WIRELESS NETWORKS 3-0-0-3

Overview of Wireless Systems, TeleTraffic Engineering-Service level, Usage, MeasurementUnits, Types, B Formulas, Overview of Digital Communication and Transmission, MultipleAccess 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, QoSMangament, HSDPA, FOMA,CDMA, Wireless Application Protocol, Bluetooth - Protocol stack, Link Types, Security, ErrorCorrection, Topology, Applications, WiMax, 4G Systems, Software Defined Radio, CognitiveRadio.

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. EldadPerahia, "*Next Generation Wireless LANs: Throughput, Robustness, and Reliability in802.11n*", Cambridge University Press, 2008.

16ES703 EMBEDDED SYSTEMS IN BIOMEDICAL APPLICATIONS 3-0-0-3

Overview of biomedical devices – Origin of bio potentials – bio potential electrodes – biopotential amplifiers, System Theory for Physiological Signals: Filters, Modeling – Embeddedsystems 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, infusionpumps, syringe pumps, dialysis equipments. Applications of embedded

systems in surgicaldevices- endoscopy/laparoscopy, medical robots, anesthesia machine, surgical table, hapticsaugmented reality in minimally invasive surgery, lithotripsy, drug delivery systems, therapeuticapplication of laser. Embedded system applications in Medical Imaging systems, Therapeuticand prosthetic devices, Tele Medical system, Micro Fluidics and Lab-on-a-chip devices, ClinicalLaboratory equipments.

TEXT BOOKS / REFERENCES:

1. Anthony Y. K. Chan, "*Biomedical Device Technology: Principles and Design*", Charles CThomas Pub. Ltd., 2008.
2. John G. webster, "*Medical Instrumentation - Application and Design*", Fourth Edition, JohnWiley 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 AutonomousBiomedical Devices and Systems for Smart Environment - Issues and Characterization*",Springer, 2010.

16ES704 EMBEDDED SYSTEMS IN ROBOTICS 3-0-0-3

Robots and Embedded Systems-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, Embedded Controllers, Interfaces, Operating System. 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. Mobile Robots, Concepts of Localization and path planning. Autonomous robots and Introduction to Robot

TEXT BOOKS / REFERENCES:

1. Thomas Bräunl, "*Embedded Robotics: Mobile Robot Design and Applications with Embedded Systems*", Third Edition, Springer-Verlag Berlin Heidelberg, 2008.
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, Pearson/Prentice Hall, 2005.
4. AnisKoubaa, "*Robot Operating System (ROS) The Complete Reference*", First Volume, Springer, 2016.
5. K.S. Fu, R.C. Gonzalez and C.S.G. Lee, "*Robotics: Control, Sensing, Vision, and Intelligence*", McGraw-Hill, New York, 1987.

16ES705 EMBEDDED SYSTEMS IN SMART GRID 3-0-0-3

Evolution of Electric Power Grid, Renewable Energy based distributed generation–Solar and Wind energy conversion systems. Energy Storage Technologies–Battery, Pumped Hydro, PHEV etc.Scope and Avenues of automation in power grid, Smart Grid–Need, Definitions, Concept, Functions & Barriers & stakeholders.Present development & International scenario in Smart Grid.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.Transmission Side automation and Distribution side automation – WAMPAC, Smart Meters, Demand response. Market Models for smart grid. Standards and Regulations for smart grid. Case studies from India and abroad.

TEXT BOOKS / REFERENCES:

1. James Momoh, "*Smart Grid: Fundamentals of Design and Analysis*", Wiley-IEEE Press, March 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu and Akihiko Yokoyama, "*Smart Grid:Technology and Applications",* Wiley, February 2012.
3. NouredineHadjsaïd and Jean-Claude Sabonnadière, "*Smart Grids*", Wiley-ISTE, May 2012.
4. Ali Keyhani and Muhammad Marwali, "*Smart Power Grids 2011*", Springer, 2011.
5. Mini S. Thomas, John Douglas McDonald,"*Power System SCADA and Smart Grids*", CRC Press, April 2015.

16ES706 DESIGN FOR INTERNET OF THINGS 3-0-0-3

Embedded Systems: Rise of embedded systems and their transition to intelligent systems and to Internet of Things -RFIDs, NFC, Web of Things - Network of interconnected and collaborating objects, Embedded systems architecture: Key hardware and software elements, typical embedded processors like ATOM. Low power and very low power embedded systems, peripherals and sensors in embedded systems, peripheral interfacing -SPI and I2C, Hardware and software protocol stacks -MAC, Routing and application layers, performance considerations. Embedded Systems Design: Partitioning to hardware and software; principles of co-design; performance of these systems - estimation of speed, throughput, power and energy consumption; hardware design elements -design, validation, and testing tools; software platforms –OS and applications, code optimization, validation and robust code generation; system integration, debugging and test methodology; tools for coding, debugging, optimization, and documentation; measurement of system performance, Creating virtual prototypes -hardware software emulation. Applications: Healthcare and home automation examples.

