Department of Electronics

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The Department

Chair of the Department:
J.S. Wight
Associate Chair, Graduate Studies:
N.G. Tarr

Programs of study and research leading to the master's and Ph.D. degrees in electrical engineering are offered through the Ottawa-Carleton Institute for Electrical Engineering. The Institute, established in 1983, combines the resources of Carleton University and the University of Ottawa. For further information, including admission and program requirements, see page 126.

The Department of Electronics is concerned with the fields of applied and physical electronics. Effort is strongest in four broad areas: computer-aided design for electronic circuits; physics and fabrication technology for solid-state electronic and photonic devices; VLSI and high-speed analog integrated circuits; and microwave and photonic subsystems and circuits. Specific areas of specialization include:

Computer-Aided Circuit Design
Development of hierarchical simulators for mixed analog/digital circuits; analysis and design of switched-capacitor networks; analysis and design of high speed circuits; optimization techniques; synthesis of VLSI circuits using both algorithmic and knowledge-based approaches; analysis and simulations of communications systems links; layout synthesis and module generation

Phototonic Devices
Waveguides and holographic optical elements for optical interconnects; electro-optic modulators and switches; waveguides for sensing applications.

Solid State Devices
Fundamental semiconductor device physics; device design and novel device structures; device modelling for CAD; new fabrication processes; submicron and quantum effect devices; photovoltaics; semiconductor sensors and transducers

Integrated Circuit Engineering
Design and development of linear and digital integrated circuits; fabrication processes and test techniques; MOS, bipolar and BiCMOS ICs; VLSI; computer-aided circuit design

Analog Signal Processing
Switched-capacitor filters, transversal filters, operational amplifiers and radio frequency functions in analog signal processing applications, particularly for integrated circuit realization

Circuits
Active filters; linear and nonlinear circuit design; computer-aided circuit design; phase-locked circuits, carriers and clock synchronizers; mixers, modulators and demodulators

Microwave Electronics
Microwave amplifiers, oscillators, modulators, frequency converters, phase-shifters; use of FET and bipolar transistors, Schottky barrier, varactor, step recovery and PIN diodes; design using finline, microstrip, stripline, coax, and waveguide; monolithic microwave ICs in GaAs; miniature hybrid microwave ICs

Communications and Radar Electronics
Circuits for terrestrial and satellite communications; circuit implementation of digital modulation techniques; antenna and array design; communication channel characterization; optical communications circuits; radar transmitter and receiver design

Biomedical Electronics
Cochlear prosthesis

NSERC/BNR Chair in CAD

The joint Natural Sciences and Engineering Research Council/Bell Northern Research Chairs in Computer-Aided Design are currently held by Dr. Michel Nakhla and Dr. Q.J. Zhang. This is part of a planned expansion of the department in the area of CAD for VLSI.

NSERC/OCRI Chair in High Speed Integrated Circuits

The joint Natural Sciences and Engineering Research Council/Ottawa-Carleton Research Institute Chair in High Speed Integrated Circuits is currently held by Dr. W.M. Snelgrove.

TRIO

The Department is part of the TRIO (Telecommunications Research Institute of Ontario) Centre of

Excellence. Current research areas of the Centre with major participation from the Department are: integrated services digital networks, mobile and portable wireless networks, VLSI in communications, and millimetre wave/optical antennas and circuits for personal communications.

Micronet

The Department is a member, along with seven other Canadian universities and several major industrial organizations, of Micronet, the federally-sponsored network on Microelectronic Devices, Circuits and Systems for ULSI (ultra-large scale integration). Within the Department Micronet supports research on: device structures, modelling and fabrication processes for submicron CMOS and BiCMOS ICs; high-speed filters, phase detectors, A-to-D converters, frequency synthesizers and other circuit elements for silicon ICs operating at radio frequencies; analysis and optimization of interconnects for high-speed ICs; and automated generation of custom cells for VLSI design.

