M.Tech course in Electronics & Communication Engineering
KALYANI GOVERNMENT ENGINEERING COLLEGE

Curriculum structure and syllabus of the M.Tech course in Electronics & Communication Engineering

First Semester

Core compulsory Subjects	L – T – P	Marks	Credit
MH-901 Advanced Engineering Mathematics	4 0 0	100	4
EC-901 Physical Electronics	4 0 0	100	4
EC-902 Digital Signal Processing Processing	4 0 0	100	4
Elective – I	4 0 0	100	4
Elective – II	4 0 0	100	4
EC-xxx Elective Lab I	0 0 6	100	3
		TOTAL – 600	23

Second Semester

EC-1001 Advanced Process Control & Instrumentation	4 0 0	100	4
EC-1002 Advanced Digital System Design	4 0 0	100	4
Elective – III	4 0 0	100	4
Elective – IV	4 0 0	100	4
EC 1091 Advanced Digital System Design Lab	0 0 3	50	2
EC-1092 Elective LabII	0 0 6	100	3
EC-1092 M. Tech Seminar		50	2
		TOTAL- 600	23

Third Semester

Elective – V	4 0 0	100	4
Grand Viva		100	4
Project (Stage I)		400	16
		TOTAL- 600	24

Fourth Semester

Project (Stage II) Thesis & Viva Voce	600	24

Elective Subjects for 1st semester (Any two)

EC- 903 Information theory & coding
EC-904 Remote Sensing
EC-905 Bio Medical System Engineering

EC-906 VLSI Design
EC-907 VLSI Technology
CS-901 Theory of Automata
EC-908 Advanced Communication System
EC-909 Mobile Communication
EC-910 Image Processing
EC-911 Advanced Microprocessor Based Systems
EC-912 Artificial Intelligence & Robotics

Elective Lab I (Any one)

EC-991 VLSI Design
EC-992 Advanced Communication I
EC-993 Microprocessor based system design

Elective Subjects for 2nd semester (Any two)

EC – 1003	Optoelectronic & Display Devices
EC – 1004	Superconducting Devices & Application
EC – 1005	Internet Technology & Application
EC – 1006	Satellite Communication Systems
EC – 1007	VLSI Circuits & Systems
EC – 1008	Microwave Measurement Techniques
EC – 1009	Bio Informatics
CS – 1001	Computer Architecture & Parallel Processing
EC- 1010	CMOS Analog VLSI Design
EC- 1011	Theory of Transistors

Elective Lab II (Any one)

EC – 1091	Device characterisation & simulation
EC – 1092	Microwave Measurement
EC – 1093	Process Control

Elective Subject for 3rd semester

EC- 1101	CAD-CAM
EC-1102	Advanced Electronics Materials & Devices
CS- 1101	Embedded System Design

One subject may be chosen from the above or 1st semester elective subjects.

MH 901
ADVANCED ENGINEERING MATHEMATICS
4 0 0
4 Credits

Non-linear Differential Equations: Iterative, Variational and Perturbation Methods.
Integral Equations: Boundary value problems; Boltzmann transport equation in e.m. field; Hilbert Schmidt theory.

Green's Functions : Application to physical problems; Green's function by eigenfunction method; Solution of initial and boundary value problems.

Probability Theory : Different probability spaces; Distribution functions and their decomposition; Expectation and its properties, Algebraic theory of Markov chains; Random walk problem; Renewal theory; Two-stage Markov process; Queuing theory; Fokker-Planck equation in continuous stochastic processes.

Modern Discrete MathematicsRelations and Diagraphs:Mathematical structures, Binary relations, boolean matrices and operations, Equivalence relation, Principle of partition.

Algebraic systems of single composition : Group, Symmetric group, Cyclic Group, Sub group, Cosets and Quotient Group, Language's theorem.Systems of Double compositions : Ring, Integral domains, Field, Ideal, Module.

Congruencies : The ring Zm, Euler function (m), Fermat Theorem, Homomorphism and Isomorphism, Kernel polynomial ring, Quotient field, Galois fields, Prime field, Primitive element and Primitive polynomials, Minimal polynomials, Applications to coding and information.

Boolean Algebra : Basic operations, Switching functions and circuits.

Combinatories : Generating functions : Permutations and combinations, Construction of Binary and quaternary Sequences.

