UCSD ECE
Power Engineering Depth

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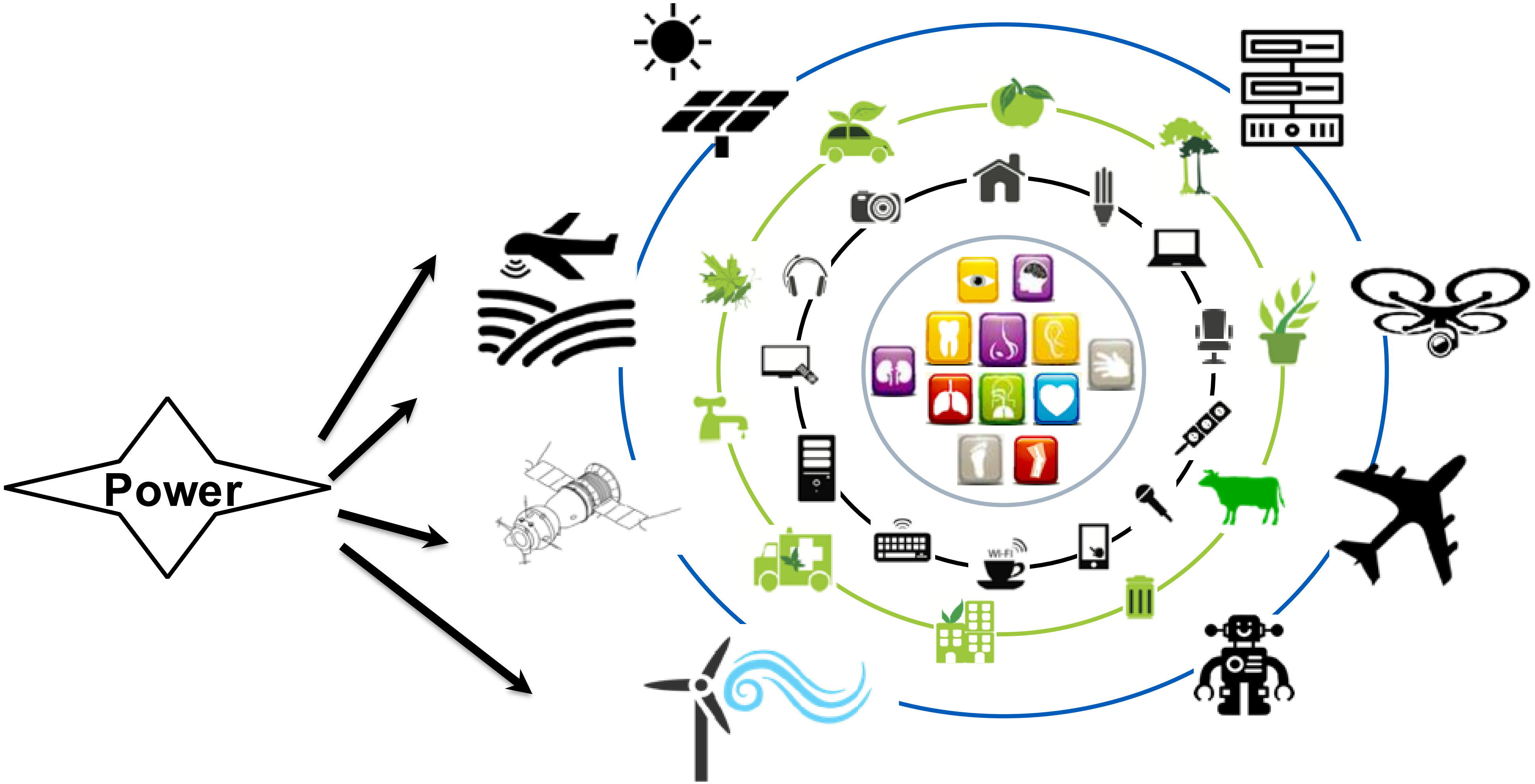
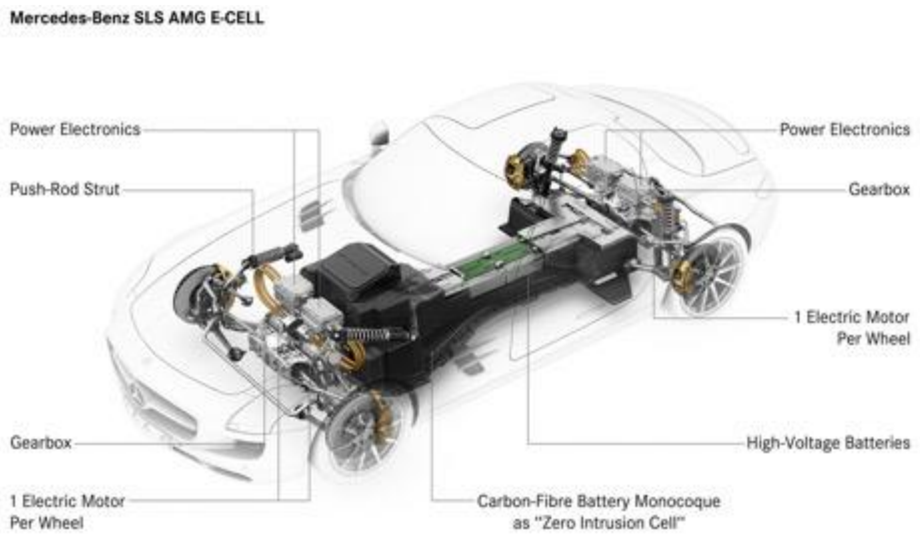
