### Electrical and Computer Engineering

#### Program Requirements
Subject to the approval of the departmental chair, a student may take up to half of the course credits in the program in other disciplines (e.g., Mathematics, Computer Science, Physics).

Master's programs with a thesis earn the Master of Applied Science degree, while other master's programs earn the Master of Engineering degree.

#### M.A.Sc. Electrical and Computer Engineering (5.0 credits)
Requirements:

1. **2.5 credits in courses** 2.5
2. **2.5 credits in Thesis** 2.5

Total Credits 5.0

#### M.Eng. Electrical and Computer Engineering (5.0 credits)
Requirements - by project:

1. **4.5 credits in courses** 4.5
2. **0.5 credit in project** 0.5

Total Credits 5.0

Requirements - by coursework:

1. **5.0 credits in courses** 5.0

#### M.A.Sc. Electrical and Computer Engineering with Specialization in Data Science (5.0 credits)

Requirements - by Thesis (5.0 credits)

1. **0.5 credit in:**
   - DATA 5000 [0.5] Data Science Seminar
2. **0.5 credit from data science elective courses:**
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5003 [0.5] Discrete Stochastic Models
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software
   - SYSC 5103 [0.5] Software Agents
   - SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   - SYSC 5201 [0.5] Computer Communication
   - SYSC 5207 [0.5] Distributed Systems Engineering
   - SYSC 5300 [0.5] Advanced Health Care Engineering
   - SYSC 5303 [0.5] Interactive Networked Systems and Telemedicine
   - SYSC 5306 [0.5] Mobile Computing Systems
   - SYSC 5401 [0.5] Adaptive and Learning Systems
   - SYSC 5404 [0.5] Multimedia Compression, Scalability, and Adaptation
   - SYSC 5405 [0.5] Pattern Classification and Experiment Design
   - SYSC 5407 [0.5] Planning and Design of Computer Networks
   - SYSC 5500 [0.5] Designing Secure Networking and Computer Systems
   - SYSC 5703 [0.5] Integrated Database Systems
   - SYSC 5706 [0.5] Analytical Performance Models of Computer Systems

3. **1.5 credits in courses** 1.5
4. **2.5 credits in:**
   - in the area of data science (each candidate submitting a thesis will be required to undertake an oral defence of the thesis)

Total Credits 5.0

Requirements - by Project (5.0 credits)

1. **0.5 credit in:**
   - DATA 5000 [0.5] Data Science Seminar

2. **1.0 credit from data science elective courses:**
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5003 [0.5] Discrete Stochastic Models
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software
   - SYSC 5103 [0.5] Software Agents
   - SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   - SYSC 5201 [0.5] Computer Communication
   - SYSC 5207 [0.5] Distributed Systems Engineering
   - SYSC 5300 [0.5] Advanced Health Care Engineering
   - SYSC 5303 [0.5] Interactive Networked Systems and Telemedicine
   - SYSC 5306 [0.5] Mobile Computing Systems
   - SYSC 5401 [0.5] Adaptive and Learning Systems
   - SYSC 5404 [0.5] Multimedia Compression, Scalability, and Adaptation
   - SYSC 5405 [0.5] Pattern Classification and Experiment Design
   - SYSC 5407 [0.5] Planning and Design of Computer Networks
   - SYSC 5500 [0.5] Designing Secure Networking and Computer Systems
   - SYSC 5703 [0.5] Integrated Database Systems
   - SYSC 5706 [0.5] Analytical Performance Models of Computer Systems

3. **3.0 credits in courses** 3.0
4. **0.5 credit in:**
   - SYSC 5900 [0.5] Systems Engineering Project in the area of data science

Total Credits 5.0

Requirements - by Coursework (5.0 credits)

1. **0.5 credit in:**
   - DATA 5000 [0.5] Data Science Seminar

2. **1.5 credits from data science elective courses:**
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5003 [0.5] Discrete Stochastic Models
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software

SYSC 5900 [0.5] Systems Engineering Project in the area of data science

Total Credits 5.0

UNOFFICIAL 2017-2018 Carleton University Graduate Calendar
### Cooperative Master's Degree (5.0 credits)
Participation in the Cooperative Master's program is subject to acceptance by a suitable sponsoring organization.

**Requirements - by thesis**
1. **3.0 credits in courses**
2. **2.0 credits in Thesis**

Total Credits **5.0**

**Requirements - by project**
1. **4.0 credits in courses**
2. **1.0 credit in two 0.5-credit projects (Each project conducted in one of two work terms)**

Total Credits **5.0**

### Ph.D. Electrical and Computer Engineering (10.0 credits)
Subject to the approval of the advisory committee, a student may take up to half of the course credits in the program in other disciplines (e.g., Mathematics, Computer Science, Physics).

**Requirements:**
1. **1.5 credits in courses**
2. A comprehensive examination involving written and oral examinations and a written thesis proposal, to take place before the end of the fourth term of registration
3. **8.5 credits in a thesis which must be defended at an oral examination**

Total Credits **10.0**

### Graduate Courses
In all programs, the student may choose graduate courses from either university with the approval of the adviser or advisory committee. Course descriptions may be found in the departmental section of the calendar. All courses are of one term duration. Only a selection of courses listed is given in a particular academic year. The following codes identify the department offering the course.

#### Carleton University
- ELEC Department of Electronics
- SYSC Department of Systems and Computer Engineering

#### University of Ottawa
- EACJ School Electrical Engineering and Computer Science

### Course List by Research Area
#### BIOMEDICAL ENGINEERING
**Systems and Computer Engineering (Carleton)**
- SYSC 5300 (ELG 6130) Advanced Health Care Engineering
- SYSC 5301 (ELG 6131) Advanced Topics in Biomedical Engineering
- SYSC 5302 (ELG 6321) Biomedical Instrumentation
- SYSC 5303 (ELG 6133) Interactive Networked Systems and Telemedicine
- SYSC 5304 (ELG 5127) Medical Image Processing
- SYSC 5307 (ELG 6307) Biological Signals

**School of Engineering and Computer Science (Ottawa)**
- EACJ 5303 (ELG 5123) Health Care Engineering

#### COMPUTER AIDED DESIGN FOR ELECTRONIC CIRCUITS
**Department of Electronics (Carleton)**
- ELEC 5401 (ELG 6341) Signal Integrity in High-Speed Designs: Modeling and Analysis
- ELEC 5402 (ELG 6342) Introduction to Electronic Design Automation Algorithms and Techniques
- ELEC 5404 (ELG 6344) Neural Networks for High-Speed/High-Frequency Circuit Design
- ELEC 5405 (ELG 6340) Advanced Linear and Nonlinear Circuit Theory and Applications
- ELEC 5504 (ELG 6354) Analysis of High-Speed Electronic Packages and Interconnects
- ELEC 5506 (ELG 6356) Simulation and Optimization of Electronic Circuits
- ELEC 5508 (ELG 6358) Computer Methods for Analysis and Design of VLSI Circuits
- ELEC 5704 (ELG 6374) Advanced Topics in CAD
- ELEC 5803 (ELG 6383) Behavioural Synthesis of ICs