Difference equation : Difference operators, recurrence relations, Linear and Non-linear difference equations: Methods of solution, Random numbers: Fibonacci sequence.

Graph Theory : Formal definition; Subgraphs, Walk, Path, Hamiltonian path, Cycle, Euler graph, Planar graph, Tree: Binary tree, Spanning tree, Fundamental circuits: Cutsets, Tie sets, Shortest path, Minimal spanning tree, Algorithms.

Numerical Methods : Solution of matris equation by generalised inverse technique, Numerical evaluation of determinant; Computation of eigenvalues and eigenvectors, Matrix inversion by partitioning; Optimisation technique by conjugate gradient method and method of steepest descent. Fast-Fourier Transformation (FFT) algorithms; FFT of real functions; Convolution; correlation and auto-correlation using FET; Computation of Fourier integrals using FFT; Solution of boundary value problems by relaxation methods; Solution of integral equations by variational methods.

EC 901
PHYSICAL ELECTRONICS
4 0 0
Credits 4

Introduction to semiconductor Physics : Review of quantum mechanics, electrons in periodic lattices, E-k diagrams, Quasiparticles in semiconductors, electrons, holes and phonons. Boltzmann transport equation and solution in the presence of low electric and magnetic fields – mobility and diffusivity ; Carrier statics; High field effects : velocity saturation, hot carriers and avalanche breakdown.

Semiconductor junctions : Schottky, homo and hetero-junction band diagrams and I-V characteristics, and small signal switching models ; Two terminal and surface states devices based on semiconductor junctions.

MOS structures : Semiconductor surfaces; The ideal and nonideal MOS capacitor and diagrams and CVs; Effects of oxide charges, defects and interface states; Characterization of MOS capacitors: HF and Lf cvS, AVALANCHE INJECTION; High field effects and breakdown.

Characterization of semi conductors: Four probe and Hall measurement; CVs for dopant profile characterization; Capacitance transients and DLTS.

EC 902
DIGITAL SIGNAL PROCESSING
4 0 0
4 Credits

Discrete time signals and systems: Convolution and frequency response. Discrete time Fourier and Z-transforms: Properties, analysis of discrete time systems. The DFT; Definition and properties, circular convolution calculation, FFT and Chirp transform. Relationship between continuous and discrete time systems; sampling time and frequency normalization, discrete time processing of continuous time signals. Difference equation for digital filters: definition and properties. FIR filters, IIR filters. Digital filter design techniques: Impulse invariance. Bilinear transformation, finite difference, window design methods, frequency sampling optimization algorithms. Parametric signal modelling: Auto regressive signal modelling based on linear prediction, pole zero modelling. Time varying auto regressive models. Parametric signal modelling in the presence of noise. applications, spectral analysis. Power spectral analysis using DFT, Maximum entropy spectral estimation (MEM)Adaptive signal processing: time adaptive systems. LMS algortihm. 2 D signal processing: filter design and implementation. 2 D spectral factorization and analysis.

EC 903
INFORMATION THEORY & CODING TECHNIQUES
4 0 0
Credits 4

Sources-memoryless and Markov; Information; Entropy; Extended sources; Shanon's noiseless coding theorem; Source coding; Mutual information; Channel capacity; BSC and other channels; Shanon's channel capacity theorem; Continuous channels; Comparison of communication systems based on Information Theory; Channel Coding-block and convolutional block codes-majority logic decoding; Viterbi decoding algorithm; Coding gains and performance.

EC 904
REMOTE SENSING
4 0 0
Credits 4

Transmission of Solar Radiation through the Atmosphere : Solar radiation spectrum; Radio infrared and optical windows of the earth's atmosphere; Spectrum of solar radiation transmitted through

the atmosphere, Emissions from the disturbed sun, Reflection, Absorption and Emission from Earth and Atmosphere.

Variation of the earth's reflectivity with angle of incidence, wavelength and geographical location; Seasonal variation of reflectivity; Solar radiation reflected from the earth; Absorption of solar radiation by the earth; Thermal radiation from the earth; Thermal radiation from the atmospheric constituents; Thermal emission from cloud, rain, snow and fog; Radio noise and interference at satellite heights.

Sensors and Cameras: Optical and infrared detectors and filters, Optical and infrared cameras; Microwave and Millimetrewave radiometers; Scanning systems, Mechanical and Electronic Systems; Scatterometer; Altimeter.

