ELECTIRCAL & COMPUTER ENGINEERING ONLINE (ECEA)

Courses

The following courses are only available through CU Boulder on Coursera program offerings. Please refer to the Online Programs (https://catalog.colorado.edu/online/) section of the catalog for more information.

ECEA 5000 (0.6) Special Topics
Examines a special topic in Electrical, Computer, and Energy Engineering.
Grading Basis: Letter Grade

ECEA 5001 (0.6) Special Topics
Examines a special topic in Electrical, Computer, and Energy Engineering.
Grading Basis: Letter Grade

ECEA 5002 (0.8) Special Topics
Examines a special topic in Electrical, Computer, and Energy Engineering.
Grading Basis: Letter Grade

ECEA 5003 (0.8) Special Topics
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ECEA 5004 (0.8) Special Topics
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ECEA 5005 (1) Special Topics
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ECEA 5006 (1) Special Topics
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ECEA 5007 (1) Special Topics
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ECEA 5008 (1) Special Topics
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ECEA 5009 (1) Special Topics
Examines a special topic in Electrical, Computer, and Energy Engineering.
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ECEA 5080 (0.8) Kalman Filter Boot Camp and State Estimation
Introduces the Kalman filter as a method that can solve problems related to estimating the hidden internal state of a dynamic system. Develops the background theoretical topics in state-space models and stochastic systems. Presents the steps of the linear Kalman filter and shows how to implement these steps in Octave code and how to evaluate the filter¿s output.
Grading Basis: Letter Grade

ECEA 5081 (0.8) Linear Kalman Filter Deep Dive and Target Tracking
As a follow-on course to "Kalman Filter Boot Camp", this course derives the steps of the linear Kalman filter to give understanding regarding how to adjust the method to applications that violate the standard assumptions. Applies this understanding to enhancing the robustness of the filter and to extend to applications including prediction and smoothing. Shows how to implement a target-tracking application in Octave code using an interacting multiple-model Kalman filter.
Grading Basis: Letter Grade

ECEA 5082 (0.8) Nonlinear Kalman Filters and Parameter Estimation
As a follow-on course to "Linear Kalman Filter Deep Dive", this course derives the steps of the extended Kalman filter and the sigma-point Kalman filter for estimating the state of nonlinear dynamic systems. You will learn how to implement these filters in Octave code and compare their results. You will be introduced to adaptive methods to tune Kalman-filter noise-uncertainty covariances online. You will learn how to estimate the parameters of a state-space model using nonlinear Kalman filters.
Grading Basis: Letter Grade

ECEA 5083 (0.8) Particle Filters and Navigation
As the final course in the Applied Kalman Filtering specialization, you will learn how to develop the particle filter for solving strongly nonlinear state-estimation problems. You will learn about the Monte-Carlo integration and the importance density. You will see how to derive the sequential importance sampling method to estimate the posterior probability density function of a system¿s state. You will encounter the degeneracy problem for this method and learn how to solve it via resampling. You will learn how to implement a robust particle-filter in Octave code and will apply it to an indoor-navigation problem.
Grading Basis: Letter Grade

ECEA 5200 (1) Digital Communications: I/Q Up/Down Conv & Wireless Channels
Provides methods to convert baseband signals to RF/passband signals in order to be transmitted, and methods to convert passband signals to baseband signals for processing at the receiver. Shows how to model wireless channels.
Grading Basis: Letter Grade

ECEA 5201 (1) Digital Communications: Modulation and Demodulation
For transmitters, shows how to modulate discrete time signals to continuous time baseband signals without loss of generality and with minimum bandwidth. For receivers, shows how to demodulate continuous time signal to discrete time signal without loss of information.
Grading Basis: Letter Grade

ECEA 5202 (1) Digital Communications: Detection, Intro Error Contr Coding
Provides optimal detection methods and an introduction to Error Control Coding, such as convolutional codes, Turbo codes, and LDPC codes.
Grading Basis: Letter Grade

ECEA 5300 (1) Programming Fundamentals for Embedded Software Development
Learners will gain exposure to fundamental programming constructs using C within the context of embedded systems. This course aims to establish a solid understanding of crucial data types, data structures, and algorithms essential for embedded software development and testing. Learners will grasp the organization of ARM and microcontroller memory organization and its relationship with the structure of an executable file. Additionally, the curriculum will delve into the intricacies of converting C code into binary executable files, accompanied by an overview of tools for inspecting and analyzing these files.
Grading Basis: Letter Grade

ECEA 5301 (1) Hands-on Embedded Software Development with Microcontrollers
Learners will utilize a standard Integrated Development Environment (IDE) to program the ARM Cortex-M microcontroller using the C programming language. This course will cover the fundamentals of programming General Purpose Input/Output (GPIO) connections, emphasizing precise timing controlled by the timer module. Additionally, learners will be introduced to the primary programming paradigm for bare-metal programming, focusing on State Machines. Mastery of asynchronous programming techniques and understanding call flow with interrupts and their handling will be emphasized. Finally, learners will receive a high-level introduction to Assembly programming for the ARM Cortex-M processor.
Grading Basis: Letter Grade

ECEA 5302 (1) Advanced Embedded Software Development with Microcontrollers
This course explores communication protocols and analog signals essential for ARM Cortex-M microcontroller programming with C. It offers an overview of serial communication techniques and provides in-depth understanding of popular protocols like UART, I2C, and SPI for interfacing Embedded Systems. Additionally, the curriculum includes Analog-Digital conversion with application development utilizing Direct Memory Access (DMA). Learners will also be introduced to integer math (fixed point) methods for achieving execution efficiency in resource-limited microcontroller systems. Finally, the course will cover power management techniques tailored for embedded systems.
Grading Basis: Letter Grade

ECEA 5305 (1) Linux System Programming and Introduction to Buildroot
Provides an overview of System Programming for the Linux operating system, or software which is interfacing directly with the Linux Kernel and C library. The basic components of a Linux Embedded System, including kernel and root filesystem details are discussed. The Buildroot build system is introduced, which students use to build their own custom Embedded Linux system through programming assignments.
Recommended: Prerequisites Knowledge of C Programming and embedded computer architecture and working knowledge of Linux command line operations, shell programming, Git, and makefiles.
Grading Basis: Letter Grade

ECEA 5306 (1) Linux Kernel Programming and Introduction to Yocto
Provides an overview of Linux Kernel Programming. The basics of Linux Kernel development and device driver development are included. Building on content covered in the previous module, the Yocto Project is also introduced as a second Embedded Linux device build system. Students develop a custom character device driver and deploy on a Yocto or Buildroot based qemu emulated Embedded System.
Recommended: Prerequisites Knowledge of C Programming and embedded computer architecture and working knowledge of Linux command line operations, shell programming, Git, and makefiles.
Grading Basis: Letter Grade

ECEA 5307 (1) Embedded System Topics and Project
Building on concepts of previous courses in the series to implement a project based on a hardware platform which supports Embedded Linux, students pick a final project hardware platform and a final project topic. The project will use either Buildroot or Yocto to build a hardware image. Final project implementation will be organized in sprints based on Agile development methodology.
Recommended: Prerequisites Knowledge of C Programming and embedded computer architecture and working knowledge of Linux command line operations, shell programming, Git, and makefiles.
Grading Basis: Letter Grade

