New lab projects clarify abstract concepts, involve mainstream EE measurements, and engage sensory perception

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Motivation

- Electrical Engineering (EE) concepts are abstract and hardly intuitive, especially for non-EE majors
- Traditional teaching of concepts such as *Fourier series* and *Transfer functions of filters* is based on math and often limited to simplest examples, to which students do not relate
- We strive to create a new learning environment to overcome these shortcomings in the context of EECS 314 (a large course for non-EE majors)

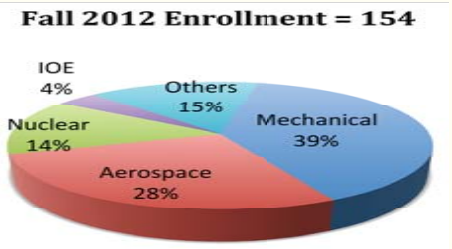
Goals

- Create new Lab experiments that engage students in many activities:
  - *Discover* **real-life applications** *of the theory*
  - *Do preliminary experiments on the Internet*
  - *Compare* **intuitive** *expectations to* **actual** *lab data*
  - **Listen to the sounds**, *including music*
  - **Build filter circuits**; *use them to listen to the music*
- Highlight practical applications of EE
- Emphasize the value of transferable hands-on skills for other Engineering fields

What We Report

- Two novel EECS 314 Lab projects developed for Fall 2012, successfully taught in a class of 154
- Results of surveys (quantitative and qualitative) focused on the student perception of these Lab projects

Student Demographics

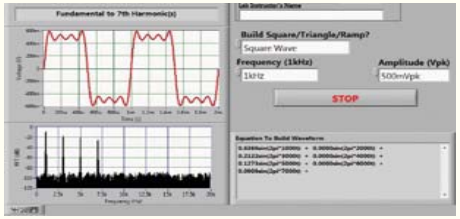


- 90 juniors
- 64 seniors

Spectra Lab

The Spectra Lab includes 3 modules:

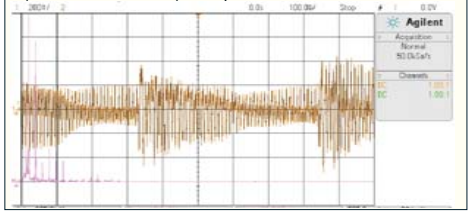
- (1) **Traditional**: Measure the FFT spectra of standard waveforms (sine, square, ramp, etc.); compare the lab data with theoretical predictions
- (2) **Unique** (developed in 2007 by A. Ganago *et al.*): **Fourier Synthesizer.vi** – LabVIEW ® program that builds standard waveforms as partial sums of harmonics, displays the waveform, spectrum, and analytical formula (see the screenshot); plays the sounds via a speaker



This module engages sensory perception of the sounds of signals in addition to the mental perception of the scientific information (plots and equations)

- (3) **New module that invites students to explore the spectra of musical instruments:**

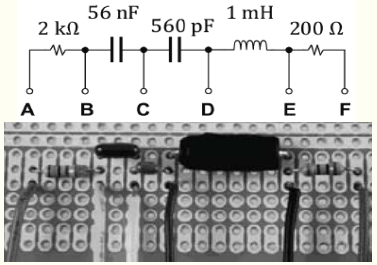
This module is based on the Virtual Keyboard ® - Internet freeware that produces sounds as played by various instruments (piano, flute, bass guitar, etc.). In the Pre-Lab students listen to the sounds and try to assess how many harmonic components each of them involves **(this is direct application of Fourier theorem to the sounds of music!)**. In the Lab, they actually measure the FFT spectra of the same signals (see the screenshot), compare different sounds, etc.



Filters Lab

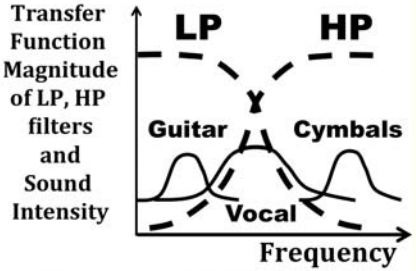
The Filters Lab includes 5 modules:

- (1) **Soldering:** each team (2 students) solders their own circuit (see the diagram and photo) for further In-lab work



Depending on the connections, this circuit acts as a Low-Pass filter (for module 2), a High-Pass filter (module 3), allows students to observe resonance (module 4), etc.

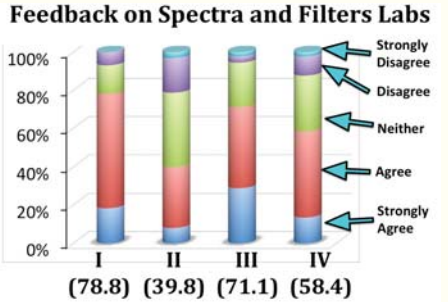
- In the new module (5) students apply the Low- and High-Pass filters to the sounds of music. In the Pre-Lab, they "build" digital filters using Audacity ® freeware on the Internet and listen to the clip of music that includes 3 sources of sounds:



Without any filter, the entire music is clearly heard; through the **Low-Pass** filter, the cymbals are not heard; through the **High-Pass** filter, the guitar is lost. **This experience helps students relate their music perception to the theory of Transfer functions.** The actual circuit soldered in the Lab has the same transfer functions as students modeled in Pre-Lab. Their intuitive understanding is related to hard-boiled data measured in the Lab. **Students also observe the similarity between the functionalities of the modeled digital filter and of the real circuit they soldered**, reaffirming the theory. Finally, they play their favorite music thorough their soldered filters!

Results of the Surveys

Feedback on the Spectra and Filters Labs was collected using professional version of SurveyMonkey that allows us to maintain anonymity of respondents.



The statements for Multiple-Choice questions:

(I) The Spectra Lab and Filters Lab have been interesting
(II) I feel that my learning in the Spectra Lab is valuable for what I do outside this course
(III) Listening to music helped me understand how filters work
(IV) I feel that my learning in the Filters Lab is valuable for what I do outside this course

The numbers show (Agree + Strongly agree), %

In their open-ended statements students confirm that Fourier theorem *"finally makes sense"*, call both Labs *"very cool"*, *"amazing"*, and *"relevant"* to their fields of study; they also found soldering very useful, memorable, and enjoyable.

Conclusions

The new Lab projects foster students' interest in EE, their understanding of its abstract concepts, and appreciation of the value of learning EE for their fields. They add enjoyment to the academic environment and blend in with the more traditional Labs.

Acknowledgments

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- Thanks to John DeBusscher for writing the LabVIEW code for **Fourier Synthesizer.vi**