ECE 592-091

Special Topics in Electrical Engineering: Resonant Power Converters

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Course Description

ECE 592-091: Resonant Power Converters course covers the analysis, modeling, design, and control of high-frequency power resonant rectifiers, inverters, and DC-DC converters. More specific topics are:

- ***A general overview of the advantages, concepts, and challenges in designing and operating high-frequency resonant converters***. Some of the topics include the converters' classification (half-wave, voltage or current driven, series- or parallel-loaded), zero-voltage and zero-current switching (ZVS and ZCS) notions, low *dv*/*dt* and *di*/*dt* switching concepts, loss mechanisms and loss calculation, synchronous rectification concept, modeling of nonideal and nonlinear reactive elements, selection and modeling of semiconductor switches for application in resonant converters, figures of merit for resonant converters comparison (switch stress, output-power capability), etc.
- ***Modeling, analysis, and design of Class D and Class E voltage- and current-driven resonant rectifiers***. Three types of rectifiers will be studied, namely, the half-wave, bridge, and transformer center-tapped rectifiers. A detailed analysis will be provided of the voltage- and current-driven Class D rectifiers and a current-driven Class-E rectifier.
- ***Modeling, analysis, and design of Class D and Class E series- and parallel-loaded resonant inverters***. Class-D series, parallel, and LLC resonant inverters and Class E ZVS resonant inverter will be studied in more detail. An overview of the advanced inverter topologies will be provided (Classes DE, EF_n and E/F_n, push-pull, etc.).
- ***Resonant Power Converters*** consisting of a cascaded connection of a resonant inverter and a rectifier will be studied. The operation principles will be discussed, and design procedures will be outlined for selected combinations of compatible inverters and rectifiers. The principle of operation of ZVS and ZCS quasi-resonant DC-DC converters will be illustrated with an example of a Buck ZVS quasi-resonant converter.
- ***Resonant converter modeling and control***. Extended Describing Function (EDF) modeling approach of resonant converters will be outlined and illustrated. Frequency control will be explained and illustrated on the example of an LLC inverter. Phase-controlled resonant inverters and converters will be introduced and used to illustrate the phase-control concept.

Learning Outcomes

At the end of this course, students should be able to:

- Understand the operation of resonant power rectifiers, inverters, and resonant DC-DC converters. Classify different types of resonant converters and explain their applications
- Provide steady-state models of the most common resonant converters and derive analytical expressions that describe the relation between circuit components, the input power source, the output load, and the operating frequency
- Identify and calculate the resonant converter losses
- Design practical resonant rectifiers, inverters, and converters adhering to typical application requirements and practical constraints
- Derive a large- and small-signal model of a resonant converter
- Design a phase-shift controller for a resonant converter
- Design a frequency controller for a resonant converter
- Use MATLAB, Simulink, and LTSpice to analyze and simulate resonant power converters

Prerequisites: ECE 534 or equivalent

Textbook:

Resonant Power Converters - *Marian K. Kazimierczuk; Dariusz Czarkowski*
Edition: Second Edition
ISBN: 1-118-58586-0
Web Link: TBD

Cost: N/A

This textbook is required.

Topics:

Resonant Power Conversion - Introduction
Resonant Power Converters – classification and overview; Overview of concepts relevant for Resonant Power Converters - Semiconductor switches for resonant converter – an overview - Hard-switching vs. ZVS and ZCS switching - Loss modeling in resonant converters - Understanding non-idealities and nonlinear phenomena in reactive elements and switches - Synchronous rectification
Resonant Power Rectifiers
Class D Current-Driven Rectifiers
Class D Voltage-Driven Rectifiers
Class E low *dv*/*dt* Rectifiers
Resonant Power Inverters
Resonant Inverters - introduction
Class D Series Resonant Inverter
Class D Parallel Resonant Inverter
Class D LLC Resonant Inverter
Class E ZVS Resonant Inverter
Overview of advanced resonant inverters
Resonant Power Converters
Resonant converters – topologies, principle of operation, efficiency, DC voltage transfer function
Design of a selected resonant converter
Quasiresonant converters; example of a Buck ZVS QRC
Resonant Power Converters Modeling and Control
Large- and small-signal modeling of resonant converters; Extended Describing Function
Frequency control; Design of a frequency controller - example
Phase-shift modulation; phase-controlled resonant converters
Phase-shift controller – design example
Advance control topics and solutions
Guest Lecture

Grading:

Component	Weight
Homework (8 assignment, the best 7 will be graded)	40%
Project	25%
Exam	35%
Attendance	1%
Total	101%

Cross-listing in other departments: N/A