ECEA 5315 (0.6) Real-Time Embedded Systems: Concepts and Practices
Learn fundamentals concepts and practices for real-time embedded systems including hardware, firmware and software configurations, cyclic executive approach (small scale), RTOS (Real-Time Operating System), and real-time extensions to embedded operating systems (real-time Linux). The three approaches are compared and contrasted. Standard approaches for programming and integration of hardware, firmware, and software to provide real-time services (with deadline requirements) are covered.
Grading Basis: Letter Grade

ECEA 5316 (0.8) Real-Time Embedded Systems: Theory and Analysis
The Real-Time Embedded Systems Theory and Analysis course provides an in-depth and full mathematical derivation and review of models for scheduling policies and feasibility determination by hand and with rate monotonic tools along with comparison to actual performance for real-time scheduled threads running on a native Linux system.
Grading Basis: Letter Grade

ECEA 5317 (0.8) Real-Time Embedded Systems: Mission-Critical, SW Application
This course covers the difference between systems you can bet your life on (mission critical) and those which provide predictable response and quality of service (reliable).
Grading Basis: Letter Grade

ECEA 5318 (0.8) Real-Time Embedded Systems: Project
In the final course, we put it all together into a working real-time system and application with multiple services to synchronize with the real world via machine vision.
Grading Basis: Letter Grade

ECEA 5330 (0.6) Computer Aided Verification: Foundations of CAV
Foundations of Computer Aided Verification covers modeling finite-state systems for verification, writing properties as temporal logic formulae or automata, using model checkers to verify properties of a model, specifying fairness constraint to model environment and assumptions, and applying abstraction techniques to verification problems.
Grading Basis: Letter Grade

ECEA 5331 (0.8) Computer Aided Verification: Decision Proc HW Model Checking
Decision Procedures and Hardware Model Checking covers describing constraints in DIMACS and SMT-LIB2 format, applying satisfiability (SAT) solvers to sets of constraints, using Binary Decision Diagrams (BDDs) to manipulate Boolean functions, applying BDD-based approaches to the model checking of hardware models, and applying SAT-based approaches to the model checking of hardware models.
Grading Basis: Letter Grade

ECEA 5332 (0.8) Computer Aided Verification: Software Verification
Software Verification covers modeling systems with unbounded state space - unbounded data types and unbounded control (stack, concurrency), proving correctness of programs using Hoare Logic, proving termination of programs using ranking functions, using the Dafny program verifier, and using Abstract Interpretation as a technique for inferring invariants and using Apron library.
Grading Basis: Letter Grade

ECEA 5333 (0.8) Computer Aided Verification: Cyberphysical Systems
Verification of Cyberphysical Systems covers writing simulators from ordinary differential equations, implementing switching software-based control designs and writing closed-loop simulations, checking stability and safety arguments through Lyapunov and barrier functions, evaluating closed-loop control systems for stability, safety and other temporal requirements, and using verification tools such as Flow* and S-Taliro to check functional properties of closed-loop systems.
Grading Basis: Letter Grade

ECEA 5340 (0.8) Embedding Sensors and Motors: Sensors, Sensor Circuit Design
Sensors and Sensor Circuit Design covers temperature, flow and rotary sensors, and getting started with the Cypress PSOC development kit, including three hands-on lab experiments connecting different types of sensors to the development kit and record sensor data.
Grading Basis: Letter Grade

ECEA 5341 (0.8) Embedding Sensors and Motors: Motors, Motor Control Circuits
Motors and Motor Control Circuits covers motors and how to integrate them to analog and digital circuits, lab experiments measuring parameters of a DC motor, integrating the motor and a rotary sensor into the PSoC development kit.
Grading Basis: Letter Grade

ECEA 5342 (0.8) Embedding Sensors and Motors: Pressure and Motion Sensors
Pressure and Motion Sensors covers accelerometers and pressure sensors, and how to accommodate high-speed response of these sensors in a circuit. The course also covers range finders and how to use these sensors to detect proximate objects, as well as resistive and capacitive touch screens, and the associated applications for each of these technologies.
Grading Basis: Letter Grade

ECEA 5343 (0.6) Embedding Sensors and Motors: Sensor Manufact, Process Ctrl
Sensors and PID Control covers gyroscopes and how to optimize resolution of sensors using analog to digital converters, proportional-integral-derivative (PID) control, and how this method is used to create a closed loop sensor feedback system.
Grading Basis: Letter Grade

ECEA 5346 (1) Embedded Interface Design: User Exp I/F Design for Emb Sys
An introduction to usability and user experience (UX) design methods for embedded devices. UX methods are presented for user analysis, planning, research, design, and verification with discount and formal UX processes. Includes specifics on embedded interface components, human factors and cognitive psychology, applied UX tools for wireframes, sketches, testing, surveys. Includes practical design, programming exercises in Python, QT, Node.js, HTML.
Grading Basis: Letter Grade

ECEA 5347 (1) Embedded Interface Design: Rapid Prototyping Emb I/F Designs
Presents methods, practices for rapid prototyping embedded interfaces for devices, systems, people. Introduces applied lean, UX methods for design decisions in the prototype cycle. Specific focus on using cloud-based services to prototype key system elements. Examines best practices for device data, wearables, voice user interfaces, connected product designs. Includes practical IoT-style development with programming in Python, Node.js, Amazon Web Services.
Grading Basis: Letter Grade

ECEA 5348 (1) Embedded Interface Design: M2M, IoT I/F Design & Protocols
Study protocols and design practices for Machine to Machine (M2M) and Internet of Things (IoT) communications between embedded devices. Includes low-level, personal and local area network, IoT application, and low-power wide area network protocols. Also examines message queueing, API design, and cloud connectivity approaches. Programming exercises introduce Python, Node.js, and Amazon Web Services for learning interface and integration design methods.
Grading Basis: Letter Grade

ECEA 5349 (1) Sensors for a Carbon Free World: Electric Vehicle Sensors
¿Electric Vehicle Sensors¿ starts with a discussion on how electric vehicles work differently from gasoline or diesel fuel powered vehicles and the major types of electric vehicles. It then moves to the unique components of full electric and hybrid electric vehicles, and how in-vehicle and outside battery charging systems work. We reference all the sensors that are used for in-vehicle and outside unique components. Then we do a deep dive into how each of these sensors work.
Grading Basis: Letter Grade

ECEA 5350 (1) Sensors for a Carbon Free World: Wind Turbine Sensors
¿Wind Turbine Sensors¿ starts with a discussion on how wind turbines generate electricity for the grid. It then moves to the major components of a wind turbine and how the generator transfers power to the grid. We reference all the sensors that are used in wind turbines. Then we perform detailed calculations on power efficiency, kinetic energy, DC power generation, and DC to AC conversion. Last, we do a deep dive into how each sensor in a wind turbine works.
Grading Basis: Letter Grade

ECEA 5351 (1) Sensors for a Carbon Free World: Solar Power Sensors
¿Solar Power Sensors¿ starts with a discussion on the photovoltaic process for generating electricity for the grid. It then moves to the types of solar cells: monocrystalline vs. polycrystalline, thin film, perovskite. We the move to the major components of a solar cell, how electricity is transferred to the grid, and how solar power grids are constructed. We reference all the sensors that are used in solar cells. Then we perform detailed calculations on solar irradiance, shading and efficiency. Last, we do a deep dive into how each sensor in a solar cell works.
Grading Basis: Letter Grade

