CAS Education Workshop
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TURNING STUDENTS ON TO CIRCUITS

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INTRODUCTION:

TODAY’S STUDENTS AND THEIR NEEDS

How do today's students compare to those of earlier generations?

Today's students have not tinkered.

– They cannot relate theory to practice.

– They don't understand why theory is useful - they think it's "just math".

Today’s students are impatient.

– They have grown up with computer games.

– They are used to immediate gratification.

– They cannot wait two semesters to find out why theory is useful.

Today's students think that all they need to know is how to use computers.

- They think that all they need to do is press keys…

- …and that *somebody else*, *somewhere*, will come up with the hardware.

- They do not realize that in today's globalized economy, maintaining a technological edge requires *dealing with the physical world*.

Thus:

- Today's students are totally different from those decades ago.
- *Yet, we keep teaching them using half-century-old approaches!*

Things have to change! We need to:

- Make students see why theory is useful.
- Show them that there are other things besides software.
- Give them immediate gratification.
- Motivate them.
- Do all this as early as possible.

- To accomplish this, we need a *lab* that is fun for the students.

- It should not be a software-based lab.

  – Such a lab would reinforce the idea that software is everything.

  – Multimedia, software-based signal processing, software-based control systems are great,

    but not for the first lab.

- Best candidate: **the first circuits lab**.

Classical approach to the first circuits lab

- Dry instructions.
- Reinforces impression that engineering is not fun.
- Wastes a unique opportunity to excite students – *does not work!*

Kit-based approach

- Students build a kit little-by-little.
- Motivating.
- Not easy to cover all points that should be covered.
- Not easy to make compatible with order in which theory should be taught.
- Requires tight coordination between different instructors, year after year.

A FIRST CIRCUITS LAB FOR TODAY'S STUDENTS

Practical considerations

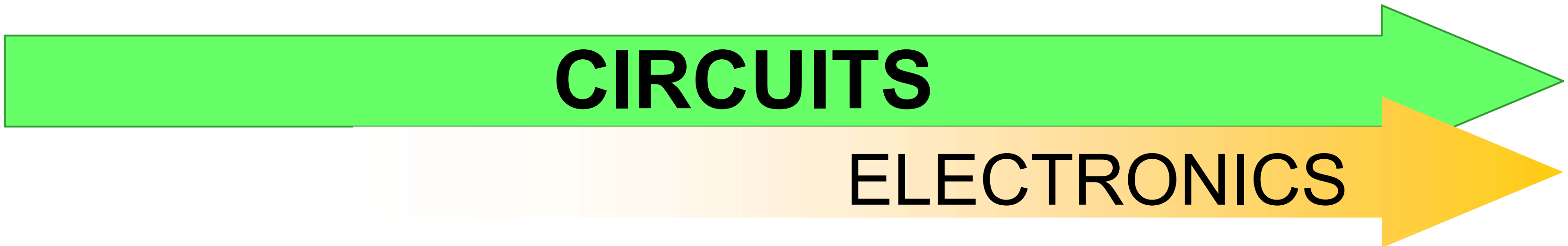
At Columbia, we have searched for a way to create a lab that would:

- Not interfere with order in which topics should be taught in theory class.
- Not require tight coordination between instructors.
- Not interfere with the rest of the curriculum – it should only *help* it.

We wanted a first lab that would:

- Use applications to convince students that what they learn is *real* and *useful.*
- Make students tinker and explore.
- Be exciting and rewarding.
- Make connections to subsequent classes (signals, systems, electronics, communications…).

Our solution:



- Used to motivate circuits.
- Compatible with first circuits class.
- Background provided in lab manual.

Basic lab philosophy, part 1

- Use active learning techniques ("constructivist learning theory", J. Bruner).

- Relate to students' senses as often as possible.
  - This is the iPod generation.
  - Use sound as the main unifying theme.

- Use equipment as simple as possible. Students should not lose the forest for the trees.

