DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

INTRODUCTION

In July 2000, the Department of Electrical Engineering adopted a new name and identity – ***Department of Electrical & Computer Engineering*** – to reflect the department's efforts in developing greater emphasis on information and communications technology through our research and academic programmes.

Electrical and Computer Engineering are among the most challenging and exciting areas of engineering, and are the key disciplines in today's highly technological society. Electrical and computer engineers have been driving the evolution of technology by being able to effectively apply fundamental concepts while pursuing frontier research, creating new ideas, designing and developing new products. Electrical and computer engineering also involves incorporating knowledge from other disciplines to successfully implement a design, whether a device or a system.

The Department of Electrical & Computer Engineering (ECE) is a fairly large department and has highly professional staff who are world-class experts in their respective fields. Our academic and research staff members are constantly engaged in ground-breaking research activities encompassing a wide range of topics. These span diverse areas such as automatic control, biomedical engineering, communications, computer-aided design (CAD), computer vision and image processing, computers and computer networks, digital signal processing, electronics, intelligent systems, parallel and distributed processing, microelectronic materials and devices, microwave engineering, power engineering and very large scale integrated (VLSI) circuits design.

Our department currently offers two full-time undergraduate degree programmes, **B.Eng. (*Electrical Engineering*)** and **B.Eng. (*Computer Engineering*)**, as well as graduate programmes leading to Masters and Ph.D. degrees for candidates aspiring to a rewarding career.

The electrical and computer engineering landscape is evolving rapidly and poses many challenges to engineers today. In order to prepare our graduates for the challenges ahead, the undergraduate degree programmes had been specially engineered to equip students with a strong foundation in computing, engineering, mathematical and scientific fundamentals (including Biology) during their first two years of study. Senior students will also have the opportunity to enrol in specialised courses that will expose them to the latest technology developments in their areas of interest. Design, which is the heart of engineering, is integrated throughout through various project and independent study modules. The programmes also include the requisite courses in writing, humanities, and social sciences. By providing our graduates with a combination of broad-based fundamentals and specialised knowledge, ECE Dept strives to produce elite engineers who would be best positioned to lead in tomorrow's world.

An engineering education prepares students for a wide range of careers; in fact, many of our country's leaders received an engineering education. More specifically, ECE graduates can

look forward to bright and challenging careers in research, design and development, manufacturing, marketing, management, and other exciting fields. Apart from commercial and government organisations, graduates of the Department are also highly sought after by high technology companies in the following sectors:

Communications:	wireless products including mobile phones, pagers, etc.
Computers:	peripherals, embedded systems, information appliances, etc.
Electronics:	for consumers, automotive industry, defence, etc.
Internet:	networked applications, Internet protocols, etc.
Multimedia:	development for video games, entertainment, education, etc.
Semiconductors:	IC design, wafer fabrication, assembly & test, etc.
Software:	development for engineering design automation, commerce, etc.

A number of enterprising graduates have also become entrepreneurs, setting up new businesses that find innovative ways of applying electrical and computer engineering technologies.

Department Laboratories

Laboratory work and projects are important parts of the training of ECE students. The Department has extensive laboratory facilities for its teaching and research activities, and these include:

Advanced Control Laboratory
Biomedical Engineering Laboratory
Communications Laboratory
Computer Communication Networks Laboratory
Control Simulation Laboratory
Digital Electronics Laboratory
Digital Systems & Applications Laboratory
Electrical Machines & Drives Laboratory
High Voltage Laboratory
Linear Electronics Laboratory
Open Source Software Laboratory
Magnetic Media Laboratory
Mechatronics & Automation Laboratory
Microelectronics Laboratory
Microwave Laboratory
MMIC Modelling & Packaging Laboratory
Mobile Multimedia Research Laboratory
MOS Device Laboratory
PCB Fabrication Facility
Power Systems Laboratory
Power Technology Laboratory
Radar & Signal Processing Laboratory
Signal Processing & VLSI Design Laboratory

Vision & Image Processing Laboratory

B.Eng. (Electrical Engineering)

Electrical Engineering deals with the practical and innovative applications of electrical sciences and other associated disciplines. Mobile wireless communications, design and fabrication of microchips, intelligent robots, computers and information technology are a sample of the exciting applications that you would be dealing with. The B.Eng. (Electrical Engineering) curriculum is specially designed to provide its graduates with a head-start in these rapidly advancing fields. It is deliberately crafted to provide the requisite balance of breadth and depth for a professional electrical engineering education. It also seeks to establish a solid foundation for life-long learning throughout an electrical engineer's career. The programme is fully accredited by the Professional Engineering Board (PEB) Singapore and the Institution of Electrical Engineers (IEE) UK.

B.Eng. (Computer Engineering)

Computer Engineering exploits the synergy between electrical engineering and computer science and enables engineers to incorporate computing devices into almost all aspects of modern living. Computer Engineering covers a wide range of areas, including artificial intelligence, computer-aided design, control, digital and wireless communications, embedded computing systems, microelectronics, multimedia networking and communications, parallel and distributed systems, robotics, and software engineering. The B.Eng. (Computer Engineering) students have the flexibility and opportunity to combine advanced electrical and computer engineering, and computer science modules to achieve high levels of technical competence which is not possible in other similar non-engineering degree programmes. Strongly project-oriented in nature, students can look forward to gaining invaluable hands-on practical experience throughout the programme. Like its B.Eng. (Electrical Engineering) counterpart, the B.Eng. (Computer Engineering) programme has been designed to meet the accreditation requirements of PEB Singapore and IEE (UK).

Admission

Candidates who are interested in the B.Eng. (Electrical Engineering) programme have to gain admission into Faculty of Engineering and follow a common first year of study. They will then be streamed (in accordance with their choice and academic performance) to complete the engineering course in one of the four possible branches, with Electrical Engineering being one of the major branches.

For the B.Eng. (Computer Engineering) programme, students are admitted directly to the course from their first year onwards and they will therefore not be involved in the streaming exercise mentioned in the preceding paragraph.