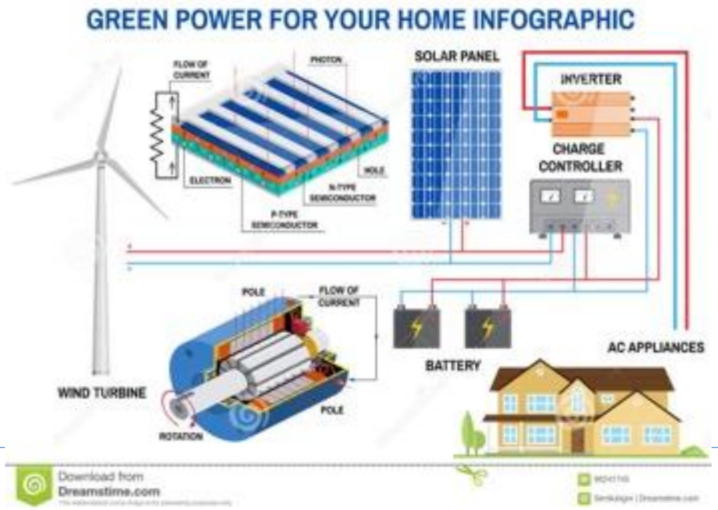
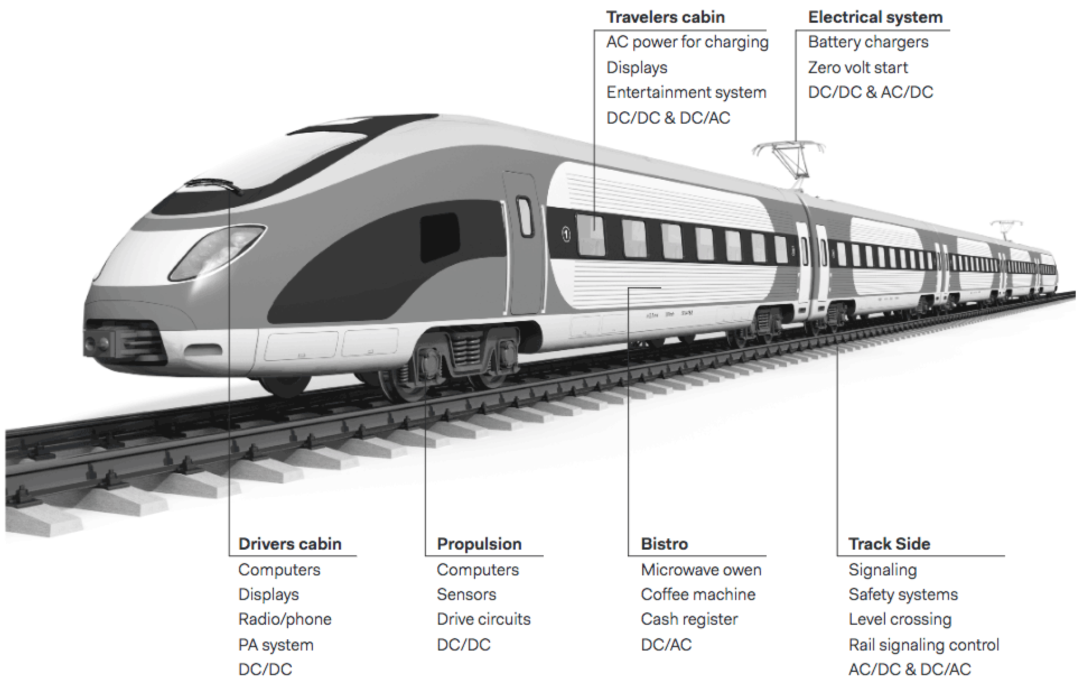
The World of Electronic Devices Needs Power



