M.Tech. in Electronic Systems Design (ESD) - Specializations in Systems on Chip (SoC) and Embedded Systems (EMS)

Proposed Programme Curriculum

(Effective from academic year 2014-15)

International Institute of Information Technology
Bangalore – 560100
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Rationale For A New M. Tech. Program in Electronic Systems Design (ESD) - With Specializations in Systems On Chip (SoC) and Embedded Systems (EMS)

The genesis of IIITB has been towards contributing to the domain of Information Technology (IT) with a vision to focus on education, research, entrepreneurship, innovation and be in the forefront in each and every emerging area in it. This has seen IIIT Bangalore emerge in the past 14 years of its existence as an institute of national prominence in several domains of IT – Software Engineering, Computer Science, Data Science and Networking and Communications.

With the onset of a new wave of revolution being unleashed by the Internet of Things (IoT) due to the availability of extremely low cost and low power hardware platforms in the form of SoCs and Embedded System boards, we are seeing the emergence of a new convergence between hardware and software. Its potential is limited only by human imagination and its impact is being seen in the rapid evolution it is fostering in different domains, such as, automation, e-health, mobile communication, smart home, automotive sector, consumer electronics, pervasive computing, computer architecture, etc.

To address this convergence it is imperative that we educate and train our future students to appreciate the nuances of both hardware and software and their interplay in the domain of embedded systems. This will help in the growth of highly skilled manpower needed to support electronics system design and manufacturing (ESDM) in our country and world. In alignment with the national and state policies to foster growth and entrepreneurship in ESDM as outlined by DIETY and the Government of Karnataka, respectively, several of our faculty members have submitted proposals targeting funding for several large R&D projects. The majority of top MNCs in the areas of electronic design have R&D centers in Bangalore. Furthermore, incentives from Govt., MNCs and large public sectors have started many middle and small scale ESDM initiative in country.

IIITB is participating in the creation of the ESDM ecosystem through its incubation center – already supporting the incubation of couple of companies in ESDM and Embedded Systems area.

The new M. Tech. program is being proposed to meet the above vision and objectives. Moreover, it follows same total credits and rules of existing regular MTech.

The choice of naming the new curriculum “Electronic Systems Design – With Specializations in System on Chip (SoC) and Embedded Systems (EMS)” from amongst many others reflects the focus on Embedded Systems, and the availability of extremely low cost and low power Embedded System hardware platforms in the form of SoCs, which integrate not only the core digital functionality, but also the analog mixed signal functionalities. It is also consistent with the curriculum name being adopted by several reputed universities all over the world.

In the new curriculum, 50% of the students will specialize in SoC and 50% will specialize in EMS. The decision of a student going to either of the two stream will be based on his performance in the first semester and the number of students preferring a particular stream. The students will be given this information during the counseling done on joining the program and at the start of the program.

Overall M.Tech. in ESD Programme Structure

Tables 1 and 2 provide a summary of the credit distribution in the M.Tech. programme.

Table : Overview of the curriculum

Preparatory Term (3 weeks)	**0 credits** • C Programming • Principles of Electronics • (PASS / FAIL mandatory courses)
Semester 1 (15 weeks)	**16 credits** • 5 core courses • (3 X 4 credits + 2 X 2 credits = 16 credits)
Semester 2 (15 weeks)	**18 credits** • One ESD Theory Core and 4 Electives • (1 X 2 credits + 4 X 4 credits = 18 credits)
Summer (8 weeks)	**9 credits** • 2 Non-Technical Courses + *ESD Project + Seminar • (2 X 3 credits + 1 X 2 credits + 1 X 1 credit= 9credits) (*This is a ESD project with Industry Practices of 6 months duration – will start during 2nd semester and the final evaluation will be in summer semester)
Semester 3 (15 weeks)	**16 credits** • 4 electives
Semester 4 (26 weeks)	**16 credits** • Internship / Thesis

Total	**75 credits**

Table : Credit Distribution

Proposed	Credits	%
ESD Core Course Credits	21	28 %
Non-Technical Core Course Credits	6	8 %
Elective Course Credits	32	43 %
Internship / Thesis Credits	16	21 %
Total credits requirement for M.Tech.	**75**	

Area of specializations

The proposed M.Tech. in ESD curriculum has two area of specializations:

- System on Chip (SoC)
- Embedded Systems (EMS)

Preparatory courses

Students entering the M.Tech in ESD programme are expected to come with some prior knowledge of C programming and basic electronics. While we do not wish to conduct full-fledged C programming courses at the Masters level, we will provide an opportunity for the students to hone up their C programming skills in a structured way as part of the preparatory term. The preparatory term has one course in programming (covering C). The other course on basic electronics will provide an opportunity to get hands-on with circuits and simulation tools. The two courses will not carry any credit. However, they are mandatory courses with a PASS/FAIL grade. The Programming and Basic Electronics courses will be taught with emphasis on hands-on activities.

ESD Core courses

Core courses are those that all the students must take mandatorily. The complete list of core courses is provided in Table 1 below.

Table : List of core ESD courses

C Programming	0	Prep term
Basic Electronics	0	Prep term

Analysis and Design of Digital IC	4	Semester1
Introduction to CMOS Fabrication and Analog CMOS VLSI Design	4	Semester 1
MATHS for ESD	4	Semester 1
Operating Systems	2	Semester 1
Principles of Embedded systems	2	Semester 1
ESD Engineering Practices (Theory)	2	Semester 2
ESD Projects with Industry Practices (Project of 6 months)	2	Summer
Seminar	1	Summer

Apart from courses in the Preparatory term, the core courses to be covered in the first regular semester are:

- Analysis and design of Digital IC (4 credits)
- Introduction to CMOS fabrication and Analog CMOS VLSI Design (4 credits)
- Mathematics for ESD (4 credits)
- Operating Systems (2 credits)
- Principles of Embedded Systems (2 credits)

The second semester will have one core course on the Theory of Electronic Systems Design Engineering Practices for two credits. This will be followed by a project course that lays emphasis on usage of industry-oriented software engineering practices for two credits. Details regarding objectives, syllabus and lecture hours for each course are provided in the Appendix-A. The elective courses are listed in Appendix B and C.

Summer Non-Technical Core courses

Table 2 below lists the courses to be offered in the summer semester. The total number of credits for non-technical summer courses is now 6.

Table : List of Non-Technical Core courses

Marketing and Strategy	3	Summer
Technical Communication	3	Summer
Total Non-technical core credits	**6**	

Electives

The number of electives to be completed by each student is **eight**. Thus the total number of credits that can be accumulated through electives is now 32 credits. Each elective will be associated with one or more area of specializations with the exception of elective courses from the Information Technology and Society area of specialization, which will be offered as open electives. Each student is required to take at least **five** electives from his/her area of specialization. For example, for a student from the SoC area of specialization, all electives that are listed under EMS area of specialization (and not cross-listed under SoC) will be considered as open electives. The open electives also includes courses from IT-Society, Data-Science (DS), Software-Engineering (SE), Networking and Communication (NC), Computer Science (CS) streams of our regular MTech in IT curriculum. Students from the regular M. Tech. in IT curriculum specializing in CS, DS, SE, and NC can also take the electives offered in the new M. Tech. in ESD curriculum as open electives. Moreover, these electives can also be taken as regular electives by students from the iMTech curriculum.

Design of an elective course will be addressed in details by the faculty concerned. This design of the course will be presented to faculty-meeting/Senate before being offered to students.