ECEA 5360 (0.8) FPGA Design for Embedded Systems: Intro to FPGA Dsgn for ES
The Intro to FPGA Design for Embedded Systems course covers entering and compiling FPGA designs using Quartus Prime, recalling a list of common PLD architectures and the applications for which they are best suited, along with complexities, capabilities and trends of Field Programmable Gate Arrays (FPGA) and Complex Programmable Logic Devices (CPLD).
Grading Basis: Letter Grade

ECEA 5361 (0.8) FPGA Design for Embedded Systems: Hardwr Desc Lang FPGA Dsgn
The Hardware Description Languages for FPGA Design course covers design of programmable logic circuits using both VHDL and Verilog hardware description languages, and recalling the steps in a standard FPGA Design flow.
Grading Basis: Letter Grade

ECEA 5362 (0.8) FPGA Design for Embedded Systems: FPGA Softcore Proc, IP Acq
The FPGA Softcore Processors and IP Acquisition course covers evaluating the tradeoff between implementing or acquiring Intellectual Property (IP) cores, understanding the process of creating softcore processors by study and implementation, and describing and demonstrating FPGA design verification techniques, including simulation of test benches using ModelSim.
Grading Basis: Letter Grade

ECEA 5363 (0.6) FPGA Design for Embedded Systems: Building FPGA Projects
Building FPGA Projects explores building a working FPGA embedded system by embedding a soft core processor in an Altera MAX10 FPGA, and using onboard analog IP to interface to real variables. This course also emphasizes understanding and practice of all aspects of FPGA development, including conception, design, implementation, and debugging.
Grading Basis: Letter Grade

ECEA 5365 (1) Soft Processor Design for FPGAs: Expanded FPGA Training with NIOS II
This course covers configuration of a NIOS II CPU project. Device selection is based on the DE10-Lite development board, used for simulation and verification of the initial basic design. A CPU will be implemented that transmits a test pattern to the VGA connector along with external I/O using the user switches to set the output pattern for display.
Grading Basis: Letter Grade

ECEA 5366 (1) Soft Processor Design for FPGAs: Volatile Memory Interface
This course covers requirements for interfacing with external memory and methods for verifying proper configuration, data access and timing. The DE10-Lite board¿s SDRAM will be used to demonstrate this process. A memory test project will be implemented to show the read and write cycles on the external memory are operating correctly.
Grading Basis: Letter Grade

ECEA 5367 (1) Soft Processor Design for FPGAs: Video Processing in FPGA
This course will cover key concepts related to video signals, including types of video input as well as the additional components of a video system used to capture data and structure it for display. Additionally, there will be a discussion of the bandwidth requirements in an embedded system for the proper capture and processing of signals.
Grading Basis: Letter Grade

ECEA 5370 (1) Network Systems Foundation
In this course, students will learn the most important principles in network systems. This will center on the layered design of networks, and cover the link layer (Ethernet), network layer (IP), transport layer (TCP, UDP), and application layer (HTTP, gRPC). With those as a foundation, student will learn about network security problems and how some current solutions work at different layers.
Equivalent - Duplicate Degree Credit Not Granted: CSCA 5063
Grading Basis: Letter Grade

ECEA 5371 (1) Network Principles in Practice: Linux Networking
In this course students will learn how networking is designed and used in the Linux operating system. This will be learned in the context of networking principles and the application to real modern uses ¿ building network operating systems (that power network appliances) and using Linux to support connectivity in modern containerized and virtualized applications (such as a Kubernetes network plugin).
Equivalent - Duplicate Degree Credit Not Granted: CSCA 5073
Grading Basis: Letter Grade

ECEA 5372 (1) Network Principles in Practice: Cloud Networking
In this class, students will learn about the networking abstractions and services for building applications in the cloud, and the technology underlying cloud networking. Students will be able to architect complex applications in the cloud. In understanding how the cloud providers created their networks, students will be in a better position to troubleshoot applications and analyze different possible ways of architecting applications, and even help design the next generation of networking for cloud providers.
Equivalent - Duplicate Degree Credit Not Granted: CSCA 5083
Grading Basis: Letter Grade

ECEA 5375 (1) Microcontrollers: Basic Architecture and Design
This course introduces students to the architecture and design of Microcontrollers (MCUs), which are small processors used in a myriad of products. The main MCU components of the processor, memory, I/O interfaces and their interconnections will be examined, with a focus on the processor. The process of optimizing performance, energy usage and cost will be explored in a project where students will begin the development of an MCU in a system context.
Grading Basis: Letter Grade

ECEA 5376 (1) Microcontrollers: Memory and Peripheral Interface Design
This course expands on MCU architecture and design, with detailed analysis of the memory and peripheral interface components and how they are selected and used in specific systems. Special emphasis will be placed on the power control system and the various techniques used to optimize power and energy in a system. Many memory and peripheral components will be added to the course project.
Grading Basis: Letter Grade

ECEA 5377 (1) Microcontrollers: Intelligent DMA and AI at the Edge
This course analyzes DMA in MCUs and its impact on power and energy. The basic concepts of Artificial Intelligence (AI) inference are presented, and the special challenges of AI implementations in small, low power systems (AI at the Edge) will be explored. Special emphasis will be on components which accelerate AI functions with minimal power. The course project will be expanded with DMA and AI functions.
Grading Basis: Letter Grade

ECEA 5380 (1) Dsgn Domain-Specifc Arch Proc: Domain-Specific CPUs
There is a growing need to develop heterogeneous processor solutions for embedded signal processing, speech recognition, language translation, image and vision recognition, and Artificial Intelligence. Using modern highly abstracted processor development tools, Domain Specific Processors can be developed using data driven techniques in 30 days. This course and its series of courses utilizes a RISC-V open architecture processor core
Grading Basis: Letter Grade

ECEA 5381 (1) Dsgn Domain-Specifc Arch Proc: Domain-Specific CPU Optimizn
Domain-Specific CPU Optimization enables the processor architect to break through challenges of Dannard¿s Scaling and Moore¿s Law by optimizing the processor resources for the specific domain. Utilizing a highly abstracted processor development tool chain, students will explore optimizing a 5-stage RISC-V processor core with the addition of multi-stage instructions, hardware loops, L0 caches, and other techniques
Grading Basis: Letter Grade

ECEA 5382 (1) Dsgn Domain-Specifc Arch Proc: Validating Optimized CPUs
To manage time and risk, the design flow must integrate a verification process for Domain-Specific Processors that have been optimized for embedded signal processing, speech recognition, language translation, image recognition, and Artificial Intelligence. Through the use of integrated verification tools which incorporate Universal Verification Methodology, UVM, the highly abstracted processor development strategy shortens development schedules and reduces risk.
Grading Basis: Letter Grade

ECEA 5385 (1) Industrial IoT Markets and Security
In Markets and Security, students will learn about markets (Transportation, Agriculture and more), platforms (IBM Watson Cloud services for example), software and services, networking basics, wireless communications protocols and a thorough introduction to computer security.
Grading Basis: Letter Grade

ECEA 5386 (1) Developing Industrial IoT: Proj Planning, Machine Learning
Products don't design and build themselves. In this course, students learn how to staff, plan and execute a project to build a product. We explore sensors, which produce tremendous volumes of data, and then storage devices and file systems for storing big data. Finally, we study machine learning and big data analytics.
Grading Basis: Letter Grade

ECEA 5387 (1) Developing Industrial IoT: Modeling and Debugging Embed Sys
In this course, to study hypothetical scenarios, students learn about Digital Twins, using SystemC to model physical systems highly instrumented with sensors and actuators. We also look deeper into the Automotive and Transportation market segment, studying technologies and opportunities in that market space. Students learn techniques for debugging deeply embedded systems, then we examine technical idea promotion within a company, and learning from failures.
Grading Basis: Letter Grade

