Electrical Engineering and Computer Sciences

II Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits (AL/3)
ECS 102	Introduction to Programming	2	1	4	3	0	10	6	O to F	3

III Semester

	Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits (AL/3)
DC	ECS201	Discrete Mathematics I	3	0	4.5	0	0	7.5	3	O to F	3
	ECS203	Basic Electronics	3	0	4.5	0	0	7.5	3	O to F	3
MD	MTH201	Multivariable Calculus	3	1	4.5	0	0	8.5	4	O to F	3

IV Semester

	Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits (AL/3)
DC	ECS202	Data Structures and Algorithms									4 (3+1)
	ECS204	Introduction to Signal Processing and Systems	3	1	4.5	0	0	8.5	4	O to F	3
MD	MTH202	Probability and Statistics	3	1	4.5	0	0	8.5	4	O to F	3

DC: Departmental Compulsory Course; **MD:** Mandatory Course from Other Department; **RD:** Recommended Course from Other Department

Computer Science and Engineering (CSE)

V Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS301	Principles of Communication	3	0	7.5	0	0	10.5	3	O to F	4
ECS303	Computer Organization	3	0	7.5	0	0	10.5	3	O to F	4
ECS 305	Discrete Mathematics II	3	0	7.5	0	0	10.5	3	O to F	4
ECS 307	Theory of Computation	3	0	7.5	0	0	10.5	3	O to F	4
ECS 309	DE I	3	0	7.5	0	0	10.5	3	O to F	4
Total Credits		**15**	**0**	**37.5**	**0**	**0**	**52.5**	**15**		**20**

VI Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS302	Operating Systems	3	0	7.5	0	0	10.5	3	O to F	4
ECS304	Introduction to Data Science and Machine Learning	3	0	7.5	0	0	10.5	3	O to F	4
ECS 306	Algorithms	3	0	7.5	0	0	10.5	3	O to F	4
ECS 308	DE II	3	0	7.5	0	0	10.5	3	O to F	4
	OE VII									
Total Credits (from department only courses)		**12**	**0**	**30**	**0**	**0**	**42**	**12**		**16**

VII Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS401	DE III	3	0	7.5	0	0	10.5	3	O to F	4
ECS403	DE IV	3	0	7.5	0	0	10.5	3	O to F	4
ECS405	DE V	3	0	7.5	0	0	10.5	3	O to F	4
ECS407	DE VI	3	0	7.5	0	0	10.5	3	O to F	4
	OE VIII									
Total Credits (from department only courses)		**12**	**0**	**30**	**0**	**0**	**42**	**12**		**16**

VIII Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS402	Concurrency Theory	3	0	7.5	0	0	10.5	3	O to F	4
ECS404	DE VIII	3	0	7.5	0	0	10.5	3	O to F	4
ECS406	DE IX	3	0	7.5	0	0	10.5	3	O to F	4
ECS408	DE X	3	0	7.5	0	0	10.5	3	O to F	4
	OE IX									
Total Credits (from department only courses)		**12**	**0**	**30**	**0**	**0**	**42**	**12**		**16**

IX Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS599	DE XI	3	0	7.5	0	0	10.5	3	O to F	4
ECS501	MS Thesis	0	0	36	0	4	40	4	O to F	16
Total Credits		**3**	**0**	**43.5**	**0**	**4**	**50.5**	**7**		**20**

X Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS501	MS Thesis	0	0	36	0	4	40	4	O to F	16
Total Credits		**0**	**0**	**36**	**0**	**4**	**40**	**4**		**16**

Electronics and Communication Engineering (ECE)

V Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS301	Principles of Communication	3	0	7.5	0	0	10.5	3	O to F	4
ECS303	Computer Organization	3	0	7.5	0	0	10.5	3	O to F	4
ECS 321	Electronic Devices	3	0	7.5	0	0	10.5	3	O to F	4
ECS 323	Control Systems	3	0	7.5	0	0	10.5	3	O to F	4
ECS 325	Analog Circuits	3	0	7.5	0	0	10.5	3	O to F	4
ECS 327	Electronics Lab I	0	0	1	3	0	4	3	O to F	1
Total Credits		**15**	**0**	**38.5**	**3**	**0**	**56.5**	**18**		**21**

VI Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS 322	Electromagnetic Theory	3	0	7.5	0	0	10.5	3	O to F	4
ECS 324	Digital Signal Processing	3	0	7.5	0	0	10.5	3	O to F	4
ECS 326	Digital Circuits and Systems	3	0	7.5	0	0	10.5	3	O to F	4
ECS 328	Communication Systems	3	0	7.5	0	0	10.5	3	O to F	4
ECS 330	Electronics Lab II	0	0	2	6	0	8	6	O to F	3
	OE VII									
Total Credits (from department only courses)		**12**	**0**	**32**	**6**	**0**	**50**	**18**		**19**

VI I Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS421	Nonlinear Systems	3	0	7.5	0	0	10.5	3	O to F	4
ECS423	DE I	3	0	7.5	0	0	10.5	3	O to F	4
ECS425	DE II	3	0	7.5	0	0	10.5	3	O to F	4
ECS427	DE III	3	0	7.5	0	0	10.5	3	O to F	4
	OE VIII									
Total Credits (from department only courses)		**12**	**0**	**30**	**0**	**0**	**42**	**12**		**16**

