Modern Power Electronics Courses at UCF

Issa Batarseh, John Shen, and Sam Abdel-Rahman

School of Electrical Engineering and Computer Science
University of Central Florida
Orlando, Florida, USA
University of Central Florida - EECS

- A large School of Electrical Engineering and Computer Science (EECS) with ~70 faculty, ~500 graduate students and ~2000 undergraduate students
- Power electronics and sustainable energy systems are one of the focus areas with 6 participating faculty
Power Electronics and Energy Systems Courses

Power Electronics

- EEL5245 Power Electronics I
- EEL6246* Power Electronics II
- EEL6317* Power Semiconductor Devices

Power Systems

- EEL4216 Fundamentals of Electric Power Systems
- EEL4205 Electric Machinery
- EEL6255* Advanced Power Systems Analysis
- EEL6208* Advanced Machines

EMA5586 Photovoltaic Materials

EMA5937 Fuel Cell Technology

* Graduate students only
The Dilemma of Teaching Power Electronics: Depth vs Breadth with Limited Class Hours?

- Conversion Technology
  - Circuit theory
  - Conversion efficiency
  - Switching matrices
  - Signal processing
  - EMI and filter circuit
  - Magnetic components
  - Rotating machines

- Power Semiconductor Technology
  - Power devices
  - Power ICs
  - Drive circuits
  - Protection circuits
  - Heat sinks

- Power Control Technology
  - IC control packages
  - Microelectronic circuits
  - Microprocessor circuits
  - Digital and analog electronic circuits
  - Control theory: transient and stability issues
  - Digital and information signal processing
  - Simulation
The UCF Approach

- Emphasize DEPTH over BREADTH in each class. Focusing on one topology with all its design and analysis aspects covered in depth instead of spending time evenly among all converter topologies.
- Use sequel classes to expand scope and coverage.
EEL 5245 Power Electronics I

- **Objectives:**
  This course is designed to present the basic concepts of power electronics: topologies, devices, and control. Converter analysis, design, modeling, and control of switching converters will be presented as relevant to different applications. Web content, computer analysis, and simulation tools will be emphasized.

- **Textbook:**

- **Instructional websites:**
  Web Courses, instructor-students communication website for lecture notes, assignments, quizzes, handouts, discussions, grades…etc.
  UCF FEEDS, course video streaming for on-campus and remote students.

- **Evaluation:**
  Homeworks, 2 Midterm exams, Practical design and simulation project, final exam.
Topics:

I. Introduction:
   - Applications
   - Converter classification

II. Non-isolated dc-dc converters
   - Linear vs. switching regulators and the PWM concept
   - Basics of steady-state analysis
   - Buck: CCM and DCM
   - Boost: CCM and DCM
   - Buck-boost CCM and DCM
   - 4th order converters
   - Non-idealities and transformer model for non-idealities
III. Converter design
   – Conduction and Switching Power losses
   – ICs and components selection for practical designs

IV. Converter control
   – Introduction to closed-loop control
   – Converter transfer functions
   – Converter stability
   – Closed loop compensation design

V. Isolated dc-dc converters
   – Buck-derived converters
   – Boost-derived converters
   – Multi-output converters
EEL 5245 Power Electronics I (Cont’)

**Design Project Example**

Design of a compensated closed loop non-isolated power converter with steady-state and dynamic performance emphasis.
- MathCAD / Matlab analysis and design.
- PSpice simulation of time and frequency domains.
Closed loop bode-plots
Magnitude and phase

Closed loop simulation
Load step-up and step-down
EEL 6246 Power Electronics II

• **Objectives:**
  This course is designed to cover advanced topics in power electronics: soft-switching techniques, small-signal modeling, control techniques, magnetic design.

• **Textbook:**

• **Instructional websites:**
  Web Courses, instructor-students communication website for lecture notes, assignments, quizzes, handouts, discussions, grades…etc. UCF FEEDS, course video streaming for on-campus and remote students.