The Electrical and Computer Engineering Curriculum

The electrical and computer engineering curriculum enables students to design a customized program comprising a specific set of modules, tailored to meet their individual interests and career goals. Table ECE 1 shows the general structure of the B.Eng. (Electrical Engineering) and B.Eng. (Computer Engineering) programmes while Figure A provides an overview of the programmes. Design is emphasised throughout the curriculum through various project and independent study modules.

Table ECE 1: General structure of the B.Eng. (Electrical Engineering) and B.Eng. (Computer Engineering) programmes.

			MC
1	Engineering Modules:	**Total:** (i) Year 1 Technical & Supportive Modules (common for all FoE students) (ii) ECE Core Modules (common for all ECE students) (iii) ECE Breadth Electives (iv) ECE Depth Electives (v) ECE project & independent study modules	**110**
2	Non-Engineering Modules #	(i) Technical Communications I (ii) Technical Communications II (iii) Economics (EC1310 or EC1311) (iv) Human Resource Management (v) Law (vi) A module in National Education (vii) Genes & Society (viii) – (x) Three Cross Faculty Modules (CFMs) – can be from the following list of non-technical electives, or take from approved list of CFMs offered by other faculties or a mixture of both. Non-technical electives include: • Financial Accounting • Management & Organisation • Sociology	2 2 4 3 3 4 4 9-12
# To be reviewed to include General Education Requirement (GER) modules.			

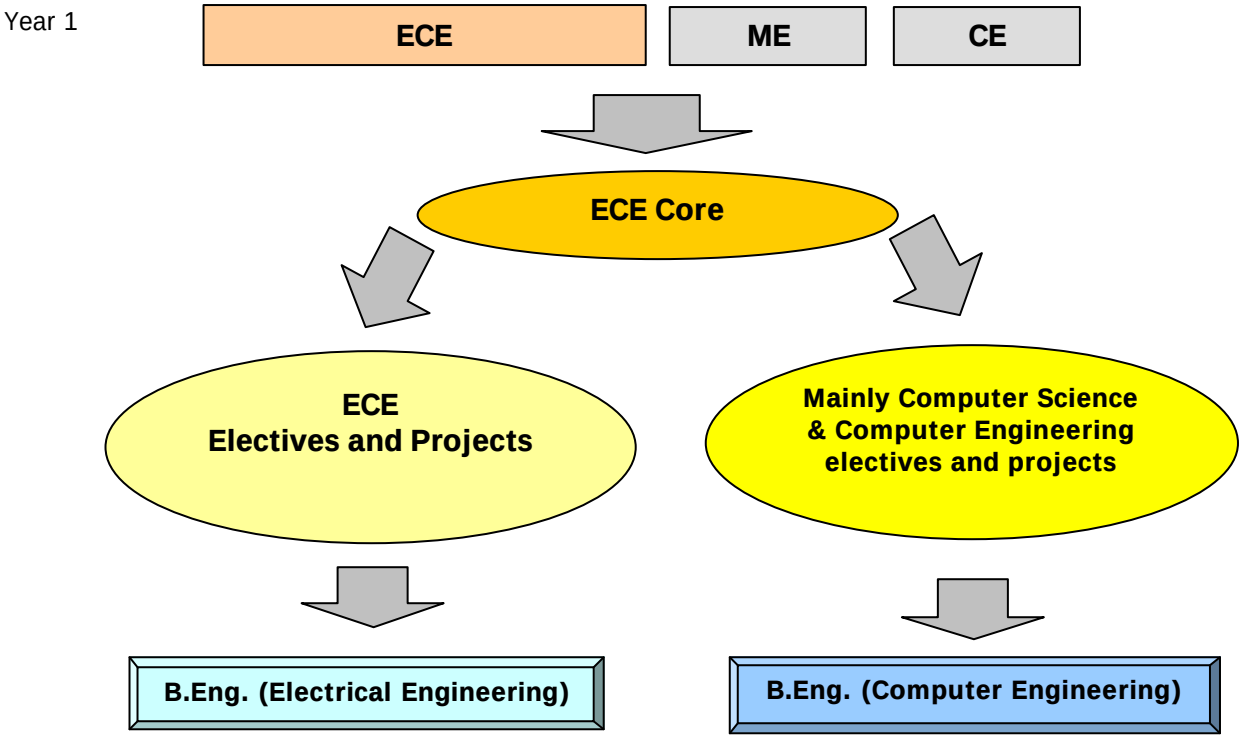

Figure A: An overview of the B.Eng. (Electrical Engineering) and B.Eng. (Computer Engineering) Programmes

For the first stage of both programmes, students will receive a broad-based training which seeks to establish a strong foundation in mathematics, engineering sciences, and computing. For the second stage of both programmes, students will enrol on electrical and computer engineering core modules that focus on fundamental knowledge in electrical and computer engineering. These core modules provide the needed foundation for a variety of specialised technical areas in electrical and computer engineering.

During their senior years of study, students may specialise in certain fields of electrical and computer engineering through their selection of technical electives. Students in both programmes need to choose nine elective modules from the following concentrations: Communications, Computer Engineering, Computer Science (these modules are mainly offered by the School of Computing), Control & Automation, Microelectronics, Power Engineering and Engineering Science. The modules in each concentration are categorised as breadth or depth modules. A breadth module enables students to achieve a broad understanding of concepts in the particular concentration. A depth module is a higher level module that provides greater depth and coverage in the particular concentration.

To achieve "breadth", students need to take at least four breadth electives. Each of the breadth electives must be chosen from each of any four concentrations for B.Eng. (Electrical Engineering) students while B.Eng. (Computer Engineering) students need to choose three

breadth electives from the Computer Engineering and Computer Science concentrations and one breadth elective from one of the other concentrations.

To achieve depth and coverage, students need to take a minimum of four depth electives. For B.Eng. (Computer Engineering) students, at least four of the depth electives must be from the Computer Engineering and/or Computer Science concentrations.

In addition to the above, the main project modules taken by B.Eng. (Computer Engineering) students must be related to the Computer Engineering and/or Computer Science areas.