VIII Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS422	Plasma and Plasmonics	3	0	7.5	0	0	10.5	3	O to F	4
ECS424	DE IV	3	0	7.5	0	0	10.5	3	O to F	4
ECS426	DE V	3	0	7.5	0	0	10.5	3	O to F	4
ECS428	Nanoelectronics: Fundamentals and Applications	3	0	7.5	0	0	10.5	3	O to F	4
	OE IX									
Total Credits (from department only courses)		**12**	**0**	**30**	**0**	**0**	**42**	**12**		**16**

IX Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS 521	DE IX	3	0	7.5	0	0	10.5	3	O to F	4
ECS501	MS Thesis	0	0	36	0	4	40	4	O to F	16
Total Credits		**3**	**0**	**43.5**	**0**	**4**	**50.5**	**7**		**20**

X Semester

Course No.	Course Title	Lec Hr	Tut Hr	SS Hr	Lab Hr	DS Hr	AL	TC Hr	Grading System	Credits
ECS501	MS Thesis	0	0	36	0	4	40	4	O to F	16
Total Credits		**0**	**0**	**36**	**0**	**4**	**40**	**4**		**16**

DEPARTMENT OF ELECTRICAL ENGINEERING & COMPUTER SCIENCE

ECS 102: Introduction to Programming (3)

Course Content

- Data types, Variables, Identifiers.
- Variable declaration, Assignment statement.
- Input/output, Comments.
- Operators and Expressions.
- Conditional expressions. Conditional statements: if-then, if-then-else, nested conditionals, switch-case.
- Loops: for, while, repeat.
- Arrays, multi-dimensional arrays.
- Functions. Recursion.
- Pointers. Memory and its management.
- Structures. Data Structures.

References

1. Schaum's Outline of Programming with C by Byron Gottfried, McGraw-Hill India.
2. Programming in ANSI C by Balaguruswamy.
3. The C Programming Language by Kernighan and Ritchie, Prentice-Hall India. (This is a standard reference to C. Slightly advanced though.)

ECS 201: Discrete Mathematics I (3)

Course Content

- Mathematical proofs, proofs by induction, by contradiction, proving the contrapositive.
- Basic counting techniques, pigeon-hole principle, recurrence relations, generating functions, principle of inclusion and exclusion, Mobius inversion.
- Graphs, trees - definitions. Connectivity, paths, cycles, Eulerian walks, Hamiltonian cycles, cliques, colourings, graph matching, planarity.
- Some other topics from combinatorics and graph theory.

References

1. Peter Cameron, Combinatorics: Topics, Techniques, Algorithms, Cambridge University Press, 1995.
2. JH van Lint, RM Wilson, A Course in Combinatorics, 2nd Ed., Cambridge University Press, 2001.
3. R Graham, D Knuth, O Patashnik, Concrete Mathematics: A Foundation for Computer Science, 2nd Ed., Addison-Wesley, 1994.

ECS 203: Basic Electronics (3)

Course Objectives

The objective of this course is to impart basic background in analog and digital circuits. The course would use simple models; detailed description of the semiconductor devices would be covered in a separate course. The internal circuits of the blocks used in this course (such as op-amps, logic gates) will not be covered in this course. Instead, the broad behavioral description of these blocks will be used to explain the circuit operation.

Course Content

- Thevenin's theorem
- RC circuits (single capacitor)
- Diodes and diode circuits (finding V_o-V_i relation,
- clipper, peak detector, clamper, voltage doubler)
- Zener diodes and voltage limiter circuit
- Half-wave and full-wave rectifier circuits
- BJT: basic functionality
- BJT common-emitter amplifer in the mid-band region
  (frequency response not covered)
- Introduction to op-amps
- Analysis of op-amp circuits in the linear region
- Inverting/non-inverting amplifier, summer
  integrator
- Schmitt trigger
  oscillator based on Schmitt trigger
- Boolean logic
- Basic digital gates and truth tables

- function minimisation using Karnaugh maps
- Combinatorial circuit blocks
  (MUX, DEMUX, encoders, decoders)
- introduction to sequential circuits
- NAND and NOR latch
- flip-flops
- shift registers and counters
- review of DAC and ADC

Suggested Lab Experiments:

- diode clipper/clamper/voltage doubler
- BJT common-emitter amplifier
- op-amp circuits: inverting/non-inverting amplifiers
  integrator, summer
- op-amp circuits: oscillator based on Schmitt trigger
- binary counter
- synchronous counter

References

1. William H. Hayt & Jack E. Kemmerly Engineering Circuit Analysis McGraw-Hill Book Company Inc. 1971
2. R.L.Boylstead, Electronic Devices and Circuit Theory, 11^{th} edition.
3. M. Morris Mano & M. D. Ciletti, Digital Design, Prentice Hall of India, 2008.
4. Horowitz, Paul, and Winfield Hill. *The Art of Electronics*. 2nd ed. Cambridge, UK: Cambridge University Press, 1989. ISBN: 9780521370950

ECS 202: Data Structures and Algorithms (4)

Course Content

- Random-access-machine model, concept of problem size, and asymptotic behaviour of time/space complexity.
- Estimation of time/space complexity by smooth functions and order notations.
- A simple example of worst-case time/space complexity analysis.