Power Engineering Applications



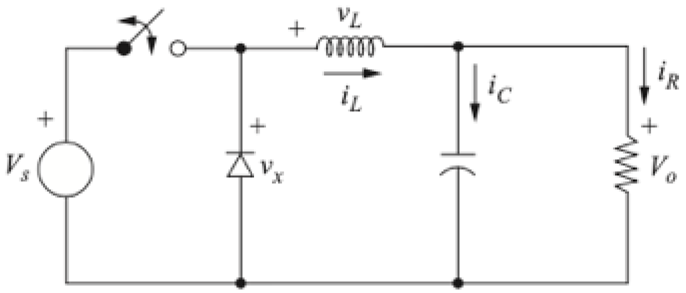


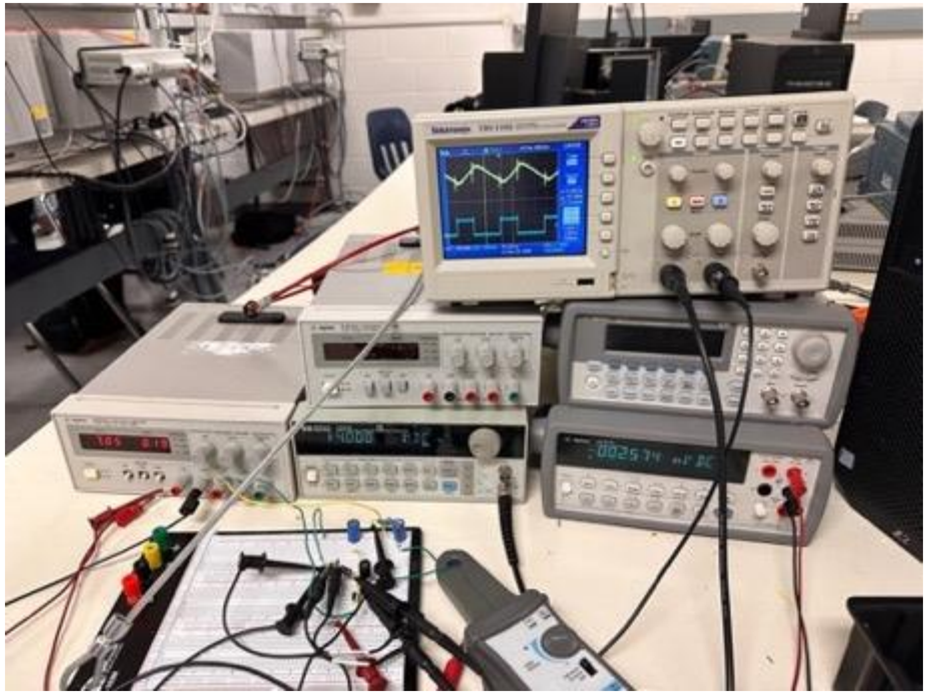


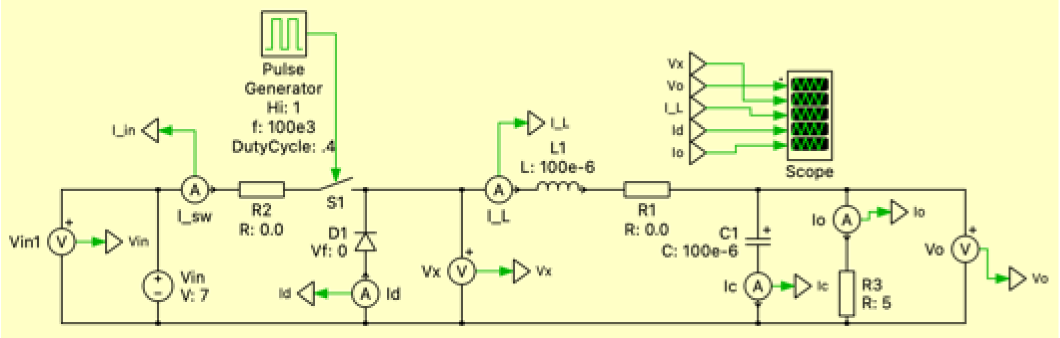
- No design fits all needs
  - Power, voltages, currents,
  - Transient response
  - …

Power Engineering Skills

- Fundamentals on renewable energy and power generation: solar and wind energy systems, and energy storage
- Power conversion and delivery in renewable energy, distribution, electric vehicles, car, trains, airplane, submarines, etc.
- Power converter operation and optimization for DC-DC, AC-DC, 3-phase systems
- Modeling and control of power systems, power converters, and energy storage, etc.
- Electric machines and control
- Operation, data analysis, and optimization in power grid, renewable energy, etc.
- Application of AI and machine learning in energy forecasting, power management, and control







Power Engineering Jobs

Consumer electronics	Automotive	Components	Air, Space, Defense	National Labs
Apple	Tesla	Qualcomm	SpaceX	NREL
Google	Ford	Intel	Lockheed	LBNL
Meta	GM	Texas Instruments	Boeing	LLNL
GE	Mercedes-Benz (Daimler)	Analog Devices	Raytheon	LLNL

Job positions with an undergraduate degree in this depth:

- Start with an application engineer position where you can test and design test boards for certain products
- Participate and design power systems.

Current Courses on Power Engineering

Power Electronics	☐ ECE 121A (F):	Power Systems Analysis and Fundamentals (ECE 35)
	☐ ECE 121B (W):	Power Systems Analysis and Fundamentals (ECE 121A)
	☐ ECE 125A (W):	Introduction to Power Electronics I (ECE 121A)