**School of Engineering and Computer Science (Ottawa)**
- EACJ 5705 (ELG 5195) Digital Logic Design

#### COMPUTER AND SOFTWARE ENGINEERING
**Systems and Computer Engineering (Carleton)**
- SYSC 5003 (ELG 6103) Discrete Stochastic Models
- SYSC 5005 (ELG 6105) Optimization Theory and Methods
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<th>Course Code</th>
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<tr>
<td>SYSC 5006 (ELG 6106)</td>
<td>Design of Real-Time and Distributed Systems</td>
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<td>SYSC 5409</td>
<td>Interactive Media and Digital Art</td>
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<td>SYSC 5101 (ELG 6111)</td>
<td>Design of High Performance Software</td>
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<td>SYSC 5102 (ELG 6112)</td>
<td>Performance Measurement and Modeling of Distributed Applications</td>
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<td>Software Agents</td>
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<td>SYSC 5104 (ELG 6114)</td>
<td>Methodologies For Discrete-Event Modeling And Simulation</td>
</tr>
<tr>
<td>SYSC 5105 (ELG 6115)</td>
<td>Software Quality Engineering and Management</td>
</tr>
<tr>
<td>SYSC 5106 (ELG 6118)</td>
<td>Topics in Information Systems</td>
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<td>SYSC 5508 (ELG 6158)</td>
<td>Digital Systems Architecture</td>
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<td>SYSC 5701 (CSI 5117)</td>
<td>Operating System Methods for Real-Time Applications</td>
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<td>SYSC 5703 (ELG 6173)</td>
<td>Integrated Database Systems</td>
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<td>SYSC 5704 (ELG 6174)</td>
<td>Elements of Computer Systems</td>
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<td>SYSC 5706 (ELG 6176)</td>
<td>Analytical Performance Models of Computer Systems</td>
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<td>SYSC 5708 (ELG 6178)</td>
<td>Model-Driven Development of Real-Time and Distributed Software</td>
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<td>SYSC 5806 (ELG 6186)</td>
<td>Object Oriented Design of Real-Time and Distributed Systems</td>
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<td>EACJ 5009 (ELG 5383)</td>
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<td>Switching and Traffic Theory</td>
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<td>EACJ 5200 (ELG 5120)</td>
<td>Queuing Systems</td>
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<tr>
<td>EACJ 5218 (ELG 5122)</td>
<td>Analysis/Perf Eval: Comp Comm</td>
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<td>EACJ 5206 (ELG 5126)</td>
<td>Source Coding and Data Compress.</td>
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<td>EACJ 5208 (ELG 7185)</td>
<td>Wireless Ad Hoc Networking</td>
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<td>EACJ 5500 (ELG 5371)</td>
<td>Digital Comm by Satellite</td>
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<tr>
<td>EACJ 5605 (ELG 7177)</td>
<td>Topics in Communications I</td>
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<td>EACJ 5606 (ELG 7178)</td>
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<td>EACJ 5607 (ELG 5374)</td>
<td>Computer-Communication Network</td>
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<td>EACJ 5639 (ELG 5396)</td>
<td>Internetworking Technologies</td>
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<td>EACJ 5384/COMP 5406 [0.5] (ELG 5384,CSI 5105,LEG 5384)</td>
<td>Network Security and Cryptography</td>
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<td>ELEC 5605 (ELG 6365)</td>
<td>Optical Fibre Communications</td>
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<tr>
<td>ELEC 5606 (ELG 6366)</td>
<td>Phase-Locked Loops and Receiver Synchronizers</td>
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<td>SYSC 5109 (ELG 6119)</td>
<td>Teletraffic Engineering</td>
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<td>Algebraic Coding Theory</td>
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<td>SYSC 5606</td>
<td>Introduction to Mobile Communications</td>
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<td>SYSC 5607</td>
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<td>SYSC 5608</td>
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<td>SYSC 5609</td>
<td>Digital Television</td>
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<td>SYSC 5700</td>
<td>Spread Spectrum Systems</td>
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<tr>
<td>SYSC 5802</td>
<td>Introduction to Information and System Science</td>
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<tr>
<td>SYSC 5804</td>
<td>Advanced Topics in Communications Systems</td>
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<td>Fourier Optics</td>
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<td>Secure Comm and Data Encryption</td>
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<td>Stochastic Systems</td>
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<td>Stochastic Processes</td>
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<td>EACJ 5132</td>
<td>Smart Antennas</td>
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<tr>
<td>EACJ 5133</td>
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<td>EACJ 5360</td>
<td>Digital Watermarking</td>
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<td>Information Theory</td>
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**INTEGRATED CIRCUITS AND DEVICES**

**Department of Electronics (Carleton)**

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<tr>
<td>ELEC 5502</td>
<td>Analog Integrated Filters</td>
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<td>ELEC 5503</td>
<td>Radio Frequency Integrated Circuit Design</td>
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<td>ELEC 5509</td>
<td>Integrated Circuit Technology</td>
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<td>ELEC 5600</td>
<td>Digital Integrated Circuit Testing</td>
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<td>ELEC 5703</td>
<td>Advanced Topics in Solid State Devices and IC Technology</td>
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<tr>
<td>ELEC 5705</td>
<td>Advanced Topics in VLSI</td>
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<td>ELEC 5706</td>
<td>Submicron CMOS and BiCMOS Circuits for Sampled Data Applications</td>
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<td>Microsensors and MEMS</td>
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<td>Theory of Semiconductor Devices</td>
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<td>High-Speed and Low-Power VLSI</td>
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<td>Surface-Controlled Semiconductor Devices</td>
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<td>ELEC 5804</td>
<td>VLSI Design</td>
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<td>ELEC 5805</td>
<td>VLSI Design Project</td>
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<td>ELEC 5808</td>
<td>Signal Processing Electronics</td>
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<td>ELEC 5809</td>
<td>Nonlinear Electronic Circuits</td>
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**Systems and Computer Engineering (Carleton)**

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<tr>
<td>SYSC 5803</td>
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<td>EACJ 5103</td>
<td>Parallel Processing with VLSI</td>
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<td>EACJ 5208/</td>
<td>Wireless Ad Hoc Networking</td>
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**MICROWAVES AND ELECTROMAGNETICS**

**Department of Electronics (Carleton)**

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<td>ELEC 5409</td>
<td>Microwave and Millimeterwave Integrated Circuits</td>
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<tr>
<td>ELEC 5501</td>
<td>Passive Microwave Circuits</td>
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<tr>
<td>ELEC 5602</td>
<td>Microwave Semiconductor Devices and Applications</td>
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<td>ELEC 5604</td>
<td>Radar Systems</td>
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<td>ELEC 5607</td>
<td>Fundamentals of Antenna Engineering</td>
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<tr>
<td>ELEC 5608 (ELG 6368)</td>
<td>Fourier Optics</td>
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<td>ELEC 5609 (ELG 6369)</td>
<td>Nonlinear Microwave Devices and Effects</td>
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<td>ELEC 5707 (ELG 6377)</td>
<td>Microsensors and MEMS</td>
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<td>ELEC 5709 (ELG 6379)</td>
<td>Advanced Topics in Electromagnetics</td>
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<td>ELEC 6368</td>
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**School of Engineering and Computer Science (Ottawa)**

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<tr>
<td>EACJ 5305 (ELG 5108)</td>
<td>Electromagnetic Compatibility</td>
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<td>EACJ 5401 (ELG 5104)</td>
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<td>EACJ 5402 (ELG 5379)</td>
<td>Numerical Methods: Electromagnetiques</td>
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**PHOTONIC SYSTEMS**

**Department of Electronics (Carleton)**

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<td>ELEC 5702 (ELG 6372)</td>
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<td>ELEC 5705 (ELG 6375)</td>
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<td>ELEC 5708 (ELG 6378)</td>
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<td>Advanced Topics in Electromagnetics</td>
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<td>EACJ 5004 (ELG 5381)</td>
<td>Photonics Networks</td>
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<td>EACJ 5201 (ELG 5103)</td>
<td>Optical Communications Systems</td>
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<td>EACJ 5404 (ELG 7100)</td>
<td>Topics in Electromagnetics I</td>
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**SIGNAL, SPEECH, AND IMAGE PROCESSING**