- Elementary data-structures: arrays, lists, queues, stacks and their applications.
- Binary search algorithm, binary trees, binary-search-tree data-structure.
- Balanced binary-search-tree: Red-Black trees.
- Hashing for insert, search, delete.
- Heap data structure.
- Efficient data structures, apart from those listed above, for sets with the following group of operations:
  - ✓ insert, delete, membership
  - ✓ insert, delete, minimum
  - ✓ union, intersection, difference
  - ✓ disjoint-set union
- Sorting algorithms, including the average case analysis of quick-sort.
- Greedy paradigm with examples.
- Divide and conquer paradigm with examples.
- Dynamic-programming paradigm with examples.
- Definition of graphs, paths, trees, cycles. Data structures for graphs: adjacency lists, adjacency matrix.
- Graph algorithms: Depth First Search, Breadth First Search, Minimum Spanning Tree.

References

1. AV Aho, J Hopcroft, JD Ullman, Data Structures and Algorithms, Addison- Wesley, 1983.
2. TH Cormen, CF Leiserson, RL Rivest, C Stein, Introduction to Algorithms, 3rd Ed., MIT Press, 2009.
3. AV Aho, J Hopcroft, JD Ullman, The Design and Analysis of Algorithms, Addison-Wesley, 1974.
4. MT Goodrich, R Tamassia, DM Mount, Data Structures and Algorithms in Java, 5th Ed., Wiley, 2010. (Equivalent book in C also exists.)

ECS 204: Introduction to Signal Processing and Systems (3)

Course Content

Introduction to the Course and Basic Concepts; Signals & their Transformation; Elementary Signals in the Continuous and Discrete Time Domains; Classification of Systems; Properties of Linear Time Invariant Systems; Convolution, Invertibility, Stability and Causality; Unit Step and Impulse Responses; Systems Described by Differential & Difference Equations; Fourier Series; Introduction to Fourier Transform for Continuous Time signals; Fourier Transform of Periodic Functions; Fourier Transform Properties; Fourier Analysis of Discrete Time Signals & Systems; Properties of DTFT; Convolution, Modulation & Other Properties of DTFT; Introduction to Sampling; Spectrum of Sampled Signals, Aliasing; Introduction to Laplace Transform; Properties of Laplace Transform; Introduction to Z Transform; Properties of Z Transform.

References

1. Signals and Systems, A V Oppenheim, A S Willsky, and S H Nawab, 2nd Edition, PHI Learning Pvt. Ltd, New Delhi

ECS 301: Principles of Communications (4)

Course Content

This course includes the following contents:

- Introduction: Signal and Spectra
- Amplitude Modulation Systems
- Angle Modulation
- Pulse Modulation and Digital Transmission of Analog Signals
- Digital Modulation and Transmission
- Random Variables and Processes
- Mathematical Representation of Noise
- AM Reception Performance Under Noise
- FM Reception Performance Under Noise
- Phase Locked Loops
- Optimal Reception of Digital Signal
- Noise in Pulse Code Modulation and Delta Modulation Systems
- Information Theoretic Approach to Communication
- Error-Control Coding

- Communication Systems and Component Noises
- Spread Spectrum Modulation
- Miscellaneous Topics in Communication Systems

References:

1. Principles of Communication Systems (SIE) 4E Paperback – 1 Jul 2013 by Herbut Taub (Author), Donald L. Schilling (Author), Goutam Saha (Author)

ECS 307: Discrete Mathematics I (4)

Course Content

- Mathematical proofs, proofs by induction, by contradiction, proving the contrapositive.
- Basic counting techniques, pigeon-hole principle, recurrence relations, generating functions, principle of inclusion and exclusion, Mobius inversion.
- Graphs, trees - definitions. Connectivity, paths, cycles, Eulerian walks, Hamiltonian cycles, cliques, colourings, graph matching, planarity.
- Discrete probability. Sample space, events, probability - basic laws, discrete random variable, expectation, linearity of expectation, independence, conditioning, Bayes theorem, Bernoulli, binomial and geometric distributions, moments and deviations, Markov, Chebyshev inequalities, Chernoff bounds.
- Application of probabilistic methods in combinatorics and graph theory.

Books and References

1. Peter Cameron, Combinatorics: Topics, Techniques, Algorithms, Cambridge University Press, 1995.
2. JH van Lint, RM Wilson, A Course in Combinatorics, 2nd Ed., Cambridge University Press, 2001.
3. David Stirzaker, Elementary Probability, 2nd Ed., Cambridge University Press, 2003.
4. Noga Alon, Joel Spencer, The Probabilistic Method, 3rd Ed., Wiley Interscience, 2008.
5. R Graham, D Knuth, O Patashnik, Concrete Mathematics: A Foundation for Computer Science, 2nd Ed., Addison-Wesley, 1994.

