BME 51A Sample Syllabus

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December 26, 2015

1 Catalog copy

Introduction to measuring, modeling, and designing electronics circuits, emphasizing voltage dividers and complex impedance. Lab-based course, culminating in simple negative-feedback op amp circuit for amplifying audio signals.

Prerequisites: Math 19A (single-variable differential calculus) and high-school physics.

Recommended: Physics 5C (electricity and magnetism).

2 Overview of course

This course is centered around the design labs—the lectures exist to provide just-in-time instruction in the theory and skills needed for doing the designs. Unlike EE circuits courses, this course is not primarily building foundations for later design work, but doing design and debugging from the beginning of the course.

There are three main concepts from electronics that form the spine of the course:

- voltage dividers,
- complex impedance, and
- negative-feedback amplifiers.

There is very little memory work in the course—everything that needs to be memorized fits on one sheet of paper. Instead, the course focuses on applying the same fundamental building blocks in different situations.

As in all engineering design, a big part of the work is learning to subdivide a problem into smaller subproblems, with each subproblem clearly defined with clear interfaces, so that the subproblems can solved independently.

In addition to the basic design skills, this course also teaches

- measurement skills using standard electronics lab equipment and low-cost data logging equipment designed for the course;
- modeling and graphing skills, fitting a variety of mathematical models to the data collected, and displaying both the data and the fitted curves;
- technical writing skills, presenting coherent design reports on each design done, including discussion of design choices made and measurements on the completed prototype; and
- prototyping skills, including both breadboarding and soldering.

3 Partner work

All student lab work is expected to be done in pairs, with the partners changing for every lab. The point of having two people working on a project is not for one to do all the work while the other watches, but for each to do some work independently, then swap results and check each other's work, combining the best of each.

Each partner is responsible for every error in the final design and report—check anything your partner did before you turn in the report!

Partners are changed on each design exercise, so that students have experience of working with different partners of different skill levels, and so that no one is stuck for the entire quarter with either a deadbeat partner or one who insists on doing it all themselves.

Design reports are normally turned in by the pair of partners, but anyone can opt to turn in an individual report (properly acknowledging the work of the partner), if they believe that the partner was not sufficiently helpful in doing the work.

4 Textbook

Because there did not exist a suitable textbook for this course, Prof. Karplus has been writing one. The current draft is available from LeanPub at https://leanpub.com/applied_electronics_for_bioengineers. When Prof. Karplus teaches the course, student registered for the course will be given coupons for free electronic copies of the book, and the book will be kept at a relatively low price (under $20) for other offerings of the course.

The textbook is designed around the course and contains both the background material and the design assignments for the labs. Currently the textbook is written for both BME 51A and 51B, but it may be split into two volumes in future.

5 Lab fees

Students will be charged a lab fee to cover the parts and tools that are issued to the students for the lab. Current estimate is $65 per student, but may need to be slightly higher to cover risk of price fluctuations. Almost all of the materials needed for BME 51A are usable also for BME 51B, which will add only another $15 in parts.

The combined tools and parts list for BME 51A plus 51B will vary slightly from year to year, but can be estimated from the BME 101/L parts list for Spring 2016:
http://gasstationwithoutpumps.wordpress.com/tools-and-parts-list-for-applied-electronics-s2016

6 Time budget

As a 4-unit course, this course is intended to take a median of 12 hours a week (120–132 hours total for the quarter). That time will be spent approximately as follows:

3.5 hours	scheduled lectures
1.5 hours	reading
2 hours	prelab homework
3.5 hours	scheduled lab
1.5 hours	writing design report

The workload will not be exactly this each week—because most labs are 2-week labs, some weeks will have more prelab homework and some will have more writing.

Students will be asked to log their hours on spreadsheets shared with the instructor, so that accurate assessment of time actually spent on the course can determined.

7 Evaluation

Students will be evaluated primarily on the design reports turned in for each design assignment. These reports will be assessed for accuracy, completeness, quality of design, quality of writing, and quality of scientific graphics.

Any reports (except the last one) that do not meet minimal standards or that have errors in non-redundant parts (schematics and component values) will have to be redone until acceptable.

Students are also required to demonstrate working circuits in lab for each design exercise.

The prelab homeworks contribute only marginally to the overall evaluation—it is essential that students do them, in order to be able to do the design work, but they are intended for practice and formative feedback, not summative evaluation.

Similarly, participation in lecture classes contributes marginally to overall evaluation—students who do not ask or answer questions in class or who miss class entirely will have difficulty doing the designs.

8 Schedule

The course is constructed around the weekly labs:

1. identifying components and soldering headers.

2. sampling and aliasing—demonstrating and understanding fundamental limitations of digital representation of signals.

3. using thermistors to measure temperature, calibrating thermistor against lab thermometers, using voltage divider to convert varying resistance to varying voltage, and recording temperature as a function of time. (2 weeks)

4. characterizing DC behavior of electret microphone and using characteristics to determine current-to-voltage conversion. Observing voltage waveforms on oscilloscope and measuring magnitude. (2 weeks)

5. measuring hysteresis in a Schmitt trigger, using measured hysteresis to design relaxation oscillator. Measure changing frequency of hysteresis oscillator to act as capacitive touch sensor.

6. characterize impedance of loudspeaker as function of frequency and fit both linear and non-linear impedance models.

7. design and solder a low-power audio amplifier using op amps. (2 weeks)

In the current draft of the textbook, the course covers Chapters 0 (Why an electronics class?) through 17 (Low-power audio amplifier lab).

Approximate lecture topics by week (will need some tweaking based on holidays and needs of individual classes):

1. administrivia, getting and installing PteroDAQ data acquisition system, sampling, aliasing
2. lab report guidelines, introduction to gnuplot, resistors, voltage dividers,
3. thermistors, using gnuplot to fit model to data.
4. optimization using voltage dividers, using gnuplot to plot transformations of data, capacitors, electret microphones,
5. using gnuplot to fit models to microphone data, load lines
6. complex impedance, RC filters, Bode plots, inductance,
7. loudspeakers, fitting models to loudspeaker data, hysteresis, relaxation oscillators
8. frequency measurement, op amps, negative feedback amplifiers
9. more on negative-feedback amplifiers
10. review and optional topics

9 Learning outcomes

After passing the course, a student can

- use a digital storage oscilloscope to observe a time-varying voltage,
- understand basic limitations of digital sampling of analog waveforms (discrete time and discrete values),
- measure voltage, current, and resistance with a digital multimeter,
- use a function generator,
- record time-varying waveforms on a computer,
- plot scatter diagrams of 2-D data and fit appropriate mathematical models to the data,
- plot time-varying data as curves,
- plot amplitude response as a function of frequency for RC circuits,
- measure DC characteristics of devices and plot I-vs-V curves,
- measure magnitude of impedance of devices and different frequencies and fit a complex impedance model to the data,
- design simple RC filters,
- break a design problem into subproblems with clear interfaces, and represent the subproblems as a block diagram,
- build prototypes using breadboards,
- build prototypes by soldering,

- understand hysteresis,
- design simple relaxation oscillators,
- design low-power audio amplifiers using op amps,
- draw clear and correct electronic schematics using passive components and op amps, and
- write clear, coherent design reports on designs they have done.