Project Electives /Supervised Reading

1. There are two forms of special electives called: Project Elective (PE) and Reading Elective (RE). These electives are intended for experiential and guided learning.

2. Every PE course at least have the following characteristics:
    - Overall Plan
    - Visible Output
    - Direct Supervision

3. PE and RE follow the usual letter grading pattern available to other courses.
4. Mtech students may opt for at most one PE and at most one RE course, per semester.
5. Involvement of external institutional entities if any, as part of a PE course, should be expedited within the framework of the existing collaboration and IP policies of the Institute.

These above rules are same as existing in the regular M. Tech. for IT curriculum.

Thesis/Internship

Thesis/Internship shall be of 26 weeks duration and a student can accumulate 16 credits on successful completion of thesis or internship.

For the students pursuing Internship:

- Internships to be considered as six months (not less than five months) of supervised project work carried out at industry or academic institutions.
- The internship committee will ensure that a mid-term feedback is collected (for every student pursuing internship) to ensure smooth progress towards completion.
- At the time of internship completion the internship committee will also collect the certificate (satisfactory/unsatisfactory) from concerned person of the organization. If the certificate is unsatisfactory then the institute internship committee will review the matter and if they agree with the certificate given, and then the student has to carry on the internship again at same or different place. If the certificate is satisfactory then the student full fills the requirement of internship.

For students pursuing thesis, the following guidelines hold:

- There is an M.Tech. thesis committee comprising of the supervisor and at least two more faculty members. Members of this thesis committee will serve thesis and oral examiners for each student pursuing thesis.
- The thesis style rules should be available in LMS for all thesis students to use. Additionally we should make available both Word and LaTeX style files, which comply by these rules. If a student chooses to use a word processor, other than the ones above, (s)he is welcome to do so as long as the rules are met.
- A soft copy of the thesis in .pdf format should be sent to IIITB librarian, a week before the final submission of thesis date according to the institute's calendar (which will be after the thesis's oral exam). The soft copy of thesis format must be officially approved by the librarian before the thesis goes in print and for binding.
- The M.Tech. academic calendar will have dates fixed for the following tasks specific to thesis evaluation: constitution of thesis committee, submission of draft to the committee(s) (a week before the oral examination), a week dedicated for all the M.Tech. thesis defenses, date for submission of soft copy to the librarian, and a date for final submission of the hardbound thesis to the library.

These above rules are same as existing in regular MTech for Internship and Thesis.

Appendix-A Core courses

This section provides on the core courses in the curriculum. Each subsection below contains details regarding the various core courses. Elective courses topics will be given by the respective faculty member(s) and it will be processed through the Senate, before addition to the semester's elective.

C Programming (PS 502)

Students come for M.Tech. from Electronics, Electrical and Instrumentation Engineering background. They all have varying levels of programming knowledge. Good programming skills are recognized as being a minimum pre-requisite for virtually all the courses (both core and elective). The goal of the preparatory term is to give a fast-track introduction to programming in C. The following table highlights some of the details of the course:

Course Name	C Programming
Term	Preparatory Term
Course Credits	0
Duration	3 weeks
Session duration	3 hours per day
Sessions per week	5
Total duration	45 hours (3 weeks)

Course Objectives: At the end of the course, the students should have knowledge and competencies in the following areas:

- Preliminaries: Introduction to Unix, Introduction to case study
- Data types and expressions: Variables and data types, scope and lifetime of variables, type casting and data type conversion, expression evaluation
- Control flow: if statement, if-else statement, switch-case statement, for loop, while loop, do-while loop
- Functions: User-defined functions, parameters and return values, global variables, static variables, multi-file programming, introduction to built-in libraries (math.h, string.h, etc.).
- Recursion: Recursion for divide-and-conquer
- Arrays: 1-d array, 2-d array and n-d array

- Pointers: Pointers and addresses, pointers and function arguments, pointers and arrays, address arithmetic, character pointers and functions
- More on pointers: Pointer arrays, pointers to pointers, pointers to functions
- Structures: Basics of structures, structures and functions, arrays of structures
- Advanced structures and unions: Pointers to structures, self-referential structures, unions, bit-fields
- File I/O: Text I/O sequential access, binary I/O sequential access, binary I/O random access

The course is divided into multiple **modules**. Each module is comprised of **lecture session**(s) and **lab session**(s). A session typically has a one hour lecture followed by a 2 hour lab every day.

Principles in Electronics (PS 503)

The goal of basic electronics preparatory course is to revise and clarify some of the basic concepts in electronics. This will help them to get more confidence in designing circuits and logics in regular semesters. Good electronic designing and trouble shooting skills are required throughout the MTech curriculum. The following table highlights some of the details of the course:

Course Name	Principles in Electronics (ESD)
Term	Preparatory Term
Course Credits	0
Duration	3 weeks
Session duration	3 hours per day
Sessions per week	5
Total duration	45 hours (3 weeks)

Course Objectives: At the end of the course, the students should have knowledge and competencies in the following areas:

Design of RLC filter circuits, Rectifier circuits; Ebers-Moll model applied to basic transistor circuits, BJTs and MOSFETS amplifier circuits; FET switches. Feedback and operational amplifiers and use of Opamps as amplifiers, peak detector, differentiators, integrator circuits, Schmitt Trigger and comparators. Active filters and Oscillators, TTL and CMOS, Digital gates using MOSFETs, Decoders, Multiplexers, Latch, Flip-Flops, Counters, Registers, Memories, Mealy and Moore machines, Finite State Machine, state equivalence and machine minimization; Algorithmic state machines, Analog/Digital Conversions, and Introduction to different microcontroller boards such as Arduino, Raspberry Pi, Galileo Development boards, Verilog example codes.

The course is divided into multiple **modules**. Each module is comprised of **lecture session**(s) and **lab session**(s). A session typically has a one hour lecture followed by a 2 hour lab every day.

Mathematics for Electronic Systems Design (ESD 501)

This course will cover aspects of mathematics relevant to the design and analysis of Embedded Systems, and Semiconductor devices. We will cover aspects of discrete mathematics relevant for the analysis of switching circuits such as Boolean Algebra, logics and predicate calculus needed for the analysis of real-time systems, graph theory that is relevant in the analysis of digital circuits and development of EDA tools, probability and statistics needed for reliability analysis, Monte-Carlo simulation, linear algebra and differential equations needed for circuit simulation, understanding CMOS technology and semiconductor physics. Computational geometry will also be included that is needed for robotics.

References:

1. Discrete Mathematics, Kenneth Rosen.
2. Introduction to Linear Algebra, Gilbert Strang.
3. Differential Equations, P. Blanchard, R.L. Devaney and G,R. Hall
4. Computational Geometry, Algorithms and Applications, M.de Berg, O. Cheong, M. van Kreveld, M. Overmars

Electronic Systems Design Engineering Practices

Knowledge of engineering principles is critical for any IT professional. Students can imbibe and internalize these principles only by applying in a systematic and structured manner. The Electronic Systems Design Engineering Practices course is designed with a greater emphasis on hands-on practices of well-known principles. The course is divided two components:

1. Lecture (about 25 hours) - January - April
2. Project (about 6 months duration) - January - June

While the lecture components will cover all essential concepts and principles, the project component will provide an opportunity for the students to actually put the principles into practice.