Remote Sensing Satellites: Orbits of remote sensing satellites; Remote sensing satellites – LANDSAT; Indian Remote Sensing (IRS) Satellites; INSAT, NOAA Series; NASA's Upper Atmosphere Research Satellites (UARS); TRMM satellite.

Remote Sensing of Atmosphere and Sea State: Passive and active remote sensing; Side Looking Airborne Radar (SLAR); Synthetic Aperture Radar (SAR); Along Track Scanning Radiometer (ATSR), Laboratory measurements of remote sensing parameters; Tropical rainfall measurements; Microwave sensing of sea surface.

Interpretation of Sensing Data : Photo-interpretation, image and pattern recognition; Spectral interpretation of remote sensing imagery; Interpretation of thermal maps; Colour coding and enhancement; Computer interpretation of images.

EC -905
BIOMEDICAL SYSTEM ENGINEERING
4 - 0 - 0
4 Credits

Biomedical signals : origins and dynamic characteristics, Biomedical signal acquisition and processing, Compression of biomedical signals. Analysis of biomedical signal using advanced techniques (e.g. neural networks, orthogonal transformations including singular value decomposition) and wavelet transformation, higher order spectra). Nonlinear dynamical analysis of biomedical signals. Physiological modelling, identification and simulation. Control of physiological processes and computer controlled drug infusion medical signaling (including CT Scan, MRI and Ultrasound). Medical Informatics, Artificial intelligence methods for medical decision making.

EC 906
VLSI Design
4 0 0
Credits 4

Review of MOS transistor models. CMOS logic families including static, dynamic and dual rail logic. Integrated Circuit Layout : Design Rules, Parasitics. Building blocks : ALU's FIFO's , counters. VLSI system design: Data and control path design, floorplannig, Design methodology : Introduction to hardware description languages (VHDL), logic, circuit and layout verification. Design examples.

EC -907

VLSI TECHNOLOGY
4 0 0
Credits 4

Environment for VLSI Technology : Clean room and safety requirements. Water cleaning processes and wet chemical etching techniques.

Impurity incorporation : Solid State diffusion modelling and technology; Ion Implantation modelling, technology and damage annealing; Characterisation of Impurity profiles.

Oxidation : Kinetics of Silicon dioxide growth both for thick, thin and ultrathin films. Oxidation technologies in VLSI and ULSI; Characterisation of oxide films; High K and low k dielectrics for ULSI.

Lithography : Photolithography, E-beam lithography and newer lithography techniques for VLSI/ULSI; Mask generation.

Chemical Vapour Deposition Techniques: CVD techniques for deposition of polysilicon, silicon dioxide, silicon nitride and metal films; Epitaxial growth of silicon; modeling and technology.

Metal film deposition : Evaporation and sputtering techniques. Failure mechanisms in metal interconnects; Multilevel metallisation schemes.

Plasma and Rapid Thermal Processing: PECVD, Plasma etching and RIE techniques; RTP techniques for annealing, growth and deposition of various films for use in ULSI.

Process integration for NMOS, CMOS and Bipolar circuits; Advanced MOS Technologies.

CS 901
THEORY OF AUTOMATA

4 0 0
Credits 4

Reliable Design and Fault Diagnosis – Hazards, Fault Detection in Combinational Circuits, Fault Location Experiments, Boolean Differences, Detection of multiple faults.

Synchronous Sequential Circuits and Iterative Networks – Sequential Circuits, Finite state Model, Synthesis of sychronous sequential circuits, Iterative networks.

Capabilities, Minimization and Transformation of Sequential Machines.

Asynchronous Sequential Circuits – Fundamental – Mole circuits, synthesis,State Assignment in Asynchronous Sequential Circuits, Pulse Mode Circuits.

Structure of Sequential machines – State assignment using partitions, Lattice of close partitions, Reduction of output dependency, Covers and generation of closed partitions by state splitting, Information Flow in Sequential machines, Decomposition, Synthesis of multiple machines.

State Identification and Fault Detection Experiments.

Memory, Definiteness, and information Losslessness of finite automata. Linear Sequential Machines.

EC 908
ADVANCED COMMUNICATION SYSTEMS
4 0 0
CREDITS 4

Propagation impairments at microwave and millimeter wave bands-Attenuation,depolarization ,scintillation,frequency management, System planning,Link budget, Link design for LOS and earth space paths.