ECEA 5420 (1) Antennas: Antenna Alphabet
The Antenna Alphabet course covers fundamental parameters needed to understand the antenna as a circuit and as a space device are discussed. The antenna¿s role in communication, radar, and radiometric systems is also covered. Maxwellian approach to the antenna analysis and some basic theorems conclude this course.
Grading Basis: Letter Grade

ECEA 5421 (1) Antennas: Wire Antennas
In the Wire Antennas course, Dipole, monopole, loop, Yagi-Uda and helical antennas as well as some derivatives thereof are discussed. Theory of operation, fundamental near- and far-field parameters, impedance matching techniques, and baluns are also considered.
Grading Basis: Letter Grade

ECEA 5422 (1) Antennas: Microstrip, Spiral, Aperture Antennas, and Arrays
In this course, microstrip patch, horn, reflector, and frequency independent antennas are discussed. Array theory and application to linear, planar and circular arrays are also covered. Computer aided design of several antennas and arrays are included as well.
Grading Basis: Letter Grade

ECEA 5445 (1) Stochastic Env Signal Process: Model-Based Estimation
This course covers data set organization and manipulation using vectors, matrices, and transforms. Also covered are developing parameter-based models and parameter identification methods for large environmental data sets. Applications and quantitative implementation of a variety of spectral estimation methods are emphasized, along with measurement noise, statistical and sampling error, and noise and error impact in instrument applications and calibration.
Grading Basis: Letter Grade

ECEA 5446 (1) Stochastic Env Signal Process: Statisticl Estimation, Filter
This course covers optimal linear and nonlinear estimation algorithms suitable for large and small environmental data sets and real-time data streams. Continuous and discrete time and space optimal filtering methods are explored, along with impact of error and data covariance models and matrices. Kalman filtering and Bayesian estimation methods and forecasting and prediction applications using environmental models are also covered.
Grading Basis: Letter Grade

ECEA 5447 (1) Stochastic Env Signal Process: Statistical Detection, Apps
The Statistical Detection and Advanced Applications course covers the use of signal entropy in estimation theory and applications, as well as developing estimation and detection algorithms using neural nets. Also covered are optimal signal detection algorithms based on a-priori data, the application of supervised and unsupervised learning methods in signal classification, and recognizing advanced applications of environmental signal processing algorithms.
Grading Basis: Letter Grade

ECEA 5450 (1) The Science of Spectrum Access
This course starts with a discussion on how spectrum systems access the spectrum through data up conversions into the radio frequency (RF) spectrum. The basics of RF engineering, cascading RF components, propagation, and spectrum management are covered to prepare the student how to predict RF link budgets. RF link budgets will give the students an understanding of how wireless signals are transmitted and received and access the precious resource - the electromagnetic spectrum.
Grading Basis: Letter Grade

ECEA 5451 (1) Radio Frequency Engineering
The second module is a survey of RF engineering, delving into the design of the spectrum dependent systems. Using the design considerations, this course will then apply the designs to their applications and cover the math needed to computer predicted signal powers and signal to noise ratio needed to close a wireless link.
Grading Basis: Letter Grade

ECEA 5452 (1) Signals and Propagation
This course adds the presence of noise and non-linearities to the link budget calculations. This course will cover the various channel impediments that affect an unguided media and how to help mitigate those impediments.
Grading Basis: Letter Grade

ECEA 5453 (1) The Electromagnetic Spectrum
This course provides an overview and background of spectrum system fundamentals, concepts and engineering intuition, to provide the foundational basis for professional growth in the spectrum industry. It introduces the electromagnetic (EM) spectrum with an emphasis on the Radio Frequency portion of the EM spectrum. Both active and passive utilization of the Electromagnetic Spectrum are emphasized. Spectrum regulatory agencies and international standards bodies are introduced. RF propagation, antennas, the concept of decibels, and system link budgets are introduced. The OSI and TCP/IP layered models are overviewed, along with an introduction to modern software defined radio architectures, to provide a foundational basis for advanced topics. This course is strongly recommended for all non-technical/non-engineering students to provide the foundational basis for advanced topics and as a comprehensive review including the current state-of-the-art for students with engineering backgrounds.
Grading Basis: Letter Grade

ECEA 5454 (1) Signal Fundamentals
This course provides an overview and background of spectrum system fundamentals, concepts and engineering intuition, to provide the foundational basis for professional growth in the spectrum industry. It introduces analog and digital signal fundamentals, covers signal representation in both the time and frequency domain, and the transmission properties of different frequencies. The concepts of signal power, noise, interference, receiver sensitivity and frequency filters are covered. Examples are provided using AM, FM, and GPS radio frequency broadcasts to provide intuition and understanding.
Recommended: Prerequisite Introduction to Spectrum I.
Grading Basis: Letter Grade

ECEA 5455 (1) Economics, Management and Policy
This course provides an overview and background of the fundamentals Spectrum Management and Policy and the fundamentals of Spectrum Economics, Markets and Services. This course provides an introductory overview of the key theories, problems and principles that shape current spectrum management law and policy. Students will engage in critical debate of research and regulatory decisions determining how spectrum is allocated to support current and future wireless applications. The course introduces market trends in spectrum wireless telecommunications and the importance of the sector supply and demand, consumer demand analysis and the theory on how consumers value telecom goods and services. The class covers these topics from an interdisciplinary perspective, emphasizing the complex intersection of technology, economics, business, and public policy to achieve efficient implementation of spectrum management principles within the dynamic radio frequency spectrum sector. Recommended prerequisite: Introduction to S
Grading Basis: Letter Grade

ECEA 5456 (1) Radio Services and Broadcast Applications
Radio Services and Broadcast Applications¿ builds upon ¿Spectrum Engineering Fundamentals¿ to demonstrate applications of spectrum engineering through a survey of the earliest systems accessing the radio spectrum. From the first radio messages across the Atlantic, to radio and TV broadcasts, and land mobile radio applications, the characteristics of broadcast communication and their effect on spectrum use will be covered.
Grading Basis: Letter Grade

ECEA 5457 (1) Mobile Communication: Cellular and Wi-Fi
Mobile Communication: Cellular and Wi-Fi¿ addresses most recent spectrum system developments. Cellular and Wi-Fi systems have become the prevalent consumer systems accessing the spectrum through a variety of frequencies, modulations, and licensing arrangements. This module starts by detailing cellular communication characteristics, such as power, frequency use, and its evolution to 5G. Next, the inherent characteristics of Wi-Fi communication and similar systems operated without the need for a license are contrasted.
Grading Basis: Letter Grade

ECEA 5458 (1) Radio Determination and Space Applications
As the final module in the ¿Advanced Spectrum Engineering¿ course, ¿Radio Determination and Space Applications¿ focuses on less noticed spectrum applications, crucial for the functioning of many modern systems. Beginning with radio determination, the differences between active and passive spectrum systems is highlighted. This is followed by the distinction of radio location and radio navigation services, describing applications such as radar, range measurements, GNSS systems, and microwave ovens. The module concludes by moving the distinction between passive and active systems to space, where satellite communication, telemetry, earth observation, meteorological, and radio astronomy services are detailed.
Grading Basis: Letter Grade