ECS 303: Computer Organization (4)
Course Content

- Introduction.
- Arithmetic algorithms.
  - ✓ Overview of basic digital building blocks; truth tables; basic structure of a digital computer.
  - ✓ Number representation: Integer - unsigned, signed (sign magnitude, 1’s complement, 2’s complement); Characters - ASCII coding, other coding schemes; Real numbers - fixed and floating point, IEEE754 representation.
  - ✓ Basic building blocks for the ALU: Adder, Subtracter, Shifter, Multiplication and division circuits.
- Hardware description language. Introduction to some HDL (Verilog, VHDL, BSV). Digital Design using HDLs.
- CPU.
  - ✓ CPU Sub-block: Datapath - ALU, Registers, Instructions, Execution of Instructions; CPU buses; Control path - microprogramming, hardwired logic; External interface.
  - ✓ Advanced Concepts: Pipelining; Introduction to Advanced Processors (multiprocessors and multi-cores).
  - ✓ Examples of some well known processors.
- Assembly Language Programming. Instruction set and Assembly programming for some processor, preferably the one described in class.
- Memory.
  - ✓ Memory Sub-block: Memory organization; Technologies - ROM, RAM, EPROM, Flash, etc., Virtual Memories.
  - ✓ Cache: Cache algorithms, Cache Hierarchy, Cache coherence protocols.
  - ✓ Advanced concepts: Performance, Interleaving, On chip vs Off chip Memories/Caches.
- I/O and Peripherals.
  - ✓ I/O Sub-block: I/O techniques - interrupts, polling, DMA; Synchronous vs. Asynchronous I/O; Controllers.
  - ✓ Peripherals: Keyboard, Mouse, Monitors, Disk drives, etc.

- Lab Contents.
  - ✓ Digital Design using HDLs. Simple circuit designs: For e.g. Counter, Multiplexer, Arithmetic circuits etc. Design of a Simple Processor: Includes register file, ALU, data paths.
  - ✓ FPGA Programming Programming on Xilinx Spartan 3E (or equivalent) FPGA. Handling of Inputs: through slide switches, through push buttons. Handling of Outputs: 7-segment display, LED display, LCD display. The designs developed in Part-I can be used to program the FPGA.
  - ✓ Assembly Language Programming Programming in assembly language. The assignments should cover the following concepts: Registers; different type of instructions (load, store, arithmetic, logic, branch); operand addressing modes; memory addressing modes; conditions (codes/flags and conditional branches) stack manipulation; procedure calls; procedure call conventions (load/store of; arguments on stack, activation records);

Books and References

1. Computer Organization and Design: The Hardware/Software Interface, David A Patterson, John L. Hennessy, 4th Edition, Morgan Kaufmann, 2009
2. Computer Architecture and Organization by William Stallings, PHI Pvt. Ltd., Eastern Economy Edition, Sixth Edition, 2003
3. Structured Computer Organization by Andrew S Tanenbaum, PHI/Pearson, 4th Edition
4. Computer Organization by V Carl Hamacher, Zvonks Vranesic, SafeaZaky, McGraw Hill, Vth Edition
5. Computer System Architecture by M Morris Mano, Prentice Hall of India, 2001
6. Computer Architecture and Organization by John P Hayes, 3rd Ed. McGraw Hill, 2002.
7. Assembly Language, Online notes, http://linuxassembly.org/.
8. Books related to HDL (Verilog, VHDL, BSV) programming.

ECS 321: Electronic Devices (4)

Course Content

The purpose of this course is to provide a background in basic semiconductor physics and semiconductor devices. This background would help the student to appreciate the main features of the devices covered in the course.

In the lab experiments, students will be able to make measurements and relate those with the concepts covered in the theory part.

Topics:

- carrier statistics, mobility, drift and diffusion
- Poisson's equation and continuity equation
- p-n junction in forward bias and reverse bias
- I-V curve for a p-n junction
- capacitance of a p-n junction under reverse bias
- turn-off transient for a p-n junction
- basic operation of a solar cell
- metal-semiconductor junction (I-V curve)
- BJT Ebers-Moll model
- BJT I_c-V_{ce} curve
- BJT small-signal model
- JFET: principle of operation and I-V
- MOS capacitor, C-V at low and high frequencies
- MOS transistor

Suggested Lab Experiments:

- measurement of diode I-V curve
  (need to use a current source for measurements in the forward bias range)
- turn-off transient for a diode
- measurement of I_c-V_{ce} of a BJT for different I_b values
- measurement of I_d-V_{ds} for a MOS transistor with different V_{gs} values and I_d-V_{gs} for two V_{ds} values

References

1. Fonstad, Clifton. *Microelectronic Devices and Circuits*. 2006 Electronic Edition. Available online at DSpace@MIT.

2. Howe, Roger, and Charles Sodini. *Microelectronics: An Integrated Approach*. Upper Saddle River, NJ: Prentice Hall, 1996. ISBN: 9780135885185.
3. *Modular Series on Solid State Devices*Pierret, Robert. *Volume I: Semiconductor Fundamentals*. 2nd ed. Upper Saddle River, NJ: Prentice Hall, 1988. ISBN: 9780201122954.
4. Neudeck, George. *Volume II: The PN Junction Diode*. 2nd ed. Upper Saddle River, NJ: Prentice Hall, 1998. ISBN: 9780201122961.
5. Neudeck, George.*Volume III: The Bipolar Junction Transistor*. 2nd ed. Upper Saddle River, NJ: Prentice Hall, 1989. ISBN: 9780201122978.
6. Pierret, Robert. *Volume IV: Field Effect Devices*. 2nd ed. Upper Saddle River, NJ: Prentice Hall, 1990. ISBN: 9780201122985.