	☐ ECE 125B (S):	Introduction to Power Electronics I (ECE 125A)
	☐ ECE 283 (F):	Power Management Integrated Circuits (PMIC) (102,125A)
	☐ ECE 124:	Motor Drives (ECE121B, ECE125A)
Power Systems	☐ ECE 128A (F):	Real World Power Grid Operation
	☐ ECE 128B (W):	Power Grid Modernization (ECE 35 and ECE 128A)
	☐ ECE 100s/200s (TBD):	Data Science for Power Systems/Smart Grid

- **All classes have labs and/or projects with practical hands-on experience.**

- 100s: junior/senior B.S. level
- 200s: graduate M.S. level

- Gray: currently discontinued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ECE 121A – Power Systems Analysis and Fundamentals

Topics Covered

- Introduction to power system and energy conversion
- 3-phase AC circuit analysis
- Single-phase transformers
- Three-phase transformers
- Design and modeling of transmission lines
- Power system modeling and single-line diagram
- DC & AC power flow control

Lab Outline

- Lab 1: Pre-Lab simulation software
- Lab 2: Y-Δ Connections, 3-phase source, 3-phase inductive and capacitive loads
- Lab 3: Power factor correction in three-phase system
- Lab 4: Measurement of single-phase transformer parameters and its equivalent circuit
- Lab 5: Voltage regulation and transformer characteristic under load condition

ECE 121B – Energy Conversion

Topics Covered

- Introduction to energy conversion
- Basic of magnetic circuits
- Modeling and operation of DC motors and Generators
- Steady-state analysis of three-phase induction motors
- Steady-state analysis of synchronous machines