Assessments will be done based on about 70% weight given to the project and about 30% weight given to the lecture component, thus emphasizing the importance of practicing what is being taught. The Electronic Systems Design Engineering Practices course is intended to be offered as a fifth course in the second semester because the value of the course is fully realized only when the project component happens in parallel. The following table highlights some of the details of the course:

Course Name	Electronic Systems Design Engineering Practices
Course Credits	4
Lectures hours per week	2
Total number of lecture hours (per semester)	25
Project Duration	6 Months

Course objectives: At the end of the course, students should have knowledge and competencies in the following areas:

- Practical application of project management practices
- Awareness of practices for developing programs with emphasis on quality
- Defining project tasks with guidance from well-defined process models
- Effective management of source code and design
- Familiarity with basic terminology associated with process models and quality models.

Lecture component (Theory part): The lecture component will be conducted and completed with-in the second regular semester. The following modules are recommended to be covered as a part of the lectures to be taught in class:

- Process Models (3 hours): Waterfall model, spiral model, V model, iterative models, agile methods (Scrum, XP etc.)
- Project management principles (10 hours): Planning, estimation, monitoring, control, reporting
- Testing principles (6hours): Black box testing, white box testing, non-functional testing, testing metrics
- Configuration management (3 hours): Version control, project space and version space
- Software Quality (3 hours): Quality models (CMMi, Six Sigma, ISO), formal reviews, quality metrics (product quality and process quality)

Project Component: The course includes a mandatory project of “reasonable” complexity. The project is intended to be developed and delivered over a period of 6 months in a group of 4-6 students.

Students have to choose a project in one of the following areas:

- System on Chip (Analog, Digital, Process Simulation, Verification, Synthesis, etc)
- Embedded Systems (RTOS, Robotics, Integration of Multimodal Sensors, Prototype for various embedded systems applications such as safety, health, etc)

Every project necessarily needs a faculty member as a supervisor and mentor. Faculty members can announce and mentor projects one of the following two ways:

- Linking the on-going elective projects with the Electronic Systems Design project provided it belongs to one of the above areas.
- Offering independent projects provided it belongs to one of the above areas.

The final evaluation of the project will be done at the end of the six months duration. The evaluation of project component will be based on:

- Product deliverables (as defined and evaluated by the project mentor).
- Electronic Systems Design practices (as defined and evaluated by the course instructors).

In effect, if 100 marks are allocated for the overall course, following is the recommended break up of evaluation:

- Lecture component – 30 marks (exam-based evaluation)
- Project – Electronic Systems Design practices – 20 marks (documentation-based evaluation)

- Project – Product deliverables – 50 marks (demo and testing-based evaluation)

Introduction to CMOS Fabrication and Analog CMOS VLSI Design (4 credits) (SBS/MR) (ESD 502)

Prerequisites : Kirchoff's Laws(KCL/KVL) in electrical networks, Linear circuits: Thevenin/Norton theorems, phasor analysis. Some exposure to diodes/transistors, biasing and small-signal analysis would be useful.

The course has two objectives :

(1) To introduce how CMOS VLSI chips are fabricated (VLSI Technology)

(2) To explain how robust Analog MOS circuits can be designed with a good understanding of VLSI Technology and MOS Device Physics.

The course will discuss how Analog circuits are designed in a VLSI chip environment starting from an understanding of VLSI technology and fabrication. The methodology adopted for teaching this course is to first provide a simple physical model of the MOSFET transistor that is capable of abstracting the essential electrical behavior of the device. Following this a related small-signal MOSFET model can be derived. The application of DC and small-signal analysis methods on MOSFET circuits can then follow.
The main aim of the course will be to learn how to analyze and build CMOS amplifiers that are the building blocks of almost all VLSI mixed-signal systems. At every stage of the course the students are expected to design, on paper as well as simulation, the circuits discussed in the class. An important aspect of the course will be a project in which the students are expected to design and simulate (using Spice simulator).

Topics : VLSI Technology, MOS device physics, Common-source, common-gate, common-drain, and cascode stages, Differential amplifiers, Current mirrors, Frequency response of amplifiers, One and two-stage operational amplifiers, Stability and frequency compensation, feedback networks, Memory design. The course will be useful for those interested in VLSI Design, mixed-signal embedded hardware and is a pre-requisite for RF Design.

References:

1. CMOS : Circuit Design, Layout and Simulation, R. Jacob Baker, IEEE Press/Wiley Student Edition.

2. Silicon VLSI Technology Fundamentals, Practice and Modeling, J. D. Plummer, M. D. Deal, and P. B. Griffin

Analysis and design of CMOS Digital IC (4credit hours) (MR/SKR) (ESD 503)

Topics : The theory part includes CMOS logic, latches, flip-flops, CMOS layout, MOSFET Current and Capacitances, Non-ideal MOSFET Effects, CMOS Delay Estimation, Logical effort, Delay optimization and logical effort, Power estimation: Static and Dynamic, Low-Power design, Static Combinational CMOS Logic Styles, Dynamic Combination CMOS Logic styles, Static and Dynamic Sequential Circuit Design, Technology scaling, and VLSI design methodologies. The course will include a lab component of 1credit hour. This will require students to spend 2 hours per week in the lab. Lab component includes Schematic and layout of Digital circuits using Electric. HDL simulation, and synthesis using Mentographics/Xlinix/LASI digital design software tools. Digital prototyping on FPGA board is also included in this course.

References:

1. Neil H. E. Weste and David Harris, CMOS VLSI Design: A circuits and systems perspective, 4th edition, 2011.
2. Verilog HDL: A guide to digital design and synthesis, S. Palnikar, 1996.
3. J. Rabaey, A. Chandrakasan, and B. Nikolic, "Digital Integrated Circuits," 2nd Edition, Pearson Education, 2003.

Operating Systems (2 credit hours) (PGP/SKR) (ESD 504)

The following topics will be covered course in the first regular semester:

- System calls; user vs. super- user
- Processes and threads, process scheduling and management
- IPC (Inter Process Communication) and the dining philosophers problem
- Process synchronization using mutex locks, semaphores, monitors.
- Memory, virtual memory and memory management
- Message-passing vs. shared memory
- Kernel modules: changes and compilation

There will be no project component in this course.

References:

1. A. Silberschatz, P. Galvin, G. Gagne, Operating System Concepts, 9th Edition, John Wiley and Sons, 2012.

Principles of Embedded Systems (2 Credits) (PGP) (Approved Elective) (ESD 505)

Description : Embedded systems are everywhere and most of the electronic systems have a computer inside to do smart things. Due to great demand a large number of embedded systems are available in the market from many companies. Purpose of this course is to help students understand existing architectures of embedded systems and also understand principles involved in designing such systems. In this course we will learn various issues involved in designing embedded systems meeting performance, cost, physical size and weight as well as power consumption requirements. Complex algorithms, user interface along with real time constraints make embedded computing more challenging than normal computing without any constraints on time. The course will start with Shannon's paper on switching circuits, simple microcontrollers and all the way up to distributed embedded computing. In order to understand the engineering aspects better each student or groups of students will study one of the existing platforms and share the knowledge with the class and also do some experiments on embedded systems. The course will involve more open discussions to discover principles and lab to get hands on experience in working with embedded systems.

Topics : Relay circuits, Boolean Algebra, Gates, Shift Registers, CPUs, Memories and Busses, Complex systems and Microprocessors, Embedded system design process and Formalisms for design, Instruction sets, CPU and Memory, I/O Devices and Component Interfacing, Program Design , Analysis and Optimization, Operating systems with real time constraints, Design Methodologies and Architecture design, Power management techniques for single and multi core systems, Multi core Embedded systems , Future Embedded systems, Neural computers and Quantum computers.