ECS 325: Analog Circuits (4)

Course Content

This course serves as an extension of the basic electronics course in the analog circuit domain. Advanced concepts such as feedback, current sources, non-idealities in op-amps will be covered.

Topics:

- difference amplifier
- current sources and active loads
- output stages
- internal circuit of op-amp 741
- feedback configurations with examples
- frequency response of amplifiers
- stability of amplifiers
- Bode plots
- op-amp filters
- instrumentation and isolation amplifiers
- precision rectifiers
- logarithmic amplifiers
- non-idealities in op-amps: offset voltage and bias currents
- effect of op-amp non-idealities in circuits

- sinusoidal oscillators
- sample-and-hold circuits
- introduction to CMOS analog circuits

References

1. CMOS Analog Circuit Design (The Oxford Series in Electrical and Computer Engineering) by Phillip E. Allen (Author), Douglas R. Holberg, 3rd edition.
2. Design of Analog CMOS Integrated Circuits by Behzad Razavi, 1st edition.

ECS 326: Digital Circuits and Systems (4)

Course Content

The purpose of this course is to familiarise the student with basic features of logic gates and also give sufficient exposure to modern digital components such as FPGA. Some home-work assignments based on a hardware description language would be helpful.

Topics:

- overview of logic families
- definition of noise margin
- CMOS inverter and other gates
- binary number system
- digital arithmetic
- finite state machine design, analysis, and synthesis
- introduction to hardware description languages
- array-based logic elements (memory, PLA, FPGA)
- special topics (e.g., processor design, test andverification)

References

1. J. M. Rabaey, A. Chandrakasan and B. Nikolic, *Digital Integrated Circuits: A Design Perspective*, Second Edition, Pearson/PH, 2003.

ECS 328: Communication Systems (4)

Course Content

- Introduction
- Analog Vs. Digital Communication Systems
- A General Communication System, Some Probability Theory, Probability space, random variables, density functions, independence, Expectation, conditional expectation, Baye’s rule, Stochastic processes, autocorrelation function, stationarity, spectral density
- Analog-to-digital conversion, Sampling (ideal, natural, sample-and-hold), Quantization, PCM.
- Source coding (data compression), Measuring information, entropy, the source coding theorem, Huffman coding, Run-length coding, Lempel-Ziv.
- Communication channels, Bandlimited channels, The AWGN channel, fading channels
- Receiver design, General binary and M-ary signaling, Maximum-likelihood receivers Performance in an AWGN channel. The Chernoff and union/Chernoff bounds, Simulation techniques
- Signal spaces
- Modulation: PAM, QAM, PSK, DPSK, coherent FSK, incoherent FSK
- Channel coding, Block codes, hard and soft-decision decoding, performance Convolutional codes, the Viterbi algorithm, performance bounds, Trellis-coded modulation (TCM), Signaling through bandlimited channels ISI, Nyquist pulses, sequence estimation, partial response signaling, Equalization Signaling through fading channels, Rayleigh fading, optimum receiver, performance Interleaving Synchronization, Symbol synchronization, Frame synchronization Carrier synchronization

References:

1. Simon Haykin and Michael Moher. *Communication Systems*. 5th ed, Wiley, 2009.

ECS 322: Electromagnetic Theory (4)

Course Content

- Basic concepts of electrostatics, electric potential theory, electric fields and currents, fields of moving charge, magnetic fields, time varying electromagnetic fields, Maxwell's equations. Review of Maxwell's equations, uniform plane waves in different types of media, reflection, and transmission of uniform plane waves, transmission lines, waveguides, and antennas.
- Coulomb's law and electric fields
- Gauss's law, potential and energy, conductors and dielectrics
- Laplace and Poisson equations, solution methods, and capacitance
- Biot-Savart and Ampere's laws, inductance calculation
- Magnetic materials, Faraday's law and quasi-static analysis
- Maxwell equations and uniform plane waves
- Wave propagation in dielectrics and conductors, skin effect, normal incidence
- Oblique incidence, Snell's law, and total internal reflection
- Transmission lines, Smith chart, impedance matching
- Transients and pulse propagation on transmission line
- Waveguides: Metallic and Dielectric
- Antenna fundamentals

References

1. Kong, J. A. *Electromagnetic Wave Theory*. Cambridge, MA: EMW, 2005. ISBN: 0966814398.

ECS 323: Control Systems (4)

Course Content

To understand the essentials of mathematical system modeling; to be able to assess stability and performance properties of linear systems, and be able to design lead and lag controllers for linear systems using s-domain and frequency domain techniques.

References

1. Modern Control Engineering, 5th edition by Katsuhiko Ogata

ECS 324: Digital Signal Processing (4)

Course Content

An understanding of digital signal processing fundamentals and techniques is essential for anyone whose work is concerned with signal processing applications.This course introduces the basic concepts and principles underlying discrete-time signal processing. Concepts will be illustrated using examples of standard technologies and algorithms.

Topics covered include:

- Sampling and multi-rate systems
- Oversampling and quantization in A-to-D conversion
- Properties of LTI systems
- Digital filter design
- Discrete Fourier Transform and FFT
- Parametric signal modeling
- Applications in speech/audio processing, autonomous vehicles and software radio

References

1. Digital Signal Processing by A. V. Oppenheim and R. W. Schafer

ECS 305: Discrete Mathematics II (4)

Course Content

Modular first half: Abstract algebra

- Group theory: definition of groups, cosets and Lagrange's theorem, subgroups, normal subgroups, quotient groups, group action and Burnside's lemma.