Course Offerings

The structure of the courses offered allows a well-integrated master's or Ph.D. program of study to be chosen appropriately related to the field of thesis research. Device- and integrated-circuit-oriented courses cover: fabrication, semiconductor device theory, semiconductor device design, integrated circuit design and integrated circuit reliability. Circuit-oriented courses include: signal-processing electronics, micro-processor electronics, computer-aided circuit design, phase-locked circuits, filter circuits, RF and microwave circuits, antenna and array design. Systems-oriented courses cover: optical fibre communications and radar systems.

IC Fabrication Facilities

Excellent facilities are available for the fabrication of solid state devices and integrated circuits for research purposes. These include a class-100 clean room in which all basic processes required in silicon monolithic technology can be carried out. The clean room houses facilities for photomask generation and photolithography, modern diffusion furnaces, a rapid thermal annealer, low-pressure chemical vapour deposition systems, ECR and reactive ion etchers, e-beam, RF and magnetron sputtering systems for metal deposition, and a SEM. Equipment for thick film deposition, scribing, bonding, and automatic testing is also available. Comprehensive test facilities are available for IC characterization, including wafer probers, HP4145 Semiconductor Parameter Analyzers and an automated C-V measurement station.

Computing Facilities

The Department has excellent computing facilities available for both circuit design and software development, including facilities for IC design and layout on the silicon chip, allowing IC fabrication either through the Canadian Micro-electronics Corporation or in house. The graduate CAD laboratory consists of twenty-five SUN workstations interconnected via ETHERNET. Industry standard IC design, layout and synthesis software such as EDGE, Synopsys, HSPICE, SILOS, Verilog and VHDL is available, along with the process and device simulation tools SUPREM, SEDAN, Bipole, PISCES and MINIMOS. The Department also has a full COMMON LISP development system running on the SUN network.

Measurement Facilities

Advanced instrumentation is available supporting automated testing of both analog and digital integrated circuits at frequencies up to 2 GHz. Low noise test facilities include a phase noise measurement system, dynamic signal analyzers, spectrum analyzers, network analyzers, arbitrary waveform generators, digital sampling oscilloscopes, digital data analyzers and generators, and RF frequency synthesizers, all of which may be controlled using the IEEE 488 interface.

The Department has up-to-date facilities for circuit development and measurement at microwave frequencies ranging up to 22 GHz. There are also facilities for work at optical frequencies. Thin-film microwave integrated circuits can be fabricated in house; there is provision for the fabrication of GaAs MMICs through foundry services. Special purpose microwave equipment includes automated network analyzers, spectrum analyzers and frequency synthesizers, and a complete microwave link analyzer. Data generators and error-detection equipment is available for work on digital communications. Industry standard software, such as SERENADE (SUPERCOMPACT, HARMONICA) and ACADEMY (TOUCHSTONE, LIBRA) is available for the computer-aided design and layout of microwave integrated circuits.

The research laboratories maintain extensive collaboration with government and industrial research and development agencies in the Ottawa area.

Graduate Courses*

The courses offered by the Department of Electronics are as follows:

- Engineering 97.551F1 (ELG6351)
Passive Microwave Circuits
Review of EM theory for guided waves; transmission lines and waveguides. Propagation in ferrites. Characteristics of planar transmission lines, both single and coupled; stripline, micro-strip, coplanar lines, slotline. Representation of discontinuities in transmission lines and waveguides. Scattering-matrix characterization of microwave junctions and discontinuities. Microwave network analysis. Design theory (including CAD), characteristics, and use of microwave components such as impedance transformers, filters, hybrids, directional couplers, isolators and circulators with particular emphasis on their realization in microwave integrated circuits.
B.A. Syrett.

- Engineering 97.555F1 (ELG6355)
Passive Circuit Theory
General description of networks, leading to matrix representation of n-terminal lumped and distributed networks. Elements of matrix algebra as applied to networks. Properties of network functions; poles and zeros of driving point and transfer functions. Foster and Cauer canonic forms. Synthesis of lossless two-ports, single and double-terminated. Modern filter theory; approximation of characteristics by rational functions; Butterworth and Chebyshev approximations. General parameter filters; graphical design. Elliptic filters, predistortion. Phase response and group delay; all-pass and Bessel filters.
P.D. van der Puije.