Lab Outline

- Lab 1: Pre-Lab simulation software
- Lab 2: Characteristic of DC generators
- Lab 3: Characteristic of DC motors
- Lab 4: Rotor locked and no load test of induction motors and its equivalent circuit
- Lab 5: Torque characteristic and speed control
- Lab 6: Measurement of synchronous machine circuit parameters

ECE 125A – Power Electronics I

- **Topics Covered**
  - Overview of power semiconductor devices and characteristics
  - Diode (Uncontrolled) rectifiers
  - Controlled AC-DC rectifiers
  - Non-Isolated DC-DC converters
  - Isolated DC-DC converters
  - Power loss calculation and thermal considerations
  - Snubber circuits
- **Lab Outline**
  - Lab 1: Pre-Lab simulation software
  - Lab 2: Sim. Half-wave single-phase diode rectifiers with R, RL, and LC Loads
  - Lab 3: Sim. Full-wave single-phase diode rectifiers with R, RL, and LC Loads
  - Lab 4: Sim. Full-wave three phase diode rectifiers with R, RL, and LC Loads
  - Lab 5: Buck converter CCM and DCM operations
  - Lab 6: Boost converter CCM and DCM operations
  - Lab 7: Buck-Boost converter CCM and DCM operations

ECE 125B – Power Electronics II

- **Topics Covered**
  - State-space modeling of DC/DC converters
  - Single-phase and three-phase inverters
  - PWM switching techniques for DC/AC inverters
  - Closed loop control of power converters
  - Grid interface and control of solar panels
  - Applications of power electronics in power & energy
  - Soft switching and resonant converters
- **Lab Outline**
  - Lab 1 & 2: Closed loop modeling of DC-DC Converters
  - Project 1: Modeling of 6-step 3-phase inverter under inductive, unity power factor, and capacitive conditions
  - Project 2: Implement Sine-PWM & SVM switching patterns under Inductive, Resistive, and capacitive conditions
  - Project 3: Design and modeling Closed-Loop control system for grid-tied operation
  - Project 4: Implement MPPT for Solar panels connected to grid through 3-Phase inverter
  - Presentation: Each group will present all the projects combined in one presentation at the end of quarter

ECE 124 – Introduction to Motor Drives

- **Topics Covered**
  - Describe the operation of DC motor drives to satisfy four-quadrant operation to meet mechanical load requirements.
  - Design torque, speed and position controller of DC motor drives.
  - Describe the operation of induction machines in steady state that allows them to be controlled in induction-motor drives.
  - Learn speed control of induction motor drives in an energy efficient manner using power electronics.

- **Lab Outline**
  - Project 1: Modeling of H-Bridge Converter with RLE load and design current and voltage loops using different control techniques
  - Project 2: Control design and modeling of speed and torque control of separately excited DC motors
  - Project 3: Design and modeling of full-bridge controlled rectifier and implement field weakening control of DC motor above base speed
  - Project 4: Open-loop and closed-loop control of induction motors using 3-Phase PWM converters and constant V/f control method
  - Presentation: Each group will present all the projects combined in one presentation at the end of quarter

ECE 128A – Real World Power Grid Operation

Description

This course provides practical insights into the operation of the power grid. It will cover the same subjects, and depth, that actual power system operators' certification course covers. It systematically describes the vital grid operator's functions, the processes required to operate the system, and the enabling technology solutions deployed to facilitate the processes. The course uses actual case histories, and real examples of best in-class approaches from across the nation and the globe. It presents the problems encountered by operators and the enabling solutions to remedy them. Industry tools will be provided to the students.

Opportunities for the Students

ECE graduates with aspirations of working in the power systems field will find this course extremely beneficial as it tackles real operational situations and solutions that cannot be found elsewhere. The demand for engineering graduates, at utility companies and companies that cater to them, such as consulting firms, equipment suppliers and system integrators, has increased by many folds over the last few years. Students who take this course, with its real-life examples and solutions in the operational aspects of the power grid, will have a clear advantage in seeking these new job opportunities.

