ECE 533: Power Electronics Design & Packaging

In Workflow

1. 14ECE GR Director of Curriculum (dgyu@ncsu.edu; paulf@ncsu.edu)
2. COE CC Coordinator GR (rfillin@ncsu.edu)
3. COE CC Chair GR (john_classen@ncsu.edu)
4. COE Final Review GR (rfillin@ncsu.edu)
5. COE Dean GR (reeves@csc.ncsu.edu)
6. dchopki2 (dchopki2@ncsu.edu)
7. dchopki2 (dchopki2@ncsu.edu)
8. dchopki2 (dchopki2@ncsu.edu)
9. ABGS Coordinator (mlnosbis@ncsu.edu)
10. ABGS Meeting (mlnosbis@ncsu.edu)
11. ABGS Chair (mlnosbis@ncsu.edu)
12. Grad Final Review (mlnosbis@ncsu.edu)
13. PeopleSoft (none)

Approval Path

1. Thu, 12 Jan 2017 00:00:28 GMT
   Donna Yu (dgyu): Approved for 14ECE GR Director of Curriculum
2. Thu, 12 Jan 2017 16:08:26 GMT
   Robyn Fillinger (rfillin): Approved for COE CC Coordinator GR
3. Thu, 12 Jan 2017 18:23:29 GMT
   John Classen (john_classen): Approved for COE CC Chair GR
4. Thu, 12 Jan 2017 18:45:18 GMT
   Robyn Fillinger (rfillin): Approved for COE Final Review GR
5. Thu, 12 Jan 2017 19:01:58 GMT
   Douglas Reeves (reeves): Approved for COE Dean GR
6. Fri, 03 Feb 2017 23:01:39 GMT
   Douglas Hopkins (dchopki2): Approved for dchopki2
7. Tue, 14 Feb 2017 16:11:03 GMT
   Douglas Hopkins (dchopki2): Approved for dchopki2
8. Wed, 15 Feb 2017 13:02:52 GMT
   Melissa Nosbisch (mlnosbis): Approved for dchopki2
   Peter Harries (pjarrie): Approved for ABGS Coordinator
10. Thu, 23 Mar 2017 12:30:52 GMT
    Melissa Nosbisch (mlnosbis): Approved for ABGS Meeting

New Course Proposal

Date Submitted: Wed, 19 Oct 2016 22:52:09 GMT

Viewing: ECE 533: Power Electronics Design & Packaging

Changes proposed by: dchopki2

Change Type
Major

Course Prefix
ECE (Electrical and Computer Engineering)
**Title**
Power Electronics Design & Packaging

**Abbreviated Title**
Pwr Elect Des & Pkg

**College**
College of Engineering

**Academic Org Code**
Electrical & Computer Engineering (14ECE)

**CIP Discipline Specialty Number**
14.1001

**CIP Discipline Specialty Title**
Electrical and Electronics Engineering

**Term Offering**
Spring Only

**Year Offering**
Offered Every Year

**Effective Date**
Spring 2017

**Previously taught as Special Topics?**
Yes

**Number of Offerings within the past 5 years**
4

<table>
<thead>
<tr>
<th>Course Prefix/Number</th>
<th>Semester/Term Offered</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECE 792</td>
<td>Spr 2013</td>
<td>6</td>
</tr>
<tr>
<td>ECE 592</td>
<td>Spr 2015</td>
<td>10</td>
</tr>
<tr>
<td>ECE 592</td>
<td>Spr 2016</td>
<td>10</td>
</tr>
</tbody>
</table>

**Course Delivery**
Face-to-Face (On Campus)

**Grading Method**
Graded/Audit
Credit Hours
3

Course Length
16 weeks

Contact Hours (Per Week)

<table>
<thead>
<tr>
<th>Component Type</th>
<th>Contact Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>3</td>
</tr>
</tbody>
</table>

Course Is Repeatable for Credit
No

Instructor Name
Douglas C. Hopkins, PhD

Instructor Title
Professor

Grad Faculty Status
Full

Anticipated On-Campus Enrollment
Open when course_delivery = campus OR course_delivery = blended OR course_delivery = flip

<table>
<thead>
<tr>
<th>Enrollment Component</th>
<th>Per Semester</th>
<th>Per Section</th>
<th>Multiple Sections?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>20</td>
<td>20</td>
<td>No</td>
<td>Course enrollment numbers should increase with a permanent number.</td>
</tr>
</tbody>
</table>