References:

1. Computers as Components, Principles of Embedded Computing System Design, Wayne Wolf, Princeton University, Morgan Kauffman Publishers, Academic Press, 2001
2. IEEE Papers as required
3. Published material from TI, ADI, ARM, Intel and others
4. Software Development for Embedded Multi-core Systems: A Practical Guide Using Embedded Intel Architecture, Max Domeika

Appendix-B SoC Electives

Testing and Design For Testability (4 Credits) (SKR/EF) (ESD 601)

Introduction to Testing**:** VLSI Testing Process and Test Equipment; Test Economics and Product Quality; Fault Modeling; Test Methods : Logic and Fault Simulation; Testability Measures; Combinational Circuit Test Generation; Sequential Circuit Test Generation; Memory Test; DSP based Analog and Mixed Signal Test; Model based Analog and Mixed Signal Test; Delay Test; IDDQ Test; Design For Testability : Digital DFT and Scan Design; Built In Self Test; Boundary Scan Standard; Analog Test Bus Standard; System Test and Core Based Design; The Future of Testing.

References:

1. Essentials of Electronic Testing For Digital, Memory & Mixed –Signal VLSI Circuits - M. Bushnell & V. D. Agrawal

High Level Synthesis and Optimization of Digital Circuits (4 Credits) (SKR) (ESD 602)

Topics : Logic Optimization and Synthesis : Combinational Logic Synthesis : Two Level – Multiple input & multiple output minimization by exact and heuristic algorithms; Symbolic Minimization and Encoding Problems; Multiple level logic synthesis; Technology mapping; Sequential Logic Synthesis : State minimization, State assignment – For two level and multiple level logic, Multiple FSM realization, Hierarchical FSMs; High Level Synthesis : Architectural Models, Quality Measures, Design Description Languages, Register Transfer Components, Design Representation, Design Transformations, Design Partitioning, Scheduling, Allocation, Resource Sharing and Binding, Data-path and Control generation, Design Flow in High Level Synthesis, Design Methodologies in High Level Synthesis, System Level Design and Synthesis; Physical Design Synthesis : Placement, Floor-planning, Routing and Compaction.

References:

1. G. De Micheli, Synthesis and Optimization of Digital Circuits, McGraw Hill - International Students Edition.
2. D. D. Gajski, N. D. Dutt, A.C.H. Hu and S. Y. Lin, High Level Synthesis : Introduction to Chip and System Design, Kluwer Academic Publishers.
3. D. D. Gajski, F. Vahid, S. Narayan and J. Gong, Specification and Design of Embedded Systems, Prentice Hall.
4. Naveed Sherwani, Algorithms for VLSI Physical Design Automation, Kluwer Academics.

Journals : Design and Test of Computers, IEEE / ACM Journal on Electronic Design Automation / IEEE Transactions on CAD, Computers and VLSI Systems.

Conference Proceedings : International VLSI Conference/ Design Automation Conference (DAC) / International Conference on Computer Aided Design (ICCAD) / Asia South Pacific Design Automation Conference (ASPDAC).

Functional Verification of SoC Designs (4 Credits) (SKR) (ESD 701)

Prerequisites : Digital and Analog electronics

System on Chip (SoC) designs inherit all the well known verification and validation difficulties associated with complex ASIC designs, besides adding their own set of newer problems. These arise because SoCs are primarily implemented by re-using Intellectual Property (IP) cores. It is well known that verification today constitutes about 70% to 80% of the total design effort, thereby, making it the most expensive component in terms of cost and time, in the entire design flow. It is expected to get even worse for SoC designs. In a complex SoC design flow functional verification is very important; any behavioral or functional bug escaping this phase will not be detected in the subsequent implementation phases and will surface only after the first silicon is integrated into the target system, resulting in costly design and silicon iterations. Many of the issues relate to intrinsic limitations of some of the verification approaches taken; while others have to do with the quality of the design information, by way of, design descriptions, design documentations and design specifications, from which the overall verification objectives are derived. SoCs have brought to focus the need to carry out design and verification concurrently. For the design and verification task to proceed concurrently there is a need to capture formally, design information and implementation details at various levels of abstraction. Another reason for the need to formalize is that, as designs become more complex, functional verification will have to be carried out using the divide and conquer approach. For these approaches to succeed, specifications of either, the individual modules, or individual IPs, if any are used, have to be stated formally. The proposed course will address the state of the art in the area of functional verification. It will focus on existing methodologies, tools, and practical approaches based on universal simulation, emulation, formal verification, and semi-formal verification that can be employed to overcome the SoC verification problem. A number of case studies based on real life verification projects will be presented describing the various techniques used and the effectiveness of these techniques.

Topics : Introduction : Need for high level verification. Simulation/Emulation, Formal/Semi-formal, Design Representation; High Level Design Flow and Verification Issues : System Design, Requirements, Specifications, Functional Descriptions, Implementation, Verification Problems, Verification Techniques; Simulation Based Verification : Introduction, Types of Simulation, Quality of Verification and Coverage Analysis, Test Bench Automation Emulation : Systems, Flows, FPGAs as Logic Emulators, Drawbacks, Commercial Emulators; Formal Verification Techniques for FSM Models : Model Checking and Formal Engines, SAT Solvers, BDDs, Symbolic Model Checking with BDDs, Model Checking using SAT, Model Checking in Practice, Academic and Industrial Model Checker, Equivalence Checking; Semi-Formal Verification Techniques : Symbolic Simulation, Symbolic Trajectory Evaluation, Generalized Symbolic Trajectory Evaluation, Bounded Model Checking, Guided Search, Smart Simulation; Formal Verification of Analog Mixed Signal Circuits; Case Studies : Formal, Semi-Formal, Generalized Symbolic Trajectory Evaluation, FV of Analog Mixed Signal Circuits; Verification Project : To run concurrently with theory units above.

Lab for Course Requirements: Mentor Graphics QuestaSim (Constraint Driven Verification Tool); VIS (Formal Verification Tool) from University of California, Berkeley; CheckMate (AMS FV Tool) from Carnegie Mellon University.

References :

1. Michael Huth & Mark Ryan, Logic in Computer Science : Modeling and Reasoning about Systems (Cambridge University Press), 2004
2. Kenneth L. McMillan, Symbolic Model Checking (Kluwer Academic Publishers)
3. Thomas Kropf, Introduction to Formal Hardware Verification (Springer-Verlag).
4. Journals : Design and Test of Computers, IEEE / ACM Journal on Electronic Design Automation / IEEE Transactions on CAD, Computers and VLSI Systems.
5. Conference Proceedings : International VLSI Conference/ Design Automation Conference (DAC)/ International Conference on Computer Aided Design (ICCAD)/ Asia South Pacific Design Automation Conference (ASPDAC)/ Formal Methods in Computer Aided Design (FMCAD)/ Computer Aided Verification (CAV).

Low Power CMOS VLSI Design (4 Credits) (SBS/SKR) (ESD 603)

The objective of the course is to understand the sources of power dissipation in VLSI SoCs and embedded-systems and techniques by which SoC power can be reduced at various abstraction levels from device(MOSFET transistor), through circuit and behavioral levels up to the software(operating system) level and the trade-offs between power dissipation, chip performance and area. Another objective of the course is to be able to re-design and optimize the circuits for low-power. Finally, software-hardware co-design aspects of low-power are considered.

