DELHI TECHNOLOGICAL UNIVERSITY
SCHEME OF TEACHING AND EVALUATION
MASTER OF TECHNOLOGY IN VLSI DESIGN & EMBEDDED SYSTEM (VLS)

The following alphanumeric coding scheme has been adopted
Core Courses XXXYMN
Elective Courses XXXYCMN

XXX abbreviates a particular M. Tech. program, Y – (5 for M. Tech. 1 st year, 6 for M. Tech. 2 nd year),
C – credit of the course (4/3/2),
MN – Subject code (Odd number for odd semester and even number for even semester courses

Semester-I

	S. No.	Course Code	Course Name	Type/ Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE	Total Credits
Group A	1	VLS501	Analog IC Design	Core	4	3	0	2	15	25	20	40	-	**17**
	2	VLS503	Digital CMOS IC Design	Core	4	3	0	2	15	25	20	40	-	
Group B	3	VLS5401/5403/…………	Elective 1	Elective	4	3	0	2	15	25	20	40	-	
	4	VLS5301/5303/…………	Elective 2	Elective	3	3	0	0	20	-	30	50	-	
	5	VLS5201/5203/………… /UEC5201/5203/…………	Elective 3/ University Elective I	Elective	2	2	0	0	20	-	30	50	-	

Semester-II

	S. No.	Course Code	Course Name	Type/ Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE	Total Credits
Group C	1	VLS502	Embedded System Design	Core	4	3	0	2	15	25	20	40	-	**17**
	2	VLS504	Low power VLSI Design	Core	4	3	0	2	15	25	20	40	-	

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE	Total Credits
Group D	3	VLS5402/5404/…………	Elective 4	Elective	4	3	0	2	15	25	20	40	-	
	4	VLS5302/5304/…………	Elective 5	Elective	3	3	0	0	20	-	30	50	-	
	5	VLS5202/5204/…………/ UEC5202/5204/…………	Elective 6/ University Elective II	Elective	2	2	0	0	20	-	30	50	-	

Semester-III

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE	Total Credits
	Track 1													**12**
Group E	1	VLS651	Research Project	Core	12	0		12	0	-	0	100	0	
	Track 2													
	1	VLS601	Major Project I	Core	3						40	60		
	2	VLS6401/6403/…………	Elective 7	Elective	4	3	0	2	15	25	20	40	-	**12**
	3	VLS6301/6303/…………	Elective 8	Elective	3	3	0	0	20	-	30	50	-	
	4	VLS6201/6203/…………	Elective 9	Elective	2	2	0	0	20	-	30	50	-	

Semester-IV

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE	Total Credits
Group F	**Track 1**													
	1	VLS652	Research Project	Core	12	0		12	0	-	0	100	0	**12**

	Track 2												
1	VLS602	Major Project II	Core	12	0		12	0	-	0	100	0	**12**

LIST OF ELECTIVES :

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 1	1	VLS5401	Digital Design with HDL (Verilog)	Elective	4	3	0	2	15	25	20	40	-
	2	VLS5403	Digital Signal Processing		4	3	0	2	15	25	20	40	-
	3	VLS5405	Soft Computing		4	3	0	2	15	25	20	40	-
	4	VLS5407	IC technology		4	3	0	2	15	25	20	40	-

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 2	1	VLS5301	Device modelling	Elective	3	3	0	0	20	-	30	50	-
	2	VLS5303	Reconfigurable Computing		3	3	0	0	20	-	30	50	-
	3	VLS5305	Hardware software codesign		3	3	0	0	20	-	30	50	-
	4	VLS5307	Organic and Flexible Electronics		3	3	0	0	20	-	30	50	-

	S.No.	Course Code		Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
	1	VLS5201	SEMINAR		**2**	2	0	0	2	-	100	-	-
Elective 3	2	VLS5203	Micro and Nanoelectronics	Elective	2	2	0	0	20	-	30	50	-
	3	VLS5205	Micro and Nanofabrication		2	2	0	0	20	-	30	50	-
	4	VLS5207	Field Programmable Analog Arrays		2	2	0	0	20	-	30	50	-

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
	5	VLS5209	Layout Design Skills		2	2	0	0	20	-	30	50	-

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 4	1	VLS5402	Analog Filter Design	Elective	4	3	0	2	15	25	20	40	-
	2	VLS5404	Internet enabled embedded devices		4	3	0	2	15	25	20	40	-
	3	VLS5406	CAD for VLSI Systems		4	3	0	2	15	25	20	40	-
	4	VLS5408	CMOS RF Circuit Design		4	3	0	2	15	25	20	40	-

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 5	1	VLS5302	MINOR PROJECT	Elective	3	0	0	-	-	40	-	-	60
	2	VLS5304	FPGA based Digital Signal Processing		3	3	0	0	20	-	30	50	-
	3	VLS5306	Testing and Diagnosis of Digital System Design		3	3	0	0	20	-	30	50	-
	4	VLS5308	Memory Design and Testing		3	3	0	0	20	-	30	50	-

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 6	1	VLS5202	CMOS nano neuromorphic circuits	Elective	2	2	0	0	20	-	30	50	-
	2	VLS5204	Real Time Operating Systems		2	2	0	0	20	-	30	50	-
	3	VLS5206	Clock Tree Synthesis		2	2	0	0	20	-	30	50	-