- Rings, Fields, integral domains - basic definitions and properties. Field extensions, Chinese remaindering over integers and polynomial rings. (optional: Introduction to finite fields)

Modular second half: Logic

- Propositional logic syntax and semantics.
- Tautologies, axiom system and deduction.
- Proof of soundness and completeness.

- First order logic syntax and semantics.
- Structures, models, satisfaction and validity.
- Axiomatization, soundness and completeness.
- Optional: some advanced topics.

Books and References:

1. IN Herstein, Abstract Algebra, 3rd Ed., Wiley, 1996.
2. DS Dummit, RM Foote, Abstract Algebra, John Wiley, 2004.
3. HD Ebbinghaus, J Flum, W Thomas, Mathematical Logic, 2nd Ed., Springer Verlag, 1994.
4. HB Enderton, A Mathematical Introduction to Logic, 2nd Ed., Academic Press, 2001.
5. RM Smullyan, First Order Logic, Dover Press, 1995.

ECS 306/411: Algorithms (4)

Course Content

- Amortized analysis.
- Exposure to some advanced data structures (For example, Fibonacci heaps or augmented data structures or interval trees or dynamic trees).
- As part of the course on Data Structures and Algorithms, three algorithm paradigms, namely, greedy method, divide and conquer, and dynamic programming are discussed. These algorithm paradigms should be revisited in this course, but with advanced applications and/or emphasis on their theoretical foundations as follows:
  - ✓ Greedy method: theoretical foundations of greedy method (matroids) and other applications.
  - ✓ Divide and Conquer: FFT algorithm and other applications.
  - ✓ Dynamic Programming: Bellman Ford algorithm and other applications.
- Graph algorithms: all-pairs shortest paths, bi-connected components in undirected graphs, strongly connected components in directed graphs, and other problems.
- Pattern matching algorithms.
- Lower bound on sorting.
- Algorithms for maximum flow and applications.

- Notion of intractability: NP-completeness, reduction (the proof of Cook-Levin theorem may be skipped)
- Exposure to some (one or more) topics from the following list :
  - ✓ Approximation algorithms.
  - ✓ Algebraic and number theoretic algorithms.
  - ✓ Computational Geometry.
  - ✓ Linear programming.
  - ✓ Parallel/distributed algorithms.
  - ✓ Randomized algorithms.

Books and References

1. J Kleinberg, E Tardos, Algorithm Design, Addison-Wesley, 2005.
2. TH Cormen, CF Leiserson, RL Rivest, C Stein, Introduction to Algorithms, 3rd Ed., MIT Press, 2009.
3. AV Aho, J Hopcroft, JD Ullman, The Design and Analysis of Algorithms, Addison-Wesley, 1974.

ECS 307: Theory of Computation (4)

Course Content

- Introduction: Motivation for studying theory of computation, a quick overview of the subject. Notion of formal language. Language membership problem, why this is taken as the central problem of the subject.

- Finite automata and regular expressions: DFA, NFA (with and without transitions), their equivalence. Proof that for some languages NFAs can be exponentially more succinct than DFAs. Definition of regular expressions. Proof that FAs recognize, and regular expressions denote the same class of languages, viz., regular languages.

- Properties of regular languages: Pumping lemma and its use to prove non-regularity of a language, closure properties of class of regular languages, decision properties: converting among representations, testing emptiness, etc. Minimization of DFAs, Myhill-Nerode theorem.

- Context-free grammars and languages: Derivation, parse trees. Language generated by a CFG. Eliminating useless symbols, -productions, unit productions. Chomsky normal form.
- Pushdown automata: Definition, instantaneous description as a snapshot of PDA computation, notion of acceptance for PDAs: acceptance by null states, and by empty stack; the equivalence of the two notions. Proof that CFGs generate the same class of languages that PDAs accept.
- Properties of context-free languages: Pumping lemma for context-free languages and its use to prove a language to be not context-free. Closure properties of the class of context- free languages. CYK algorithm for CFL membership, testing emptiness of CFLs.
- Turing machines: Historical context, informal proofs of undecidability. Definition of TM, instantaneous description as a snapshot of TM computation, notion of acceptance. Robustness of the model: both natural generalizations and restrictions keep the class of languages accepted invariant. (Generalizations: multi-track, multi-tape, nondeterministic, etc. Restrictions: semi-infinite tape, counter machines). Church-Turing hypothesis.
- Undecidability: Definitions of r.e. and recursive languages. Turing machine codes, the diagonalization language and proof that it is not r.e. Universal Turing machine. Universal language, its semi-decidability. Reducibility and its use in proving undecidability. Rices theorem. Undecidability of Posts correspondence problem.
- Intractability: Motivation for the notion. The class P as consensus class of tractable sets. Classes NP, co-NP. Polynomial time reductions. NP-completeness, NP-hardness. Cook- Levin theorem. Mention about boundary of tractability: 2SAT vs. 3SAT, 2D matching vs. 3D matching. Some NP-completeness proofs: vertex cover, clique, independent sets, Hamiltonian graphs, subset-sum, set cover.