Topics : Power Dissipation in Embedded Systems, MOS Transistor Device Physics (Revision), Physics of Power Dissipation in MOSFETs, Power Estimation: Probabilistic Techniques, glitching power, high-level estimation, Low Power Synthesis: Behavioral level,Logic Level, Circuit level, low-power in DSP,Low-Voltage Digital CMOS Circuits, Low-Power Memory Architectures, Power

Management in SoCs, Adiabatic Computing, Software Design for Low Power: software power estimation & optimization.
Lab : Cadence or Mentor schematic design tools. Students are expected to optimize a given RTL description of a circuit into a low-power gate-level implementation possibly including clock-gating and other techniques.

References:

1. Low-Power CMOS VLSI Circuit Design: Kaushik Roy, Sharat C. Prasad
2. Digital Integrated Circuits: Jan Rabaey, Ananth Chandrakasan

Static Timing Analysis and Digital Circuit Optimization (4 Credits) (SN) (ESD 604)

This course will cover all aspects of static timing analysis of digital circuits including concepts of delay of gates, delay modeling of gates including the Elmore delay model, logical effort, and more complicated models considering parasitic capacitance. Aspects of crosstalk analysis will also be covered. In regards to static timing analysis concepts such as PERT modeling, critical path extraction, multi-corner analysis, and early/late mode timing analysis will be discussed. In the second part of the course we examine how to optimize the delay of circuits keeping in mind area and power considerations. Convex programming formulations that allow tractable solutions to the problem will be presented. The course will involve a semester-long software project on various aspects of static timing, delay calculation and circuit optimization.

References:

1. Timing, S. Sapatnekar, Kluwer Academic Publishers
2. Convex Optimization, S. Boyd and L. Vandenberghe, Cambridge University Press

Circuit Simulation (4 Credits) (SN) (ESD 713)

Topics : This course presents the theoretical and practical aspects of the building a circuit simulator, such as SPICE. The theoretical basis of circuit simulation will require a good understanding of numerical algorithms, differential equations and Monte-Carlo analysis from a mathematical point of view. We will cover circuit formulation methods, nodal analysis, large-scale nonlinear DC and small signal AC analysis, moment matching, transient, inductive modeling and reduction techniques.

References:

Circuit Simulation, Farid Najm, Wiley Publishers

Semiconductor Device Physics (4 Credits) (MR/SBS) (ESD 605)

Topics : The course will include energy band structure of semiconductor, electron statistic distribution, carrier transport principles, drift-diffusion model, semiconductor contact interface such as Schottky contact, ohmic contact, mobility models, MOS transistors, Metal Oxide silicon capacitors, BJTs non-ideal effects, p-n junctions for solar cells, leds and laser diodes. The course will also include GSS an open source tool in TCAD to simulate semiconductor devices.

References:

1. Pierret, Robert F. *Semiconductor Device Fundamentals*. Reading, MA: Addison Wesley, 1996.
2. Simon, M Sze. *Physics of Semiconductor Devices*. 3rd edition, Wiley.

Deep Submicron Design Techniques (4 Credits) (SN) (ESD 711)

This course will provide a broad overview of the issues that arise in the design of deep-submicron VLSI chips.
Topics : MOS and CMOS transistor basics - Basic principles of MOS and CMOS transistors, field-effect principle, derivation of simple formulae; CMOS design styles - static CMOS designs, dynamic CMOS designs; Delay calculation - Delay calculation, electrical wire models, timing issues in deep-submicron circuits; Abstraction levels - Abstraction levels including RTL level, logic gate level and library based design; DFT/Circuit Reliability and Signal integrity - Latch-up in CMOS circuits, electrostatic discharge, electro-migration; Layout and physical verification

References:

1. Digital Integrated Circuits, J.M. Rabaey, A. Chandrakasan and B. Nikolic, Prentice-Hall (Second Edition)
2. Research papers of the last few years from DAC, ICCAD.
3. Deep-submicron CMOS ICs, From Basics to ASICs, Harry Veendrick. ASICs, Kluwer Publishers

Introduction to RF electronics (4 Credits) (MR/SBS) (ESD 712)

Topics : The course includes Resonant Circuits, impedance matching, transmission lines, Smith charts, Impedance matching, network representation, importance of S-parameters, Noise factors, Stability, Linearity, RF propagation and antenna-on-chip design, RF transceiver architecture. The course also includes design and simulation of RF transceivers using HFSS EDA tools, available in HiDES lab.

References:

1. Behzad Razavi, RF microelectronics,1998 Prentice Hall
2. Guillermo Gonzalez, Microwave Transistor Amplifiers Analysis and Design, 2nd edition.
3. Pozar, Microwave and RF design of wireless systems, 2000 Wiley.
4. Christopher Bowick, RF Circuit Design, 2nd edition.

Introduction to Nanoelectronics and MEMS/NEMS Devices (4 Credits) (MR) (ESD 606)

Topics **:** The course includes basics of Schrödinger equations, electrostatics, semiconductor band structures, simulation of band structures, nanoscale MOS capacitors, 3D Finfet transistors, CNT/Graphene based transistors, scattering theory for nanostructures, single electron transistors, MQCA logic gates, Accelerometers design by MEMS, Noise in MEMS, MEMS based Pressure sensor design, MEMS Packaging and assembly, Electronic interface design principles, Capacitive Position Sensing, Electrostatic actuators, modeling microresonators, Micromachining techniques for MEMS devices. The course will include open source simulation simulation tools such as SUPREM-IV - a stanford TCAD process simulator, SUGAR v3 - an open source Berkeley tool, and NEMO-3D - an open source Purdue tool.

References:

1. M. Lundstorm, and J. Guo, Nanoscale transistors: Device Physics, modeling and simulation, Spring 2005.
2. Ville Kaajakari, Practical MEMS: Design of Microsystems
3. S. Datta, Quantum transport: Atom to Transistor, Cambridge University Press, 2005.
4. C. Liu, Foundations of MEMS, Pearson Prentice Hall, 2nd edition, 2012

Appendix-C EMS Electives

Inter Device Communications (4 Credits) (JP/MR) (ESD 607)

Pre-requisites : Basic electronics, Digital Circuits, Awareness of communication protocols.

Communication between different devices happens in different ways. Various standards have been developed over time and these have evolved with usage. Some of these standards have become popular because of their inherent strengths and some because they of they ended up being widely used very early in their life. This course will cover the commonly used protocols. It also looks at certain specialized protocols to highlight how the usage scenarios mould the protocol. The course will be extremely hands on. The student will have to implement four of the protocols.

Topics : Introduction to inter-device communication; Class room exercise to specify requirements for a protocol and to design it; Specific standards/protocols including - RS-232/485, I2C, SPI, CAN, Bluetooth. Debugging of protocols using logic analyzer is also included in this course.

References:

1. Serial port complete edition by Jan Axelson
2. Particular specifications from each standards body.
3. Bluetooth Demystified, N J Muller, McGraw-Hill Telecom

Digital Signal Processing (4 Credits) (PGP/DJ) (ESD 608)

This is a first level graduate course on Digital Signal Processing principles and implementation. The course covers concepts of analog to digital conversion, LTI systems, frequency domain representation (Fourier and Z transform), Digital Filter Design, Filter realization, Fixed Point arithmetic/Quantization Effects. It will also examine application areas such as, OFDM, DCT for image/speech compression. Software implementation using Scilab and ADI Blackfin processor.