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
	4	VLS5208	Layout design and skills with analog perspective		2	2	0	0	20	-	30	50	-
	S.No.	**Course Code**	**Course Name**	**Type/Area**	**Cr**	**L**	**T**	**P**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
Elective 7	1	VLS6401	Mixed Signal Design	Elective	4	3	0	2	15	25	20	40	-
	2	VLS6403	Embedded Signal Processing		4	3	0	2	15	25	20	40	-
	3	VLS6405	Biomedical Circuits		4	3	0	2	15	25	20	40	-
	4	VLS6407	Fault Tolerant computing		4	3	0	2	15	25	20	40	-
	S.No.	**Course Code**	**Course Name**	**Type/Area**	**Cr**	**L**	**T**	**P**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
Elective 8	1	VLS6301	Speech Processing	Elective	3	3	0	0	20	-	30	50	-
	2	VLS6303	Embedded Automotive systems		3	3	0	0	20	-	30	50	-
	3	VLS6305	Machine Learning		3	3	0	0	20	-	30	50	-
	4	VLS6307	Advanced Computer Architecture		3	3	0	0	20	-	30	50	-
	5	VLS6309	Embedded Software		3	3	0	0	20	-	30	50	-
	6	VLS6311	Phase Locked Loop Design		3	3	0	0	20	-	30	50	-
	S.No.	**Course Code**	**Course Name**	**Type/Area**	**Cr**	**L**	**T**	**P**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
Elective 9	1	VLS6201	VLSI signal processing architecture	Elective	2	2	0	0	20	-	30	50	-
	2	VLS6203	FPGA based soft computing		2	2	0	0	20	-	30	50	-
	3	VLS6205	Selected topics in embedded systems		2	2	0	0	20	-	30	50	-
	4	VLS6207	Selected topics in VLSI		2	2	0	0	20	-	30	50	-

SEMESTER I

Courses

VLS501   **Analog IC Design**

MOSFET small signal model, MOS amplifiers- common source, source follower and common gate configurations, differential amplifiers: Single ended and Differential Operation, Gilbert Cell, Frequency and noise analysis of MOS amplifiers and differential amplifier, Frequency Compensation in two stage Amplifiers, Effect of loading in feedback networks, MOS operational amplifier: theory and design, performance characteristics, analysis of current mirrors: simple, cascode and wide swing cascode current mirror, Voltage reference circuits with emphasis on supply independent biasing and temperature-independent references.

Suggested Books:

1. B. Razavi, Design of Analog CMOS Integrated Circuits, Tata McGraw-Hill Publication, 2017.
2. A. Holberg, CMOS Analog Circuit Design, Oxford University Press, 2013.
3. R. Gregorian and Gabor C. Temes, Analog MOS Integrated Circuits for Signal Processing, Wiley Publication, 2008.

VLS503   **Digital CMOS IC design**
Basic fabrication process of MOS, CMOS. Stick diagram, Design rules, Layout design, MOSFET structure, I-V relationship, threshold voltage, MOS capacitance, MOS scaling and geometry effects. Depletion and enhancement load MOS inverter, CMOS inverter, static and dynamic characteristic, The Wire: Interconnect parameters: capacitance, resistance and inductance. Electrical wire models, Power Dissipation, Design of static combinational CMOS and pseudo NMOS logic circuits, Differential Cascode voltage swing logic, Transmission gates, complementary pass transistor logic, Design of and dynamic combinational logic, Static and Dynamic Sequential logic circuit design, memory, VLSI design methodology and tools, VLSI design style, Design quality.

Suggested Books:

1. Jan M Rabaey, A.P. Chadrakasan and B. Nikolic, Digital integrated circuits a design perspective, Pearson Education, 2012.
2. Sung M.O. Kang and Y. Leblebici, CMOS digital integrated circuits, Tata McGraw Hill Publication, 2014.
3. Neil H.E. Weste and K. Eshraghian, Principle of CMOS VLSI Design, Pearson Education Publication, 2003.

VLS5401   **Digital Design with HDL (Verilog)**

Introduction to finite state machine: pulse and fundamental mode of operation, realization of state table from verbal description, state diagram & Transition matrix, Mealy and Moore model machine. Reduction of flow tables of completely and incompletely specified sequential machines, concept of secondary state assignment and realization of circuits of FSM, Decomposition of FSM & composite machine equivalence between. Mealy and Moore model machine. Race and Hazard problems with asynchronous

sequential machine stuck-at and bridging faults. Introduction to design with the programmable modules: ROM, PAL, PLA, FPGA, ASIC, Algorithmic state machine: ASM Chart, data and control subsystem and implementation of ASM. Introduction to ASM designing with microprogramming.

Suggested Books:

1. S. Palnitkar, Verilog primer, Pearson Education Publication, 2003.
2. Z. Navabi, Verilog Digital System Design, Tata McGraw Hill Publication, 2005.
3. Z. Kohavi and N. K. Jha, Switching and Finite Automata Theory, Cambridge University Press, 2009.

VLS5403   Digital Signal Processing

Review: Basic elements of a DSP system, Analog to digital conversion, Digital processing of Analog signals, Z-Transform and its properties. Computation of DFT: Review of DFT and its properties, DFT as a linear transformation. Efficient computation of DFT, Decimation in time Algorithm, Decimation in frequency algorithm, Chirp-z and Goertzel Algorithm, Implementation of FFT Algorithms. General difference equation, Implementation of Discrete Time Systems: Structure of FIR systems: Direct form, Cascade form, frequency sampling, and lattice. Structure of IIR systems: Direct form, Cascade form, parallel form, Lattice and Lattice-Ladder. Design of Digital Filters: FIR Filters: Design of FIR filters using windows, Design of FIR filters using frequency sampling method, Design of FIR differentiator. Design of IIR Filter: Impulse Invariance Method, Bilinear transformations, design examples: Butterworth low pass, Frequency transformations and Least square inverse method.

Suggested Books:

1. A.V. Oppenheim and Schafer, Digital Signal Processing, Pearson Education India, 2015.
2. Sen M. Kuo and Woon-Seng S. Gan, Digital Signal Processor, Architectures, Implementations and Applications, Pearson Education Publication, 2005.