Course Purpose

The aim of this course is to increase the understanding of the dynamic phenomena in the power systems by providing practical insights into the operation of the power grid and the vital grid operator's functions and actions. The core materials are supplemented by real-world examples. It will also include details of power outages that affected millions of people in which the instructor acted as the principal investigator. The core materials of this course have been approved for system operator's education and certification. It includes a review of power system fundamentals, followed by chapters on active and reactive power flow, frequency and voltage stability.

Course Coverage

- Introduction of power systems operations and fundamentals
- Utility and independent system operators (ISO's) control rooms
- Power system equipment in generation, transmission, distribution and substations
- Real power and reactive power deficits ion the grid
- Grid frequency control
- Voltage and angle issues and remedies
- Grid oscillations
- Major disturbances and blackouts
- Geomagnetic disturbances
- Case studies on all the above
- Governing Standards

ECE 128B – Power Grid Modernization

Description

This course provides an in-depth coverage of the future power grids spanning form: power generation through the power delivery systems down to the end-user. It covers the practical aspects of the technologies, their design and system implementation. Topics include: the changing nature of transmission and distribution systems with renewable resources; intelligent grid applications; smart meters; phasor measurement units; advanced metering infrastructure; micrograds distributed energy resources and the information and communications infrastructures needed. It uses actual examples along lessons learned and best practices. Industry tools will be provided to the students.

Opportunities for the Students

All electrical utilities are modernizing their grids, albeit at different stages in this process, and are looking for graduate engineers with background in smart grid applications. Our graduates, who take this course and its sister course, Renewable and Energy Storage Resources Course, and the other power courses that ECE is offering, will be very desirable to hire in power systems jobs at utility companies, smart equipment vendors and consulting firms. Students who took this course have landed very exciting jobs in the power field.

Course Purpose

This objective of this course is to detail the areas that different utilities (large and small) are pursuing to modernize their grids and how they integrating these with their information/communications systems. It will give the student a commanding knowledge of intelligent new devices and systems that are being installed into the different parts of the grid (generation, transmission and distribution systems) as well as on the customer side. The course materials will be reinforced with unique and powerful tools and projects to enhance the hands-on experience of the student in this field.

Course Coverage

- Conventional and emerging transmission and distribution systems
- Flexible AC transmission systems (FACTS) and High Voltage Direct Current Systems (HVDC) and their use in the new transmission systems
- Phasor measurement units (PMU)
- Distribution Automation
- Fault Location Isolation and Restoration Service (FLISR) and voltage control
- Micrograds
- Smart meters
- Advanced Metering Infrastructure (AMI) and its supporting systems
- Examples from real applications
- Governing Standards

ECE 283 – Power Management ICs

- **Topics covered:**
  - Learn power management design techniques in the integrated context
  - DC-DC converter topologies and operations (2 weeks)
    - Linear regulator, switched-inductor, switched-capacitor, and hybrid converters
    - Converter examples.
  - Loss optimization and power switch sizing (1 week)
  - Analog and digital building blocks for power management ICs (2-3 weeks)
    - Digital blocks: inverter, buffer, gate drivers, level shifter.
    - Analog blocks: Ramp and PWM generator, current mirror, amplifier, comparator, current sense, etc.
  - Stability and compensation (1 week)
  - Other topics:
    - Integrated device introductions: integrated inductors, integrated capacitors
    - Pad ring and ESD protections
    - Bandgap reference circuits
    - Design examples

- **Term project: integrated Buck or 3-level Buck converter for microprocessors**

Common Q&A

- **What am I going to learn specifically compared to other depths and are there any overlaps?**
  - You can find the information on the class slides. This is a unique depth in the department so for the vast majority of the information you won't have much overlap with other depths.

- **Are there other depth classes I can take to complement this depth (I can take other ECE courses as my technical electives)?**
  - Yes. The power electronics part in power engineering can benefit from circuit classes such as ECE 65, 102, and even 164. The power system part of the power engineering can benefit from control classes such as ECE 100, 101, and 171. ECE 164 and 171 are more advanced classes which become less relevant to the power engineering depth compared with other lower-level classes.