Micro strip patch antennas-basic configuration and advantages, radiation mechanism, basic characteristics and feeding techniques, broadbanding techniques, microstrip arrays, Active integrated antennas-active devices and passive elements.

Optical communication

IM/DD, S/N ratio and BER,Power penalty, WDM- System requirements, MUX/DEMUX Devices, Fiber optic subscribe loop, coherent optical communication, optical amplifiers, fiber nonlinearities,soliton propagation, photonic switching.

Guided and unguided propagation, optical transmitters and receivers, direct detection based systems, Receiver noise projess and statistics, digital & analog fiber optic links, free space optical links, Fiber optic LAN,Elements of coherent optical communication systems.

EC 909
MOBILE COMMUNICATION
4 0 0
Credits 4

Historical review; Uses of mobile radio-different services; Land, maritime and air services; Relation to navigational systems; Cordless telephones and wireless PABXs; Cellular system and frequency reuse; Analog and digital modulation techniques for mobile radio, signalling, control and connection to fixed network; Multipath and fading channels; Path loss, Diversity techniques; Mobile radio transmitters, receivers and link designing; system examples.

EC 910
IMAGE PROCESSING
4 - 0– 0
4 Credits

Digital Image Fundamentals, Image Transforms : Fourier, Hadamard, Walsh, Discrete cosine and Hotelling Transforms ; Image Enhancement : Histogram modification, Histogram equalisation, Smoothing, Filtering, Sharpening, Homomorphic filtering. Segmentation : Pixel classification, Bi-level thresholding, Multi-level thresholding, P-tile method, Adaptive thresholding, Spectral & spatial classification, Edge detection, Hough transform, Region growing. Matching and Registration : Image modelling, Stereo mapping, Landmark matching, Rectification in geometric transformations, Match measurement, Matching of binary pattern, Distortion tolerant matching ; Digital geometry and its applications : Neighbourhood, Path, Connectedness, Holes and Surroundness, Borders, Distances, Medial Axis Transform(MAT), Shrinking and Expanding, Thinning. Introduction to Mathematical morphology and its application,

Morphological Operations, Dilation, Erosion, Opening, Closing, Smoothing, Extraction of connected components, Thinning.

EC-911
ADVANCED MICROPROCESSOR BASED SYSTEMS
4 0 0
Credits 4

Basic structure of microprocessor based system and its design: Development cycle defining the product's software, Debugging the software, integration of hardware and software. Advanced microprocessors(32 bit & 64 bit). Organization of IBM-PC/XT/AT, Mother board, BIOS and DOS interrupts.Programming using assembler Co processor; Its instruction set and programming, DMA controller, CRT controller, Floppy and hard disk ISA, EISA,IEEE and GPIB bus structure, PC compatible extension cords, Architecture of microcontroller, instruction set, programming and their use.

EC 912
ARTIFICIAL INTELLIGENCE AND ROBOTICS
4 0 0
Credits 4

Introduction to cognitive science and perception, problem representation through heuristics, problem reduction, basic heuristic search procedures; Knowledge representation and knowledge engineering; Inference engineers and expert systems; Programming languages for Al; Image recognition and computer vision; Speech recognition; the Robot arm; robot sensing, Feedback control and robot manipulation, robot learning.

EC 1001
ADVANCED PROCESS CONTROL & INSTRUMENTATION
4 0 0
Credits 4

Process variables : Field Instrumentation and Physicochemical and analytical system; Geometric and Motion sensors; Valves, Servos, Motors & Robots; Design Aspects of a Process Control System; Hardware of a Process Control System; Analysis and modelling of the dynamic and static behaviour of a process; Analysis and design of Feedback Control System; Analysis & design of Advanced Control system; Design of Control Systems for multivariable processes; Introduction to Plant Control; Process Control using Digital Computers (including use of PLCs); Process Identification and Adaptive Control.

EC 1002
ADVANCED DIGITAL SYSTEM DESIGN
4 0 0
Credits 4

Digital system design implementation options : ASICs – Full custom, gate array based, standard cell based and Programmable ASICs.

Antifuse, SRAM, EEPROM/EPROM technologies for Programmable ASICs.