- Engineering 97.556W1 (ELG6356)
Simulation and Optimization of Electronic Circuits
Computer simulation and optimization of electronic circuits. Large-scale simulation and optimization techniques. Performance driven, cost driven and profit driven circuit optimization. Introduction to advanced design methodologies: design centreing, tolerance analysis, yield maximization, postproduction tuning. Systematic formulation of real-world problems into optimization. Model parameter extraction of active and passive devices, least *p*th approximation, decomposition, sensitivity evaluation, Monte-Carlo analysis. Efficient cascaded analysis and application to VLSI systems. Practical CAD problems and methodology.
Q.J. Zhang.

- Engineering 97.557W1 (ELG6357)
Active Circuit Theory
Characterization of negative resistance one-port networks, signal generation and amplification. Active two-ports; *y, z, h, k*, chain and scattering parameters. Measurement of two-port parameters. Activity and passivity; reciprocity, non-reciprocity, and anti-reciprocity. Gyrator as a circuit element. Stability, inherent and conditional; power gain of conjugate and mismatched two-port amplifiers. Amplifier gain sensitivity. Oscillators, maximal loading, and frequency sensitivity. Active filter design; gyrator, negative immittance converter (NIC) and operational amplifier used as functional elements. Practical realization of gyrators and NICs. Active network synthesis.
Prerequisite: Engineering 97.555 or equivalent.
P.D. van der Puije.

- Engineering 97.558F1 (ELG6358)
Computer Methods for Analysis and Design of VLSI Circuits
Basic principles of CAD tools used for analysis and design of VLSI circuits and systems. Formulation of circuit equations. Sparse matrix techniques. Frequency and time-domain solutions. MOS and bipolar macro-models. Relaxation techniques and timing analysis. Noise and distortion analysis. Transmission line effects in high-speed designs. Interconnect analysis and crosstalk simulation. Asymptotic waveform estimation. Mixed frequency/time domain techniques. Sensitivity analysis and its application in optimizing circuit performance.
M.S. Nakhla.

- Engineering 97.559F1 (ELG6359)
Integrated Circuit Technology
Survey of technology used in silicon VLSI integrated circuit fabrication. Crystal growth and crystal defects, oxidation, diffusion, ion implantation and annealing, gettering, chemical vapour deposition, etching, materials for metallization and contacting, and photolithography. Structures and fabrication techniques required for submicron devices. Applications in advanced CMOS and BiCMOS processes.
N.G. Tarr.

***** F,W,S indicates term of offering. Courses offered in the fall *and* winter will be followed by T.
The number following the letter indicates the credit weight of the course: 1 denotes a half-course credit, 2 denotes a full-course credit, etc.

• Engineering 97.562W1 (ELG6362)
Microwave Semiconductor Devices and Applications
Review of basic semiconductor physics, PN junctions and Schottky barriers. Discussion of basic principles of operation, characteristics and applications of varactor diodes (tuning, parametric amplifiers, frequency multipliers), p-i-n diodes (switches, limiters, attenuators, phase shifters), IMPATT and Gunn diodes (negative resistance amplifiers and oscillators), microwave bipolar transistors and MESFETs (amplifiers and oscillators). Design theory (including CAD) of amplifier matching networks. Discussion of microwave device/circuit fabrication technology (discrete, hybrid, monolithic).
B.A. Syrett.

• Engineering 97.563W1 (ELG6363)
Electromagnetic Wave Propagation
Review of groundwave, skywave and transionospheric propagation modes relevant to radar, communications and other systems operating in the medium frequency to extra high frequency bands. The occurrence and magnitude of various types of electromagnetic noise: physical principles involved, modelling and prediction techniques, and limitations of such techniques in practical situations.