ECEA 5459 (1) The Electromagnetic Spectrum
This first modules serves as an introduction to the value of the electromagnetic spectrum. It begins with a technical tutorial on the physics of spectrum and then how spectrum is divided up into services per band. Concluding with a discussion on the three primary dimensions of spectrum sharing.
Grading Basis: Letter Grade

ECEA 5460 (1) History of Spectrum Management
This second module reviews the spectrum licensing methods that have been attempted over the years. Topics covered include the first regulatory bodies, the international spectrum concerns, and what issues arose across the various licensing methods.
Grading Basis: Letter Grade

ECEA 5461 (1) Spectrum Sharing
The final module covers the way spectrum licenses are distributed presently with predictions towards the future. Globally spectrum licenses are being distributed through spectrum auctions while more flexible sharing mechanisms are being investigated and deployed. This module covers advanced sharing techniques while considering the technical and regulatory impediments.
Grading Basis: Letter Grade

ECEA 5462 (1) Consumer Demand and Valuation
This course uses fundamental economic tools to understand management decisions about consumer demand in telecom markets. The course emphasizes costs, benefits and incentives in understanding consumer behavior and how this behavior affects firms and market performance. The course comprises four parts. Part I introduces supply and demand. Part II examines empirical methods for consumer demand analysis. Part III presents consumer choice theory and Part IV applies the theory to consumer demand for telecom goods and services.
Grading Basis: Letter Grade

ECEA 5463 (1) Firm Supply and the Structure of the Market
This course uses fundamental economic tools to understand management decisions about firm organization and telecom market structure. The course emphasizes costs, benefits and incentives in understanding the production technology of firms and how this technology affects market performance. The course comprises four parts. Part I introduces production functions. Part II examines the short- and long-run costs of production. Part III describes the organization of the firm and it¿s profit objective and Part IV examines the firm¿s profit objective in a competitive telecom market.
Grading Basis: Letter Grade

ECEA 5464 (1) Optimal Pricing with Market Power
This course uses fundamental economic tools to understand management decisions about telecom pricing. The course emphasizes costs, benefits and incentives in understanding firm pricing and how these decisons affect market performance. The course comprises four parts. Part I introduces principles of monopoly pricing. Parts I examines pricing with market power. Part III presents theories of oligopoly competition and Part IV examines the role of government when telcom markets fail.
Grading Basis: Letter Grade

ECEA 5600 (1) Optical Engineering: First Order Optical System Design
This course will introduce first order optical system design, including an introduction to using OpticStudio as a computational design tool.
Grading Basis: Letter Grade

ECEA 5601 (1) Optical Engineering: Optical Efficiency and Resolution
This course begins with Maxwell¿s equations and introduces the concept of finite sized optics into the design as well as introducing tools to design and analyze systems with many optical elements.
Grading Basis: Letter Grade

ECEA 5602 (1) Optical Engineering: Design High-Performance Optical Systems
Design low aberration instruments via identification of 3rd order aberrations, calculations of Seidel coefficients, choice of optical layout and numerical optimization. Select and incorporate light sources into designs and calculate radiometric efficiency. Design optical systems to manipulate Gaussian beams.
Grading Basis: Letter Grade

ECEA 5603 (1) Capstone Design Project in Optical System Design
Learners will design a zoom telephoto camera, including: Paraxial design of zoom and telephoto lens functions; Specification of the imaging chip and aperture stop. Calculation of resolution and radiometric efficiency; Design, analysis and optimization of multi-element lenses. Requires ability to run OpticStudio. Preparation of a report documenting the results.The report will be peer graded.
Repeatable: Repeatable for up to 2.00 total credit hours.

ECEA 5605 (1.2) Active Optical Devices: LEDs and Semiconductor Lasers
You will learn about semiconductor light emitting diodes (LEDs) and lasers, and the important rules for design. You will do several homework assignments to cement your understanding of the material, as well as answering short questions during the presentation segments. After this course, you will be able to analyze and design semiconductor LED and laser sources.
Grading Basis: Letter Grade

ECEA 5606 (1.2) Active Optical Devices: Nanophotonics and Detectors
Nanophotonics and Detectors covers the basics of nanophotonic light emitting devices and optical detectors, including metal semiconductor, metal semiconductor insulator, and pn junctions, photoconductors, avalanche photodiodes and photomultiplier tubes.
Grading Basis: Letter Grade

ECEA 5607 (0.6) Active Optical Devices: Displays
The Displays course will cover the basics of electronic display devices, including liquid crystals, electroluminescent, plasma, organic light emitting diodes, and electrowetting based displays.
Grading Basis: Letter Grade

ECEA 5610 (1.4) Foundations of Quantum Mechanics
Introduces essential concepts and tools of quantum mechanics to engineering graduate students who may not have undergraduate level quantum mechanics background. Topics to be discussed include the concepts of quantum states, operators and measurements, one-dimensional potential problems, time evolution of quantum systems and ensembles of identical particles.
Recommended: Knowledge of undergraduate-level differential equations and linear algebra.
Grading Basis: Letter Grade

ECEA 5611 (0.8) Theory of Angular Momentum
Introduces the quantum mechanical concept of angular momentum operator and its relationship with rotation operator. It then covers the properties of the angular momentum operators and their eigenvalues and eigenfunctions. Finally, it offers an in-depth discussion on the theory of angular momentum addition.
Recommended: Knowledge of undergraduate-level differential equations and linear algebra.
Grading Basis: Letter Grade

ECEA 5612 (0.8) Approximation Methods
Introduces commonly used approximation methods in quantum mechanics. They include time-independent perturbation theory, time-dependent perturbation theory, tight binding method, variational method and the use of finite basis set. In each case, a specific example is given to clearly show how the method works.
Recommended: Knowledge of undergraduate-level differential equations and linear algebra.
Grading Basis: Letter Grade

ECEA 5615 (0.6) Fourier Optics: Fourier Transforms in 1D and 2D
This course covers the integral definition of Fourier transform and its properties, equivalence of 1-D temporal and spatial Fourier transforms, and Fourier transform pairs as 1-D plots and 2-D images. Emphasis is placed on utilizing Fourier transform pairs and properties to construct complex Fourier transforms in both 1-D and 2-D, and generalizing the Fourier transform to 2-D images and fields.
Grading Basis: Letter Grade

ECEA 5616 (0.8) Fourier Optics: Optical Wave Propagation and Imaging
This course demonstrates constructing arbitrary solutions to Maxwell's Equation as a superposition of plane waves and wave propagate through space. Learners develop clear intuition for plane wave propagation and Gaussian beams, how to compare, contrast, and analyze coherent and incoherent imaging systems, how to formulate and visualize a wave theory of aberrations, and applying numerical techniques to optical beam propagation.
Grading Basis: Letter Grade

ECEA 5617 (0.8) Fourier Optics: Numerical Techniques in Wave Optics
Numerical Techniques in Wave Optics explores the algorithmic efficiency of the FFT, how the FFT simplifies the calculation of optical beam propagation, and aberrations as just polynomial deformations of wavefronts.
Grading Basis: Letter Grade

ECEA 5618 (0.8) Fourier Optics: Holography, Optical Information Processing
In Holography and Optical Information Processing, we study using optical correlations for pattern recognition, and show how to invent holographic systems to record and transform optical fields. We extend ideas of holography to computer generated and digital holography, and further generalize the Fourier approach to broadband femtosecond fields. Finally, we use Fourier decomposition to invent and evaluate novel optical systems.
Grading Basis: Letter Grade

