

ECE Course Outline

ECE4xxx - Guitar Amplification and Effects (2-3-3)

Prerequisites: (ECE 3043 [min C] or ECE 3741 [min C]) and ECE 3084 [min C]

Corequisites: None

Catalog Description: Mathematical analysis and laboratory measurement of vibrating strings, electromagnetic pickups, vacuum tube amplifiers, solid-state distortion and swept filter effects, and loudspeakers.

Textbook(s):

No textbook specified.

Topical Outline:

- Historical perspective
- Acoustics of vibrating strings
 - The 1-D wave equation
 - Interpretation of pluck as initial condition
 - Traveling waves
- Electromagnetic pickups
 - Physical principles
 - Linear circuit models
 - Effect of location
- High voltage safety procedures
- Vacuum tube properties
 - Electrodynamic principles
 - Small-signal and large-signal models
- Vacuum tube amplifiers
 - Biasing, gain, input/output impedance, frequency response
 - Distortion characteristics
- Solid-state distortion effects
 - Germanium vs. silicon BJTs
 - Overdriven transistor amplifiers
 - Diode-based waveshaping circuits
- Swept filter effects
 - "Wah" pedals
 - Allpass filters and "phaser" effects
 - FETs as variable resistors
 - Bucket-brigade devices and "flanger" effects
- Loudspeaker modeling

Objective: This class explores the fields of acoustics, electromagnetics, electronic circuits, device physics, and signal and system theory and through the specific platform of the electric guitar and its commonly associated amplifiers and effects devices. The distinction between these tools begins to break down, since amplifiers are often deliberately driven to distortion as an effect, and in the hands of a skilled and thoughtful player, the various effects

pedals musicians often employ may be better thought of as part of the complete "instrument." The guitars, amplifiers, and effects explored in this course are not just intriguing motivational examples for traditional ECE topics; we feel that they are technological and cultural artifacts worthy of study in their own right in the spectrum of systematic musicology. They are part of our history. We believe that Jimi Hendrix, wrestling his Fuzz-Faced Stratocaster in front of his Marshall amplifier stack, was a transcendent example of a cyberphysical system -- a beautifully unstable feedback loop of sweat, circuitry, and sound.

Grading: Grades will be assigned based on performance on homework assignments and laboratory exercises, as well as a couple of midterm quizzes and a final exam. The homeworks, which are intended to hone analytical skills, will emphasize real circuits that have been used by real musicians, and not typical "textbook" problems. Laboratories will be integrated throughout the course.

Role in our program: This class is designed to complement (i.e. be in a similar spirit of, but not overlap too much with) our other audio/music related classes such as ECE4445 Audio Engineering (originally developed by Marshall Leach, now taught by Allen Robinson), ECE4446 Audio Engineering Lab, Bill Hunt's special topics class on Musical Acoustics for the Creation of Musical Instruments, and my own class on Analog Circuits for Music Synthesis. We expect that a course like this would be of interest to students in the new Bachelor of Science in Music Technology program who choose the Electrical Engineering concentration.

References: Because of the interdisciplinary nature of the course, we currently do not anticipate assigning any particular required text, since no single text encompasses all of the areas we want to explore at an appropriately deep level mathematical and engineering sophistication. We may draw material from some of the following references.

- IEEE Spectrum, [The Cool Sound of Tubes](#)
- Books:
 - D.J. Dailey, [Electronics for Guitarists](#)
 - M. Blencowe, [Designing Tube Preamps for Guitar and Bass](#)
 - M. Blencowe, [Designing Power Supplies for Tube Amplifiers](#)
 - D. Hunter, [Guitar Amplifier Handbook - Understanding Tube Amplifiers and Getting Great Sounds](#)
 - M. Jones, [Valve Amplifiers, Third Edition](#)
 - M. Jones, [Building Valve Amplifiers](#)
 - R. Kuehnel, [Vacuum Tube Circuit Design: Guitar Amplifier Preamps](#)
 - R. Kuehnel, [Vacuum Tube Circuit Design: Guitar Amplifier Power Amps](#)
 - R. Kuehnel, [Circuit Analysis of a Legendary Tube Amplifier: The Fender Bassman 5F6-A, Third Edition](#)
 - R.C. Megantz, [Design and Construction of Tube Guitar Amplifiers](#)
- Articles by R.G. Keen:
 - [The Technology of the Fuzz Face](#)
 - [The Technology of the Tube Screamer](#)
 - [The Technology of Wah Pedals](#)
 - [The Technology of Phasers and Flangers](#)
- Articles by Don Tillman:
 - [Pickups Part 1: Response Effects of Guitar Pickup Position and Width](#)
 - [Response Effects of Guitar Pickup Mixing](#)
 - [Pickups Part 3: Pickup Response Demonstration Applet](#)
- Our proposed ECE4xxx course is heavily inspired by UIUC's Phys [193/493](#): Physics of Music/Physics of Musical Instruments, taught by [Prof. Steve Errede](#). ECE4xxx primarily differs from Phys 493 by focusing more heavily on electronics than acoustics.
 - [The History of the Development of Electric Stringed Musical Instruments](#)
 - [Electronic Transducers for Musical Instruments](#)
 - [Waves I: Introduction to Waves - Traveling Waves](#)
 - [Mathematical Musical Physics of the Wave Equation](#)
 - [Vibrations of Real Strings](#)
 - [Complex Vibrations & Resonance](#)

- [Measurement of the Electromagnetic Properties of Electric Guitar Pickups](#)
- [Instructions for using the HP3562A Dynamic Signal Analyzer for Electric Guitar Pickup Complex Impedance Measurements](#)
- [PC-based Setup for Measurement of Vacuum Dual-Triode and Vacuum Power Tube Parameters](#)
- [Vacuum Dual-Triode Voltage Amplifier](#)
- [Theory of Distortion I/II](#)