• Engineering 97.564W1 (ELG6364)
Radar Systems
Fundamentals; range equation, minimum detectable signal, radar cross-section, pulse repetition frequency, range ambiguities. Classes of Radar; CW, FM-CW, MTI, tracking, air surveillance, SSR, PAR, MLS, SAR, SLAR, OTH, 3D and bistatic radars. Radar subsystems; transmitters, antennas, receivers, processors, displays, detection criteria; CFAR receivers, noise, clutter, precipitation. Waveform design; ambiguity functions, pulse compression. Propagation characteristics; Earth's curvature, refraction, diffraction, attenuation.
P.C. Strickland.

• Engineering 97.565F1 (ELG6365)
Optical Fibre Communications
Transmission characteristics of and design considerations for multi-mode and single-mode optical fibre waveguides; materials, structures, and device properties of light-emitting diodes and laser light sources; photo-diodes, avalanche detectors; repeater design; coupling devices for fibres; noise generation and measurements; inter-modulation, cross-modulation, and non-linearity characterization; analog systems, digital systems, system design accounting for component signal degradation; data bus systems.
D. Beckett, J. Goodwin, L. Tarof, K. Visvanatha.

• Engineering 97.566F1 (ELG6366)
Phase-Locked Loops and Receiver Synchronizers
Phase-locked loops; components, fundamentals, stability, transient response, sinusoidal operation, noise performance, tracking, acquisition and optimization. Receiver synchronizers: carrier synchronizers including squaring loop, Costas loop, and remodulator for BPSK, QPSK BER performance; clock synchronizers including early/late gate, inphase/midphase, and delay line multiplier; direct sequence spread spectrum code synchronizers including single dwell and multiple dwell serial PN acquisition, delay locked loop and Tau-Dither loop PN tracking; frequency hopped spread spectrum time and frequency synchronization.
Calvin Plett.

• Engineering 97.567F1 (ELG6367)
Antennas and Arrays
Terminology and definitions; radiation patterns, beamwidth, beam efficiency, gain, effective area, aperture efficiency, polarization. Basic antenna categories; pencil, defocused, split, multiple, shaped, scanning beam. Basic antenna types; dipole, horns, paraboloid, offset gridded multi-beam, beam-waveguide Cassegrain, Yagi, log-periodic, helix, lens, array. Aperture fundamentals: Fourier transform, phase errors, stationary phase, Rayleigh range, PWS, Woodward synthesis. Field fundamentals; Maxwell's equations, dipoles, radiation and mutual impedance, duality, slotted waveguide. Reflector antennas; GO, Fermat's principle, GO synthesis, physical optics. Paraboloids, dual-polarized reflector, shaping, Cassegrainian feed, profile errors, multi-beam reflectors. Phased array fundamentals; space factor and immersed element pattern, Z-transform, grating lobe diagram, blind spots, thinned arrays, series/corporate/matrix feed, feed systems and phase shifter design.
P.C. Strickland.

• Engineering 97.568W1 (ELG6368)
Fourier Optics
Generalized 2-D Fourier analysis, Fourier-Bessel transforms. Transfer function of an optical system. 2-D sampling theory. Scalar diffraction theory; Helmholtz equation, Green's theorem, Helmholtz-Kirchoff integral equation. Fresnel-Kirchoff and Rayleigh-Sommerfeld diffraction theories. Fraunhofer diffraction. Eikonal equations. The lens as an optical transformer. Optical imaging. Tomography with non-diffracting sources; Fourier slice theorem, filtered and backprojection algorithm. Tomography with non-diffracting sources; Born and Rytov approximations. Bragg cells and their application in correlators and spectrum analyzers. Holography, volume holograms, computer-generated

holograms, optical elements. Analog optical computing; photorefractives, spatial light modulators. Holographic memories and data storage. Generalized optical processors. Spatial filters; van der Lugt, phase-only, and binary phase-only filters. Optical pattern recognition.
R.G. Harrison.