ECEA 5630 (1) Semiconductor Devices: Semiconductor Physics
Semiconductor Physics introduces the basic concepts in quantum theory of solids and presents the theory describing the carrier behaviors in semiconductors.
Grading Basis: Letter Grade

ECEA 5631 (1) Semiconductor Devices: Diode: pn junction and metal semiconductor contact
Presents in-depth discussion on pn junction and metal-semiconductor contact including the equilibrium behavior, current and capacitance responses under bias, breakdown, non-rectifying behavior and surface effect.
Grading Basis: Letter Grade

ECEA 5632 (1) Semiconductor Devices: Transistor: Field Effect Transistor and Bipolar Junction Transistor
Presents in-depth discussion on metal-oxide-semiconductor field effect transistor (MOSFET) and bipolar junction transistor (BJT) including the equilibrium characteristics, modes of operation, switching and current amplifying behaviors.
Grading Basis: Letter Grade

ECEA 5700 (0.8) Power Electronics: Introduction to Power Electronics
Introduces the basic concepts of switched-mode converter circuits for controlling and converting electrical power with high efficiency. Principles of converter circuit analysis are introduced and developed for finding steady-state voltages, current, and efficiency of power converters. Assignments include a dc-dc converter simulation, inverting dc-dc converter analysis, and modeling of an electric vehicle system and a USB power regulator.
Grading Basis: Letter Grade

ECEA 5701 (1) Power Electronics: Converter Circuits
Introduces more advanced switched-mode converter concepts. Realization of power semiconductors in inverters or in converters having bidirectional power flow is explained. Power diodes, power MOSFETs, and IGBTs are explained, including their switching time origins. Equivalent circuit models are refined to include the effects of switching loss. Several well-known converter circuit topologies are explored, including those with transformer isolation.
Grading Basis: Letter Grade

ECEA 5702 (1.2) Power Electronics: Converter Control
This course teaches feedback system design to control a switching converter. Equivalent circuit models derived in previous courses are extended to model small-signal ac variations. These models are then solved for important converter transfer functions and regulator system. Finally, the feedback loop is modeled and designed to meet requirements such as output regulation, bandwidth and transient response, and disturbance rejection.
Grading Basis: Letter Grade

ECEA 5703 (1) Power Electronics: Magnetics Design
Covers magnetic component analysis and design, including inductors and transformers in power electronic converters. First introduced are inductor and transformer physical principles, including concepts of inductance, core material saturation, inductors airgap and energy storage, reluctance and magnetic circuit modeling, transformer-equivalent circuits, magnetizing and leakage inductance. Multi-winding transformer model details are covered, plus optimizing inductors in switched-mode power converters.
Grading Basis: Letter Grade

ECEA 5705 (0.8) Modeling, Control of Power Elec: Avged-Sw Modeling and Sim
Focuses on practical design-oriented modeling and control of pulse-width modulated switched-mode power converters using analytical and simulation tools in time and frequency domains. A design-oriented analysis technique, the Middlebrook's feedback theorem, is introduced and applied to analysis and design of voltage regulators and other feedback circuits. Furthermore, circuit averaging and averaged-switch modeling techniques are also covered in detail.
Grading Basis: Letter Grade

ECEA 5706 (0.6) Modeling, Control of Power Elec: Tech Dsgn-Oriented Analysis
Focuses on two techniques of design-oriented analysis, Middlebrook's extra-element theorem (EET), and n-extra-element theorem (NEET). It is shown how EET simplifies circuit analysis and design, provides insights into effects of circuit elements initially neglected, and to formulate design approaches. NEET allows designers to easily derive complex transfer functions in circuits such as converter filters and averaged circuit models.
Grading Basis: Letter Grade

ECEA 5707 (0.6) Modeling, Control of Power Elec: Input Filter Design
To meet electromagnetic interference (EMI) requirements and mitigate effects of switching noise, switching power converters often require input filters. Using extra-element theorem, it is shown how adding an input filter may compromise system stability, and impedance criteria are formulated to mitigate system stability issues. Input filter design techniques are developed for single-stage and multi-stage filters to meet several design criteria.
Grading Basis: Letter Grade

ECEA 5708 (1.2) Modeling, Control of Power Elec: Current-mode Control
Control loops around switch-mode power converters are often based on current-mode control techniques. This course is focuses on analysis, modeling and design of current programmed mode or peak current mode (PCM) control, as well as average current mode (ACM) control. Sampling effects and compensation ramp concepts are introduced. Averaged dynamic models and transfer functions of PCM-controlled converters are developed.
Grading Basis: Letter Grade

ECEA 5709 (0.6) Modeling, Control of Power Elec: Mod/Ctrl 1-Phase Rect/Inv
Covers pulse-width modulated (PWM) converters connected to the single-phase ac power grid. Harmonic standards and the need for power factor correction are discussed. Modeling and control techniques for PWM rectifiers include design of input current control and output voltage control. Modeling and control of single-phase inverters are introduced in the context of a solar photovoltaic power system.
Grading Basis: Letter Grade

ECEA 5715 (1.2) Power Electronics Capstone Project
A design project that applies the material of courses ECEA 5700, 5701, 5702, 5703, and 5705 to design and verify a bidirectional dc-dc converter and its controller, to interface a lithium-polymer battery to a USB-C device. Three milestones demonstrate: design and steady-state operation of converter power stage, averaged modeling and design of converter controller, and closed-loop transient response and regulation.
Grading Basis: Letter Grade

ECEA 5716 (1) Open-Loop Photovoltaic Power Electronics Laboratory
Design, construct, and demonstrate an open-loop PV power electronics system in which a dc-dc switching converter interfaces a PV panel to a deep-discharge 12 V battery. The project includes testing and modeling of the PV panel, design and testing of the dc-dc converter and its magnetics, and use of a modern microcontroller to drive the power MOSFET.
Recommended: Prerequisites ECEA 5700, ECEA 5701, and ECEA 5703.
Grading Basis: Letter Grade

ECEA 5717 (1) Closed-Loop Photovoltaic Power Electronics Laboratory
Develop a digital controller to regulate the output voltage of the dc-dc SEPIC constructed in ECEA 5716. Modeling and measurement of the small-signal control-to-output transfer function, damping of the SEPIC internal resonance as necessary, design and implementation of a digital compensator, and demonstration of closed-loop performance.
Recommended: Prerequisites ECEA 5702 and ECEA 5716.
Grading Basis: Letter Grade

ECEA 5718 (1) Photovoltaic Power Electronics Battery Management Laboratory
Complete the photovoltaic power system of ECEA 5716-5718. Implement maximum power point tracking, charge taper, and float modes via digital control and current sensing circuitry.
Recommended: Prerequisites ECEA 5716 and ECEA 5717.
Grading Basis: Letter Grade

ECEA 5721 (0.6) Introduction to Power Switches
Power Semiconductor devices that are commonly used in power electronic circuits. Starting with the circuit models of these devices, we will identify the requirements leading to low loss circuits and learn how these can be simulated and analyzed in basic switching circuits. Department Enforced Prerequisite: Undergraduate active circuit knowledge and first exposure to SPICE.
Recommended: Prerequisite ECEA 5797.
Grading Basis: Letter Grade

ECEA 5722 (1.2) High-Voltage p-n and Schottky Diodes
Introducing the semiconductor physics background needed to understand the operation of high voltage p-n and Schottky diodes, the analysis of the electrostatic behavior of the diode, the diode current, and the circuit model for the diode. The course also includes a discussion of super junctions and high voltage termination structures. Department Enforced prerequisites: Knowledge of undergraduate physics including Ohm¿s and Gauss¿s law.
Recommended: Prerequisites ECEA 5797 and ECEA 5721.
Grading Basis: Letter Grade