TEXTBOOKS / REFERENCES

1. Barry, P., and Crowley, P., *Modern Embedded Computing*, Morgan Kaufmann, 2012.
2. Wolf, M., *Computers as Components*, Third Edition, Morgan Kaufmann, 2012.
3. Vijay Madisetti and Arshdeep Bahga, "Internet of Things: A Hands-on Approach", Hardcover – Import, 2014.

16ES707 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 Memorydesign - Virtual Memory, Storage Systems - Ware-house Scale Computers - Power optimizationin multi-core systems - Multi-core architectures for embedded systems – Programmingenvironments for multi-core.

TEXT BOOKS / REFERENCES:

1. J.L. Hennessy and D.A. Patterson, "*Computer Architecture: A Quantitative Approach*", FifthEdition, Morgan Kaufmann, 2011.
2. GeorgiosKornaros, "*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-ScalarProcessors*", McGraw Hill, 2005.
4. David Culler, J.P. Singh and Anoop Gupta, "*Parallel Computer Architecture: AHardware/Software Approach*", Morgan Kaufmann, 1998.
5. DezsoSima, Terence Fountain and Peter Kacsuk, "*Advanced Computer Architectures: A Design Space Approach* ",Pearson, 2005.

16ES708 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: Dependablechannels, survivable networks, fault-tolerantrouting. Fault recovery, Stable storage and RAID architectures, and Data replication and resiliency. 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 ComputerSociety Press, 1996.

5. Barry W. Johnson, "*Design and Analysis of Fault-Tolerant Digital System*", Addison, 1989.

16ES709 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, PerhaadMistry and Dana Schaa, "*Heterogeneous Computing with OpenCL*", Second Edition, Elsevier, 2012.
2. AaftabMunshi, Benedict Gaster, Timothy G. Mattson, James Fung and Dan Ginsburg, "*OpenCL Programming Guide*", Addison-Wesley Professional, 2011.
3. RyojiTsuchiyama, Takashi Nakamura, TakuroIizuka 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.

16ES710 SOFT COMPUTING 3-0-0-3

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 – Introduction to Support Vector Machines – Classification and Regression – Typical Applications Integrating Various Soft Computing Tools. Introduction to evolutionary algorithms-Ant Colony Optimization and swarm intelligence.

TEXT BOOKS / REFERENCES:

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

16ES711 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: AnIndustrial Approach*", Springer, 1997.

16ES712 OBJECT ORIENTED PROGRAMMING 3-0-0-3

Introduction to object oriented software design, Comparison of programming methodologies, Object Basics, Java Environment, Classes and Object, Data Members, Access Specifiers, Arrays within a Class, Array of Objects, Constructors, Default Constructors, Destructors, Static Members, Constant Members, Object Oriented Design with UML, Class s , object diagrams and sequence diagrams.

Overview of Streams, Bytes vs. Characters, File Object, Binary Input and Output, Reading and Writing Objects, Method Overriding, Polymorphism, Super, Interfaces and Abstract Classes, Packages, Use case diagrams and activity diagrams.

Introduction to Threads, Creating Threads, Thread States, Runnable Threads, Coordinating Threads, Interrupting Threads, Runnable Interface Applets: Applet Architecture- Parameters to Applet - Embedding Applets in Web page, Component diagrams and Deployment diagrams.

TEXT BOOK / REFERENCES:

1. Naughton P. and Schildt H., "*Java2 Complete Reference*", Eighth Edition, Tata Graw-Hill, 2011.
2. Ali Bahrami, "*Object Oriented Systems Development*", Second Edition, McGraw-Hill, 2008.
3. Grady Booch and Robert A. Maksimchuk, "*Object-oriented Analysis and Design with Applications*", Third Edition, Addison Wesley, 2006.
4. Jaime Nino, Fredrick a Hosch, "*An Introduction to Programming and Object Oriented Design Using Java*", Wiley India PrivateLimited, 2010.

16ES713 MACHINE LEARNING 3-0-0-3

Introduction to Machine learning, different forms of learning: supervised and unsupervised learning, classification and regression, parametric and nonparametric models, curse of dimensionality, linear and logistic regression, Basics of probability theory and probability distributions, information theory, Bayesian learning, Neural Networks, Gaussian Mixture models and the EM algorithm, Factor analysis, Principal components analysis, Independent

Component Analysis, Kernels and kernel functions, Support vector machines for regression and classification, Decision trees, CART, Ensemble Methods: Boosting - Adaboost, Gradient Boosting; Bagging - Simple methods, Random Forest, Markov and hidden Markov models, Introduction to deep learning, Examples and case studies in machine learning.