Selection of Modules

Students are required to offer modules listed in Tables ECE 2 to ECE 4 in accordance with the guidelines for the B.Eng. (Electrical Engineering) and B.Eng. (Computer Engineering) programmes as outlined above. Tables ECE 5A to 5E provide examples of possible specialization tracks. In addition, subjects offered by other departments in the Faculty of Engineering may also be taken as electives (subject to the approval of ECE Dept Head).

The information on the electrical and computer engineering curriculum in this handbook is up-to-date at the time of printing, but it should be noted that the University reserves the right to update the curricula as necessary. Applicants are advised to obtain the latest curricula information from `http://www.ece.nus.edu.sg`.

Table ECE 2: The ECE technical essential modules.

TECHNICAL ESSENTIAL MODULES	Hours per week			Hour	MC	PRE-/CO-REQUISITE
	LEC	TUT	LAB	EXAM		
YEAR1 ENGINEERING MODULES						
EG1103 Electrical and Computer Engineering	2	1	0.5	2	3	-
EG1104 Statics	2	1	0.25	2	3	-
EG1105 Thermodynamics	2	1	0.25	2	3	-
EG1106 Engineering Materials	2	1	0	2	3	-
CS1101C Programming Methodology	2	1	1	2	4	-
EG1107 Dynamics (Common Engrg students)	2	1	0.25	2	3	-
ECE CORE MODULES						
CS1102 Data Structures and Algorithms	2	1	2	2	5	CS1101C
EE2004 Semiconductor Devices	2	1	0.5	2	3	EG1103
EE2005 Electronics	2	1	0.5	2	3	EG1103 & EE2004
EE2006 Digital Design	2	1	0.5	2	3	EG1103
EE2007 Microprocessor Systems	2	1	0.5	2	3	EE2006 (Co-req)
EE2008 Circuits	2	1	0.5	2	3	EG1401, EG1402 & EG1103
EE2009 Signals	2	1	0.5	2	3	EG1401 & EG1402
EE2010 Linear Dynamic Systems	2	1	0.5	2	3	EE2008 (pre-req) EE2002 (co-req)
EE2011 Electromagnetic Fields & Waves	2	1	0.5	2	3	EE2002
ECE PROJECT & INDEPENDENT STUDY MODULES						
EE1001 Independent Study Module I	-	-	-	CA	2	-
EE1002 Independent Study Module II	-	-	-	CA	2	-
EE1003 Independent Study Module III	-	-	-	CA	2	-
EE2001 Project	-	-	6	CA	3	EE2005
EE3001 Project	-	-	4.5	CA	4	EE2001
EE4001 B.Eng. Dissertation (over 2 semesters)	-	-	6	CA	12	EE3001

Table ECE 3: The ECE supportive essential modules.

SUPPORTIVE ESSENTIAL MODULES	Hours per week			Hour	MC	PRE-/CO-REQUISITE
	LEC	TUT	LAB	EXAM		
YEAR1 ENGINEERING MODULES						
EG1401 Mathematics A	2	1	0.25	2	3	-
EG1402 Mathematics B	2	1	0.25	2	3	EG1401
ECE CORE MODULES						
EE2002 Engineering Mathematics 2A	2	1	-	2	3	EG1401 & EG1402
EE2003 Engineering Mathematics 2B	2	1	-	2	3	EG1401 & EG1402
NON-TECHNICAL MODULE						
EG1471 English*	-	(4)	-	3	-	-

* This module must be offered by students who have not passed or been exempted from the Qualifying English Test at the time of admission to the Faculty. There is no modular credit assigned to this module but a pass is required for the award of the degree.

Table ECE 4: The various concentrations and their respective elective modules

TECHNICAL ELECTIVE MODULES		Hours per week			Hour	MC
		LEC	TUT	LAB	EXAM	
COMMUNICATIONS						
Breadth	DSP Fundamentals	2	0.5	0.5	2	3
	HF Techniques	2	0.5	0.5	2	3
	Communications	2	0.5	0.5	2	3
Depth	RF Communications	2	0.5	0.5	2	3
	Digital Communications	2	0.5	0.5	2	3
	Coding Theory and Applications	2	0.5	0.5	2	3
	Microwave Circuits & Devices	2	0.5	0.5	2	3
	Fundamentals of Queueing Theory	2	0.5	0.5	2	3
	Spread Spectrum Communications	2	0.5	0.5	2	3
	MIC & MMIC Design	0.75	0.5	2.0	-	3
COMPUTER ENGINEERING						
Breadth	Software Engineering	2	0.5	0.5	2	3
	Computer Architecture	2	0.5	0.5	2	3
	Computer Communications Networks I	2	0.5	0.5	2	3
	Introduction to Computer Vision & Image Processing	2	0.5	0.5	2	3
Depth	Embedded Computing Systems	2	0.5	0.5	2	3
	Real Time Embedded Systems	2	0.5	0.5	2	3
	Knowledge Based Systems	2	0.5	0.5	2	3
	Biomedical electronics and systems	2	0.5	0.5	2	3
	Multimedia & Web Technology	2	0.5	0.5	2	3
	Advanced Design Project	2	0.5	0.5	2	3
	Computer Communications Networks II	2	0.5	0.5	2	3
	Computer Vision	2	0.5	0.5	2	3
	Image Processing	2	0.5	0.5	2	3
COMPUTER SCIENCE (modules are offered by School of Computing)						
Breadth	Operating Systems	Not available at time of printing				
	Design & Analysis of Algorithms	Not available at time of printing				
	Computer Graphics	Not available at time of printing				
	Foundations of Artificial Intelligence	Not available at time of printing				
Depth	Advanced Operating Systems	Not available at time of printing				
	Computer Animation	Not available at time of printing				
	Speech and Language Processing	Not available at time of printing				
	Advanced Computer Graphics & Virtual Reality	Not available at time of printing				
	Hardware-Software Co-design	Not available at time of printing				
CONTROL & AUTOMATION						
Breadth	Industrial Control Systems	2	0.5	0.5	2	3
	Digital Control Systems	2	0.5	0.5	2	3
Depth	Advanced Control Systems	2	0.5	0.5	2	3
	Robotics	2	0.5	0.5	2	3
	Introduction to Fuzzy/Neural Systems	2	0.5	0.5	2	3
	System Modelling & Simulation	2	0.5	0.5	2	3
	Selected Topics in Control Engineering	2	0.5	0.5	2	3
MICROELECTRONICS						
Breadth	Silicon Processing Technology	2	0.5	0.5	2	3
	Integrated Circuits Design	2	0.5	0.5	2	3
	Technology & Modelling of Silicon Transistors	2	0.5	0.5	2	3
	Microelectronic Materials	2	0.5	0.5	2	3
Depth	Optoelectronics	2	0.5	0.5	2	3