**Systems and Computer Engineering (Carleton)**

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<td>SYSC 5304 (ELG 5127)</td>
<td>Medical Image Processing</td>
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<td>SYSC 5370 (ELG 5370)</td>
<td>Multiresolution Signal Decomposition: Analysis and Applications</td>
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<td>SYSC 5404</td>
<td>Multimedia Compression, Scalability, and Adaptation</td>
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<td>SYSC 5600 (ELG 6160)</td>
<td>Adaptive Signal Processing</td>
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<td>SYSC 5601 (ELG 6161)</td>
<td>Neural Signal Processing</td>
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<td>SYSC 5602 (ELG 6162)</td>
<td>Digital Signal Processing</td>
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<tr>
<td>SYSC 5603 (ELG 6163)</td>
<td>Digital Signal Processing: Microprocessors, Software and Applications</td>
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<td>SYSC 5604 (ELG 6164)</td>
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**School of Engineering and Computer Science (Ottawa)**

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<tr>
<td>EACJ 5601 (ELG 7173)</td>
<td>Topics in Signal Processing II</td>
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<td>EACJ 5800 (ELG 5377)</td>
<td>Adaptive Signal Processing</td>
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**SYSTEMS AND MACHINE INTELLIGENCE**

**Systems and Computer Engineering (Carleton)**

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<th>Course Code</th>
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<td>SYSC 5001 (ELG 6101)</td>
<td>Simulation and Modeling</td>
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<td>SYSC 5004 (ELG 6104)</td>
<td>Optimization for Engineering Applications</td>
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<td>SYSC 5005 (ELG 5162)</td>
<td>Optimization Theory and Methods</td>
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<td>SYSC 5401 (ELG 6141)</td>
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<td>SYSC 5402 (ELG 6142)</td>
<td>Advanced Dynamics With Applications to Robotics</td>
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<td>SYSC 5405 (ELG 6102)</td>
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<td>SYSC 5803 (ELG 6183)</td>
<td>Logic Programming</td>
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**School of Engineering and Computer Science (Ottawa)**

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<tr>
<td>EACJ 5100 (ELG 5163)</td>
<td>Machine Vision</td>
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<td>EACJ 5204 (ELG 5124)</td>
<td>Virtual Environments</td>
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<td>EACJ 5207 (ELG 5161)</td>
<td>Robotics:Control/Sensing/Intel</td>
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<td>EACJ 5209 (ELG 7113)</td>
<td>Topics in Systems and Control I</td>
</tr>
<tr>
<td>EACJ 5706 (CSI 5387)</td>
<td>Data Mining and Concept Learning</td>
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<tr>
<td>EACJ 5709 (ELG 5196)</td>
<td>Neural Networks and Fuzzy System</td>
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<td>EACJ 7116 (ELG 7116)</td>
<td>Signal Proc: Intr Convex Optim</td>
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<tr>
<td>EACJ 5386 (ELG 5386)</td>
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**SYSTEMS AND MACHINE INTELLIGENCE**

**Systems and Computer Engineering (Carleton)**

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</table>
Admission
The normal requirement for admission to a master's program is a bachelor's degree in electrical engineering or a related discipline with a CGPA of B+.

Accelerated Pathway
The accelerated pathway in the M.A.Sc. and M.Eng. Electrical and Computer Engineering program is a flexible and individualized plan of graduate study for students in their final year of a Carleton B.Eng degree. Students with demonstrated academic excellence and aptitude for research may qualify for this option.

Students in their third-year of study in the B.Eng. degree should consult with both the Undergraduate Chair and the Graduate Chair to determine if the accelerated pathway is appropriate for them and to confirm their selection of courses for their final year of undergraduate studies.

Accelerated Pathway Requirements
1. At least 0.5 credit in ELEC or SYSC courses, or other approved courses, at the 5000-level with a grade of B+ or higher.
2. Minimum overall CGPA of A-.

Students may receive advanced standing with transfer of credit of up to 1.0 credit which can reduce their time to completion.
EACJ 5132 [0.5 credit]  
Smart Antennas

EACJ 5133 [0.5 credit]  
Intro to Mobile Communications

EACJ 5200 [0.5 credit]  
Queuing Systems

EACJ 5201 [0.5 credit]  
Optical Communications Systems

EACJ 5202 [0.5 credit]  
Analysis/Perf Eval: Comp Comm

EACJ 5203 [0.5 credit]  
Distributed System Software

EACJ 5204 [0.5 credit]  
Virtual Environments

EACJ 5205 [0.5 credit]  
Quality Service Mgmt/Multimed

EACJ 5206 [0.5 credit]  
Source Coding and Data Compress.

EACJ 5207 [0.5 credit]  
Robotics:Control/Sensing/Intel

EACJ 5208 [0.5 credit]  
Wireless Ad Hoc Networking

EACJ 5209 [0.5 credit]  
Topics in Systems and Control I

EACJ 5211 [0.5 credit]  
Software Engineering Proj Mgmt

EACJ 5300 [0.5 credit]  
Topics in Systems and Control II

EACJ 5301 [0.5 credit]  
Sujets choisis en systemes

EACJ 5303 [0.5 credit]  
Health Care Engineering

EACJ 5305 [0.5 credit]  
Electromagnetic Compatibility

EACJ 5308 [0.5 credit]  
Sujets choisis electromagnetiq

EACJ 5360 [0.5 credit]  
Digital Watermarking

EACJ 5369 [0.5 credit]  
Internetworking Technologies

EACJ 5384 [0.5 credit]  
Network Security and Cryptography

EACJ 5385 [0.5 credit]  
Matrix Method and Algor Sign Proce

EACJ 5386 [0.5 credit]  
Neural Networks and Fuzzy System

EACJ 5401 [0.5 credit]  
Electromagnetic Waves

EACJ 5402 [0.5 credit]  
Numerical Methods: Electromag

EACJ 5403 [0.5 credit]  
Ondes Electromagnetiques

EACJ 5404 [0.5 credit]  
Topics in Electromagnetics I

EACJ 5405 [0.5 credit]  
Topics in Electromagnetics II

EACJ 5406 [0.5 credit]  
Methodes numeriques en genie

EACJ 5500 [0.5 credit]  
Digital Comm by Satellite

EACJ 5501 [0.5 credit]  
Information Theory

EACJ 5503 [0.5 credit]  
Detection and Estimation

EACJ 5504 [0.5 credit]  
Error Control Coding

EACJ 5506 [0.5 credit]  
Principles of Digital Comm

EACJ 5507 [0.5 credit]  
Digital Signal Processing

EACJ 5508 [0.5 credit]  
Traitement numer des signaux

EACJ 5509 [0.5 credit]  
Image Proc and Image Comm

EACJ 5600 [0.5 credit]  
Topics in Signal Processing I

EACJ 5601 [0.5 credit]  
Topics in Signal Processing II

EACJ 5603 [0.5 credit]  
Topics in Signal Processing 3

EACJ 5605 [0.5 credit]  
Topics in Communications I

EACJ 5606 [0.5 credit]  
Topics in Communications II

EACJ 5607 [0.5 credit]  
Computer-Communication Network

EACJ 5702 [0.5 credit]  
Sujets choisis en telecommun
EACJ 5703 [0.5 credit]
Reliable Digital Systems

EACJ 5704 [0.5 credit]
Advanced Digital Communication

EACJ 5705 [0.5 credit]
Digital Logic Design

EACJ 5706 [0.5 credit]
Data Mining and Concept Learning
Also listed as COMP 5706.