Digital system modeling : Behavioral, structural and physical domains, levels of abstraction, basics of high level and logic synthesis. Digital modeling using hardware description languages-VHDL and Verilog.

VHDL-Syntax, entities and achitecture, pachages and libraries, interface declarations, sequencial and concurrent statements. High level design process : simulations, synthesis, place and route and vital simulation.

Design case studies. Design flow for FPGA and ASIC based design. Commercial CAD Packages.

Testing and Verification.

EC 1003
OPTOELECTRONIC AND DISPLAY DEVICES
4 0 0
Credits 4

Optical processes in semiconductors; Light-emitting diodes; Laser operating principles; Semiconductor laser structures; Solid-state and gas lasers, Photodetectors, Receiver noise considerations; Special detection systems; Solar cells; Optoelectronic modulation and switching devices; Liquid crystal devices; pornous silicon optical devices; Optical integrated circuits and its processing and applications.

EC 1004
SUPERCONDUCTING DEVICES AND APPLICATIONS
4 0 0
Credits 4

Principles of superconductivity; superconducting materials; Low-frequency devices; Josephson effects; Josephson devices; SQUIDs; magnetometers and gradiometers, Supermagnet, supercollider and magnetic train; Fabrication process; Hybrid superconductor-semiconductor devices; Superconductor interlinks in semiconductor Ics, Josephson logics, memories; AD/DA converters, etc.; Superconductor device applications; Millimeter wave generation and detection; High-Tc superconductors and their processing and applications; Future trends of superconductors.

EC 1005
INTERNET TECHNOLOGY & APPLICATION
4 0 0
Credits 4

Internet tools, e-mail, ftp and the world wide web; TCP/IP protocol and the IP address concept; Security on the net, Next generation Internet, Web searching and search engines, Web design and authoring tools; Multimedia applications; On-line services, Concept of e-commerce; intranet and its design; firewalls; Enterprise-wise information management.

EC 1006
SATELLITE COMMUNICATION SYSTEMS

4 0 0
Credits 4

Evolution and growth of communication satellites, Kepler's laws of motion, orbits, altitude control; Satellite launch vehicles-Arianne, SLV space shuttle; Subsystems of communication satellite; Spectrum allocation and Bandwidth considerations; Propagation characteristics, Satellite transponders and other sub systems; Earth station technology; Analog and digital link design; Multiple access techniques-FDMA, TDMA, SS-TDMA; Interference in FDMA systems.

EC 1007
VLSI CIRCUITS AND SYSTEMS
4-0-0
4 Credits

Introduction to VLSI systems; Timing circuit; Clock generators; Direct and PLL frequency synthesizer; Data converters; SAR, oversampled A/D and high speed converters; advanced A/D converters; filter design; Memory (volatile and non-volatile); DSP chip; CPU architecture; advanced low-power circuits.

EC 1008
MICROWAVE MEASUREMENT TECHNIQUES
4 0 0
Credits 4

Microwave components and measuring instruments, Precision measurement of electrical parameters of microwave sources and network elements. Measurement based on transmission and reflection; Radiation pattern measurements, Antenna range design and evaluation, Anechoic chamber, Measurement based on perturbation techniques, 6 port waveguide bridge; Swept frequency measurements-Network analyser systems; Frequency response test set, TDR systems; RCS measurement; EMI measurement (TEM cell).

EC 1009
BIOINFORMATICS
4 0 0
Credits

Genome sequence analysis (homology searching, scoring matrics, sequence alignment, genome mapping and assembly). Functional genomics: array technology & uses (gene discovery, disease diagnosis, drug discovery, toxicological research); data analysis (error analysis, clustering-PCA, decision trees, correlations, SOM). Gene networks-logic based models, qualitative methods quantitative methods. Metabolic pathways-measurements and analysis. The genomics and proteomics projects, data basis on the web.

CS 1001
COMPUTER ARCHITECTURE AND PARALLEL PROCESSING
4 0 0

Credits 4

Introduction : Architectural classification; Various terminologies; Parallelism in uniprocessor system; Memory interleaving; Pipelining and vector processing Instructions and arithmetic pipelines; Array processor.

Multiprocessor architecture : Inter-connection networks, Functional structures; parallel algorithms, Studies of different cases.

Data flow architecture.