• **Evaluation:**
  Homeworks, Practical design and simulation projects, Research papers study.
EEL 6246 Power Electronics II (Cont’)

Topics:

I. Soft switching converters
   Classification of soft-switching resonant converters
   QRC Zero-Current and Zero-Voltage switching topologies
   Generalized analysis
   Zero-Voltage and Zero-Current transition converters

II. Converter dynamics and control
   Advanced control techniques
   Small signal modeling
   Advanced converter transfer functions
III. Research studies, literature review and discussions in emerging power electronics topics such as:

- Soft Switching Inverters
- Solar Power Conversion Systems
- Wind Power Conversion
- Battery Charging
- Power Factor Correction
- Rectifier Circuits
- Snubber Circuits
**EEL 6246 Power Electronics II (Cont’)**

**Design Project Examples**

Design and analysis of Quasi Resonant ZVS boost converter with L-type resonant switch for high frequency applications.

- **Analysis** and derivation of modes of operation
- Design by MathCAD / Matlab
- PSpice Simulation

![Diagram of Quasi Resonant ZVS Boost Converter](image)
EEL 6317 Advanced Power Semiconductor Devices and ICs

- **Objectives:**
  To provide fundamental understanding on modern power semiconductor devices and ICs in relation to their applications in power electronic systems. Power semiconductor devices and ICs operating at high voltage and high current levels for power electronic applications. Including but not limited to p-n diodes, BJTs, MOSFETs, IGBTs, thyristors, power ICs, and SiC devices. Topics include basic device physics, avalanche breakdown, second breakdown, conductivity modulation, switching and recovery characteristics, device fabrication technology, packaging and thermal management, and application related issues.

- **Textbook:**

- **Evaluation:**
  Research papers study project and presentation, Final exam.
EEL 6317 Power Devices Topics

• Introduction: Basic power electronics applications, ideal power switching devices, various types of power semiconductor devices and their application ranges.
• Semiconductor device basics: Energy bands, electrons and holes, drift and diffusion currents, recombination and generation, basic semiconductor equations, ambipolar transport.
• PN junction theory: Forward conduction, avalanche breakdown, edge termination structures.
• Power diodes: High-voltage P-i-N diode, off-state blocking characteristics, forward conduction characteristics, reverse recovery characteristics, Schottky barrier diode, MPS rectifier.
EEL 6317 Power Devices Topics (Cont’)

- Power Bipolar Transistor and Thyristor: Power BJT, thyristor, GTO.
- Power MOSFET: Basic MOS device theory, device structure and operation, DC characteristics, switching behavior, integral diode, device fabrication, gate drive circuits, energy capability and SOA, applications.
- Insulated Gate Bipolar Transistor (IGBT): Device structure and operation, DC characteristics, switching behavior, device fabrication, gate drive circuits, ruggedness and SOA, IGBT modules.
- Emerging power devices: MCT, IGCT, super-junction devices, SiC, GaN, and diamond power devices.
- Power Integrated Circuit: need for integration, RESURF principle, BCDMOS technology.
EEL 6317 Term Paper Project

• Each student is assigned a project title. The student is expected to write a review paper based on extensive literature search and make a 25-minute presentation.

• Sample project titles include:
  – CoolMOS or Super-Junction MOSFET Technology
  – Integrated Gate Commutated Thyristors (IGCT)
  – BCDMOS Power IC Technology
  – Current Status of SiC Power Semiconductor Devices
  – IGBT Power Modules and Their Reliability
  – Survey of Thermal Management Technologies for Power Semiconductor Devices
EEL 6317 Teaching Power Semiconductor Devices Course with Multimedia Tools

• Power electronics designers tend to treat a power switching device as a black box with certain terminal characteristics instead of understanding the internal device physics. EEL6317 aims at improving this situation.

• Gaining physical insights of semiconductor devices is not a easy task with limited lecture hours (i.g. “What is conductivity modulation in IGBTs?”).

• Multimedia tools based on TCAD simulation were developed to help.
EEL 6317 Multimedia Tool  Example: Forward Conduction of IGBT
EEL 6317 Multimedia Tool Example: Reverse Blocking of IGBT
Summary

- UCF offers a series of courses in power electronics and power systems
- We emphasize on the depth instead of breadth of course contents through design projects
- We expand the scope and range of various topics through sequel courses
- Simulation and multimedia tools are widely used in teaching