References:

1. Digital Signal Processing, Oppenheim and Schaefer, PHI.

Principles of Intelligent Systems (4 Credits) (PGP) (ESD 703)

It is believed that machines with computational intelligence will soon become ubiquitous and change the world forever. This course is a small step in that direction with focus on understanding principles and tools which help in designing intelligent machines. We call a system intelligent if it has the ability to - Develop behaviors based on input data from sensors or databases; Recognize complex patterns and make intelligent decisions; Understand and interact with the environment and learn to survive and improve its performance; Repair, reconfigure and adapt to new environments; Listen to other machines or humans and communicate well; Learn from the environment and develop ability to navigate like humans. Purpose of this course is to work and learn along with students to get a good exposure to the area in terms of concepts and tools to design such systems in the future. The course will have assignments, paper presentation, an algorithm module implementation and project work. There will be no exams. Project work will involve development of an intelligent gadget or an intelligent software application.

Topics : Discussion on the nature of human intelligence : Behaviorism - All behavior is caused by external stimuli, Cognetivism - Brain designed as an Information processor, Constructivism - Learning is an active, constructive process, Humanism - Learning is a personal act to fulfill one's potential; Discussion on Artificial Intelligence and computational learning; Concepts and tools for creating artificially intelligent machines: Linear classifiers, Perceptrons and support vector machines, Data representation, Data clustering and vector quantization, Decision trees and Random forests, Adaptive Signal Processing techniques , Artificial Neural networks, Hidden Markov models and Belief Propagation Networks, Probably Approximately Correct learning, Evolutionary computing and Stochastic algorithms for learning; Some Examples where humans may have good competition : Doctorless health clinics, Pilot less aircraft design, Driverless cars, Data mining and prediction, Robot soccer and other games, Logical reasoning and knowledge representation, Research and discovery; New Honda Robot ASIMO 2012 : All features and behaviors (http://www.youtube.com/watch?v=R8UeT9r4cmg&feature=related)

References:

1. Artificial Intelligence, 3rd Edition, Patrick Henry Winston, Pearson Education, Fifth Indian Reprint, 2003
2. R. Rojas: Neural Networks, Springer-Verlag, Berlin, 1996
3. Journal Papers and other books as required

Machine Learning (4 Credits) (GS) (ESD 704)

Pre-requisites : Mathematics for IT (Gen501), Algorithms (CS 501)

This course will cover a number of machine learning techniques with emphasis on the theory behind these techniques that affects the practice of these methods. There is also a significant amount of literature on the theory of learnability that attempts to answer questions like: What is learning — can we define learning precisely in a computational sense? How can learning be quantified — how well has an algorithm learnt something? Are there inherent limitations to machine learning — can we say some concepts are more easily learnable than others? The course will cover some amount of learnability theory, just enough to appreciate why these questions (and their answers) are important, how these lead to effective learning algorithms and how these provide benchmarks for effective learning. Also we would highlight how learnability is deeply related to information theory. This part will account for approximately 15–20% of the course. The presentation and coverage of topics will be biased towards breadth and not so much on depth. Similarly it will be biased towards sound conceptual understanding of the theoretical underpinnings and not so much on mathematical rigor. The treatment will be mathematically intense but hopefully not inaccessible. A notable omission from this course is Neural Networks and the other recent extensions of neural networks to Deep Learning Networks.

Topics **:** Introduction : Course Overview. Various views of Machine Learning. Feasibility of Learning. Remarks on Noise & Error. Introduction to some common terms in ML — Training, Testing, Hypothesis,
Regression, Classification, Clustering, Inference, Prediction vs Description, Parametric vs Non-Parametric Learning, Supervised vs Unsupervised Learning, Online learning, etc. Curse of Dimensionality;
Review of Basic Statistics for ML : Distributions. Hypothesis Testing and Estimation. Basic Sampling Theory — Gibbs Sampling, Bayes Sampling, Rejection Sampling. Markov Chains and Monte-Carlo methods; Introducing Learnability Theory : Generalization theory and the VC Dimension, PAC Learning, Sample Complexity, Quick Introduction to Information Theory, Entropy, KL (Kullback-Leibler) Divergence and their relationship with Learning, Notion of MDL and Model Selection, Bias-Variance Lemma; Statistical Learning I — Regression :Statistical Decision Theory, Maximum Likelihood Estimation;
Statistical Learning II — Classification : Linear Basis Functions and Discriminant Analysis, Logistic Regression, Perceptron Classifiers, Hyperplane Separators; Statistical Learning III — Kernel Methods : Support Vector Classifier, Kernel Machines for Regression and Classification, Discriminant analysis;
Bayesian Learning I : Learning as Bayesian Inference / Estimation, Generative Models., Naive Bayes;
Bayesian Learning II : Bayesian Decision Theory, Bayesian Linear Models for Regression & Classification, Version Spaces, Bayesian Learning III — Graphical Models (4 Lectures): Bayesian Networks, Markov Random Fields, Inference in Graphical Models; Unsupervised Learning — Latent Variable or Mixture Models and Clustering (3 Lectures): Unsupervised Learning, SVD (Singular Value Decomposition), PCA (Principal Components Analysis), ICA (Independent Components Analysis), Probabilistic PCA. Cluster Analysis, Gaussian Mixtures; Learning from Sequential Data (3 Lectures): Hidden Markov Models, Linear Dynamical Systems — Kalman and Particle Filters; Reinforcement Learning (2 Lectures): Q-Learning, Temporal Difference Learning, Relationship to Dynamic Programming; Ensemble Methods : Bayesian / Conditional Methods for combining learners, Boosting & Bagging,

Tree-based methods; Pittfalls to Avoid & Other Practical Considerations (2 Lectures): Occam's Razor, Overfitting. Biases, Dealing with Large Amounts of Data, Data Snooping, Design of Learning Systems; Reflections, Discussion.

References:

1. Yaser S. Abu-Mostafa, Mailk Magdon-Ismail, and Hsuan-Tien Lin. Learning From Data — A Short Course. AMLbook.com, 2012.
2. Kevin P. Murphy. Machine Learning - A Probabilistic Perspective. Second Edition, MIT Press, 2012.
3. Christopher M. Bishop. Pattern Recognition and Machine Learning. Ed. by M.Jordan, J.Kleinberg, and B.Scholkopf. Information Science and Statistics. Springer, 2006

Model Based Hardware-Software Co-Synthesis of Embedded Systems (4 Credits) (SKR) (ESD 705)