• Engineering 97.569W1 (ELG6369)
Nonlinear Microwave Devices and Effects
Technology of discrete and integrated nonlinear devices and circuits (MMICs) up to submillimeter frequencies. Device modelling: varistor and varactor devices including Schottky, tunnel and resonant-tunnelling diodes; cryogenic devices including Josephson junctions, and SIS quasiparticle tunnel junctions; active devices including GaAs and InP MESFETs, HBTs and HEMTs. Gunn and optical effects in MESFETs. Simulation of nonlinear microwave circuits: analytical methods for global insight (algebraic harmonic balance, Volterra series, Ritz-Galerkin); numerical methods for design (integration and extrapolation, shooting methods, generalized power-series analysis, numerical harmonic balance, and the almost-periodic Fourier transform. Multi-valued solutions, jump phenomena and hysteresis, bifurcations and chaotic behaviour. Practical examples illustrating theoretical aspects: detectors, mixers, modulators, frequency multipliers, frequency dividers.
R.G. Harrison.

• Engineering 97.571F1 (ELG6371)
Optical and Microwave Remote Sensing Instrumentation
Introduction to airborne and remote sensing for environmental monitoring. Interaction of optical and microwave radiation with the Earth's surface and its impact on sensing and instrumentation design and operation. Airborne platform motion compensation schemes and their application to geometric correction of airborne imagery. Passive and active electro-optical senors. Radar systems: clutter measurement; scatterometers, real aperture strip mapping radar (SLAR); synthetic aperture strip mapping radars (SAR).
C.E. Livingstone and members of the Department.

• Engineering 97.572F1 (ELG6372)
Optical Electronics
Generation, manipulation and transmission of optical radiation, with emphasis on fundamental principles. Applications in optical sensing, optical communications and optical computing. Electromagnetic wave propagation in crystals; review of geometric optics; Gaussian beam propagation; optical fibres; dielectric waveguides for optical integrated circuits; optical resonators; optical properties of materials; theory of laser oscillation; specific laser systems; electro-optic modulators; photorefractive materials and applications; holography; optical interconnects.
B.A. Syrett.

• Engineering 97.577W1 (ELG6377)
Microelectronic Sensors
This course is concerned with the fabrication and physical principles of operation of microelectronic sensors. A large variety of sensors will be studied and the basic fabrication methods used in their production reviewed. The devices discussed will include optical sensors, fibre optic sensors, magnetic sensors, temperature sensors and, briefly, chemical sensors. A substantial portion of the course will be devoted to micro-mechanical sensors.
T.J. Smy.

• Engineering 97.578F1 (ELG6378)
ASICs in Telecommunications
The definition of Application Specific Integrated Circuits is given along with current ASIC technology trends. CMOS and BiCMOS fabrication technologies are compared for their potential use in communications circuits. Circuit building blocks such as amplifiers, switched-capacitor fiters and analog to digital converters are overviewed in the context of their communications applications. An overview of vendor technologies is followed by application examples such as line drivers, pulse shaping and equalization circuits, high-speed data transmission over twisted pair copper cables and mobile radio components and implementation issues. Students are required to submit a related literature study and design a communications integrated circuit component using a standard cell library environment.
T.A. Kwasniewski.

• Engineering 97.579W1 (ELG6379)
Advanced Topics in Electromagnetics
Recent and advanced topics in electromagnetics, antennas, radar systems, microwave devices and circuits, or optoelectronics. The subject material will vary from year to year according to research interests in the department and/or expertise provided by visiting scholars or sessional lecturers.

• Engineering 97.580F1 (ELG6380)
Theory of Semiconductor Devices
Review of solid state physics underlying device mechanisms. Equilibrium and non-equilibrium conditions in a semiconductor. Carrier transport theory. Physical theory of basic semiconductor device structures and aspects of design: PN junctions and bipolar transistors, field effect devices. Current transport relationships for transistors.

Charge control theory. Modelling of device mechanisms. Performance limitations of transistors.
T.J. Smy.

• Engineering 97.582W1 (ELG6382)
Surface-Controlled Semiconductor Devices
Basic theory of the MOS capacitor structure; charge and capacitance relationships; characterization of practical structures. MOSFET theory: classical 1-D analysis, Pao-Sah model, charge-sheet model, saturation region analysis. Small-geometry devices, scaling theory. Dynamic behaviour of MOSFETs: quasi-static models, capacitance characterization. Device modelling for CAD.
D.J. Walkey.