Books and References

1. J Hopcroft, JD Ullman, R Motwani, Introduction to Automata Theory, Languages and Computation, 3rd Ed., Pearson, 2008.

2. M Sipser, Introduction to the Theory of Computation, 2nd Ed., Thomson, 2005.
3. M Sipser, Theory of Computation, Brooks-Cole, 2008.

ECS 302: Operating Systems (4)

Course Content

- Introduction: review of computer organization, introduction to popular operating systems like UNIX, Windows, etc., OS structure, system calls, functions of OS, evolution of OSs.
- Computer organization interface: using interrupt handler to pass control between a running program and OS.
- Concept of a process: states, operations with examples from UNIX (fork, exec) and/or Windows. Process scheduling, interprocess communication (shared memory and message passing), UNIX signals.
- Threads: multithreaded model, scheduler activations, examples of threaded programs.
- Scheduling: multi-programming and time sharing, scheduling algorithms, multiprocessor scheduling, thread scheduling (examples using POSIX threads).
- Process synchronization: critical sections, classical two process and n-process solutions, hardware primitives for synchronization, semaphores, monitors, classical problems in synchronization (producer-consumer, readers-writer, dining philosophers, etc.).
- Deadlocks: modeling, chararcterization, prevention and avoidance, detection and recovery.
- Memory management: with and without swapping, paging and segmentation, demand paging, virtual memory, page replacement algorithms, working set model, implementations from operating systems such as UNIX, Windows. Current Hardware support for paging: e.g., Pentium/ MIPS processor etc.
- Secondary storage and Input/Output: device controllers and device drivers, disks, scheduling algorithms, file systems, directory structure, device controllers and device drivers, disks, disk space management, disk scheduling, NFS, RAID, other devices. operations on them, UNIX FS, UFS protection and security, NFS.

- Protection and security: Illustrations of security model of UNIX and other OSs. Examples of attacks.
- Epilogue: Pointers to advanced topics (distributed OS, multimedia OS, embedded OS, real-time OS, OS for multiprocessor machines).

All the above topics will be illustrated using UNIX and/or Windows as case-studies. The lectures will be supplemented by a set of assignments/projects on an instructional operating system. This is the lab component.

Books and References

1. Abraham Silberschatz, Peter B. Galvin, Greg Gagne, Operating System Concepts, 8th Ed., John Wiley, 2008.
2. William Stallings, Operating Systems: Internals and Design Principles. Prentice-Hall, 6th Ed., 2008.
3. AS Tanenbaum, Modern Operating Systems, 3rd Ed., Pearson, 2009.
4. AS Tanenbaum, AS Woodhull, Operating Systems Design and Implementation, 3rd Ed., Prentice Hall, 2006.
5. M. J. Bach. Design of the Unix Operating System, Prentice Hall of India, 1986.

ECS 304: Introduction to Data Science and Machine Learning (4)

Course Content

- Introduction to Data Science
- Big data technologies
- Information management in Big Data and Emerging Issues
- Supervised Learning Algorithms:
    - Logistic Regression
    - Neural Networks
    - Decision Trees
    - Nearest Neighbour
    - Support Vector Machines
    - Naïve Bayes
- ML and MAP estimates
- Bayes' Optimal Classifier
- Introduction to Graphical Models
- Generative Vs. Discriminative Models

- Unsupervised learning algorithms:
  - K-Means clustering
  - Expectation Maximization
  - Gaussian Mixture Models
  - PCA and Feature Selection
  - PAC Learnability
  - Reinforcement Learning

ECS 402: Concurrency Theory (4)

Learning Objectives

A reactive system comprises networks of computing components, achieving their goals through interaction among themselves and their environment. This course aims to develop a general-purpose theory that can be used to describe, and reason about, reactive systems. We introduce Milner's Calculus of Communicating Systems (CCS) for modelling reactive systems, its structural operational semantics, together with the notions of behavioural equivalences and recursive extensions of Hennessy-Milner logic (HML). We also study CCS with time delays, timed automata, timed behavioural equivalences and HML with time.

Course Content

- Calculus of Commu nicating systems, labelled transition systems and structural operational semantics
- Behavioural equivalences
- Theory of fixed points, Tarski's fixed point theorem
- Hennessy-Milner Logic (HML) and HML with recursion
- Theory of real-time systems
- CCS with time delays
- Timed automata and timed behavioural equivalences
- HML with time
- Modeling examples and other process algebras

Books and References

1. Reactive Systems, Modelling, Specification and Verification, Cambrid ge Press, 2007 (First Edition), Luca Aceto, Anna Ingolfsdottir, Kim G. Larsen and Jiri Srba.

2. Introduction to Concurrency Theory - Transition Systems and CCS, Springer International Publishing, 2015 (First Edition), Roberto Gorrieri and Cristian Versari.
3. Process Algebra: Equational Theories of Communicating Processes, Cambridge University Press, 2010, .J.C.M. Baeten, T. Basten and M.A. Reniers.

ECS 421/621: Nonlinear Systems (4)

Learning Objectives

This course will expose the students to various mathematical techniques used in the analysis of nonlinear systems, and their applications to various areas of science and engineering.