VLS5405   Soft Computing

Introduction of soft computing, soft computing vs. hard computing, various types of soft computing techniques, applications of soft computing. Neural Network: Structure and Function of a single neuron: Biological neuron, artificial neuron, definition of ANN, Taxonomy of neural net, Difference between ANN and human brain, characteristics and applications of ANN, single layer network, Perceptron training algorithm. Fuzzy Logic: Fuzzy set theory, Fuzzy set versus crisp set, Crisp relation & fuzzy relations ,Fuzzy systems: crisp logic, fuzzy logic, introduction & features of membership functions, Fuzzy rule base system : fuzzy propositions, formation, decomposition & aggregation of fuzzy rules, fuzzy reasoning, fuzzy inference systems, fuzzy decision making & Applications of fuzzy logic. Genetic algorithm : Fundamentals, basic concepts, working principle, encoding, fitness function, reproduction, Genetic modeling: Inheritance operator, cross over, inversion &deletion, mutation operator, Bitwise operator, Generational Cycle, Convergence of GA, Applications & advances in GA.

Suggested Books:

1. J. Yen and R. Langari, Fuzzy Logic, Intelligence, Control and Information, Pearson Education, 2002.
2. S. Rajasekaran and G.A.Vijaylakshmi Pai, Neural Networks, Fuzzy Logic and Genetic Algorithms, Prentice Hall of India, 2003.

VLS5407   IC technology

Material properties, crystal structure, point defects, dislocations, electronic properties of defects, Crystal growth and wafer preparation, Epitaxy: Vapour –phase, molecular beam epitaxy, oxidation: 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., Etching, Dielectric and polysilicon film deposition, Diffusion, Ion implantation, Metallization: Evaporation and sputtering techniques. Failure mechanisms in metal interconnects; Multi-level metallisation schemes, Packaging of VLSI devices, Yield and reliability, Process integration for NMOS, CMOS and Bipolar circuits; Advanced MOS technology. Nanoscale devices, MEMs.

Suggested Books:

1. S.M. Sze, VLSI Technology, 2nd Edition, McGraw Hill Education, 2017.
2. S.K. Ghandhi, VLSI Fabrication Principles, Wiley Publication, 2008.
3. J. D. Plummer and M. Deal, P. D. Griffin, Silicon VLSI Technology: Fundamentals, Practice and Modelling, Pearson Education Publication, 2009.

VLS5301   Device modelling

Overview of MOS transistor physics, Two-Terminal MOS structure, Flat -band voltage, Effect of Gate-substrate voltage on surface condition, Inversion, Small signal capacitance, Three-Terminal MOS structure, Body effect, regions of inversion, Pinch-off voltage, Four Terminal MOS Transistor, regions of inversion, charge sheet model, interpolation model, body referenced model, MOS transistor large-signal modeling, quasi-static operation, limitations of quasi-static model, introduction to non-quasi static model, MOS transistor small-signal modeling, considerations in MOS modeling for RF applications

MOSFET modeling for circuit simulation, Types of models, system for data acquisition and parameter extraction, properties of good models, Introduction to SPICE modeling, modeling of resistor, capacitor, inductor, diode, BJT, JFET, MOSFET, model parameters, Brief overview of BSIM and EKV model, Device and process simulator, Circuit simulation techniques, DC analysis, AC analysis, transient analysis, SPICE Modeling of Process Variation, Process corners, Monte Carlo simulation, and sensitivity/worst case analysis, Simulation of digital and analog circuits, transfer function, frequency response, Noise analysis, distortion and spectral analysis

Suggested Books:

1. Y. Tsividis, "Operation and modeling of MOS transistors",2 nd Edition, Oxford University Press, 2003.
2. P.W. Tuinenga, "SPICE: A Guide to Circuit Simulation and Analysis Using PSpice", 3rd Edition, Pearson, 1995.
3. P. Antognetti and G. Massobrio, "Semiconductor Device Modeling with SPICE", 2nd Edition, Tata McGraw-Hill, 2010.

VLS5303   **Reconfigurable Computing**

Reconfigurable Computing hardware: Device architecture, Reconfigurable Computing architecture, Reconfigurable Computing systems, Reconfiguration management, Programming Reconfigurable Systems Introduction to Reconfigurable Computing, FPGA Architectures, FPGA Design Cycle, Technology-independent optimization, Technology Mapping, Placement, Routing, Coarse-grained Reconfigurable Devices, Multi-FPGA Systems, Reconfigurable Computing Applications, Molecular Dynamics, Image processing, Video processing, Bioinformatics, Cryptography, Fault tolerant systems, FPGAs vs. Multicore architectures , Advanced Topics: Dynamic Reconfiguration ,Partial Reconfiguration.

Suggested Books:

1. S. Hauck and A. DeHon, Reconfigurable Computing: The theory and practice of FPGA based computation, Morgan Kauffman, 2007
2. Research papers

VLS5305   **Hardware Software Codesign**

Hardware/Software Co-Design, Co-Design for System Specification and Modeling, Co-Design for Heterogeneous Implementation - Single-Processor Architectures with one ASIC and many ASICs, Multi-Processor Architectures, Comparison of Co- Design Approaches, Models of Computation, Requirements for Embedded System Specification. The Hardware/Software Partitioning Problem, Hardware-Software Cost Estimation, Generation of the Partitioning Graph, Formulation of the HW/SW Partitioning Problem, Optimization, HW/SW Partitioning based on Heuristic Scheduling, HW/SW Partitioning based on Genetic Algorithms. The Co-Synthesis Problem, State-Transition Graph, Refinement and Controller Generation, Co-Synthesis Algorithm for Distributed System- Case Studies with any one application Prototyping and Emulation Techniques , Prototyping and Emulation Environments, Future Developments in Emulation and Prototyping ,Target Architecture- Architecture Specialization Techniques ,System Communication Infrastructure, Target Architectures and Application System Classes, Architectures for Control-Dominated Systems, Architectures for Data-Dominated Systems ,Mixed Systems and Less Specialized Systems Concurrency, Coordinating Concurrent Computations, Interfacing Components, Verification, Languages for System-Level Specification and Design System

Suggested Books
1. J. Staunstrup and W. Wolf, Hardware/Software Co-Design: Principles and Practice, Kluwer Academic Publication,1997.
2. R. Niemann, Hardware/Software Co-Design for Data Flow Dominated Embedded Systems, Kluwer Academic Publication, 1998.
3. G. De Micheli and R. Ernst, Reading in Hardware/Software Co-Design, Kaufmann Publishers, 2001.