EACJ 5709 [0.5 credit]
Neural Networks and Fuzzy System

EACJ 5800 [0.5 credit]
Adaptive Signal Processing

EACJ 5807 [0.5 credit]
Topics in Computers I

EACJ 5808 [0.5 credit]
Topics in Computers II

EACJ 5900 [0.5 credit]
Sujets choisis sur les ordinat

EACJ 7116 [0.5 credit]
Signal Proc: Intr Convex Optim

Electronics (ELEC) Courses
Note: The Departments of Electronics and Systems and Computer Engineering offer courses in: Biomedical and Electrical Engineering, Communications Engineering, Computer Systems Engineering, Electrical Engineering, Software Engineering and Engineering Physics.

ELEC 5200 [0.5 credit] (ELG 6320)
Advanced Topics in Integrated Circuits and Devices
Topics vary from year to year.

ELEC 5301 [0.5 credit]
Silicon Photonics
Fundamentals of silicon photonics, advanced electromagnetic theory, guided wave optics, interferometry, silicon-on- insulator (SOI) photonics, silicon based waveguide devices (planar, rib, strip), fabrication of photonic devices, passive and active silicon photonic devices such as modulators, lasers, detectors, silicon opto-electronic integration.

ELEC 5302 [0.5 credit]
Renewable and Distributed Energy Resource Technologies
Topics covered include renewable energy resources, photovoltaic systems, wind generation systems, energy storage units, electric vehicles, grid integration, distributed generation, microgrid, active distribution network, modeling and analysis of power system components, state-of-the-art power system simulation tools.

ELEC 5401 [0.5 credit] (ELG 6341)
Signal Integrity in High-Speed Designs: Modeling and Analysis
Crosstalk, distortion, ground bounce, skin effect.
Interconnect modeling/simulation, packages, ground/ power planes, Elmore delay, lossy-coupled, frequency- dependent transmission lines, telegraphs equations, extraction, measured parameters, macromodeling: passivity/causality, MoC/MRA, vector fit, model reduction, electromagnetic compatibility/interference, mixed-domain systems, concurrent analysis.
Precludes additional credit for ELEC 5704 (ELG 6374).
Prerequisite(s): permission of the Department.

ELEC 5402 [0.5 credit] (ELG 6342)
Introduction to Electronic Design Automation Algorithms and Techniques
Digital design process; overview of design automation tools/methodologies; theory of computational complexity; layout compaction; placement and partitioning; floorplanning; routing; digital simulation; switch-level simulation; logic synthesis; verification; analog and RF simulation.
Precludes additional credit for ELEC 5704 Section "Y" (ELG 6374 Section "Y").

ELEC 5404 [0.5 credit] (ELG 6344)
Neural Networks for High-Speed/High-Frequency Circuit Design
Introduction to neural network methodologies for computer-aided design of high-speed/high-frequency circuits, including modeling of passive and active devices/ circuits, and their applications in high-level design and optimization in wired and wireless electronic systems.

ELEC 5405 [0.5 credit] (ELG 6340)
Advanced Linear and Nonlinear Circuit Theory and Applications
Graph theory, incidence matrices, cutset matrices, generalized KCL, topological formulation, state-space equations, Tellegen's theorem, state-transition matrix, multi-port representation, stability, passivity, causality, synthesis of passive circuits, active networks, nonlinear dynamic circuits.

ELEC 5409 [0.5 credit] (ELG 6349)
Microwave and Millimeterwave Integrated Circuits
ELEC 5501 [0.5 credit] (ELG 6351)
Passive Microwave Circuits

ELEC 5502 [0.5 credit] (ELG 6352)
Analog Integrated Filters
The fundamentals and details of analog continuous-time and SAW filters. Comparison to switched-capacitor filters. Review of filter concepts, types of filters, approximations, transformations. Building blocks such as op amps, transconductance amplifiers, and gyrators. Design using cascaded second-order sections, multiple loop feedback and LC ladder simulations.

ELEC 5503 [0.5 credit] (ELG 6353)
Radio Frequency Integrated Circuit Design

ELEC 5504 [0.5 credit] (ELG 6354)
Analysis of High-Speed Electronic Packages and Interconnects
Introduction to modeling, simulation and optimization of high-speed VLSI packages; models for packages, interconnects and ground/power planes; lumped, distributed and EM models for interconnects; delay, crosstalk and switching noise; moment matching techniques; concurrent thermal/electrical analysis of IC packages and boards.

ELEC 5506 [0.5 credit] (ELG 6356)
Simulation and Optimization of Electronic Circuits
Introduction to computer simulation and optimization of electrical circuits. Time- and frequency-domain formulations for sensitivity analysis and optimization. Optimization techniques for performance-, cost- and yield-driven design of electronic circuits. Optimization approaches to modeling and parameter extraction of active and passive elements.

ELEC 5508 [0.5 credit] (ELG 6358)
Computer Methods for Analysis and Design of VLSI Circuits

ELEC 5509 [0.5 credit] (ELG 6359)
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, CVD, etching, materials for metallization and contacting, and photolithography. Structures and fabrication techniques required for submicron MOSFETs. Applications in advanced CMOS processes.

ELEC 5600 [0.5 credit] (ELG 6360)
Digital Integrated Circuit Testing
Production testing of digital integrated circuits. Outline of methods of testing used in production. Testing schemes and design for testability. Faults and fault models, yield estimates, testability measures, fault simulation, test generation methods, sequential testing, scan design, boundary scan, built-in self test, CMOS testing.

ELEC 5602 [0.5 credit] (ELG 6362)
Microwave Semiconductor Devices and Applications
Theory of operation for microwave diodes (varactor, p-i-n, Gunn, IMPATT) and transistors (BJT, MESFET, HBT, HEMT). Small-signal, large-signal, and noise models for CAD. Diode oscillators and reflection amplifiers. Design of transistor oscillators and amplifiers. Discussion of technology/fabrication issues and MMIC applications.

ELEC 5604 [0.5 credit] (ELG 6364)
Radar Systems
Fundamentals; range equation, minimum detectable signal, radar cross-section, pulse repetition frequency, range ambiguities. Radar classes: 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.

ELEC 5605 [0.5 credit] (ELG 6365)
Optical Fibre Communications
Transmission characteristics of and design considerations for multi-mode and single-mode optical fibre waveguides; materials, structures, and device properties of laser light sources; properties and performance of p-i-n and avalanche photodiodes; types of optical fibre signal formats, preamplifier topologies, noise, receiver sensitivity, transmitter design, link design.

ELEC 5606 [0.5 credit] (ELG 6366)
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 remodelulator for BPSK, QPSK BER performance; clock synchronizers including early-late gate, in-phase/midphase, and delay line multiplier.
ELEC 5607 [0.5 credit] (ELG 6367)  
Fundamentals of Antenna Engineering  
Basic properties of antennas (gain, radiation patterns, polarization, antenna temperature). Analysis of common antennas (dipoles, loops, helices, aperture antennas, microstrip, dielectric resonator antennas, reflectors). Analysis and design of linear and planar arrays (array factors, beam scanning, amplitude weighting, feed networks).

ELEC 5608 [0.5 credit] (ELG 6368)  
Fourier Optics  
The theory and applications of diffractive and non-diffractive coherent optics, with emphasis on holograms, tomography and high-speed optical computing. Mathematical basis: generalized 2-D Fourier transforms, transfer function of an optical system, 2-D sampling theory, Helmholtz equation, Green's theorem, and the classical diffraction theories.