Course Prerequisites, Corequisites, and Restrictive Statement
ECE 434 or with permission of instructor

Is the course required or an elective for a Curriculum?
No

Catalog Description

This course introduces design of high-performance power electronic circuits where the integrated physical topology must be considered as part of the circuit, and provides an understanding of the multitude of parasitic elements created by circuit layout, materials and fabrication techniques. This prepares the student for high-density, high-frequency design of converters, gate drive circuits and resonant topologies. The student is also introduced to a power-electronics packaging lab and primary fabrication processes, such as Direct Bonded Copper (DBC) module construction with heavy-wire bonding, two-sided and 3D power modules in layered polymers, and high-voltage isolation of circuits with encapsulate in modules.

Justification for new course:
A new research program has been established in support of the FREEDM Systems Center's and ECE's departmental educational goals. The program establishes a new teaching and research laboratory (building EB2, room B005) for power electronics design and packaging, and augments existing electronics and power electronics courses. This course has also been designated as core to the EPSE Masters program. Students at the graduate level will learn about physical circuits and broaden their design methods to be multidisciplinary. The 500 level has been chosen to accommodate advanced senior undergraduates that have interest in power electronics. Hence, the prerequisites allow for extension into the undergraduate program and linkages with the ECE 434 Fundamentals of Power Electronics course, or other electronics courses. (It should be noted that power electronics is based on the electronics sciences and not 'electrical power systems'.)
Does this course have a fee?
No

Consultation

<table>
<thead>
<tr>
<th>College(s)</th>
<th>Contact Name</th>
<th>Statement Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>College of Engineering</td>
<td>Dr. Richard Gould, MAE</td>
<td>Supportive and envisions eventually having MAE students involved</td>
</tr>
<tr>
<td>College of Engineering</td>
<td>Dr. Harrysson</td>
<td>Supportive, sharing lectures, and CAMAL (Center) providing interactive projects</td>
</tr>
</tbody>
</table>

Instructional Resources Statement
Course is taught once per year as part of regular teaching load. Only a technology ready classroom is needed.

Course Objectives/Goals
Students taking ECE 533 will develop practical and theoretical skills in the design of power electronic systems beyond software driven design and analysis outcomes. The course focuses on the physical implications of design, and on tools (such as multi-physics FEA modeling and simulation).

Student Learning Outcomes
- Demonstrate an in-depth understanding of physical (electrical, thermal and mechanical) performance metrics in power electronic circuits
- Conduct multiphysics simulations with understanding of physical (electrical, thermal and mechanical) metrics
- Determine electrical parasitic elements in physical power electronic circuits by inspection and testing
- Design a high-performance power electronic circuit for a given application

Student Evaluation Methods

<table>
<thead>
<tr>
<th>Evaluation Method</th>
<th>Weighting/Points for Each</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiz</td>
<td>30%</td>
<td>Given weekly to reinforce HW and encourage class attendance. Students are encouraged to collaborate on HW.</td>
</tr>
<tr>
<td>Midterm</td>
<td>25%</td>
<td>Formal testing of material covered in notes and lecture</td>
</tr>
<tr>
<td>Project</td>
<td>15%</td>
<td>Design driven to check skill development in modeling and simulation</td>
</tr>
<tr>
<td>Final Exam</td>
<td>30%</td>
<td>Design focused take home exam that brings together a complete design process, including suggestion of a fabrication process.</td>
</tr>
</tbody>
</table>