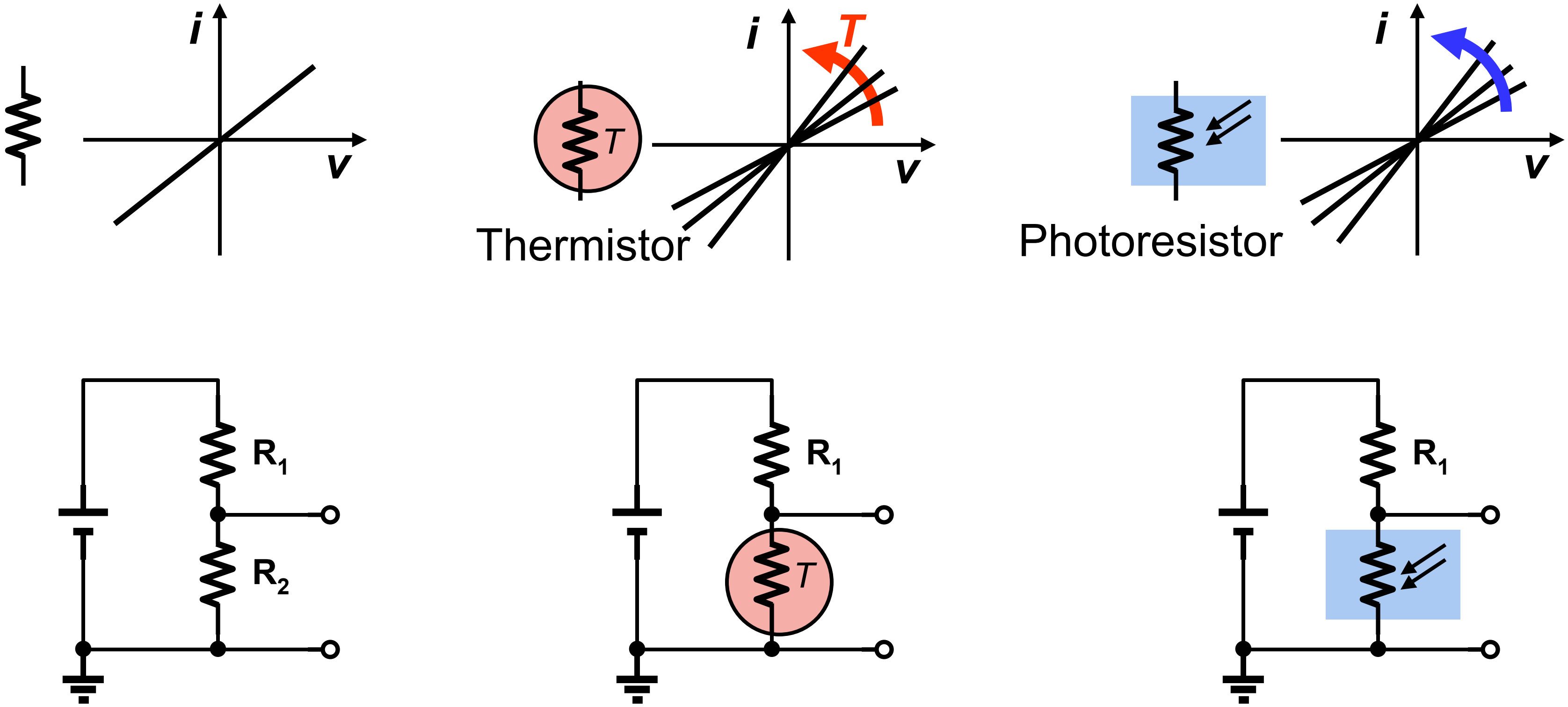
Equipment

- Oscilloscope, generators, multimeters, power supplies…
- But also a microphone, a CD/MP3 player, a power amp, and a loudspeaker.

Basic lab philosophy, part 2

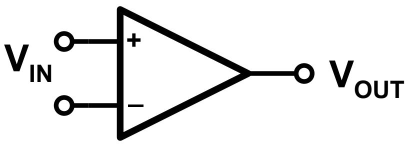
- Introduce design early on.
- Use “opportunistic” approach to introduce applications as soon as a topic allows.

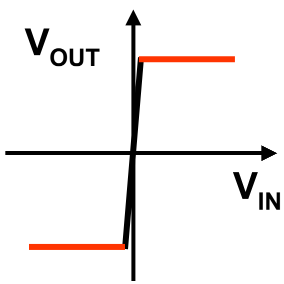
Example: 2nd week
Resistors and simple DC circuits



Opportunity: Introduce sensors in a simple way.