VLS5307   **Organic and Flexible Electronics**

Flexible Organic Electronics, benefits over conventional silicon technology, applications, Limitations, Stability, Organic Materials: Conducting Polymers and Small molecules, Electrodes, Gate Dielectrics, Substrate Materials, Organic Semiconductors: *p*-type and *n*-type, Charge Transport and Injection, Energy Band Diagram. Organic Thin Film Transistor; Basic Structure, Operating Principle; Electrical Characteristics, Extraction of Performance parameters, Classification of Different Thin Film Structures, Dual Gate OTFT, Front and Back Gate Biasing, Impact of Structural Parameters on OTFT performance.OTFT Model, Contact Resistance: Origin of Contact Resistance, Contact Resistance Extraction, Models to extract performance parameters.Introduction; Classification of OLEDs, Electrical Characteristics; Multi-layered architecture, Blocking layers, Organic Solar Cell, OLED as display Applications.

Suggested Books:

1. Hagen Klauk, Organic Electronics: Materials, Manufacturing and Applications, Wiley-VCH, 2006.
2. B. K. Kaushik, B. Kumar, S. Prajapati and P. Mittal, Organic Thin-Film Transistor Applications: Materials to Circuits. CRC Press, 2016.
3. K. Mullen and U. Scherf, Organic Light Emitting Devices: Synthesis, Properties and Applications, Wiley-VCH, 2005.

4. Hagen Klauk, Organic Electronics II: More Materials and Applications, Wiley-VCH, 2012.
5. F. Li, A. Nathan, Y. Wu and Beng S. Ong, Organic Thin Film Transistor Integration: A Hybrid Approach, Wiley-VCH, 2011.

6. W. Brutting, Physics of Organic Semiconductors, Wiley-VCH, 2005.

VLS5201   **SEMINAR**

VlS5203   **Micro and Nanoelectronics**

Silicon Compound Devices: SiGe BiCMOS Technology and Devices Si–Ge Interdiffusion, Dopant Diffusion, and Segregation in SiGe- and SiGe:C-Based Devices; **Advanced CMOS Devices:** Fully Depleted Devices: FDSOI and FinFET; Fully Depleted SOI Technology Overview; FinFETs: Designing for New Logic Technology; Reliability Issues in Planar and Nonplanar (FinFET) Device Architectures; High-Mobility Channels; **Post-CMOS Device Concepts**

Beyond-CMOS Devices; Stateful STT-MRAM-Based Logic for Beyond–Von Neumann Computing;   Four-State Hybrid Spintronics–Straintronics for Ultralow Power Computing, nanoionic Switches as Post-CMOS Devices for Neuromorphic Electronics; **Elements of Carbon Electronics** Physics-Based Compact Graphene Device Modeling

Suggested Books:

1. T. Brozek, Micro- Nanoelectronics, Emerging Device Challenges and Solutions, CRC Press, 2014.
2. C. Gontrand, Micro- Nanoelectronics Devices, Modeling of Diffusion and Operation Processes, Elsevier, 2018.

VLS5205   **Micro and Nanofabrication**

Foundations of nano-photonics, Field Emission, Gate—Oxide Tunneling and Hot Electron Effects in nano MOSFETs, Introduction to MEMS and NEMS, working principles, as micro sensors, micro actuation, MEMS/NEMS design, processing, etc., Scaling of physical systems – Geometric scaling & Electrical system scaling. The Single-Electron Transistor: The Single- Electron Transistor Single-Electron Transistor Logic, Other SET and FET Structures, Carbon Nanotube Transistors (FETs and SETs), Semiconductor Nanowire FETs and SETs, Coulomb Blockade in a Nanocapacitor, Molecular SETs and Molecular Electronics.

Introduction to lithography- Contact, proximity printing and Projection Printing, Resolution Enhancement techniques, overlay-accuracies, Mask-Error enhancement factor (MEEF), Positive and negative photoresists, Electron Lithography, Projection Printing, Direct writing, Electron resists. Lithography based on Surface Instabilities: Wetting, De-wetting, Adhesion, Limitations, Resolution and Achievable / line widths etc. Lift off process, Bulk Micro machining. Oxidation, Sputter deposition, Evaporation, Chemical vapor deposition, and other thin film deposition techniques.

Suggested Books:
1. Z. Cui, Micro-Nanofabrication: Technologies and Applications, Springer, 2005.
2. S. Cabrini and S. Kawata, Nanofabrication Handbook, CRC Press, 2012.

VLS5207   **Field Programmable Analog Arrays**

Introduction, FPAA design technologies, Discrete time FPAA, continuous time FPAA, Op-Amp based FPAA, Differential op-amps with feedback capacitor based FPAA, OTA based FPAA, Structure of FPAA.

Suggested Books:
1. E. Pierzchala, G. Gulak, L. Chua and A. R. Vázquez, Field Programmable analog arrays, Springer, 1998.
2. Research Papers

SEMESTER II

VLS502   **Embedded System Design**

Overview of Embedded Systems: Characteristics of Embedded Systems. Comparison of Embedded Systems with general purpose processors. General architecture and functioning of PIC micro controller. : Architecture, memory interfacing, interrupts, instructions, programming and peripherals . ARM : Architecture, memory interfacing , interrupts, instructions and Assembly

Language programming. Exception processing and pipeline architecture and applications. Variants of ARM architecture Digital Signal Processors: DSP Architecture, DSP applications, algorithms, data path, memory, addressing modes, peripherals. TI and Sharc family of DSP processors. System On Chip: Evolution, features, IP based design, TI OMAP architecture and peripherals. Digital Multimedia processor: Architecture and peripherals. RTOS: RT-Linux introduction, RTOS kernel, Real-Time Scheduling Bus structure: Time multiplexing, serial, parallel communication bus structure. Bus arbitration, DMA, PCI, AMBA, I2C and SPI Buses.