EC 1010
CMOS Analog VLSI Design
4 0 0
Credits 4

Introduction to analog VLSI and mixed signal issues in CMOS technologies. Basic M frequency dependent parameters. Basic MNOS/CMOS gain stage, cascade and casco stability and noise issues in amplifiers. CMOS analog blocks : Current Sources and V amplifier and OPAMP design. Frequency Synthesizers and Phased lock-loop. Non-lin Comparators, Charge-pump circuits and Multipliers. Data converters. Analog Interco issues. Low Voltage and Low Power Circuits. Introduction to RF electronics.

EC-1011
THEORY OF TRANSISTORS

The MOS transistor : Pao-Sah and Brews models; Short channel effects in MOS transistors. Hot-carrier effects in MOS transistors; Quasi-static compact models of MOS transistors; Measurement of MOS transistor parameters; Scaling and transistors structures for ULSI; Silicon-on-insulator transistors; High-field and radiation effects in transistors.

The bipolar transistor: Ebers-Moll model; charge control model; small-signal and switching characteristics; Graded base and graded-emitter transistors; High-current and high-frequency effects; Heterojunction bipolar transistors; Junction FETs; JFET, MESFET and heterojunction FET.

EC 1101

CAD-CAM
4 0 0
Credits 4

AD of Digital Circuits : Overview of VLSI System Design from structured design approach – from circuit topology to wafer fabrication through stages of layout pattern using various CAD tools, Full-custom and Semi-custom design approaches; Chip Design based on FPGA & PLD empty chips; Overview of Hardware Description Languages – VHDL & VERILOG; Design at different levels with special emphasis on FPGA and PLD; Design of sequential and Combinatorial circuits, Design of Memory Chips.

CAD of Analog Networks : Overview of PSPICE modelling of analog circuits, Basic concepts of graphs and trees; Simulation of linear and non-linear dynamic networks-Transient analysis, Network optimisation, automatic Design, Basic concepts of neural networks and Fuzzy algorithm; Bi-directional associative memory (BAM); Global stability and Lyapunov theory.

Computer-aided Engineering Drawing and Drafting : Programming Language of computer-aided drafting-LISP and AUTOLISP, Exposure to related CAD tools.

CAD & CAM: Overview of Robotics for CAM; Programming languages for Computer Controlled Numerical (CNC) machines – APT language; NC part programming for CNC and DNC machines.

EC 1102
ADVANCE ELECTRONIC MATERIALS AND DEVICES
4 0 0
Credits 4

Advance Materials: Nitride and Carbide semiconductors, Aapplications, Ceramic materials, Superconducting materials, HTS materials, Josephson junction, SQUIDs, Conducting Polymers, Hybrid circuit materials, Fibre optic materials, Electro-optic materials, Microwave materials.

Nanoelectronic Devices: Quantum electron transport through nanostructure devices, Landauer formula, Aharonov-Bohm effect. Density matrix, Quantum kinetic equation, Wigner transformation, Quantum Boltzman equation. Quantum wells, Quantum wires and quantum dots, Envelop function. Exciton inquantum wells, Si/Ge strained heterostructures. Modulation doping, HEMT. Tunnelling transport, Resonant tinnelling devices. High field transport in quantum structures, Hot electron transistors, Ballistic injection devices. Velocity modulation and quantum interference transistors, Quantum wire transistors, Quantum dot devices.

MESFET: Small signal analysis; Microwave equivalent circuit; S- parameter charaterisation using device physics MESFET as an amplifier, Design of MESFET amplifier: OPFET

MOSFETs for VLSI: Long channel and short channel MOSFET . Short channel effect, Velocity saturation, Channel length modulation, MOSFET breakdown CMOS device design: MOSFET scaling, Threshold voltage, Quantum effect on threshold voltage, Sensitivity of CMOS delay to device parameters, Performance factor of advanced CMOS devices , Bi-CMOS.

CS-1101
EMBEDDED SYSTEMS
4-0-0
4 Credits

Introduction; real time applications;Hard VS soft real time systems; Scheduling-Classical approaches; Clock and priority driven scheduling, Scheduling of a periodic and sporadic jobs; Resource access control, synchronization and control in multiprocessor scheduling, scheduling flexible computation and tasks with temporal distance constraints.
Real time communication, operating system characteristics, features and implementation, embedding of computer, microprocessors and microcontrollers in real time system implementations and their applications.