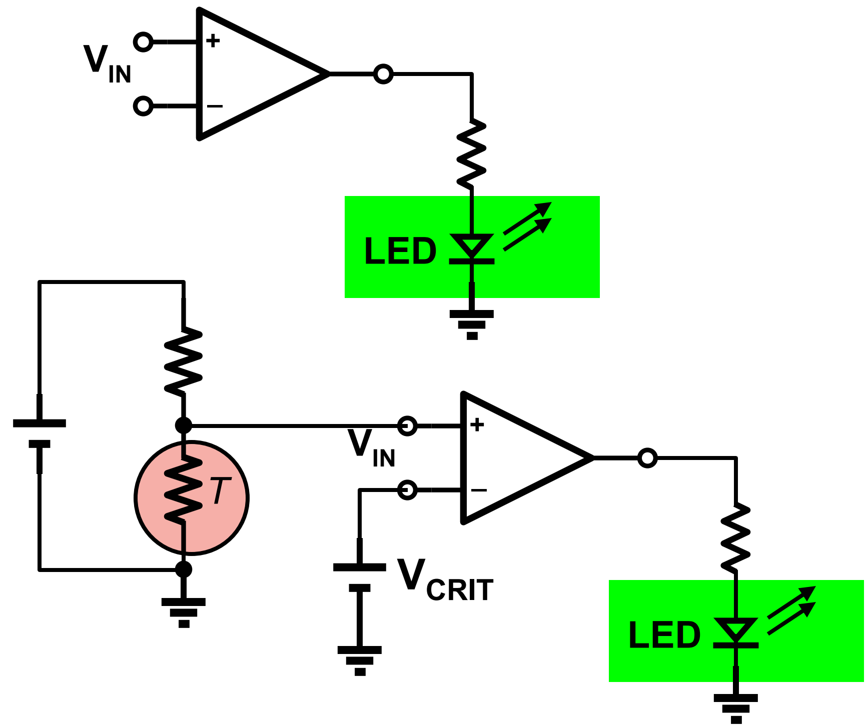
Example: 4$^{\text{nd}}$ week
Op amps and comparators





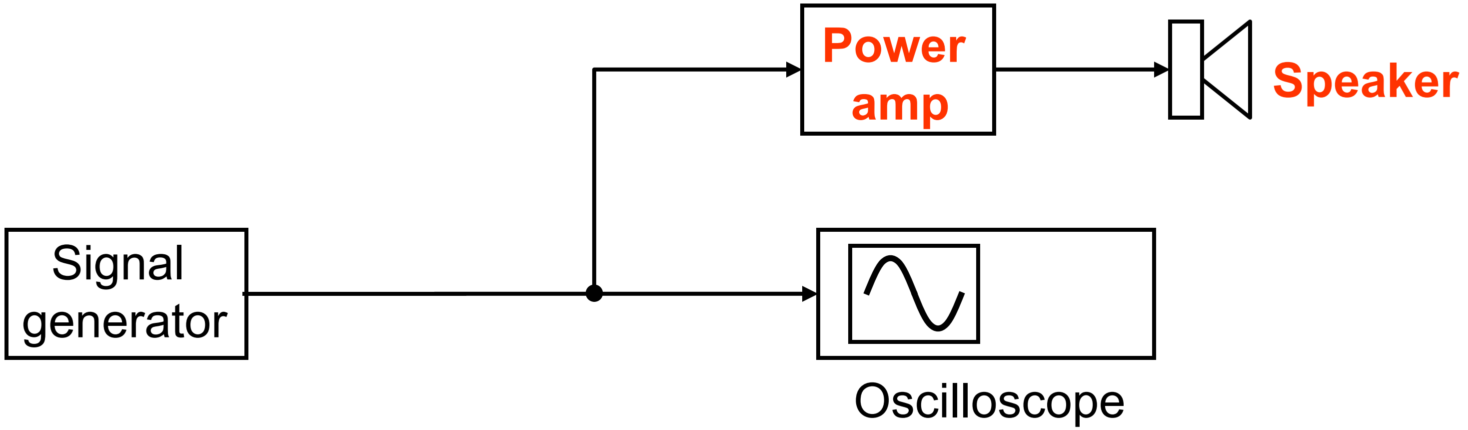
Comparator

Opportunity: Introduce nonlinearity in a simple way.



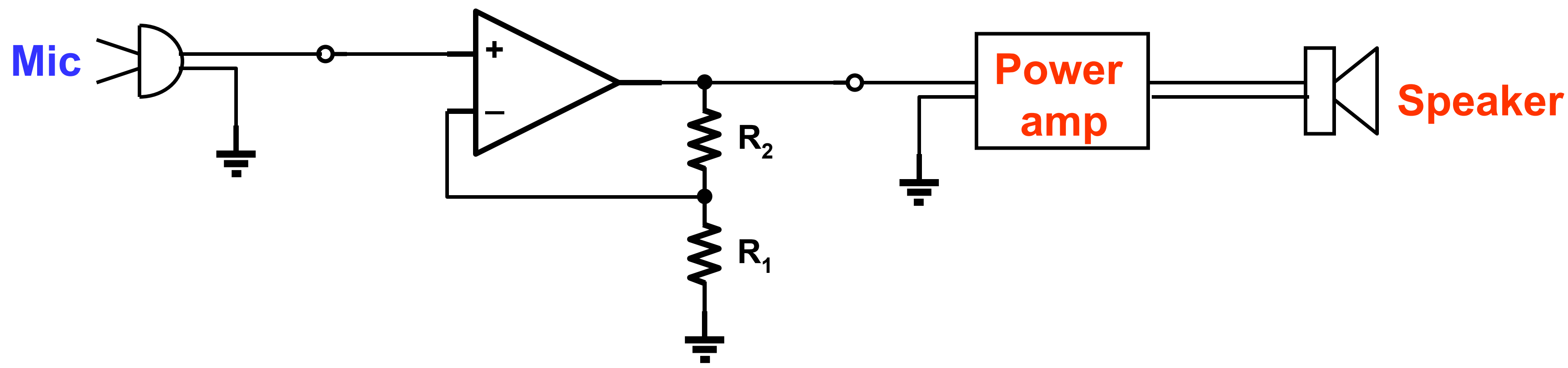
Opportunity: Introduce output transducers in a simple way.