ELEC 5609 [0.5 credit] (ELG 6369)  
Nonlinear Microwave Devices and Effects  
The physical basis and mathematical modeling of a variety of microwave/millimeter-wave devices, (some of which exhibit the most extreme nonlinear behaviour known), how they can be exploited in practical circuits and systems, and how the resulting device/circuit interactions can be analyzed.

ELEC 5701 [0.5 credit] (ELG 6371)  
Fibre and Waveguide Components for Communications and Sensors  
Optical wave propagation in dielectric waveguides. Theory and practice for passive photonic devices used for routing, filtering, and signal processing, including structural and biochemical sensors. Directional couplers and splitters, filters (gratings and etalons), Mach-Zehnder interferometers, Arrayed waveguide gratings, and dispersion compensators. Precludes additional credit for ELEC 5709W (ELG 6379W). Prerequisite(s): ELEC 3909 or equivalent.

ELEC 5702 [0.5 credit] (ELG 6372)  
Principles of Photonics  
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.

ELEC 5703 [0.5 credit] (ELG 6373)  
Advanced Topics in Solid State Devices and IC Technology  
Recent and advanced topics in semiconductor device physics, modeling, and integrated circuit fabrication technology. Topic varies from year to year according to departmental research interests. Students may be expected to contribute lectures or seminars on selected topics.

ELEC 5704 [0.5 credit] (ELG 6374)  
Advanced Topics in CAD  
Recent and advanced topics in computer-aided techniques for the design of VLSI and telecommunications circuits. Topics will vary from year to year according to the departmental research interests. Students may be expected to contribute lectures or seminars on selected topics.

ELEC 5705 [0.5 credit] (ELG 6375)  
Advanced Topics in VLSI  
Recent and advanced topics in the design of very large scale integrated circuits, with emphasis on mixed analog/digital circuits for telecommunications applications. Topic varies from year to year according to departmental research interests. Students may be expected to contribute lectures or seminars on selected topics.

ELEC 5706 [0.5 credit] (ELG 6376)  
Submicron CMOS and BiCMOS Circuits for Sampled Data Applications  
The analog aspects of digital CMOS and BiCMOS circuit design in submicron technologies including reliability; sampled analog circuits, including amplifier non-ideal characteristics and switch charge injection; CMOS/BiCMOS amplifier design considerations, leading up to standard folded-cascode and two-stage circuits.

ELEC 5707 [0.5 credit] (ELG 6377)  
Microsensors and MEMS  
Physical design of microelectromechanical systems (MEMS) and microfabricated sensors and actuators. An overview of thin and thick film processes and micromachining techniques will provide fabrication background. Device design including piezoresistive, piezoelectric, electromagnetic, thermal, optical, and chemical sensors and actuators.

ELEC 5708 [0.5 credit] (ELG 6378)  
ASICS in Telecommunications  
Introduction to modern ASIC technologies for Telecom. Review of circuit-level building blocks for typical wireline and wireless applications, including power/performance tradeoffs. Corresponding FPGA analog and digital IO circuits are discussed. A topical literature study and circuit level design exercises.
ELEC 5709 [0.5 credit] (ELG 6379)
Advanced Topics in Electromagnetics
Recent and advanced topics in electro-magnetics, 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.

ELEC 5800 [0.5 credit] (ELG 6380)
Theory of Semiconductor Devices

ELEC 5801 [0.5 credit] (ELG 6381)
High-Speed and Low-Power VLSI
High-Speed and Low-Power CMOS VLSI circuit techniques. Low and high levels of abstraction; transistor, switch, logic-gate, module, system levels. State-of-the-art techniques to optimize the performance and energy consumption of a circuit. One or more of these techniques are used in a design project.
Prerequisite(s): ELEC 4708 or ELEC 5804 or the equivalent or permission of the instructor.

ELEC 5802 [0.5 credit] (ELG 6382)
Surface-Controlled Semiconductor Devices
Fundamentals of the MOS system; MOS capacitors. Long channel behaviour: theory, limitations and performance of the SPICE level 1 and 2 models. Small geometry effects. Subthreshold operation and modeling. Hot electron effects and reliability.

ELEC 5803 [0.5 credit] (ELG 6383)
Behavioural Synthesis of ICs
Various topics related to computer analysis and synthesis of VLSI circuits including: logic synthesis, finite state machine synthesis, design methodologies, design for reuse, testing, common VLSI functions, a review of Verilog.
Prerequisite(s): Some IC design knowledge such as given in ELEC 4708.

ELEC 5804 [0.5 credit] (ELG 6384)
VLSI Design
An IC design course with a strong emphasis on design methodology, to be followed by ELEC 5805 (ELG 6385), 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 used.

ELEC 5805 [0.5 credit] (ELG 6385)
VLSI Design Project
Using state-of-the-art CMOS and BiCMOS technologies, students will initiate their own design of an integrated circuit using tools in the CAD lab and submit it for fabrication where the design warrants.

ELEC 5808 [0.5 credit] (ELG 6388)
Signal Processing Electronics
CCDs, 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.

ELEC 5809 [0.5 credit] (ELG 6389)
Nonlinear Electronic Circuits
Introduction to non-linear circuits used in today's telecommunications ICs; CMOS non-linear circuits such as direct-RF-sampling mixers, phase-detectors; digital loop-filters, DCOs, frequency synthesizers and clock-and-data-recovery are introduced. Modeling of these non-linear circuits and existing options for simulations and closed form circuit analysis is presented.
Precludes additional credit for ELEC 5705 (ELG 6375).
Prerequisite(s): permission of the Department.

ELEC 5900 [0.5 credit] (ELG 6389)
Engineering Project I
A one-term course, carrying 0.5 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. Written and oral reports are required. This course may be repeated for credit.

ELEC 5901 [1.0 credit] (ELG 6389)
Engineering Project II
A one-term course, carrying full-course credit, for students pursuing the course work or co-op M.Eng. program. An engineering study, analysis and/or design project under the supervision of a faculty member. Written and oral reports are required. This course may be repeated for credit.

ELEC 5906 [0.5 credit] (ELG 6389)
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.

ELEC 5909 [2.5 credits]
M.A.Sc. Thesis

ELEC 6909 [8.5 credits]
Ph.D. Thesis
Systems and Computer Engineering (SYSC)

COURSES

SYSC 5001 [0.5 credit] (ELG 6101)
Simulation and Modeling

SYSC 5003 [0.5 credit] (ELG 6103)
Discrete Stochastic Models

SYSC 5004 [0.5 credit] (ELG 6104)
Optimization for Engineering Applications
Introduction to algorithms and computer methods for optimizing complex engineering systems. Includes linear programming, networks, nonlinear programming, integer and mixed-integer programming, genetic algorithms and search methods, and dynamic programming. Emphasizes practical algorithms and computer methods for engineering applications.

SYSC 5005 [0.5 credit] (ELG 6105)
Optimization Theory and Methods
Advanced theory, algorithms and computer methods for optimization. Interior point methods for linear optimization, advanced methods for nonlinear and mixed-integer optimization. Search methods. Applications in engineering. Prerequisite(s): SYSC 5004 (ELG 6104) or equivalent.

SYSC 5006 [0.5 credit] (ELG 6106)
Design of Real-Time and Distributed Systems
Characteristics of real-time and distributed systems. Modern middleware systems, such as CORBA, DCE, RMI for building distributed applications: advantages and disadvantages. Analyzing designs for robustness, modularity, extensibility, portability and performance. Implementation issues. Major course project. Prerequisite(s): SYSC 3303 and SYSC 5708 (ELG 6178) or similar experience.