Topics **:** INTRODUCTION : System-Design Challenges, Abstraction Levels, Y-Chart, Processor-Level Behavioral Model , Processor-level structural model, Processor-level synthesis, System-Level Behavioral Model, System Structural Model, System Synthesis, System Design Methodology, Missing semantics , Model Algebra, System-Level Models, Platform Design, System Design Tools, Summary; SYSTEM DESIGN METHODOLOGIES : Bottom-up Methodology, Top-down Methodology, Meet-in-the-middle Methodology, Platform Methodology, FPGA Methodology ,System-level Synthesis, Processor Synthesis ,Summary; MODELING : Models of Computation, Process-Based Models , State-Based Models, System Design Languages , Net-lists and Schematics , Hardware-Description Languages, System-Level Design Languages, System Modeling , Design Process , Abstraction Levels, Processor Modeling, Application Layer, Operating System Layer, Hardware Abstraction Layer, Hardware Layer, Communication Modeling, Application Layer, Presentation Layer, Session Layer, Network Layer,
Transport Layer, Link Layer, Stream Layer , Media Access Layer, Protocol and Physical Layers, System Models , Specification Model, Network TLM, Protocol TLM, Bus Cycle-Accurate Model (BCAM), Cycle-Accurate Model (CAM), Summary; SYSTEM SYNTHESIS : System Design Trends, TLM Based Design, Automatic TLM Generation, Application Modeling, Platform Definition, Application to Platform Mapping , TLM Based Performance Estimation, TLM Semantics, Automatic Mapping, GSM Encoder Application, Application Profiling, Load Balancing Algorithm, Longest Processing Time Algorithm, Platform Synthesis, Component data models, Platform Generation Algorithm, Cycle Accurate Model Generation, Summary; SOFTWARE SYNTHESIS : Preliminaries, Target Languages for Embedded Systems, RTOS, Software Synthesis Overview, Example Input TLM, Target Architecture, Code Generation, Multi-Task Synthesis, RTOS-based Multi-

Tasking, Interrupt-based Multi-Tasking, Internal Communication, External Communication , Data Formatting, Packetization, Synchronization, Media Access Control,
Startup Code, Binary Image Generation, Execution, Summary; EMBEDDED DESIGN PRACTICE: System Level Design Tools, Academic Tools , Commercial Tools , Outlook, Embedded Software Design Tools, Academic Tools, Commercial Tools, Outlook, Hardware Design Tools, Academic Tools, Commercial Tools , Outlook , Case Study, Embedded System Environment, Design Driver: MP3 Decoder, Results, Summary.

References:

1. Embedded System Design : Modeling, Synthesis and Verification – D. D. Gajski, S. Abdi, A. Gerstlauer, G. Schriner, Springer

Principles of Multimedia & Multimedia Architectures (4 Credits) (JP) (ESD 706)

Topics : Introduction to Multimedia – What is multimedia? Multimedia & Hypermedia, WWW, Overview of Multimedia Software Tools; Multimedia Authoring & Tools – Multimedia Authoring, Some Useful Editing & Authoring Tools, VRML; Graphics and Image Data Representation – Data Types, Popular file formats; Color in Image and Video – Color Science, Color Models in Images & Video; Fundamental Concepts in Video – Types of Video Signals, Analog Video, Digital Video; Basics in Audio – Digitzation of Sound, MIDI, Quantization and Transmission of Audio; Multimedia Data Compression – Lossless & Lossy Compression Algorithms, Image Compression Standards; Basic Video Compression Techniques – Compression based on Motion Compensation, H.261, H.263; MPEG Video Coding – MPEG – 1, MPEG – 2, MPEG – 4 (H.264), MPEG – 7, MPEG – 21; Basic Audeo Compression Techniques – ADPCM (G.726), Vocoders; MPEG Audio Compression – Psychoacoustics, MPEG audio – Strategy/Compression Algorithm/MPEG-2AAC, MPEG-4; Multimedia Communication and Retrieval – Computer & Multimedia Networks; Multimedia Network Communications and Applications, Wireless Networks, Content Based retrieval in Digital Libraries.

References:

1. Fundamentals of Multi-Media, Ze-Nian Li, Mark S. Drew, Prentice Hall of India.

Real Time Systems -- Design, Analysis and Verification (4 Credits) (EF) (ESD 609)

Topics : Basic Real-Time Concepts; Hardware Considerations; Real Time Operating Systems; Software System Design; Programming Languages and the Software Production Process; Performance Analysis and Optimization; Engineering Considerations; Verification : Analysis of Non-Real-Time Systems; Real time Scheduling and Schedulability Analysis; Model Checking of Finite State Systems; Real Time Logic, Graph- Theoretic Analysis and Mode Chart; Timed Automata, Timed Petri-Nets; Process Algebra

References:

1. Real Time Systems Design and Analysis – Phillip A. Laplante, IEEE Press & John Wiley Student Edition.

2. Real Time Systems : Scheduling, Analysis and Verification – Albert M. K. Chang, IEEE Press & John Wiley Student Edition)

Cyber Physical Systems (4 Credits) (SKR/EF) (ESD 610)

Topics : Introduction; Sensors & Actuators, Memory Architectures, Interfacing To Sensors & Actuators, Interrupts, Model Based Design, Modal Behaviour, Extended and Timed Automata, Composition of State Machines, Hierarchical State Machines, Multi-Tasking, Operating Systems, Scheduling Anamolies, Temporal Logic, Comparing State Machines, Reachability, Execution Time Analysis, Synchronous Reactive, Dataflow, and Security.

References:

1. Introduction to Embedded Systems – A Cyber-Physical Systems Approach, E. A. Lee and S. A. Seshia

Embedded Software Verification and Validation (4 Credits) (MDS) (ESD 707)

Topics : Embedded software usually are a part of safety critical systems, and hence, there is extra focus and rigour in their verification and validation. Several certification and safety standards emphasize usage of mathematical and formal techniques to verify such software. This course will deal with techniques for embedded software verification and validation. Relevant techniques from software testing and model checking will be covered from the side of functional testing and verification. From the side of non-functional validation, worst case execution analysis, schedulability analysis and safety assurance techniques will be covered.

References:

1. Embedded Systems and Software Validation, Abhik Roychoudhury, Morgan Kaufmann (Elsevier), 2009.
2. Principles of Model Checking, Christel Baier and Joost-Pieter Katoen, MIT Press, 2008.
3. Appropriate papers on the above topics.

Design and Analysis of Embedded Software Systems (4 Credits) (SC) (ESD 708)

Topics : Software Architectures for Embedded Systems : AUTOSAR, RING, FRAME; Software Model Development Environment (SMDE) in Embedded System : Simulink, Esterel etc. based development platforms; Programming for Embedded System : Memory constrained environment performance;

Testing of Embedded System Software : Performance, Response, Memory Requirements etc.

References:

1. Details will be provided by Prof. Sujit Chakraborty

Computational Perception Using Multimodal Sensors (4 Credits) (DJ) (ESD 611)

Topics : This course will provide the students with a unified view on representations, statistical models, and algorithms to automatically analyze people's behavior in interactions, using single and multiple perceptual modalities (mainly vision and audio). The course will emphasize the comparison between modalities and the discussion of their individual and combined advantages, while introducing modeling tools for localization, segmentation, tracking, recognition, using probabilistic graphical models as the underlying formalism. The course trains students to record and analyze human-human and human-computer interactions using Kinect sensors, with interesting applications in gaming and behavioral training.

References:

1. Murphy, Kevin P. *Machine learning: a probabilistic perspective*. The MIT Press, 2012.
2. Bishop, Christopher M. "Pattern recognition and machine learning (information science and statistics)." (2007).
3. Thiran, Jean-Philippe, Ferran Marqus, and Herve Bourlard. *Multimodal Signal Processing: Theory and applications for human-computer interaction*. Academic Press, 2009.

Wireless Sensor Networks (4 Credits) (JB / DD) (ESD 709)

Pre-requisites : Fundamentals of Computer Networking and Communication
Smart environments represent the next evolutionary development step in building, utilities, industrial, home, shipboard, and transportation systems automation. Like any sentient organism, the smart environment relies first and foremost on sensory data from the real world. Sensory data comes from multiple sensors of different modalities in distributed locations. Along with sensing abilities, the ability of the sensor nodes to communicate using radio channels enables the sensor nodes to form cooperative networks. In this course, we will explore the wireless sensor networks, the challenges involved, architectures, communication protocols and applications. It is expected that labs and a project will be a significant part of the course.