• Engineering 97.583F1 (ELG6383)
Silicon Compilers: Automated IC Synthesis
Various topics related to computer analysis and synthesis of integrated circuits including automatic programable logic array/finite state machines compilers, silicon compilers and automatic test plan generators.
Prerequisite: Some IC design knowledge as given, for example, by Engineering 97.469.
J.P. Knight.

• Engineering 97.584F1 (ELG6384)
VLSI Design
An integrated circuit design course with a strong emphasis on design methodology, to be followed by 97.585 in the second term. The design philosophies considered will include Full Custom design, standard cells, gate-arrays and sea-of-gates using CMOS and BiCMOS technology. State-of-the-art computer-aided design tools are available on a network of SUN workstations.
M.C. Lefebvre.

• Engineering 97.585W1 (ELG6385)
VLSI Design Project
A continuation of 97.584. Students will have reviewed and tested earlier designs in the course, and will initiate their own design of an integrated circuit and submit it for fabrication where the design warrants. This course will require considerable project time in our CAD laboratory.
M.C. Lefebvre.

• Engineering 97.586F1 (ELG6386)
Computer-Aided Design: Circuit Design Aids
This course will cover a variety of computer tools for creating and analyzing integrated circuit designs. The theoretical part of the course will cover the methods and algorithms used in CADENCE, ELECTRIC and/or similar tools. In particular, logic simulation, fault simulation, placement routing, layout verification, and synthesis will be considered.
J.P. Knight.

• Engineering 97.587W1 (ELG6387)
Microprocessor Electronics
This course introduces the student to the analysis and design of a microprocessor-based system, integrating the three design aspects: signal representation and processing, hardware and software. Topics discussed are stochastic processes, digital signal representation (as applied to a microprocessor system design), conversion and arithmetic errors, real-time applications software support, micro-architecture of VLSI systems, innovative modern micro- and DSP-processors, bit slices, A/D and D/A converters, controller chips. Students will be given design examples and prepare their own microcomputer system designs.
Prerequisite: Engineering 97.476 or equivalent.
T.A. Kwasniewski.

• Engineering 97.588F1 (ELG6388)
Signal Processing Electronics
Signal processing from the viewpoint of analog integrated circuit design. CCD’s, transversal filters, recursive filters, switched capacitor filters, with particular emphasis on integration of analog signal processing techniques in monolithic MOS ICs. Detailed op amp design in CMOS technology. Implications of nonideal op amp behaviour in filter performance. Basic sampled data concepts, detailed Z transform analysis of switched capacitor filters, oversampled A/D converters and more complex circuits. Noise in analog and sampled analog circuits, including calculation of dynamic range and signal to noise ratio.
M.A. Copeland.

• Engineering 97.589F1, W1 (ELG6389)
Advanced Topics in Electronics
A course dealing with selected advanced topics of recent interest in the broad field of solid state devices, electronic circuits, and electromagnetics. Specified topics to be announced each year. Course usually given on a seminar basis with student presentations on assigned topics.

• Engineering 97.590F1, W1, S1
Engineering Project I
A one-term course, carrying half-course credit, for students pursuing the course work M.Eng. program. An engineering study, analysis and/or design project under the supervision of a faculty member. Results will be given in the form of a written report and presented orally. This course may be repeated for credit.

• Engineering 97.591F2, W2, S2
Engineering Project II
A one-term course, carrying full-course credit, for students pursuing the course work M.Eng. program

or the cooperative M.Eng. program. An engineering study, analysis and/or design project under the supervision of a faculty member. Results will be given in the form of a written report and presented orally. This course may be repeated for credit.

- Engineering 97.596F1, W1, S1
Directed Studies
Various possibilities exist for pursuing directed studies on topics approved by a course supervisor, including the above listed course topics where they are not offered on a formal basis.

- Engineering 97.599F4, W4, S4
M.Eng. Thesis

- Engineering 97.699F, W, S
Ph.D. Thesis