Course Content

Fixed Points; Linear Stability Analysis; Saddle-Node Bifurcations; Pitchfork Bifurcations; Nonlinear Pendulum; Phase Portraits; Conservative Systems; Hamiltonian Dynamics; Limit Cycles; Hopf Bifurcations; Lorentz Map; Logistic Map; Chaos; Lyapunov Exponent; Cantor Set and Fractals; Strange Attractors; Perturbation Techniques for Nonlinear ODEs; Ponderomotive Theory; WKB Approximation; Multiple-Scale Analysis: Nonlinear Plasma Waves.

Books and References

1. Steven H. Strogatz, *Nonlinear Dynamics And Chaos* (Westview Press, Massachusetts, 2001).
2. Edward Ott, *Chaos in Dynamical Systems* (Cambridge University Press, Cambridge, 2002)
3. Herbert Goldstein, *Classical Mechanics* (Pearson Education, Essex, 20II)
4. Allan J. Lichtenberg and Michael A. Lieberman, *Regular and Chaotic Dynamics* (Springer, New York, 1992).
5. Ronald C. Davidson, *Methods in Nonlinear Plasma Theory* (Academic Press, New York, 7972)

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ECS 422/622: Plasma and Plasmonics (4)

Learning Objectives

This course will expose the students to various theoretical concepts of plasma science and plasmonics.

Course Content

Mathematical Preliminaries; Maxwell's Equations; Origin of Permittivity; Single Particle Dynamics in EM Fields; Plasma Kinetic Theory; Plasma Fluid Dynamics; Linear Plasma Waves; Surface Plasmon Polaritons; Spoof Surface Plasmons; Negative Index Materials; Particle Traps; Numerical Methods in Electromagnetics.

Books and References

1. Kushal Shah, *Plasma and Plasmonics* (Ane Books, New Delhi, 2017).
2. David J. Griffiths, *Introduction to Electrodynamics* (Pearson Education, Essex, 2014)
3. John D. Jackson, *Classical Electrodynamics* (John Wiley and Sons, New York, 1999)
4. Dwight R. Nicholson, *Introduction to Plasma Theory* (Wiley, New York, 1983)
5. Ronald C. Davidson, *Methods in Nonlinear Plasma Theory* (Academic Press, New York, 1972)
6. Stefan A. Maier, *Plasmonics: Fundamentals and Applications* (Springer, New York, 2007)
7. Allan J. Lichtenberg and Michael A. Lieberman, *Regular and Chaotic Dynamics* (Springer, New York, 1992)
8. Allen Taflove and Susan C. Hagness, *Computational Electrodynamics: The Finite-Difference Time-Domain Method* (Artech House, London, 2005)

ECS 428/628: Nanoelectronics: Fundamentals and Applications (4)

Learning Objectives

The objective of this course is to make students capable of performing the analysis of the following: (1) Semiclassical transport of charge, heat, and spin in nanoelectronic devices, and (2) Quantum transport in nanoelectronic devices.

Course Content

Nanoelectronic devices are now-a-days becoming an integral part of our life. The course is designed for engineering students with little background in quantum mechanics and statistical mechanics to be able to perform semiclassical and quantum analysis of nanoelectronic devices. On the other hand, science students with backgrounds in quantum mechanics and non- equilibrium statistical mechanics will be exposed to the applications on device front. This course is targeted to bridge the gap between the science and engineering in the interdisciplinary field of nanoelectronics. Topics include the Ohm's law from ballistic to diffusive conductors, conductance quantization, quantum vs. electrostatic capacitance, coherent and non-coherent transport, thermoelectricity and heat flow, non-equilibrium Green's function (NEGF) formalism, and spin transport.

Books and References

- Due to the very interdisciplinary nature of the course, dedicated chapter-wise class notes will be provided.

ECS 606: Digital Signal Processing (4)

Learning Objectives

An understanding of digital signal processing fundamentals and techniques is essential for anyone whose work is concerned with signal processing applications. This course introduces the basic concepts and principles underlying discrete-time signal processing.

Course Content

1. Sampling and multi-rate systems.
2. Oversampling and quantization in A/D Conversion.
3. Properties of LTI Systems.
4. Digital filter design.
5. Discrete Fourier Transform (DFT)
6. Parametric signal modeling
7. Application to speech/audio processing.

Books and References

1. Digital Signal Processing by A.V. Oppenheim and R.W. Schafer
2. Digital Signal Processing by J.G. Proakis and D.K. Manolakis, 4^{th} edition.

List of Departmental Electives

CSE

1. Randomized Algorithms
2. Approximation Algorithms
3. Combinatorial Optimization
4. Computational Complexity
5. The Graph Isomorphism Problem
6. Introduction to Software Modeling and Verification
7. Advanced Model Checking
8. Stochastic Model Checking
9. An Introduction to Perti Nets
10. Concurrency theory
11. Introduction to Cyber Physical Systems

ECE

1. Solid State Devices
2. Nanoelectronics: Fundamentals and Applications (includes emerging nanoelectronics)
3. Advanced Solid State Devices
4. Nanoscale Transistors
5. Electronic Transport in Semiconductors
6. Spin Transport (Non-Equilibrium Green's function based formalism, spin diffusion, spin pumping etc.)
7. Spintronics and Nanomagnetics
8. Nonlinear systems
9. Plasma and Plasmonics
10. Analog integrated circuits
11. Digital integrated circuits
12. Compact modeling of transistors
13. Integrated circuit device modeling and simulation
14. Random processes