ECEA 5723 (1.2) MOSFETs, IGBTs and more
Introducing active switches, gated semiconductor devices that can open or close a circuit. Included are MOSFETs, BJTs, and IGBTs as well as emerging devices such as GaN HEMTs and latching devices such as thyristors and TRIACs. The course concludes with the analysis of power modules, and device comparisons through modeling and simulation.
Recommended: Prerequisites ECEA 5797, ECEA 5721 and ECEA 5722.
Grading Basis: Letter Grade

ECEA 5724 (0.6) Power Device Fabrication
Introducing the fabrication of power devices, starting with the IC fabrication of power devices from a wafer to a packaged device. Included is an analysis of the needed high voltage termination structures, the influence of packaging parasitics and the thermal management.
Recommended: Prerequisites ECEA 5797, ECEA 5722 and ECEA 5723.
Grading Basis: Letter Grade

ECEA 5730 (0.8) Introduction to Battery-Management Systems
Introduces the need for and functional requirements placed on battery-management systems (BMS) for high-capacity lithium-ion battery packs. Overviews BMS hardware requirements and previews BMS algorithm requirements. Gives tutorial introduction to battery terminology, basic principles of battery operation, battery manufacture, and battery failure modes.
Grading Basis: Letter Grade

ECEA 5731 (0.8) Equivalent-Circuit Cell-Model Simulation
Motivates the need for mathematical models of lithium-ion cell dynamics and derives a progression of equivalent-circuit cell models of increasing fidelity. Shows how to regress laboratory data collected from physical cells to determine parameter values. Extends the single-cell model to describe battery packs and to show how to co-simulate a simplified battery and battery load. Concludes with a capstone project.

ECEA 5732 (1) Battery State-of-Charge (SOC) Estimation
Introduces physical significance of battery-cell state-of-charge (SOC) and the need for high-fidelity SOC estimates in a BMS. Derives linear and nonlinear Kalman filters (including extended Kalman filter and sigma-point/unscented Kalman filter) and applies them to estimate the states corresponding to a cell model, including SOC. Shows how to generalize efficiently to battery-pack state estimation. Concludes with a capstone project.

ECEA 5733 (0.8) Battery State-of-Health (SOH) Estimation
Introduces the concept of battery-cell health and the physical mechanisms by which lithium-ion cell health degrades. Introduces simple methods to estimate cell health and their limitations. Derives a progression of total-least-squares methods for total-capacity estimation, resulting in optimal and near-optimal estimates. Also applies Kalman-filter theory for this same purpose. Concludes with a capstone project.

ECEA 5734 (0.8) Battery-Pack Balancing and Power Estimation
Illustrates the need for balancing individual cell states-of-charge in a battery pack and presents electronics topologies and algorithm-design choices for bringing a battery pack into balance. Extends simplified power-limits methods from ECEA 5730 to give better estimates under dynamic loads using comprehensive cell model. Posits future directions for BMS algorithm research and development. Concludes with a capstone project.

ECEA 5740 (1) Analog IC Design: Op-amp Basics and Design of One-Stage Amp
The Op-amp Basics and Design of One-Stage Amplifier course first covers imperfections of amplifier and reasons behind them, then introduces learners to the most fundamental analog circuit, a simple one-stage amplifier in transistor level design. Methods of circuit analysis and design used in this basic course will be the basis for many other more complex circuits in the series.
Grading Basis: Letter Grade

ECEA 5741 (1) Analog IC Design: Two-Stage Amplifier Design
Two-Stage Amplifier Design covers two-stage amplifier circuit design based on given low-frequency specifications. Learners will have opportunity to practice skills learned in the previous course on a more complex circuit.
Grading Basis: Letter Grade

ECEA 5742 (1.2) Analog IC Design: Frequency Response, Feedback, Compensation
In the Frequency Response, Feedback and Compensation course, learners will be provided technical skills around inspecting and analyzing the frequency responses of several CMOS amplifier circuits, then apply results in a feedback system and analyze its stability, and also apply compensation techniques for two-stage amplifier.
Grading Basis: Letter Grade

ECEA 5800 (1) Control Systems Analysis: Modeling of Dynamic Systems
Covers differential equation derivation to model systems, solving these equations through Laplace transforms to determine transfer functions for simple mechanical, electrical, and electromechanical systems. We will analyze 1st and 2nd-order system dynamic responses, and explore approximating higher-order systems with 1st to 3rd-order systems. Also covered, Bounded-Input Bounded-Output (BIBO) stability, plus designing and evaluating proportional, integral, and derivative controllers.
Grading Basis: Letter Grade

ECEA 5801 (1) Feedback Control and Root Locus Design
In this course, we will sketch root loci following basic root locus plotting rules, analyze common features in root locus plots, and extract the overall control gain at a desirable closed-loop pole location. We will use Bode plots to design controllers and determine system stability, and also design PD, Lead, PI, Lag, PID, and Lead-Lag compensators.
Grading Basis: Letter Grade

ECEA 5802 (1) Frequency-Domain and State-Space Design
In this course, we will cover state-space equations and their relationship to transfer function representations of systems. We will design a full-state feedback control law and introduce a reference input to the state feedback system. Finally, we will design an estimator for a system and explore the concept of duality and how estimator design is related to control-law design.
Grading Basis: Letter Grade

ECEA 5838 (1) Nonlinear Dynamics
This course introduces the mathematical tools for analyzing nonlinear differential equations, focusing on behaviors such as equilibria, periodic orbits, and chaos. Students will learn to perform phase plane analysis, assess the existence and uniqueness of solutions, and simulate nonlinear systems using numerical methods. Emphasis is placed on understanding two-dimensional system dynamics, providing a foundation for interpreting and predicting the behavior of nonlinear dynamical systems.
Grading Basis: Letter Grade

ECEA 5839 (1) Nonlinear Stability
This course introduces the fundamental concepts of stability in nonlinear systems, focusing on Lyapunov stability, Krasovskii-LaSalle principles, and passivity. Students will learn to analyze invariant set stability using Lyapunov methods, identify passive systems, and evaluate input-to-output stability. Topics include input-to-state stability and the small-gain theorem, with an emphasis on both theoretical frameworks and practical applications for nonlinear stability analysis.
Grading Basis: Letter Grade

ECEA 5840 (1) Nonlinear Control
This course builds on nonlinear stability concepts to explore the design of control strategies for nonlinear systems. Topics include linearization, feedback linearization, control Lyapunov functions, backstepping, and passivity-based control. Students will learn to identify suitable control approaches and design feedback controllers tailored to specific nonlinear systems. The course also introduces hierarchical control methods, providing a comprehensive foundation for advanced nonlinear control design.
Grading Basis: Letter Grade

ECEA 5850 (0.8) Kalman-Filter Boot Camp and State-Estimation Application
Introduces the Kalman filter as a method that can solve problems related to estimating the hidden internal state of a dynamic system. Develops the background theoretical topics in state-space models and stochastic systems. Presents the steps of the linear Kalman filter and shows how to implement these steps in Octave code and how to evaluate the filter¿s output.
Grading Basis: Letter Grade