SYSC 5007 [0.5 credit] (ELG 6107)
Expert Systems
Survey of some landmark expert systems; types of architecture and knowledge representation; interferingencing techniques; approximate reasoning; truth maintenance; explanation facilities; knowledge acquisition. A project to implement a small expert system will be assigned. Also listed as COMP 5007. Prerequisite(s): COMP 4007 or COMP 5001 (CSI 5113) or permission of the Department.

SYSC 5101 [0.5 credit] (ELG 6111)
Design of High Performance Software
Designing software to demanding performance specifications. Design analysis using models of computation, workload, and performance. Principles to govern design improvement for sequential, concurrent and parallel execution, based on resource architecture and quantitative analysis. Prerequisite(s): SYSC 5704 (ELG 6174) and a course in software engineering, or equivalent.

SYSC 5102 [0.5 credit] (ELG 6112)
Performance Measurement and Modeling of Distributed Applications
Performance measurements, metrics and models of middleware based systems and applications. Benchmarks, workload characterization, and methods for capacity planning and system sizing. Performance monitoring infrastructures for operating systems and applications. Introduction to the design and analysis of experiments and the interpretation of measurements. Prerequisite(s): SYSC 5101 (ELG 6611) or equivalent.

SYSC 5103 [0.5 credit] (ELG 6113)
Software Agents
Agent-based programming; elements of Distributed Artificial Intelligence; beliefs, desires and intentions; component-based technology; languages for agent implementations; interface agents; information sharing and coordination; KIF; collaboration; communication; ontologies; KQML; autonomy; adaptability; security issues; mobility; standards; agent design issues and frameworks, applications in telecommunications. Prerequisite(s): Knowledge of Java, C/C++ or Smalltalk.

SYSC 5104 [0.5 credit] (ELG 6114)
Methodologies For Discrete-Event Modeling And Simulation

SYSC 5105 [0.5 credit] (ELG 6115)
Software Quality Engineering and Management
All aspects of software quality engineering. Software testing, at all stages of the software development and maintenance life cycle. Software reviews and inspections. Use of software measurement and quantitative modeling for the purpose of software quality control and improvement. Precludes additional credit for CSI 5111 (COMP 5501). Prerequisite(s): an undergraduate course in software engineering such as SYSC 4800 or SEG 3300, or equivalent, and basic statistics.
SYSC 5108 [0.5 credit] (ELG 6118)
Topics in Information Systems
Recent and advanced topics in the field of Information Systems and its related areas.

SYSC 5109 [0.5 credit] (ELG 6119)
Teletraffic Engineering
Congestion phenomena in telephone systems, and related telecommunications networks and systems, with an emphasis on the problems, notation, terminology, and typical switching systems and networks of the operating telephone companies. Analytical queuing models and applications to these systems.
Prerequisite(s): SYSC 5503 (ELG 5503) or ELG 5119 (EACJ 5109) or equivalent.

SYSC 5200 [0.5 credit] (ELG 6120)
Algebraic Coding Theory
Review of Algebra, Finite Fields, Linear Block Codes and their Properties, Hamming Codes, Cyclic Codes, Hadamard Matrices and Hadamard Codes, Golay Codes, Reed-Muller Codes, BCH and Reed-Solomon Codes, Decoding Algorithms, Coding Bounds.
Precludes additional credit for SYSC 5507 (ELG 6157).

SYSC 5201 [0.5 credit] (ELG 6121)
Computer Communication
Precludes additional credit for EACJ 5607 (ELG 5374) or SYSC 4602 (ELG 4181).
Prerequisite(s): Undergraduate preparation in probability theory equivalent to STAT 3502.

SYSC 5207 [0.5 credit] (ELG 6127)
Distributed Systems Engineering
Techniques for representing distributed systems: graphical and textual models. Processes, threads, synchronization and inter-process communication techniques, RPC.
Prerequisite(s): permission of the Department.

SYSC 5300 [0.5 credit] (ELG 6130)
Advanced Health Care Engineering
Healthcare and technology; overview of medical devices and sensors; safe and effective use and management of technology; telemedicine; medical databases, data collection, storage, retrieval and computers in medicine; electronic patient records, PACS; clinical decision-support systems.
Also listed as BIOM 5401 (BMG 5318).
Precludes additional credit for EACJ 5303 (ELG 5123).
Prerequisite(s): permission of the instructor.

SYSC 5301 [0.5 credit] (ELG 6131)
Advanced Topics in Biomedical Engineering
Topics vary from year to year.
Also listed as EACJ 5127 (ELG 6131).
Prerequisite(s): permission of the Department.

SYSC 5302 [0.5 credit] (ELG 6321)
Biomedical Instrumentation
Instrumentation designed to measure physiological variables related to the function of the heart, lungs, kidney, nervous and musculo-skeletal system; emergency, critical care, surgery and anaesthesia equipment.
Also listed as EACJ 5302 (ELG 6321).
Precludes additional credit for BIOM 5100 (BMG 5103).
Prerequisite(s): permission of the instructor.

SYSC 5303 [0.5 credit] (ELG 6133)
Interactive Networked Systems and Telemedicine
Telemanipulator; human motoring and sensory capabilities; typical interface devices; mathematical model of haptic interfaces; haptic rendering; stability and transparency; remote control schemes; time delay compensation; networking and realtime protocols, history and challenges of telemedicine; telemedicine applications: telesurgery, telemonitoring, telediagnosis and telehomecare.
Also listed as BIOM 5402 (BMG 5402).
Prerequisite(s): permission of the Department.

SYSC 5304 [0.5 credit] (ELG 5127)
Medical Image Processing
Mathematical models of image formation based on the image modality and tissue properties. Linear models of image degradation and reconstruction. Inverse problems and regularization for image reconstruction. Image formation in radiology, computed tomography, magnetic resonance imaging, nuclear medicine, ultrasound, positron emission tomography, electrical impedance tomography.
Also listed as BIOM 5200 (BMG 5105).

SYSC 5306 [0.5 credit] (ELG 6136)
Mobile Computing Systems
Systems to build mobile applications. Covers data link layer to application layer. Emphasis on existing wireless infrastructure and IETF protocols. Focuses on view of mobile application developer; communication systems, middleware and application frameworks, defacto standards proposed/developed by industry consortia.
Precludes additional credit for COMP 5402 (CSI 5142).
Prerequisite(s): EACJ 5607 (ELG 5374) or SYSC 5201 (ELG 6121) or permission of the Department.
SYSC 5307 [0.5 credit] (ELG 6307)
Biological Signals
Modeling of neuromuscular biological signals, including subthreshold phenomena, active behaviour of cell membranes, and innervation processes. Measurement of biological signals, including electrode effects. Time domain, frequency domain, and adaptive filtering techniques for noise reduction.
Precludes additional credit for BIOM 5101 (BMG 5104).

SYSC 5370 [0.5 credit] (ELG 5370)
Multiresolution Signal Decomposition: Analysis and Applications

SYSC 5401 [0.5 credit] (ELG 6141)
Adaptive and Learning Systems
Prerequisite(s): SYSC 5502 (ELG 6152) or equivalent.

SYSC 5402 [0.5 credit] (ELG 6142)
Advanced Dynamics With Applications to Robotics

SYSC 5403 [0.5 credit] (ELG 6143)
Network Access Techniques
A range of access technologies with emphasis on broadband access. Physical channels and the state-of-the-art of coding, modulation, multiplexing strategies to overcome physical impairments. Including high-speed transmission over twisted pair, wireless, fibre and co-axial media.
Prerequisite(s): SYSC 5503 (ELG 6153), and SYSC 5504 (ELG 6154) or ELG 5375 (EACJ 5506).