	VLSI Circuits & Systems Design	2	0.5	0.5	2	3
	Selected Topics in Microelectronics	2	0.5	0.5	2	3
	Silicon Device Reliability	2	0.5	0.5	2	3
	Principles & Practice of Optical Data Storage	2	0.5	0.5	2	3
	CMOS VLSI Systems Design Project	0.5	0.5	4.0	-	6
POWER ENGINEERING						
Breadth	Power Electronics	2	0.5	0.5	2	3
	Power Systems Technology	2	0.5	0.5	2	3
	Electrical Machines	2	0.5	0.5	2	3
Depth	Power Systems Analysis & Protection.	2	0.5	0.5	2	3
	Electric Drives and Control	2	0.5	0.5	2	3
	Power Systems Dynamics & Control.	2	0.5	0.5	2	3
	Power Semiconductor Devices & ICs	2	0.5	0.5	2	3
	Magnetic Recording Systems	2	0.5	0.5	2	3
	Magnetic Media Technology	2	0.5	0.5	2	3
ENGINEERING SCIENCE						
Depth	Electronics III	2	0.5	0.5	2	3
	Engineering Mathematics V	2	0.5	-	2	3
	OR & Optimization	2	0.5	-	2	3
	Quality Control. & Reliability Engineering.	2	0.5	-	2	3

Table ECE 5A: Possible Tracks in Communications

Cellular Mobile Communications	Multimedia Communications	Microwave & RF System	Microwave & RF CAD
Electronics III	Electronics III	Electronics III	Electronics III
DSP Fundamentals	DSP Fundamentals	DSP Fundamentals	High Frequency Techniques
Communications	Communications	High Frequency Techniques	RF Communications
High Frequency Techniques	Digital Communications	Communications	Microwave Circuits & Devices
Digital Communications	Coding Theory and Applications	RF Communications	MIC & MMIC Design
Coding Theory and Applications	Fundamentals of Queuing Theory	Digital Communications	Optoelectronics
Spread Spectrum Communications	Computer Communication Networks I		

Table ECE 5B: Possible Tracks Computer Engineering And Computer Science

Embedded Systems	Networking	Multimedia Signal Processing
Embedded Computing Systems	Computer Communication Networks I	Intro to Computer Vision & Image Processing
Operating Systems*	Operating Systems*	Operating Systems *
DSP Fundamentals	DSP Fundamentals	DSP Fundamentals
Real Time Embedded Systems	Computer Communication Networks II	Computer Vision
Software Engineering	Fund. of Queueing Theory	Image Processing
Hardware-Software Co-design*	Multimedia Web Technology	Speech & Language Processing*
Advanced Design Project	Software Engineering	Coding Theory And Applications
Computer Architecture		Computer Communication Networks I

* : offered by School of Computing

Table ECE 5C: Possible Tracks in Control & Automation

Advanced Control	Mechatronics & Automation	Control Applications in Power Electronic Drives/Systems
Digital Control Systems	Industrial Control Systems	Industrial Control Systems
Real Time Systems	Digital Control Systems	Digital Control Systems
Advanced Control Systems	DSP Fundamentals	Electrical Machines
Intro to Fuzzy/Neural Systems	Electric Drives & Control	Electric Drives & Control
System Modeling and Simulations	Robotics	Power Systems Dynamics & Control

Table ECE 5D: Possible Tracks in Microelectronics

General Specialization	General Specialization wit Basic Design	VLSI design	Manufacturing	Optoelectronics
Silicon Processing Technology	Silicon Processing Technology	Integrated Circuits Design	Silicon Processing Technology	Microelectronics Materials
Technology & Modeling of Silicon Transistors	Integrated Circuits Design	CMOS VLSI Systems Design Project	Technology & Modeling of Si Transistors	Optoelectronics
Microelectronics Materials	Technology & Modeling of Silicon Transistors	VLSI Circuits & Systems Design	Microelectronics Materials	Principles & Practice of Optical Data Storage
	Microelectronics Materials		Quality Control & Reliability Engineering	
			Silicon Device Reliability	

Table 5E: Possible Tracks in Power Engineering

Power Electronics & Drives	Power Systems	Magnetic Recording Systems
Power Electronics	Power Electronics	Digital Control Systems
Power Systems Technology	Power Systems Technology	Electric Drives & Control
Digital Control Systems	Industrial Control Systems	Magnetic Recording Systems
Electric Drives & Control	Power System Analysis & Protection	Magnetic Media Technology
Power Semiconductor Devices & Ics	Power System Dynamics & Control	

BRIEF DESCRIPTION OF ECE COURSES

ECE Core Modules (Technical Essential Modules)

EE2001 Project

Each student is required to design, build and test an electronic circuit.

EE2002 Engineering Mathematics 2A

Laplace Transforms - initial value theorem, final value theorem, convolution. Matrices. Eigenvalues and Eigenvectors. Quadratic forms. Solution of differential equations. Vector calculus - scalar and vector fields, line, surface, volume integrals, curl, divergence, Green's theorem, Stokes theorem.

EE2003 Engineering Mathematics 2B

Complex functions. Cauchy-Riemann equations. Laurent series. Conformal mapping. Random variables. Probability density function. Applied statistics. Random process. Stationarity and ergodicity. Power spectral density.