ECEA 5851 (0.8) Linear Kalman Filter Deep Dive and Target Tracking
As a follow-on course to "Kalman Filter Boot Camp", this course derives the steps of the linear Kalman filter to give understanding regarding how to adjust the method to applications that violate the standard assumptions. Applies this understanding to enhancing the robustness of the filter and to extend to applications including prediction and smoothing. Shows how to implement a target-tracking application in Octave code using an interacting multiple-model Kalman filter.
Grading Basis: Letter Grade

ECEA 5852 (0.8) Nonlinear Kalman Filters and Parameter Estimation
As a follow-on course to "Linear Kalman Filter Deep Dive", this course derives the steps of the extended Kalman filter and the sigma-point Kalman filter for estimating the state of nonlinear dynamic systems. You will learn how to implement these filters in Octave code and compare their results. You will be introduced to adaptive methods to tune Kalman-filter noise-uncertainty covariances online. You will learn how to estimate the parameters of a state-space model using nonlinear Kalman filters.
Grading Basis: Letter Grade

ECEA 5853 (0.8) Particle Filters and Navigation
As the final course in the Applied Kalman Filtering specialization, you will learn how to develop the particle filter for solving strongly nonlinear state-estimation problems. You will learn about the Monte-Carlo integration and the importance density. You will see how to derive the sequential importance sampling method to estimate the posterior probability density function of a system¿s state. You will encounter the degeneracy problem for this method and learn how to solve it via resampling. You will learn how to implement a robust particle-filter in Octave code and will apply it to an indoor-navigation problem.
Grading Basis: Letter Grade

ECEA 5900 (1) Introduction to Modeling for Formal Verification
This course introduces the basic concepts of functional verification and model checking, highlighting their importance in modern system designs. It explains different modeling formalisms for representing the behavior of hardware and software, which are either suitable for automated analysis or can represent data-dependent controls that are common in computing system designs. Additionally, it describes system compositions with respect to different communication models
Grading Basis: Letter Grade

ECEA 5901 (1) Temporal Logic Model Checking
This course introduces two temporal logics, linear time logic (LTL) and computation tree logic (CTL) for formally specifying desired properties of computing systems. It then introduces graph-based algorithms to decide the truth of properties specified in these logics against transition system models of target systems under verification. To improve the scalability of model checking to handle large and complex verification problems, symbolic model checking methods for CTL properties will be covered. This involves formulation of CTL model checking problems as Boolean logic operations, and introduction of ordered binary decision diagrams (OBDDs) as a method to efficiently support these Boolean operations.
Grading Basis: Letter Grade

ECEA 5902 (1) Model Checking with SAT and SMT
This course introduces the fundamentals of model checking with a focus on SAT (Propositional Satisfiability) and SMT (Satisfiability Modulo Theories). You will learn key techniques for verifying systems, including conflict-driven clause learning (CDCL), proof methods, and theory-specific solvers. Topics cover translating Boolean circuits to CNF, bounded and unbounded model checking, and advanced techniques like interpolation. Ideal for those seeking to understand and apply model checking methods in practical scenarios.
Grading Basis: Letter Grade

ECEA 5903 (1) Safety Verification Using Invariants
This course introduces the fundamentals of invariant-based safety specifications and automated verification techniques. Students will learn, through representative examples, safety design requirement specification using invariants, and basic techniques to strengthen them to enable correctness proofs through induction. Students will also learn formal modeling and deductive verification techniques for reasoning about the correctness of concurrent system design. In addition, this course introduces the state-of-the-art safety invariant checking technique, namely, Incremental Construction of Inductive Clauses for Indubitable Correctness (IC3), also called Property Directed Reachability (PDR).
Grading Basis: Letter Grade

ECEA 5910 (1) Stochastic Simulation
This course covers methods to estimate quantitative properties of random processes using Markov Chain models. Both continuous-time and discrete-time models are examined. Special attention is given to ¿fast¿ simulation of rare events using importance sampling and related techniques. Advantages and hazards of importance sampling are investigated. Methods are applied to example problems in biochemical reaction networks.
Grading Basis: Letter Grade

ECEA 5911 (1) Formal Verification of Probabilistic Systems
This course introduces the fundamentals of formal modeling and verification of systems that exhibit probabilistic behavior. Probabilistic modeling formalisms include discrete-time Markov chain (DTMC), continuous-time Markov chain (CTMC), and Markov decision process (MDP). This course also introduces multiple probabilistic temporal logic formalisms for system-design requirement specification. Probabilistic verification focuses on probabilistic model checking techniques for transient and steady-state analysis of the stated probabilistic modeling formalisms. In addition, this course introduces the PRISM probabilistic modeling language and probabilistic model checking tools.
Grading Basis: Letter Grade

ECEA 5912 (1) Formal Verification of Timed Systems
Safety critical systems often include hard real-time constraints that must be met for proper operation. This course introduces methods to model the timing behavior of these systems and to specify properties that these systems are expected to satisfy. This course will then introduce methods to verify these timing properties are satisfied using a technique called timed system model checking. The core aspect of these methods that is unique from other model checking methods is the requirement to effectively and efficiently represent time. Therefore, this course will introduce symbolic methods that can be utilized during state reachability analysis. Next, this course will introduce an alternative model for representing timed systems called timed Petri nets. Finally, this course will conclude with advanced topics in timing verification that will highlight various improvements and optimizations that can improve the efficiency of timing verification.
Grading Basis: Letter Grade

ECEA 5913 (1) Formal Verification of Hybrid Systems
Safety critical systems often include both continuous and discrete (hybrid) dynamical behavior. This course introduces methods to model hybrid dynamical behavior inherent in these systems and to specify properties that these systems are expected to satisfy. This course will then introduce methods to verify these hybrid properties are satisfied using a technique called hybrid system model checking. The core aspect of these methods that is unique from other model checking methods is the requirement to effectively and efficiently represent continuous behavior. Therefore, this course will introduce symbolic methods that can be utilized during state reachability analysis. Next, this course will introduce an alternative model for representing hybrid systems called hybrid Petri nets. Finally, this course will conclude with advanced topics in hybrid system verification that will highlight various improvements and optimizations that can improve the efficiency of hybrid system verification.
Grading Basis: Letter Grade

ECEA 5934 (1) Engineering Genetic Circuits: Design
Gives an introduction to the biology and biochemistry necessary to understand genetic circuits. It starts by providing an engineering viewpoint on genetic circuit design and a review of cells and their structure. The second module introduces genetic parts and the importance of standards followed by a discussion of genetic devices used within circuit design. The last two modules cover experimental techniques and construction methods and principles applied during the design process.
Grading Basis: Letter Grade

ECEA 5935 (1) Engineering Genetic Circuits: Modeling and Analysis
Covers mathematical models and analysis methods used to describe genetic circuits in the field of synthetic biology. The first module introduces modeling methods and standards for modeling. The following three modules cover different methods for the simulation of models to predict a genetic circuit's behavior in silico. Methods covered include ordinary differential equation analysis and stochastic analysis. The course ends with an introduction to genetic circuit technology mapping, the process of assigning physical biological parts to implement the functional design specification.
Grading Basis: Letter Grade

ECEA 5936 (1) Engineering Genetic Circuits: Abstraction Methods
Given the substantial computational requirements for simulation of even modest size genetic circuits, model abstraction is essential. To reduce the cost of simulation, this course first describes methods to simplify the original reaction-based model by applying several reaction-based abstractions. Second, this course introduces state-based (logical) abstraction methods and analysis techniques that have commonly been applied to electronic circuits.
Grading Basis: Letter Grade