SYSC 5404 [0.5 credit]
Multimedia Compression, Scalability, and Adaptation
This course covers media compression, in-depth issues of scalability in the compression domain (including audio, images, video, 2D and 3D graphics), and adaptation towards various contexts; as well as covering various popular media encoding standards (including JPEG and MPEG).

SYSC 5405 [0.5 credit] (ELG 6102)
Pattern Classification and Experiment Design
Introduction to a variety of supervised and unsupervised pattern classification techniques with emphasis on correct application. Statistically rigorous experimental design and reporting of performance results. Case studies will be drawn from various fields including biomedical informatics. Also listed as BIOM 5405 (BMG 5111). Prerequisite(s): undergraduate introductory probability and statistics.

SYSC 5406 [0.5 credit]
Network Routing Technologies
The course covers routing technologies for high-speed networks. The course addresses in-depth issues and technologies in traffic engineering, MPLS (Multiprotocol Label Switching) system components and architecture, constraint-based routing, quality of service, protection and restoration, virtual private networks, cross layer interworking, and special topics.

SYSC 5407 [0.5 credit]
Planning and Design of Computer Networks
Planning process of computer networks; needs and technical requirements; modeling of different network planning problems; exact and approximate algorithms; topological planning and expansion problems; equipment (switch, router) location problem; approximate and optimal routing algorithms; presentation of various case studies.

SYSC 5408 [0.5 credit]
Cross Layer Design for Wireless Networks
Quality of service measures at different layers. Parameter adaptation, tradeoffs, and optimization at physical, data-link, network, transport, and application layers. Examples of cross-layer design in cellular, ad hoc, sensor, local area, green, and cognitive radio networks.

SYSC 5409 [0.5 credit]
Interactive Media and Digital Art
Interactive digital technologies as new media for art and entertainment. Topics include essential features of the digital media, interactivity, computer games and gamification, interactive stories, serious games, virtual worlds and social networks, and digital art.
Precludes additional credit for SYSC 5807 (ELG 6187).

SYSC 5500 [0.5 credit]
Designing Secure Networking and Computer Systems
Network security with coverage of computer security in support of networking concepts. Covers various security issues in data networks at different protocol layers. Routing security, worm attacks, and botnets. Security of new mobile networks and emerging networked paradigms such as social networks and cloud computing.
Precludes additional credit for SYSC 5801 Section “X” (ELG 6181).
SYSC 5502 [0.5 credit] (ELG 6152)
Advanced Linear Systems

SYSC 5503 [0.5 credit] (ELG 6153)
Stochastic Processes
Basic concepts of randomness, as applied to communications, signal processing, and queueing systems; probability theory, random variables, stochastic processes; random signals in linear systems; introduction to decision and estimation; Markov chains and elements of queueing theory.
Precludes additional credit for EACJ 5109 (ELG 5119).

SYSC 5504 [0.5 credit] (ELG 6154)
Principles of Digital Communication
Precludes additional credit for EACJ 5506 (ELG 5375).
Prerequisite(s): SYSC 5503 (ELG 5503) or ELG 5119 (EACJ 5109) or equivalent (may be taken concurrently).

SYSC 5506 [0.5 credit] (ELG 5170)
Information Theory
Measure of information: entropy, relative entropy, mutual information, asymptotic equipartition property, entropy rates for stochastic processes; data compression: Huffman code, arithmetic coding; channel capacity: random coding bound, reliability function, Blahut-Arimoto algorithm, Gaussian channels, coloured Gaussian noise and 'water-filling'; rate distortion theory; network information theory.
Precludes additional credit for EACJ 5501 (ELG 5170).
Prerequisite(s): SYSC 5503 (ELG 6153) or EACJ 5109 (ELG 5119) or equivalent.

SYSC 5508 [0.5 credit] (ELG 6158)
Digital Systems Architecture
New architectural concepts are introduced. Discussion of programmable architectures (micro-controllers, DSPs, GP) and FPGAs. Memory interfacing. Scalable, superscalar, RISC, CISC, and VLIW concepts. Parallel structures: SIMD, MISD and MIMD. Fault tolerant systems and DSP architectures. Examples of current systems are used for discussions.
Prerequisite(s): SYSC 4507 or equivalent.

SYSC 5600 [0.5 credit] (ELG 6160)
Adaptive Signal Processing
Theory and techniques of adaptive filtering, including Wiener filters, gradient and LMS methods; adaptive transversal and lattice filters; recursive and fast recursive least squares; convergence and tracking performance; implementation. Applications, such as adaptive prediction, channel equalization, echo cancellation, source coding, antenna beamforming, spectral estimation.
Precludes additional credit for EACJ 5800 (ELG 5377).
Prerequisite(s): SYSC 5503 (ELG 5503) or ELG 5119 (EACJ 5109) or equivalent; SYSC 5602 (ELG 6162) or EACJ 5507 (ELG 5507) or equivalent.

SYSC 5601 [0.5 credit] (ELG 6161)
Neural Signal Processing
Precludes additional credit for EACJ 5709 (ELG 5796).
Prerequisite(s): SYSC 5503 (ELG 6153) or equivalent. May be taken concurrently with SYSC 5503 (ELG 5503).

SYSC 5602 [0.5 credit] (ELG 6162)
Digital Signal Processing
Precludes additional credit for EACJ 5507 (ELG 5376).

SYSC 5603 [0.5 credit] (ELG 6163)
Digital Signal Processing: Microprocessors, Software and Applications
Characteristics of DSP algorithms and architectural features of current DSP chips: TMS320, DSP-56xxx, AD-21xxx and SHARC. DSP multiprocessors and fault tolerant systems. Algorithm/software/hardware architecture interaction, program activity analysis, development cycle, and design tools. Case studies: LPC, codecs, FFT, echo cancellation, Viterbi decoding.
Prerequisite(s): SYSC 5602 (ELG 6162) or EACJ 5507 (EACJ 5507) or equivalent.

SYSC 5604 [0.5 credit] (ELG 6164)
Advanced Topics in Digital Signal Processing
Recent and advanced topics in the field of digital signal processing and its related areas.
Prerequisite(s): SYSC 5602 (ELG 6162) or EACJ 5507 (EACJ 5507) or equivalent.
SYSC 5605 [0.5 credit] (ELG 6165)
Advanced Digital Communication
Techniques and performance of digital signalling and equalization over linear bandlimited channels with additive Gaussian noise. Fading multipath channels: diversity concepts, modeling and error probability performance evaluation. Synchronization in digital communications. Spread spectrum in digital transmission over multipath fading channels. Precludes additional credit for EACJ 5704 (ELG 5780). Prerequisite(s): SYSC 5504 (ELG 6154) or equivalent.

SYSC 5606 [0.5 credit] (ELG 6166)
Introduction to Mobile Communications
Mobile radio channel characterization: signal strength prediction techniques and statistical coverage; fading; delay spread; interference models and outage probabilities. Digital modulation and transmission system performance. Signal processing techniques: diversity and beamforming, adaptive equalization, coding. Applications to TDMA and CDMA cellular systems. Prerequisite(s): SYSC 5503 (ELG 5503) and SYSC 5504 (ELG 6154) (may be taken concurrently with SYSC 5606).