EE2004 Semiconductor Devices

Structure of solids. Physics of Semiconductors. PN Junction. Bipolar Transistors. Field-Effect Transistors. Introduction to IC Fabrication.

EE2005 Electronics

Diode and diode circuits. Zener Diodes. Linear regulated power supplies. Operational Amplifiers and Applications. Analog to Digital and Digital to Analog Conversion. Bipolar Transistor Circuits. MOSFET Circuits.

EE2006 Digital Design

Introduction to VHDL with emphasis on modeling of digital circuits. Mixed logic notation. Combinational circuits. Sequential circuits. Programmable Logic Devices. Storage Devices. IC logic families. Design of state machines - from problem specification to implementation.

EE2007 Microprocessor Systems

Computer Organization. The microprocessor and instruction set architecture. Assembly language programming. Interfacing to microprocessors. Memory and IO systems design. Asynchronous events: interrupts, handshaking. Computer communications and networking.

EE2008 Circuits

Circuit elements - energy storage and dynamics. Transient response. First and second order systems. State Variable analysis of Circuits. Laplace Transform analysis. Frequency Response of Circuits. Phase and amplitude plots. Relationship between time and frequency response.

EE2009 Signals

Signal representation. Continuous time and discrete time signals - periodic signals, spectral representation. Aperiodic signals. Continuous time Fourier transform. Discrete time Fourier transform. Sampling. Spectral Analysis. Power and energy spectrum. Modulation.

EE2010 Linear Dynamic Systems

Introduction to systems. Time and frequency domain descriptions of systems. Time domain analysis of continuous time systems. Time domain analysis of discrete time systems. Stability and natural response. Interconnected systems and feedback.

EE2011 Electromagnetic Fields and Waves

Transmission-line techniques. Fields and field operators. Electrostatics and magnetostatics. Electromagnetic waves: plane-wave propagation, behaviour at interface between media, shielding. Case studies.

CS1102 Data Structures and Algorithms (*offered by School of Computing*)

Data abstraction. Data structures such as stacks, queues, trees (including binary search tree, heap and AVL trees), hashing tables, and graphs; together with corresponding algorithms (tree and graph traversals, minimum spanning trees. Simple algorithmic paradigms, such as generate-and-test (search) algorithms, greedy algorithms and divide-and-conquer algorithms.

ECE Project & independent study modules (Technical Essential Modules)

EE3001 Project

Students are required to participate in a group project to study the application and commercialization of engineering technology.

EE4001 BEng Dissertation

Each student is required to work on a two-semester project which involves some element of research and development in electrical engineering.

ECE Technical Elective Modules – Communications

DSP Fundamentals

One and two dimensional z-transform. Inverse z-transform. Properties of z-transform. One and two dimensional Discrete Fourier transform. Properties of DFT. Inverse DFT. Fast Fourier transform. Circular and linear convolution. Linear time-invariant system. FIR and IIR digital filters. Rectangular and Hamming windows.

High-Frequency Techniques

Guided waves: coaxial lines, planar lines, waveguides, cavities. Scattering parameters: scattering matrix, network analysis. RF components: various coaxial, planar and waveguide components. Wire antennas: retarded potential; Hertzian and half-wave dipoles; broadside and endfire arrays. Electromagnetic interference: metallic shielding, aperture leakage, inductive and capacitive couplings.

Communications

Coding: line and variable length codes, digital facsimile systems. Teletraffic engineering: traffic intensity, grade of service, lost calls cleared model, queuing theory. Multiple access techniques:

circuit, message & packet switching; frequency, time and code division multiple access; frequency & time division duplexing. Television systems: camera & scanning systems, resolution & bandwidth, luminance and chrominance signals, colour TV systems. Telecommunications systems. Mobile radio communication systems: frequency reuse, cellular structures, signal propagation.

Radio-Frequency Communications

Time-varying electromagnetic fields: plane-wave propagation, waveguides, evanescent modes. Antennas: antenna parameters; polarisation; radiation patterns; near and far zone; wire, Yagi, aperture, reflector and microstrip antennas. RF amplification: stability, constant gain circles, small-signal narrowband design. RF generation: conditions for steady-state oscillation, oscillator design, dielectric resonators. RF receivers: receiver parameters, mixers, overall noise temperature. RF systems: system gain, terrestrial systems, satellite systems.

Digital Communications

Review of mathematical preliminaries. Optimum receiver principles. Digital modulation techniques. Performance of coded systems. Introduction to spread-spectrum theory. Direct sequence spread spectrum. Fast and slow frequency-hopped spread spectrum. Pseudo random sequences.

Coding Theory and Applications

Information measures. Source and channel models. Source coding: Huffman coding; Run-length code; Linear predictive coding; Transform coding. Channel coding: Linear block codes; Cyclic codes; Bose-Chaudhary-Hocquenghem codes.

Microwave Circuits and Devices

Microwave amplifiers: theory, microwave transistors, LNA and multistage design. Oscillator theory: nonlinear negative resistance, startup, stability, power generation. Gunn and IMPATT diode oscillators. Planar passive components: coupled lines, hybrid couplers, power dividers / combiners. PIN diode switches and phase shifters. Mixers and detectors: theory, mixer diodes and matching, detectors, single-ended and balanced diode mixers, FET mixers.

Fundamentals of Queueing Theory

Queueing systems. Performance measures of queueing systems. Markov chains. Poisson process. Birth-death process. Renew Process. Birth-death queueing systems. Markov queueing systems. Bulk arrival systems. Bulk service systems. M/G/I queueing systems. Priority queues: non-preemptive and preemptive. Service time dependent priorities.

Spread Spectrum Communications

Direct-Sequence Spread Spectrum (DSSS) Systems. Binary Shift-Register Sequence for SS Systems. Frequency – Hopped Spread Spectrum (FHSS) Systems. Code Tracking Loops. Spreading Code Synchronization. Code Division Multiple Access (CDMA) Systems.

MIC & MMIC Design

Review of Fundamental Design Concepts. MIC Design: fabrication technique, modeling of active and passive network, microstrip and coplanar. MMIC Design: lump element design,

foundry's rules, modeling of active and passive network, design techniques – Layout and DRC Checks.