Suggested Books

1. Raj Kamal, Embedded System, Tata McGraw-Hill, 2004.
2. K. J. Ayala, The 8051 Microcontroller, Thomson DelMar Learning, 2006.
3. Deshmukh, Microcontrollers, Tata McGraw-Hill, 2006.
4. W. Wolf, Computer as components, Harcourt India Pvt. Ltd, 2002.
5. P. A. Laplante, Real time System and Analysis, Wiley, 2006.

VLS504   Low power VLSI Design

Study of power dissipation in digital ICs, Technology and device scaling, Power estimation techniques, Logical effort and transistor sizing, Low power flip flop and latch design, Low power techniques at circuit, logic architecture and system level, clocked gating, switching activity reduction, parallel and pipelined architecture at low voltage, Low voltage low power arithmetic circuit, Low power clocked tree design, Adiabatic logic, Asynchronous circuits

Suggested Books

1. G. K. Yeap, Practical Low Power Digital VLSI Design, Kluwer Academic Publishers, 2002.
2. J. Rabaey and Pedram, Low power design methodologies, Kluwer Academic Publishers, 1997.
3. K. Roy and S. Prasad, Low-Power CMOS VLSI Circuit Design, Wiley, 2000.

VLS5402   Analog Filter Design

Frequency response of bilinear and second order transfer functions, Design parameters, Active realizations: SAB, MAB, Effect of A(s), RCCR Transformation, Sensitivity Analysis. Filter approximation Functions: Butterworth, Chebyshev, Pole locations, Filter specifications, Comparison of maximally flat and equal ripple response, Frequency Transformation: Low pass to High pass, Low pass to band pass, Low pass to band elimination. Ladder simulation by element replacement, GIC and optimal design, Realization of simple ladders, Gorski Popiel embedding technique, Bruton's FDNR technique, Operational Simulation of ladder. Switch capacitor filter, Log domain filters, Current Mode Active block based Filters: Circuit structure and analysis of operational trans -

impedance Amplifier (OTIA) and various generations of current Conveyers, MOSFET-C Filters and techniques of non-linearity cancellation in MOS circuit.

Suggested Books:

1. G. Ferri and N. C. Guerrini, Low voltage low power CMOS current conveyors, Kluwer Academic Publishers, 2003.
2. R. Schaumann and Mac E.Van Valkenberg, Design of Analog Filters, Oxford, 2007.

VLS5404   **Internet enabled device**

Application driven Network Architecture, Review of various wireless and wireline communication protocols, Emergence of Wireless Sensors nodes, operating system for DENs, low power MAC, discovery, topology formation, collective communication, aggregation and in network processing, multihop routing, synchronization, Ad hoc routing, distributed control, coverage and security, emerging standards.

Suggested Books

1. C. Toh, Ad Hoc Mobile Wireless Networks: Protocols and Systems, Pearson Education India, 2015.
2. K. Sohraby, D. Minoli and T. Znati, Wireless Sensor Networks Technology, Protocols, and applications, Wiley-Blackwell, 2007.
3. C.S. Ram Murty and B.S. Manoj, Ad HOC Wireless Networks: Architectures & Protocols, 2nd Ed, Pearson Education, 2004.

VLS5406   **CAD for VLSI Systems**

VLSI automation algorithms, General graph theory and basic VLSI algorithms, Partitioning, problem formulation, classification of partitioning algorithms, Group migration algorithms, simulated annealing & evolution, other partitioning algorithms, Placement, floor planning & pin assignment, problem formulation, simulation base placement algorithms, other placement algorithms, constraint based floor planning, floor planning algorithms for mixed block & cell design, general & channel pin assignment
Global Routing, problem formulation, classification of global routing algorithms, Maze routing algorithm, line probe algorithm, Steiner tree based algorithms, ILP based approaches, problem formulation, routing, two layers over the cell routers constrained & unconstrained via minimization, compaction, problem formulation, one-dimensional compaction, two dimension based compaction, hierarchical compaction

Suggested Books:

1. N.A. Shervani, Algorithms for VLSI Physical Design Automation, Springer international, 1998.
2. S.M. Sait and Habib Youssef, VLSI Physical Design Automation – theory and practice, World Scientific, 1999.

3. S.H. Gerez, Algorithms for VLSI Design Automation, John Wiley & Sons, 1998.
4. Trimburger, Introduction to CAD for VLSI, Kluwer Academic publisher, 2002.

VLS5408   CMOS RF Circuit Design

MOSFET behavior at RF frequencies and their Spice modeling, Parasitic elements at higher frequencies, RF filter design, matching and biasing networks, VLSI Implementation of RF system blocks, LNA design with VLSI technology, mixers, Oscillators, VCO, RF synthesizers, Power amplifier design.

Suggested Books:

1. T.H. Lee, The Design of CMOS Radio-Frequency Integrated Circuits, Cambridge University Press, 2004.
2. B. Razavi. RF Microelectronics, Pearson Education India, 2013.

VLS5302   Minor Project

VLS5304   FPGA based Digital Signal Processing

Overview of DSP, FPGA technology life cycle, DSP technology requirements, Fixed and floating point number representation, Different architectures of adders, multipliers, FPGA based implementation of logarithmic and exponential functions. FPGA based implementation of fourier transforms, cryptography algorithm for FPGAs, CORDIC Algorithm and its applications, Hardware and time optimization for FPGA based FIR digital filters.