SYSC 5607 [0.5 credit] (ELG 6167)
Source Coding and Data Compression
Discrete and continuous sources. Discrete sources: Huffman coding & run length encoding. Continuous sources: waveform construction coding; PCM, DPMC, delta modulation; speech compression by parameter extraction; predictive encoding; image coding by transformation and block quantization. Fourier and Walsh transform coding. Applications to speech, television, facsimile. Prerequisite(s): SYSC 5503 (ELG 5503) or ELG 5119 (EACJ 5109) or equivalent.

SYSC 5608 [0.5 credit] (ELG 6168)
Wireless Communications Systems Engineering
Multi-user cellular and personal radio communication systems; frequency reuse, traffic engineering, system capacity, mobility and channel resource allocation. Multiple access principles, cellular radio systems, signalling and interworking. Security and authentication. Wireless ATM, satellite systems, mobile location, wireless LANs, wireless local loops, broadband wireless, etc. Prerequisite(s): SYSC 5503 (ELG 5503) or ELG 5119 (EACJ 5109), and SYSC 5504 (ELG 6154) or ELG 5375 (EACJ 5506), or their equivalents. May be taken concurrently.

SYSC 5609 [0.5 credit] (ELG 6169)
Digital Television

SYSC 5700 [0.5 credit] (ELG 6170)
Spread Spectrum Systems
Types of spread spectrum systems, FH, DS-SS, TH-SS using impulse-radio. Hybrid DS/FH-SS. Pseudo-noise generators: statistical properties of M sequences, Galois field connections, Gold codes, OVSF codes. Code tracking loops, initial synchronization of receiver spreading code. Performance in interference environments and fading channels. CDMA systems. SS applications in UWB communications and Imaging systems. Prerequisite(s): SYSC 5504 (ELG 6154) or equivalent.

SYSC 5701 [0.5 credit] (CSI 5117)
Operating System Methods for Real-Time Applications
Principles and methods for operating system design with application to real-time, embedded systems. Concurrent programming: mechanisms and languages; design approaches and issues; run-time support (kernel). Methods for hard real-time applications. Methods for distributed systems. Programming assignments in a suitable programming language. Prerequisite(s): SYSC 3303 or SYSC 5704 (ELG 6174) or equivalent courses and/or experience. Programming experience in high level and assembly languages.

SYSC 5703 [0.5 credit] (ELG 6173)
Integrated Database Systems

SYSC 5704 [0.5 credit] (ELG 6174)
Elements of Computer Systems
Concepts in basic computer architecture, assembly languages, high level languages including object orientation, compilers and operating system concepts (including concurrency mechanisms such as processes and threads and computer communication). Designed for graduate students without extensive undergraduate preparation in computer system engineering (or equivalent experience). Prerequisite(s): programming experience with at least one high level language and permission of the Department.

SYSC 5706 [0.5 credit] (ELG 6176)
Analytical Performance Models of Computer Systems
Analytical modeling techniques for performance analysis of computing systems. Theoretical techniques covered include single and multiple class queuing network models, together with a treatment of computational techniques, approximations, and limitations. Applications include scheduling, memory management, peripheral devices, databases, multiprocessing, and distributed computing. Prerequisite(s): SYSC 5003 (ELG 6103), SYSC 5503 (ELG 5503) or ELG 5119 (EACJ 5109), or equivalent.
SYSC 5708 [0.5 credit] (ELG 6178)
Model-Driven Development of Real-Time and Distributed Software
Advanced development of real-time and distributed systems by model-driven development that shifts the focus from coding to modeling. Different types of models. Generating code by model transformations. Design patterns for distributed/concurrent systems with examples from communication applications. Design issues for reusable software.
Prerequisite(s): knowledge of UML and operating systems concepts, and permission of the Department.

SYSC 5709 [0.5 credit] (ELG 6179)
Advanced Topics in Software Engineering
Recent and advanced topics in the field of software engineering and related areas. Primary references are recent publications in the field.
Prerequisite(s): permission of the Department.

SYSC 5800 [0.5 credit] (ELG 6180)
Network Computing
Design and Java implementation of distributed applications that use telecommunication networks as their computing platform. Basics of networking; Java networking facilities. Introduction to open distributed processing; CORBA, JavaIDL, JavaRMI, CGI/HTTP, DCOM, Componentware; Enterprise JavaBeans, ActiveX, Agents: Java code mobility facilities. Security issues; Java security model.

SYSC 5801 [0.5 credit] (ELG 6181)
Advanced Topics in Computer Communications
Recent and advanced topics in computer-communication networks intended as a preparation for research. Students are expected to contribute to seminars or present lectures on selected topics.
Prerequisite(s): SYSC 5201 (ELG 6121) or ELG 5374 (EACJ 5607) or equivalent and permission of the Department.

SYSC 5802 [0.5 credit] (ELG 6182)
Introduction to Information and System Science
An introduction to the process of applying computers in problem solving. Emphasis on the design and analysis of efficient computer algorithms for large, complex problems. Applications in a number of areas are presented: data manipulation, databases, computer networks, queueing systems, optimization. Also listed as MATH 5802, COMP 5802, ISYS 5802.

SYSC 5803 [0.5 credit] (ELG 6183)
Logic Programming
Review of relational databases, first order predicate calculus, semantics of first order models, deductive querying. Proof theory, unification and resolution strategies. Introduction to Prolog, and/or parallelism and Concurrent Prolog. Applications in knowledge representation and rule-based expert systems.

SYSC 5804 [0.5 credit] (ELG 6184)
Advanced Topics in Communications Systems
Recent and advanced topics in communications systems. Prerequisite(s): permission of the Department.

SYSC 5806 [0.5 credit] (ELG 6186)
Object Oriented Design of Real-Time and Distributed Systems
Advanced course in software design dealing with design issues at a high level of abstraction. Design models: use case maps for high-level behaviour description; UML for traditional object-oriented concerns. Design patterns. Forward, reverse, and re-engineering. Substantial course project on applications chosen by students.
Prerequisite(s): permission of the Department.

SYSC 5807 [0.5 credit] (ELG 6187)
Advanced Topics in Computer Systems
Recent and advanced topics in computer systems. The course will generally focus on one or more of the following areas: specification, design, implementation, and modeling/analysis. Students may be expected to contribute to lectures or seminars on selected topics.
Prerequisite(s): permission of the Department.

SYSC 5808 [0.5 credit] (ELG 6188)
Communications Network Management
Prerequisite(s): SYSC 5201 (ELG 6121) or equivalent.

SYSC 5900 [0.5 credit] (ELG 6188)
Systems Engineering Project
Students pursuing the non-thesis M.Eng. program conduct an engineering study, analysis, and/or design project under the supervision of a faculty member.

SYSC 5901 [1.0 credit] (ELG 6188)
Systems Engineering Project
Project similar to SYSC 5900, but either of greater scope or longer duration.

SYSC 5905 [2.0 credits] (ELG 6188)
M.C.S. Thesis
Also listed as MATH 5905, COMP 5905.

SYSC 5906 [0.5 credit]
Directed Studies

SYSC 5908 [1.5 credit] (ELG 6196)
M.Sc. Thesis in Information and Systems Science
Also listed as MATH 5908, ISYS 5908, COMP 5908.

SYSC 5909 [2.5 credits]
M.A.Sc. Thesis

SYSC 6909 [8.5 credits]
Ph.D. Thesis
**Summer session:** some of the courses listed in this Calendar are offered during the summer. Hours and scheduling for summer session courses will differ significantly from those reported in the fall/winter Calendar. To determine the scheduling and hours for summer session classes, consult the class schedule at central.carleton.ca.

Not all courses listed are offered in a given year. For an up-to-date statement of course offerings for the current session and to determine the term of offering, consult the class schedule at central.carleton.ca.