Selected Hands-on design work on (a) Passive Network — MIC filter and coupler, and (b) Active Network — MMIC oscillator and mixer

ECE Technical Elective Modules – Computer Engineering

Software Engineering

Software project planning, requirements analysis, data flow methods. Software development, object-oriented design, portability and re-use. Software quality assurance, testing strategies and techniques. Case studies.

Computer Architecture

Syllabus not available at time of printing

Computer Communication Networks I

Network requirements, architecture and software. Direct link networks. Packet and cell switching. Internet protocol and internetworking.

Introduction to Computer Vision & Image Processing

Elements of a vision system. 2-D discrete Fourier transform: theory and applications. Image enhancement techniques. Error-free & lossy compression. Segmentation methods. Representation and description. Recognition.

Embedded Computing Systems

Selection of microprocessors and DSPs for various applications. Hardware design and implementation of embedded and general purpose computer systems System interfacing basics: techniques and standards. Communications strategies. Operating systems Design issues. Hardware/software integration. Design to meet regulatory standards. Design case studies.

Real Time Embedded Systems

Introduction to real-time and embedded systems. Time critical I/O handling. Real-time embedded software design. Concurrent programming. Real-time operating systems. Scheduling and time- critical processing. Deadlock management. Process communications. Case studies of real-time embedded systems.

Knowledge-based Systems

Introduction to knowledge-based Systems. Declarative programming languages (Prolog). Control structures and search strategies. Knowledge acquisition. Knowledge representation. Expert systems and case studies.

Biomedical electronics and systems

Introduction to biomedical engineering. Basic anatomy and electro-physiology. Biomedical instrumentation. Bio-potential Measurements. Biomedical signal analysis. Special topics.

Multimedia & Web Technology

Introduction, Web Architecture & Applications Overview, HTML Format, Design Rules, User Interface Elements, Universal Resource Locator & Hyper Text Transfer Protocol, Javascripts & Server-side Programming, Web Server Installation, Configuration and Maintenance, Multimedia Programming Paradigm, Multimedia Programming based on the Web, Media, Multimedia Data Compression, Synchronization, Multimedia Communication, Multimedia Authoring & Presentation, Electronic Commerce: Security issues & payment schemes

Advanced Design Project

This module requires planning and conduct of independent engineering research, development or design projects in areas that involve the use of digital/computational hardware related to one or more (but not limited to) of the following: digital systems, embedded systems, real-time systems.

Computer Communication Networks II

TCP and end-to-end protocols. Congestion control and resource allocation. Network security. Applications.

Computer Vision

Part I of the course studies advanced 2D vision such as edge detection, image segmentation, boundary features, shape features, spatial moments, texture analysis, and mathematical morphology. Part II introduces the basic background for modern 3D vision, with concepts such as Marr's paradigm, active and purposive vision, rigid body transformations, calibration problems, correspondence and flow, epipolar geometry, structure from stereo, and structure from motion.

Image Processing

Introduction to digital image processing techniques for enhancement, compression, restoration. 2-D signals and systems, sampling and scanning, transforms (DCT, KLT etc) and subband decomposition (Wavelets), grayscale transformations. Entropy-based compression, vector quantization, block truncation coding, transform coding, predictive coding, image degradation models, Wiener filter, constrained deconvolution. Efficient representation of multimedia data, including video, and image. State-of-the-art compression technologies with emphasis will be given to a number of standards, including H.26x, MPEG, and JPEG. Current research results in multimedia communications will be reviewed through student seminars in the last weeks of the course.

ECE Technical Elective Modules – Computer Science

Operating Systems *(offered by School of Computing)*

The aim of this module is to introduce students to basic programs of the computer system such as assemblers, macro processors, linkers, compilers, and operating systems that are essential for programming. This module covers machine structure, assembly language programming, macros, linkers, regular expressions and lexical analysis, context free grammars and syntax analysis, syntax directed translation and code generation, processes

and concurrency, mutual exclusion, process communication and synchronization, deadlocks, scheduling, memory management, file management, and I/O management.

Design and Analysis of Algorithms *(offered by School of Computing)*
This module is to teach students different techniques of designing and analyzing algorithms. In this, module students learn about the framework for algorithm analysis, for example lower bound arguments, average case analysis, and the theory of NP-completeness. In addition, students are exposed to various algorithm design paradigms. The module serves two purposes: firstly, to improve the students' ability to design algorithms in different areas, and secondly, to prepare students for the study of more advanced algorithms. The module covers lower and upper bounds, recurrences, basic algorithm paradigms (such as prune-and-search, dynamic programming, branch-and- bound, graph traversal, and randomized approaches), amortized analysis, NP-completeness, and some selected advanced topics.

Computer Graphics *(offered by School of Computing)*
The aim of this module is to understand what is computer graphics. In this class, we will introduce the hardware devices available, review the mathematics related to the understanding, and discuss the fundamental areas of computer graphics. After this class, students are expected to understand the basic computer graphics terminology, concepts, and be able to design and implement simple 2D and 3D interactive computer graphics related programs. The module covers graphics hardware overview, 2D algorithms (line, circle, polygon filling), mathematics for computer graphics, geometric transformations, 3D modeling, and 3D renderings (Z-buffer, ray tracing).

Foundations of Artificial Intelligence *(offered by School of Computing)*
The module introduces students to the basic concepts in search and knowledge representation as well as to a number of sub areas of artificial intelligence to allow them to have a good foundation and overview of the discipline. The emphasis of the module is in covering the essential concepts in AI. The module covers Turing test, blind search, iterative deepening, production systems, heuristic search, A*algorithm, minimax and alpha-beta procedures, predicate and first-order logic, resolution refutation, nonmonotonic reasoning, assumption-based truth maintenance systems, inheritance hierarchies, the frame problem, certainly factors, Bayes' rule, frames and semantic nets, planning, learning, natural language, vision, and expert systems and LISP.