TEXT BOOKS / REFERENCES:

1. Christopher M. Bishop, *"Pattern Recognition and Machine Learning"*, Springer, 2006.
2. Kevin P. Murphy, *"Machine Learning: A Probabilistic Perspective"*, The MIT Press, 2012.
3. Trevor Hastie, Robert Tibshirani, Jerome Friedman, *"The Elements of Statistical Learning: Data Mining, Inference, and Prediction"*, Second Edition, Springer, 2009.
4. Bernhard Schölkopf and Alexander J. Smola, *"Learning with Kernels - Support Vector Machines, Regularization, Optimization, and Beyond",* MIT Press, 2001.
5. Tom M. Mitchell, "*Machine Learning"*, McGraw-Hill, 1997.

16ES714 CRYPTOGRAPHY AND NETWORK SECURITY 3-0-0-3

Classical Encryption Techniques – Symmetric Cipher Model – Steganography – AESCipher-Symmetric Cipher – Multiple Encryption and triple DES – Blocks Cipher – stream Cipher – Confidentiality using symmetric encryption – Placement of encryption function – randomnumber generation – Introduction to number theory – Cryptosystems – message authenticationand Hash functions – requirements – functions – course – Hash and MAC algorithms – secureHash algorithms – Digital signatures and authentication protocols – standard – authenticationapplications – Electronic mail security - S/MIME-IP security – overview- architecture – websecurity - 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.

16ES715 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 HinrichSchutze, "*Foundations of Statistical Natural Language Processing*", MIT Press, 1999.
3. Sandra Kubler, Ryan McDonald and JoakimNivre, "*Dependency Parsing Synthesis Lecturers on Human Language Technologies*", Morgan and Claypool Publishers, 2009.

16ES716 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-TimeWorkshop 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 DSPPlatform*", Prentice Hall, 2000.
3. Andy Bateman and Iain Paterson-Stephens, "*The DSP Handbook, Algorithms, Applications and Design Techniques*", Prentice-Hall, 2002.
4. RulphChassaing, "*DSP Applications Using C and the TMS320C6x DSK*", John Wiley and Sons, 2002.
5. B Venkataramani and M Bhaskar, "*Digital Signal Processors: Architecture, Programming and Applications*", Tata McGraw Hill, 2002.

16ES717 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, PrenticeHall, 2002.
3. Joseph DiStefano III, Allen J. Stubberud and Ivan J. Williams "*Feedback and Control Systems*"*,Second Edition,* Schaum's Outline Series, Mcgraw-Hill, 2014.
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.

16ES718 OBJECT ORIENTED ANALYSIS AND DESIGN 3-0-0-3

Introduction to object oriented software design, Comparison of programming methodologies, Object Basics, Java Environment, Classes and Object, Data Members, Access Specifiers, Arrays within a Class, Array of Objects, Constructors, Default Constructors, Destructors, Static Members, Constant Members, Object Oriented Design with UML, Class s , object diagrams and sequence diagrams.

Overview of Streams, Bytes vs. Characters, File Object, Binary Input and Output, Reading and Writing Objects, Method Overriding, Polymorphism, Super, Interfaces and Abstract Classes, Packages, Use case diagrams and activity diagrams.

Introduction to Threads, Creating Threads, Thread States, Runnable Threads, Coordinating Threads, Interrupting Threads, Runnable Interface Applets: Applet Architecture- Parameters to Applet - Embedding Applets in Web page, Component diagrams and Deployment diagrams.

TEXT BOOKS/ REFERENCES:

1. Naughton P. and Schildt H., "*Java2 Complete Reference*", Eighth Edition, Tata McGraw- Hill, 2011.
2. Ali Bahrami, "*Object Oriented Systems Development*", Second Edition, McGraw-Hill, 2008.
3. Grady Booch and Robert A. Maksimchuk, "*Object-oriented Analysis and Design with Applications*", Third Edition, Addison Wesley, 2006.
4. Jaime Nino, Fredrick a Hosch, "*An Introduction to Programming and Object Oriented Design using Java*", Wiley India Private Limited, 2010.

16ES719 VIDEO PROCESSING 3-0-0-3

Introduction - Image Representation - Image Digitization, Geometric Transformations, Linear image filtering and correlation- Image Smoothing - Edge Detectors - Corner Detectors. Noise reduction, Image Segmentation, Morphological image processing, Digital video processing.

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 HinrichSchutze, "*Foundations of Statistical Natural LanguageProcessing*", MIT Press, 1999.
3. Sandra Kubler, Ryan McDonald and JoakimNivre, "*Dependency Parsing Synthesis Lecturers on Human Language Technologies*", Morgan and Claypool Publishers, 2009.

16ES798 DISSERTATION 8

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

16ES799 DISSERTATION 14

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