Topical Outline/Course Schedule

<table>
<thead>
<tr>
<th>Topic</th>
<th>Time Devoted to Each Topic</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction to electro-physical PE systems</td>
<td>1-1.5 wks</td>
<td>Introduction to electro-physical PE systems with presentation and discussion of physical specimens; intro of a Framework to understand multidisciplinary electro-physical design; and review of the complete cradle-to-grave design process of a power supply. A key discussion is understanding of terminology.</td>
</tr>
<tr>
<td>2. Introduction to Equipment and Fabrication Processes</td>
<td>~1 wk</td>
<td>Introduce equipment and fabrication procedures for creating power circuits in organic and ceramic materials, includes tour of the PREES lab in EB2</td>
</tr>
<tr>
<td>3. Self Directed Readings in Power Modules</td>
<td>2nd &amp; 3rd Qtr</td>
<td>Assign parallel self-directed readings in power module design and fabrication from the CRC text.</td>
</tr>
<tr>
<td>Course</td>
<td>Duration</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------</td>
<td>------------</td>
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</tr>
<tr>
<td>4. Modeling &amp; Simulation with Multiphysics Software</td>
<td>1.5 wks</td>
<td>Background and usage of parameter estimation software (Q3D), electrical circuit analysis (PLECS &amp; SPICE), and multiphysics simulation and analysis software (COMSOL).</td>
</tr>
<tr>
<td>5. Power Semiconductors &amp; Packaging</td>
<td>1 wk</td>
<td>Specific lecture modules will include dielectric materials, housing/molding materials, metals/metallization materials; power semiconductor devices and testing; and interpreting data sheets.</td>
</tr>
<tr>
<td>6. High Frequency &amp; Resonant Circuit Design</td>
<td>1 - 1.5 wks</td>
<td>Lectures in high frequency circuits including resonance; tying together time &amp; frequency domains; introduction to EMC/EMI design techniques; and review of pulse power electronics and measurement techniques. Beginning of Circuit Design Project. Student begins design of their own buck or boost circuit to fabricate in PREES Lab.</td>
</tr>
<tr>
<td>7. Thermal &amp; Heat Transfer Systems</td>
<td>1 wk</td>
<td>Introduce thermal circuits and thermal management; modeling, simulation, materials; and development of Design Guidelines. Provide applications and representative circuit layouts.</td>
</tr>
<tr>
<td>8. Stress &amp; Strain in Mechanical Structures</td>
<td>1.5 wks</td>
<td>Introduce mechanical structures and stress management in PE circuits and modules. Introduction to Reliability Testing</td>
</tr>
<tr>
<td>9. Power Circuit Design Process</td>
<td>0.5 wks</td>
<td>Introduce PE circuits, including a buck or boost converter as an possible project topic. Model the design process of a circuit based on uses of glass epoxy and DBC substrates.</td>
</tr>
<tr>
<td>10. MIDTERM</td>
<td>1 Lect.</td>
<td>MIDTERM – In-class test &amp; Simulation Project. Begin circuit fabrication in PREES Lab.</td>
</tr>
<tr>
<td>11. High Frequency Gate Drive Design</td>
<td>1.5 wks</td>
<td>Lectures on high-frequency Gate Drive circuits, designs and interactions with the power circuit. Design covers high-voltage (10’s kV) systems.</td>
</tr>
<tr>
<td>12. Electro-Physical Gate Drive Design</td>
<td>1.5-2 wks</td>
<td>Model the design process for electro-physical design of a gate driver circuit. Included are multiphysics simulation, and lab fabrication experience.</td>
</tr>
<tr>
<td>13. Additive Manufacturing</td>
<td>0.75-1 wks</td>
<td>Introduction of 3D printing of PE systems with tours of the I&amp;SE Lab</td>
</tr>
<tr>
<td>14. Course Summary</td>
<td>1-2 wks</td>
<td>Summation, review and modeling in class of a complete high performance power electronics circuit, including gate drive effects. Completion of Project</td>
</tr>
<tr>
<td>15. FINAL EXAM</td>
<td>Exam wk</td>
<td>FINAL EXAM – Take-home exam focused on circuit designs impacted by various fabrication processes.</td>
</tr>
</tbody>
</table>

### Syllabus

ECE-592 Syllabus-General.pdf

### Additional Documentation

Graduate Course Syllabus Checklist.pdf

### Additional Comments

minosbis 1/13/2017: 1) Suggest using a different number, 537 is available, since the prerequisite is 534. The prerequisite should be lower than this number. 2) Syllabus needs improvement on a few required items from the Graduate Syllabus Checklist: items 10 (grade breakdown, what constitutes the different letter grades), 11 (late assignments), 12 (attendance policy). 3) Why is textbook TBD on syllabus? When is this determined? Are all that are listed available electronically?
minosbis 2/14/2017: Still need to address the following:
1) Suggest using a different number, 537 is available, since the prerequisite is 534. The prerequisite should be lower than this number
2) Syllabus needs improvement on a few required items from the Graduate Syllabus Checklist: item 4 (cost of texts), 10 (grade breakdown, what constitutes the different letter grades), 11 (late assignments),

2/15/2017: Syllabus has been updated.

ABGS Reviewer Comments:
- The syllabus is very difficult to read, especially the area of grading and percentages. I suggest redo this area and detail more about the mini projects and what exactly the instructor is looking for in each.

Course Reviewer Comments


Key: 11028