Suggested Books:

1. R. Woods, J. McAllister, G. Lightbody and Y. Yi, FPGA- based Implementation of Signal Processing Systems, 2008.

VLS5306   Testing and Diagnosis of Digital System Design

Faults in digital circuits: Fault modelling, fault detection, redundancy, equivalence, fault location, fault dominance. Stuck at faults, bridging faults, stuck open faults, Transient faults, Permanent faults. Testing of Combinational circuits: Test generation for combinational logic circuits: Path sensitization, Boolean difference method etc CAD scheme for combinational digital circuits: D-algorithm, PODEM, FAN algorithm Testing of sequential circuits: State identification experiments, checking experiments and machine identification. Fault tolerance techniques for sequential circuits, Easily Testable Design and Diagnosis of Sequential Machine Self-checking and fail safe logic: Checking circuits &self-checking, Totally self-checking: m/n code self-checkers and equality self checkers. Self-checking in PLAs. Self-stabilizing fault tolerant circuits Fail safe design. Design for testability: controllability and observability. Random test generation, transition count testing, signature analysis, syndrome testable design, RMC, Level sensitive scans design. BIST: LSSD on-chip self-test, BILBO, BIDCO. Fault detection in RAM and Microprocessor.

Suggested Books:

1. P. K. Lala, Fault Tolerant and Testable Hardware Design, Prentice Hall International editions, 1985.
2. M. Abramovici, M. A. Breuer and A. D. Friedman, Digital System Testing and Testable Design, Wiley, 1994.

VLS5308   Memory Design and Testing

SRAM technologies – MOS, SOI , SRAM Cell structures and architecture, peripheral circuit operation, SOI technology, Advanced SRAM architectures and technologies, Application specific SRAMs, DRAM – DRAM technology development, CMOS DRAM, cell theory and advanced cell structures, soft error failure in DRAM. Non-volatile Memories: Masked ROMs, High density ROM, PROM, CMOS PROMS, EPROM, Floating gate EPROM cell, One time programmable EPROM, EEPROM, EEPROM technology and architecture, Non-volatile SRAM, Flash Memories.

 RAM fault modelling, Electrical testing, Pseudo Random testing, Megabit DRAM Testing, non-volatile memory modelling and testing, IDDQ fault modelling and testing, Application specific memory testing, RAM fault modelling, BIST techniques for memory. Genera reliability issues, RAM failure modes and mechanism, Nonvolatile memory reliability, reliability modelling and failure rate prediction, Design for Reliability, Reliability Test Structures, Reliability Screening and qualification, Radiation effects, Single Event Phenomenon (SEP). RAMs (FRAMs), GaAs FRAMs, Analog memories, magneto resistive RAMs (MRAMs), Memory Hybrids and MCMs (2D), Memory Stacks and MCMs (3D), Memory MCM testing and reliability issues.

Suggested Books:

1. A. Pavlov and M. Sachdev, CMOS SRAM Circuit Design and Parametric Test in Nano-Scaled Technologies: Process-Aware SRAM Design and Test, Springer, 2008.
2. K. Ishibashi and K. Osada, Low Power and Reliable SRAM Memory Cell and Array Design, Springer, 2011.

VLS5202   CMOS nano neuromorphic circuits
Introduction to classic neuromorphic circuits, (Leaky) Integrate and fire neural circuits, Ion channel models and circuits: Hodgkin-Huxley model/FitzHugh-Nagumo model/ thermodynamic model and circuits, Synapse circuits -excitatory, Hyper polarizing inhibitory, shunting inhibitory, Dendritic Computations, Cable Theory and Compartmental Models, Hsu model, Spike timing dependent plasticity,
Structural plasticity, Connectivity -Address event representation, Rent's rule, Glial Cells, Large scale systems.

Suggested Books:

1. S.P. Mohanty and A. Srivastava, Nano-CMOS and Post-CMOS Electronics: Devices and modelling, IET, 2016

VLS5204   Real Time Operating Systems
Introduction: Definition, Typical Real Time Applications; Digital Control, High Level Controls, Signal Processing etc., Release Times, Deadlines, and Timing Constraints, Hard Real Time Systems and Soft Real Time Systems, Reference Models for Real

Time Systems: Processors and Resources, Temporal Parameters of Real Time Workload, Periodic Task Model, Precedence Constraints and Data Dependency. Real Time Scheduling: Common Approaches to Real Time Scheduling: Clock Driven Approach, Weighted Round Robin Approach, Priority Driven Approach, Dynamic Versus Static Systems, Optimality of Effective-Deadline-First (EDF) and Least-Slack-Time-First (LST) Algorithms, Offline Versus Online Scheduling, Scheduling A periodic and Sporadic jobs in Priority Driven and Clock Driven Systems.

Suggested Books:
1. K.C. Wang, Embedded and Real-Time Operating Systems, Springer, 2017
2. R. Mall, Real-Time Systems: Theory and Practice, Pearson, 2006

VLS5206   Clock Tree Synthesis

X-tree clock routing algorithm, H-tree clock routing algorithm, terminologies relating to clock network synthesis and routing, Design Status, Start of CTS Phase, Clock Tree Synthesis, CTS Goals, Define Clock Root Attributes, Stop, Float and Exclude Pins, Generated and Gated Clocks , User-defined or Explicit Stop Pins, Defining an Explicit Float Pin, Preserving Pre-Existing Clock Trees, Impact of Preexisting Clock Cells, Logical Design Rule Constraints, Non-Default Clock Routing.

Suggested Readings:
1. C.J. Alpert, D.P. Mehta and S.S. Sapatnekar, Handbook of Algorithms for Physical Design Automation 1st Edition, CRC Press, 2008.
2. A.B. Kahng, J. Lienig, I.L. Markov and J. Hu, VLSI Physical Design: From Graph Partitioning to Timing Closure, Springer, 2011.
3. T.J. Liang, Clock Tree Synthesis for Timing Convergence and Timing Yield Improvement in Nanometer Technologies, University of Wisconsin--Madison, 2005.