Computer Animation *(offered by School of Computing)*
Computer animation is applied extensively in many fields from fantasy entertainment to science, engineering, medicine and military. The newest 3D interactive devices, together with powerful graphics card (PC) and engine (Workstations) technologies make it possible to interactively animate a complex model. The proposed module will explore systematically the computer animation techniques: interactive devices, mobile data structure and soft object modeling , various motion control and deformation techniques, techniques for animation of natural phenomena, collision detection and animation systems.

Speech and Language Processing *(offered by School of Computing)*
This is a project-based course aims to provide students with hands-on experience through project development by applying the latest technologies in speech and language processing.

The course covers the following areas: Basic knowledge on human language: Human voice and human languages, phonemes, syllabuses, words form and meaning, printed fonts, handwriting, part-of-speech, sentences, paragraphs and text. Language processing technique includes: techniques and algorithms for speech recognition, dynamic time wrapping(DTW), Hidden Markov Modelling(HMM), speech feature vectors, vector quantizations(VQ), speech synthesis, PSOLA technique, morphological analysis, word segmentation, part-of-speech and parsers, word spotting, sentences understanding, representation of sentence in logic, text retrieval, text knowledge extraction. The teaching of the course will be algorithm oriented and theories are introduced using program examples. The mastering of the technologies through practical experiences is the main approach. Part of the course materials will be composed by the students through a seminar series.

Advanced Operating Systems *(offered by School of Computing)*
The aims of this module are to explore operating systems concepts not covered in CS2106 by addressing both new topics and discussing in-depth the implementation of familiar concepts. The topics will include process scheduling, synchronization, IPC, distributed system, concurrency control in distributed & non-distributed systems, load distribution, advanced file systems, storage management, protection, reliability, security, and case study of the implementation of 'real' operating systems.

Advanced Computer Graphics & Virtual Reality *(offered by School of Computing)*
The aim of this module is to provide a general treatment of graphics modeling, interactive 3D graphics and virtual reality, and visualization. The module covers: (a) graphics modeling: mathematics of 3D graphics; rendering and ray tracing; polygonal, parametric surface and CSG models; and modeling natural phenomena; (b) interactive 3D graphics and virtual reality: 3D interactions and devices; immersive and non-immersive VR systems; modeling of virtual world; and applications; and (c) visualization: visualizing scalar data in 1D, 2D and 3D; visualization systems and their applications.

Hardware-Software Co-design *(offered by School of Computing)*
(Prereq: (i) Programming languages (ii) Introduction to Embedded Systems)
Motivation: An advanced course on embedded systems. The aim of this course is to introduce the student to the fundamental issues in hardware/software codesign including issues in system design, various conceptual models that can be used to capture system behaviour, system partitioning and estimation, and synthesis of software and hardware.

ECE Technical Elective Modules –Control & Automation

Industrial Control Systems
Signal processing and conversion: transducers, actuators, instrumentation amplifiers, non-linear amplifiers. Grounds, shields and power supplies. Digital data communication : OSI model in process control, fieldbuses, GPIB (IEEE 488) interfacing. PID control: tuning methods and refinements, auto-tuning principles and implementation, available industrial PID controllers and their operation. Advanced control : Feed-forward, cascade, Smith. Sequence control.

Digital Control Systems

Sampling, Z-transforms and pulse transfer functions. Zero order hold, Discrete equivalence. Sampled Data Systems. Control system design in the digital domain. Transient and Steady State Analysis. Frequency domain analysis and design

Advanced Control Systems

System description. Controllability; Selection of pole locations for good design. Observer design; observability; full-order and reduced-order observers. Combined control law and observer. Introduction of reference input. Non-linearities: non-linearities in control systems, use of root-locus in analysis of non-linear systems. Describing functions, use of describing functions in analysis and design of control systems, non-linear ordinary differential equations, singular points, phase plane analysis.

Robotics

Introduction, Spatial Descriptions and Transformations, Manipulator Forward and Inverse Kinematics, Mechanics of Robot Motion, Robot Dynamics, Static Forces and Torques, Trajectory Planning, Robot Control.

Introduction to Fuzzy/Neural Systems

Fuzzy set theory, fuzzification, defuzzification. Neural network structures and training.

System Modeling and Simulation

Models. Principles and phases of physical modeling. Basic relationships in physics. Bond graphs. Non-parametric and parametric identification methods. Tools for model building. Simulation and model use.

ECE Technical Elective Modules - Microelectronics

Silicon Processing Technology

Silicon wafer preparation: czochralski crystal growth, wafer preparation, crystal properties. Epitaxy: growth kinetics, reactor design consideration, epilayer film properties. Oxidation: growth mechanisms and kinetics, oxidation techiques and systems, oxide properties. Reactive plasma etching: plasma properties, selectivity, anisotropy, plasma chemistry and etch processes, end point detection, plasma damage. Dielectric and polysilicon film deposition, growth processes, properties. Lithography. Solid state diffusion: diffusion models, Fick's laws, Gaussian and erfc profiles, properties of diffused layers. Ion implantation: range theory, types of implants, damage and anneal. Metallization: metallization choices, depostion systems and conditions, reliability issues.

Integrated Circuits Design

IC Fabrication Technology, Inverter Design, CMOS Design, nMOS Design, Elementary Analog Building Blocks, Transconductors Design, A/D and D/A Converters, Design Exercise.

Technology and Modelling of Silicon Transistors

OS capacitor: low and high frequency capacitances, physical models and equivalent circuits. MOS Transistor: long and short channel MOSFET's, characteristics, threshold voltage and

body effect, subthreshold behaviour, device scaling, short-channel effects, CMOS process. MOSFET modelling. gate, drain and dielectric engineering. Bipolar Transistors : structures and high current effects. Conventional and Polyemitter BJT. BICMOS technology.

Microelectronic Materials

Crystal Structure. Elementary quantum mechanics, Schrodinger's equation. Band theory of solids. Optical properties of semiconductors. Surfaces and interfaces. Dielectric Materials. Phase transitions.