Topics : The Sensor Network Concept - Introduction: The vision of Smart Environment, Applications, How are sensor networks different?**;**

Applications; Architecture -Hardware Components, Operating Systems and execution, Introduction to Cross-bow Motes family; Physical Layer : Wireless Channel and transceiver design considerations for WSN, Adaptability, Antenna considerations; Medium Access and Routing : Requirements and design constraints for MAC for WSN, Low-duty cycle protocols (S-MAC), IEEE 802.15.4 MAC protocol, Adhoc routing protocol (like AODV) and mesh networks; Localization and Positioning - Localization Approaches: Proximity, Trilaterations and Triangulation; Collaborative Signal Processing and Distributed Computation; Detection, estimation, classification problems; Energy-efficient distributed algorithms; Time Synchronization and Routing Protocols.

References:

1. Protocols and Architecture for Wireless Sensor Networks, Holger Karl and Andreas Willing, Wiley
2. Wireless Sensor Networks: An Information Processing Approach, Feng Zhao, L. Guibas, Elsevier

Embedded Systems for Healthcare (4 Credits) (SBS/RC/BG) (ESD 612)

In this course, we will look at how mobile communications have, and can be, leveraged as effective tools for strengthening health systems and improving health outcomes. We will concentrate our study on resource-limited settings, where the burden of infectious diseases is highest, where chronic conditions are often left unattended, where the healthcare infrastructure is least developed, and where the uptake of mobile communications is also the highest. We will start with the definitions and scope of ICT for healthcare (eHealth followed by mHealth), and then present a state of the art of mHealth as it stands today, with a special focus on the challenges that prevent its widespread adoption. In this landscape analysis, we will present the different areas and diseases where mHealth has been used, and illustrate these with concrete examples from pilots and large-scale implementations. Thereafter, we will look at the technological aspects of mHealth implementations, introduced through our own conceptual framework. Special emphasis will be placed on the mHealth front-end user devices, the most widespread modes of communications (SMS being the primary focus) and mobile ‘apps’ which are gaining ground. The underlying open-source development approach will be presented, as well as the increasing use of cloud computing as the back-end of mHealth. The course will conclude with descriptions of the main technology platforms already is use for data collection, communication and aggregation: a study of these platforms is important since any new implementation necessarily has to interface with them and co-exist and co-operate. A case-study at the end of the course will allow the audience to design a new mHealth solution based on the expected health outcomes, the IT infrastructure available, and the local user profiles. This will allow the audience to appreciate the fact that hi-tech is not always necessary nor desirable, and that the primary focus of mHealth should be on the 'Health' part rather than the 'm' technology.

Course includes the following topics:
Communicable Diseases - bacteria, viruses and parasites, Non-Communicable disease - diabetes, cardiovascular, cancer, COPD, Nervous system-the processor and wiring, Circulatory System-the plumbing, Blood-fluid to fuel and protect, Lungs-the exhaust system, Overview of current laboratory techniques, Point of care diagnostic systems, Pulse oximetry-turning blood composition and pressure into electrical waveforms, Waveform analysis to derive respiration rate, Picking up and amplifying electrical activity of the heart, Waveform analysis to determine diagnosis, Standard invasive and noninvasive methods, Non invasive imaging technique, Microfluidic tools, Ongoing work to create chips for complex assays (PCR), Building better limb replacements-embedded systems arms and legs, The future-prosthetic eyes and mind controlling computers, The care process, its bottlenecks and challenges, The potential of mobile communications for healthcare, mHealth as a part of eHealth, Challenges faced by mHealth today, The economics of mHealth, Ethical and regulatory issues, Conceptual framework for implementation: Constituent elements of mHealth, Technical architectures of mHealth, Implementations, with illustrative cases, User front-end: devices and means of communication, Cloud computing as back-end: future frontier for storage and access. Major open-source platforms for the development and implementation of mHealth, Data collection and communication platforms, Data aggregation and analysis platforms, Interoperability issues, Electronics of implantable sensors and systems, Wireless transmission standards for biomedical systems, Body-area networks: potential and challenges, Instrumentation for measuring physiological parameters, Embedded electronics for data acquisition and storage, Signal processing: hardware and software, Wireless transmission and reception

Actuators, Sensors and Robotics (4 Credits) (GP) (ESD 613)

Topics : Introduction to Measurable Physical Properties: Distance, Force, Light and Electromagnetic Radiation, Sound, Smell, Texture; Sensors and their Characterization : Position, Force/Torque, Light, Sound, etc; Basic Properties: Accuracy, Dynamic Range, Repeatability; Linear and Rotary Encoders; Force/Torque Measurement devices; Photocells; Piezosensors; Hall Effect and other EM sensors...; Actuators and their Characterization - Position, Force/Torque, Light, Sound, etc; Basic Properties: Accuracy, Dynamic Range, Repeatability; Linear and Rotary Motors; Photodiodes; Piezoactuators; Voice Coils; Applications in Robotics, Automotive, ...

Image Signal Processing (4 Credits) (NS) (ESD 710)
This is already an approved elective course.

Computer Vision (4 Credits) (GP) (ESD 614)
This is already an approved elective course.

Mixed Signal Design (4 Credits) (SBS) (ESD 702) -
New elective course.

Appendix-D Overall List of Electives for M. Tech. ESD

Colour Codes :

Black – SOC Electives
Blue – Embedded Systems Electives
Red – Course Numbers
Green – Existing IT Electives

Semester II

- **Testing and Design For Testability (ESD 601)**
- **High Level Synthesis and Optimization of Digital Circuits (ESD 602)**
- **Low Power CMOS VLSI Design (ESD 603)**
- **Static Timing Analysis and Digital Circuit (ESD 604)**
- **Semiconductor Device Physics (ESD 605)**
- **Introduction to Nano-Electronics and MEMS/NEMS devices (ESD 606)**
- **Inter Device Communications (ESD 607)**
- **Digital Signal Processing (ESD 608) (NCE 603)**
- **Real Time Systems - Design, Analysis and Verification (ESD 609)**
- **Cyber Physical Systems (ESD 610)**
- **Computational Perception Using Multimodal Sensors (ESD 611)**
- **Embedded Systems for Healthcare (ESD 612)**
- **Actuators, Sensors and Robotics (ESD 613)**
- **Computer Vision (ESD 614)**

Semester III

- **Functional Verification of SoC Designs (ESD 701)**
- **Mixed Signal Design (ESD 702)**
- **Principles of Intelligent Systems (ESD 703)**
- **Machine Learning (ESD 704) (CS/DS 706)**
- **Model Based Hardware-Software Co-Synthesis of Embedded Systems (ESD 705)**

- **Principles of Multimedia & Multimedia Architectures (ESD 706)**
- **Embedded Software Verification and Validation (ESD 707)**
- **Design and Analysis of Embedded Software Systems (ESD 708)**
- **Wireless Sensor Networks (ESD 709) (NCE 702)**
- **Image Signal Processing (ESD 710)**
- **Deep Submicron Design Techniques (ESD 711)**
- **Introduction to RF Electronics (ESD 712)**
- **Circuit Simulation (ESD 713)**