VLS5208   Layout design and skills with analog perspective

CMOS Physical design: MOS I/V Characteristics; MOS Device Model:-Small Signal Model, SPICE Models; Layout of basic devices- NMOS, PMOS, Resistor, Capacitor; Introduction to Physical verification (DRC), Analysis and design of single stage amplifiers: Common sources amplifier (CS) - with resistive, diode connected and Current source load; CS amplifier with degeneration, source follower, common gate amplifier and cascode amplifier. Analysis and design of differential amplifier, two stage operational amplifier.

Suggested Books

1. P. Allen and D.R. Holberg, CMOS Analog Circuit Design, Oxford University press, 2013.
2. B. Razavi, Design of Analog CMOS Integrated Circuits, Tata McGraw Hill, 2002.
3. Sedra and Smith, Microelectronics circuits, Oxford University Press, 2017.

4. R.L.Geiger, P. Allen and N.R.Strader, VLSI Design Techniques for Analog and Digital Circuits,Tata McGraw Hill, 2010.

SEMESTER III

VLS6401   Mixed Signal Design

Switched Capacitor Circuits: Introduction to Switched Capacitor circuits basic building blocks, Operation and Analysis, Non-ideal effects in switched capacitor circuits, Switched capacitor integrators first order filters, Switch sharing, biquad filters. Phased Lock Loop (PLL):Basic PLL topology, Dynamics of simple PLL, Charge pump PLLs-Lock acquisition, Phase/Frequency detector and charge pump, Basic charge pump PLL, Non-ideal effects in PLLs-PFD/ CP non-idealities, Jitter, in PLLs, Delay locked loops, applications. Data Converter Fundamentals: DC and dynamic specifications, Quantization noise, Nyquist rate D/A converters-Decoder based converters, Binary-Scaled converters, Thermometer-code converters, Hybrid converters. Nyquist Rate A/D Converters: Successive approximation converters, Flash converter, Two-step A/D converters, Interpolating A/D converters, Folding A/D converters, Pipelined, A/D converters, Time-interleaved converters.

Suggested Books:

1. J. Baker, CMOS mixed signal circuit design, Wiley student edition, 2008.
2. D.A. Johns and K. Martin, Analog integrated circuit design, Wiley student edition, 2011.
3. P. E. Allen and Douglas and R. Holberg, CMOS analog circuit design, Oxford university press, 2011.

VLS6403   Embedded Signal Processing

Ohm's and Kirchhoff's laws in the complex form and the concept of impedance. Passive and active analogue filters and the concepts of transfer function, cutoff frequency and Bode plots. Operational Amplifier. Fourier, Laplace and z transformation of continuous and discrete signals and systems. Sampling theorem. The concepts of poles, zeros and amounts surfaces. Stability and causality. Analysis and synthesis of analogue and digital filters. Auto- and cross-correlation, matched filters. Examples of applications. Implementation of digital filters in signal processors (DSP), choice of filter architecture with regard to the numerical limitations, real-time programming of DSPs in an imperative language.

Suggested Books:
1. Sen M. Kuo and Woon-Seng Gan, Embedded Signal Processing with the Micro Signal Architecture, Wiley, 2007.
2. R. Oshana, DSP for Embedded and Real-Time Systems, Newnes, 2012

VLS6405   Biomedical Circuits

Introduction, circuit variables, sources and resistances, node-voltage method, 21 mesh current method, source transformation, Thevenin equivalent, biopotentials, power with phasors, electrodes, transducers, biosensors, biopotential amplifiers, biotelemetry, cardiovascular measurements, electrosurgical units, recording of ECG, EEG, ERG.

Suggested Books:

1. R. S. Khandpur. Biomedical Instrumentation: Technology and Applications,Tata McGraw Hill Publishers, 2004.
2. R. S. Khandpur. Handbook Of Biomedical Instrumentation, Tata McGraw Hill Publishers, 2014.

VLS6407   Fault Tolerant computing

Concept of reliability; Parallel computing modules and architectures; Applications of coding theory for fault-tolerant systems; Redundancies: static, dynamic and hybrid; Architecture of fault-tolerant computers; Fault-tolerant multiprocessors and distributed systems principles; Various concepts of operating system; Study of fault-tolerance in softwares; Introduction to the concept of system diagnosis.

Suggested Books:
1. Daniel P. Siewiorek and R.S. Swarz , Reliable Computer Systems Design and Evaluation, AK Peters Ltd,1998.
2. D.K. Pradhan, Fault-Tolerant Computing: Theory and Techniques Vol. I,II, Prentice-Hall, 1986.
3. B.W.Johnson, Design and Analysis of Fault Tolerant Digital System, Addison-Wesley, 1989.

Elective 8

VLS6301   Speech Processing

Speech signal: production, perception, acoustic- phonetic characterization, signal processing methods for speech recognition, pattern- comparison techniques, speech recognition system design and implementation issues, speech recognition based on connected word models, task oriented applications of automatic speech recognition.

Suggested Books:

1. L. Rabiner and B. H. Juang, Fundamentals of speech recognition, Prentice Hall, 1993.

VLS6303 Embedded Automotive systems

Automotive Architectures: Vehicle Functional Domains and Their Requirements, Application of the AUTOSAR Standard Intelligent Vehicle Technologies ,**Embedded Communications:** A Review of Embedded Automotive Protocols, FlexRay Protocol, Dependable Automotive CANs, **Embedded Software and Development Processes:** Product Lines in Automotive Electronics, Reuse of Software in Automotive Electronics, Automotive Architecture Description Languages, Model-Based Development of Automotive Embedded Systems, **Verification, Testing, and Timing Analysis:** Testing Automotive Control

Software, Testing and Monitoring of FlexRay-Based Applications, Timing Analysis of CAN-Based Automotive Communication Systems, Scheduling Messages with Offsets on Controller Area Network—A Major Performance Boost, Formal Methods in the Automotive Domain: The Case of TTA

Suggested Books

1. N. Navet and F.S. Lion, Automotive Embedded Systems Handbook 1st Edition, CRC Press, 2008.
2. T. Weather Jr. and C.C. Ilunter, Automotive computers and control system, Prentice Hall Inc., 1984.
3. W. Ribbens, Understanding Automotive Electronics, Butterworth-Heinemann, 2012.