Optoelectronics

Photometric and radiometric units. Bandgap engineering in III-V and II-VI compound semiconductors. Exciton, isoelectronic traps. LED, semiconductor laser and photodetector device structure and operational characteristics. Display devices.

VLSI Circuits and Systems Design

CMOS and bipolar analog design. Op-amps and current mirrors. BiCMOS op-amp and logic design. Dynamic circuits. Pipelining technique. Reservation table. State diagram. Test vector generation. D-algorithm.

Silicon Device Reliability

General Failure Mechanisms in ICs: Overview of IC Assembly Process, Classification of Failure Mechanisms, Bonding-related, Packaging-related, Electrical Stress and Metallization Failures. Technology Specific Failure Mechanisms: Hot-Carrier Effects and CMOS Latch-up. IC Yield and Reliability: Mechanisms of Yield Loss in VLSI, Modelling of Yield Loss Mechanisms, Reliability Definitions and Common Failure Distribution Functions. Failure Analysis Techniques: FA Methodology, Failure Verification, Fault Localization, Sample Preparation and Physical/Chemical Characterization.

Principles and Practice of Optical Data Storage

Overview of optical data storage, physical and geometric optics. Read and write techniques, optical pickup heads and computer modelling of optical disk systems. Design and manufacturing processes of optical disk media. Applications. High density recording.

CMOS VLSI Systems Design Project (Duration: One year)

VLSI system design methodology, design flow, test and testability, issues in mixed-mode IC design, clock and timing, design project.

ECE Technical Elective Modules – Power Engineering

Power Electronics

Introduction to power processing using power semiconductor switches. Power semiconductor switches and characteristics. Single- and three-phase AC-to-DC diode bridge rectifiers. Line commutated converters: half-controlled and fully controlled. Operation in the inversion region. DC-to-DC choppers: single- and two-quadrant operation. Basic principles of DC-to-AC inverters. Single-phase and three-phase (six-step) voltage source inverters. Cooling of power

semiconductor devices. Elementary heat-sink and magnetic component design. Basic snubber operation. Application examples of power electronics.

Power System Technology

Power system components; Per unit notation; Fault level. Generation of electrical energy; types, characteristics; cogeneration; Cost of generation; Tariff structure. Power transmission: line parameters, generalised constants, line performance, reactive power compensation. High voltage cables; electric stress; power losses in cables . Distribution; radial and ring main systems, economic conductor size.

Electrical Machines

Three-phase transformers. Synchronous machines. Design, construction and operation of stepper motors, reluctance motors, p.m. motors, universal motors, ac servomotors and single-phase induction motors. Control aspects of small motors.

Power System Analysis and Protection

Modelling of power systems: bus admittance and bus impedance matrices, network building algorithms. Load flow studies: problem formulation, computer solution techniques, applications. Fault analysis: symmetrical components, sequence impedance networks, symmetrical and unsymmetrical faults. Protection: components, relay coordination; protection of distribution systems; differential, and earth fault protection systems.

Electric Drives and Control

Fundamentals of power semiconductor controlled electric drives. DC motor drives: phase-controlled and chopper controlled converters. Induction motor drives: voltage control and variable frequency control. Synchronous motor drives: open-loop, closed-loop variable frequency control. Drives application examples.

Power Systems Dynamics and Control

Synchronous Machine Modelling and Dynamics. Steady-state operation. Transient parameters. Transient and steady state stability. Multi-machine representation of stability. Penalty factor method of determining optimum dispatch. Unit commitment. System Load/ frequency characteristics. Integral frequency control of interconnected systems. Voltage and Reactive Power Control. Transmission system operating limits.

Power Semiconductor Devices and ICs

Introduction to power devices. Carrier physics in power devices: mobility, resistivity, life-time, high-level injection. Breakdown voltage and junction termination: avalanche breakdown, punch-through breakdown. Power devices: power MOSFET for synchronous rectifiers, power diode and recovery phenomena, power transistor and quasi-saturation effects, gate turn-off thyristor, MOS-controlled bipolar device. Smart power ICs: evolution, high-voltage power MOSFETs in integrated circuits, technological limitations in power ICs, protection techniques in power ICs.

Magnetic Recording Systems

Magnets and magnetic materials. Magnetization process; magnetic characteristics, B/H and M-H characteristics of soft and hard magnetic materials. Magnetic circuits; permeance and leakage flux. Principles of magnetic recordings; methods of reading and writing; modelling

and mathematical representation read/write processes. Magnetic heads and media design. Characteristics of heads and media. Technology of recording systems. Optical technology.

Magnetic Media Technology

Physics of materials; basic magnetization process. Magnetic moments; Ferromagnetic materials; band theory of metals; domains. Magnetic recording systems; media types and deposition techniques. Thin-film and particulate media and their characterization. Head/media interface problems. Surface measurement techniques. Vacuum technology; sealing techniques, leak detection and trouble shooting. Contamination control; cleaning systems and cleaning techniques.

ECE Technical Elective Modules – Engineering Science

Electronics III

Analog filters: fundamental concepts, filter types, Butterworth, Chebyshev and Bessel approximations, passive filter design, active filter design, switched capacitor filters; RF Amplifiers: Hybrid-π and y-admittance parameters, RF tuned-amplifier, RF and IF amplifier design; Oscillators: Colpitts and Hartley types; Modulators, demodulators and mixers: AM and FM.

Engineering Mathematics V

This module helps the students in developing understanding of numerical methods and their applications in electrical engineering problems. They are also useful to final-year projects. Besides the fundamental concepts of numerical analysis, various methods to solve ordinary and partial differential equations numerically will be taught. Symbolic computations using existing Mathematica Package will also be presented.

Operations Research and Optimization

Decision-making in operations research. Mathematical programming: basic properties of linear programming, simplex and revised simplex methods. Transportation model, network model. Linear integer programming, dynamic programming, non-linear programming. Queueing models and practice, Markovian decision process.

Quality Control and Reliability Engineering

Introduction to basic statistical process control techniques to improve quality. Process capability studies. Techniques for acceptance sampling. Reliability analysis of components and systems. Reliability data analysis. Introduction to robust design.