VLS6305   Machine Learning

Introduction to Machine Learning: Learning Associations; Classification, Regression, Annotation, Supervised Unsupervised, Semi supervised, learning Basic tools: Linear classification, regression, Feature maps, Trees, Instance based classifiers. Supervised Learning, Vapnik - Chervonenkis Dimension, Probably Approximately Correct Learning, Noise, Learning Multiple Classes, Regression, Model Selection and Generalization, Dimensions of a Supervised Machine Learning Algorithm. Decision Tree Learning, Linear Discrimination: Reinforcement Learning ,Single State Case: K-Armed Bandit, Elements of Reinforcement Learning, Model-Based Learning Value Iteration Policy methods Policy evaluation Policy iteration Policy gradient Policy Iteration Temporal Difference Learning Exploration Strategies Deterministic Rewards and Actions Nondeterministic Rewards and Actions Eligibility Traces.

Suggested Books:

1. E. Alpaydin, Introduction to machine learning, MIT Press, 2004
2. S. Roger and M. Girolami, A first course in machine learning, CRC Press, 2016

VLS6307   Advanced Computer Architecture

Parallel Computer Models, Program and Network Properties, System Interconnect Architecture, Advanced processor technology, Instruction-set architectures, CISC Scalar processors, RISC, Scalar processors, Superscalar processors, VLIW architectures, Vector and symbolic processors. Memory Hierarchy, Cache basics & cache performance, Reducing miss rate and miss penalty, Multilevel cache hierarchies, Main memory organizations, Design of memory hierarchies. Symmetric shared memory architectures, Distributed shared memory architectures, Models of memory consistency, Cache coherence protocols (MSI, MESI, MOESI), Scalable cache coherence, Overview of directory based approaches, Design challenges of directory protocols, Memory based directory protocols, Cache based directory protocols, Protocol design tradeoffs, Synchronization.

Suggested Books:

1. K. Hwang, Advanced computer architecture, McGraw Hill, 2010.

2. D. A. Patterson and J. L. Hennessey, Computer organization and design, Morgan Kaufmann, 2nd Ed, 2010.
3. J. P. Hayes, Computer Architecture and Organization, McGraw Hill, 2017.

VLS6309   Embedded Software
Embedded software, features, design patterns for embedded software, models of computation, assemblers, interpreters, compilers, C in embedded environment, high level embedded programming languages, Optimization of execution time, energy and power, program size. Program validation and testing, embedded operating system, processes,
context switching, scheduling policies, inter process communication, power optimization strategies, Real time OS, distributed embedded systems.

Suggested Books:
1. C. Walls, Embedded Software: The Works, Newness, 2012.
2. K. Qian, D.D. Haring and Li Cao, Embedded Software Development with C, Springer, 2009.

VLS6311   Phase Locked Loop Design
Phase locked loops' requirements, Integer/ fraction-N PLLs, delay locked loops, injection locked loops, sub-sampled PLLs, Building Blocks- Phase/ frequency detectors, charge pumps, LC/ ring oscillators, multi modulus frequency dividers, Active/ passive loop filters.

Suggested Books:
1. R. Best; Phase-Locked Loops, McGraw Hill, 2007.
2. C. Quemada, G. Bistue and I. Adin; Design Methodology for RF CMOS Phase Locked Loops, Artech House, 2009.

VLS6201   VLSI signal processing architecture

Introduction to DSP Systems: Introduction; representation of DSP algorithms: Block Diagram, signal flow graph, data flow graph, dependence graph. Iteration Bound: Data flow graph representations, loop bound and iteration bound, longest path matrix algorithm, iteration bound of Multirate data flow graphs. Pipelining and Parallel Processing: Pipelining and parallel processing of FIR digital filters, pipeline interleaving in digital filters: signal and multichannel interleaving. Retiming, Unfolding and Folding: retiming techniques; algorithm for unfolding, Folding transformation, systolic architecture design, systolic array design methodogy. Fast Convolution, Filters and Transforms: Cook-toom algorithm, modified cooktoom algorithm, winogard algorithm, iterated convolution Algorithm strength reduction in filters and transforms.

Suggested Books:

1. K.K. Parhi, VLSI Digital Signal Processing Systems: Design and Implementation, John Wiley & Sons, 1999.
2. Richard J and Higgins, Digital Signal Processing in VLSI, Prentice Hall, 1991.
3. M.A. Bayoumi, VLSI Design Methodology for DSP Architectures, Kluwer, 1994.
4. U. Meyer – Baese, Digital Signal Processing with FPGAs, Springer, 2004.

VLS6203 FPGA based soft computing
FPGA neurocomputers, FPNA:Applications and implementations, FPGA implementation of very large associative memories, FPGA implementation of neocognitrons, implementation of fully and partially connected MLP, FPGA implementation of non-linear predictors, implementation of self-organizing feature maps in reconfigurable hardware.

Suggested Books:

1. N. Nedjah and L. de M. Mourelle, Hardware for Soft Computing and Soft Computing for Hardware, Springer, 2013.
2. A.R. Omondi and J.C. Rajapakse, FPGA implementation of neural networks, Springer, 2005.

VLS6205   Selected topics in embedded systems
From Research papers

VLS6207 Selected topics in VLSI
From research papers.