Example: 3d week
Signals and the oscilloscope

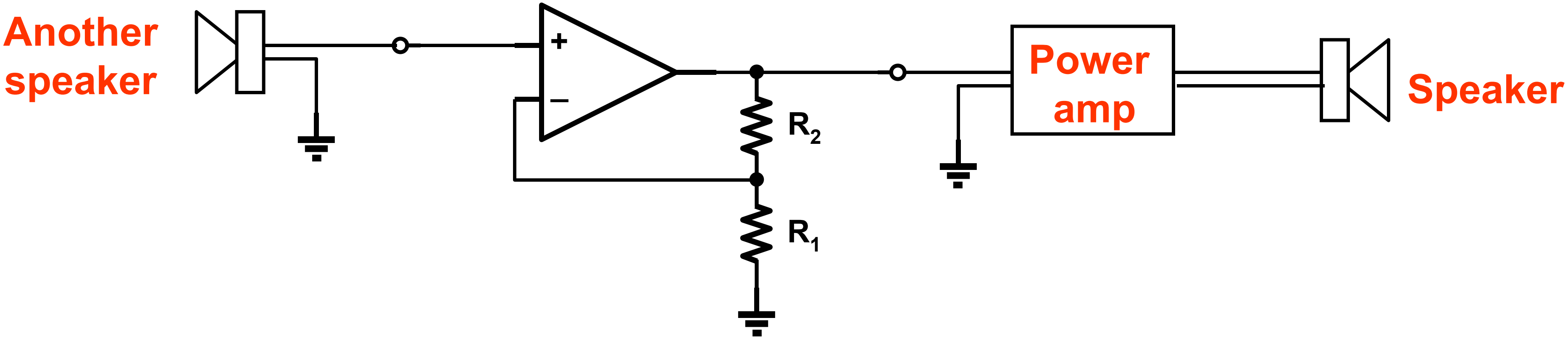


- *Hear* signals.
- Use *real* signals as well.
- Can hear generator signal, but not mike signal! *Why?*
- Not enough gain! Motivate voltage ampl. experiment.

Example: 5th week
Op amp – based amplifiers

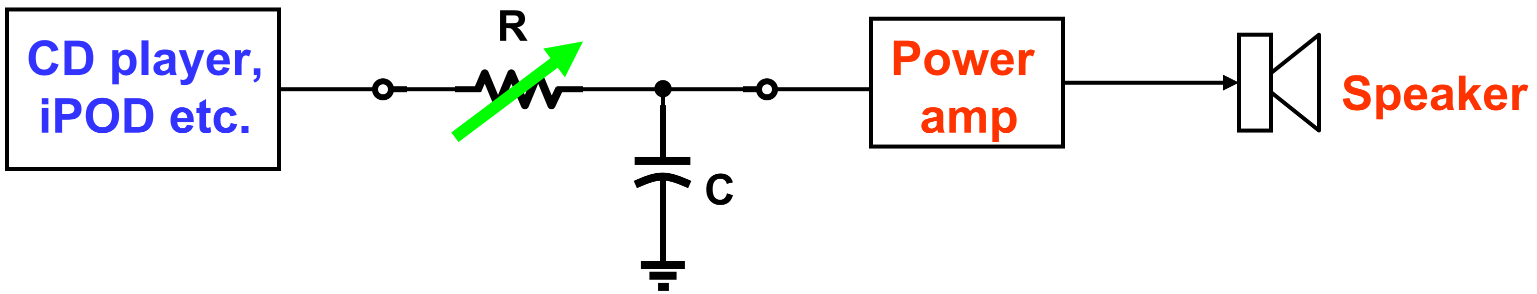


- Design voltage amplifier to amplify microphone signal.
- Hear the result.
- *Opportunity*: Introduce transducer reversibility.
  Can a loudspeaker act as a microphone? Find out:



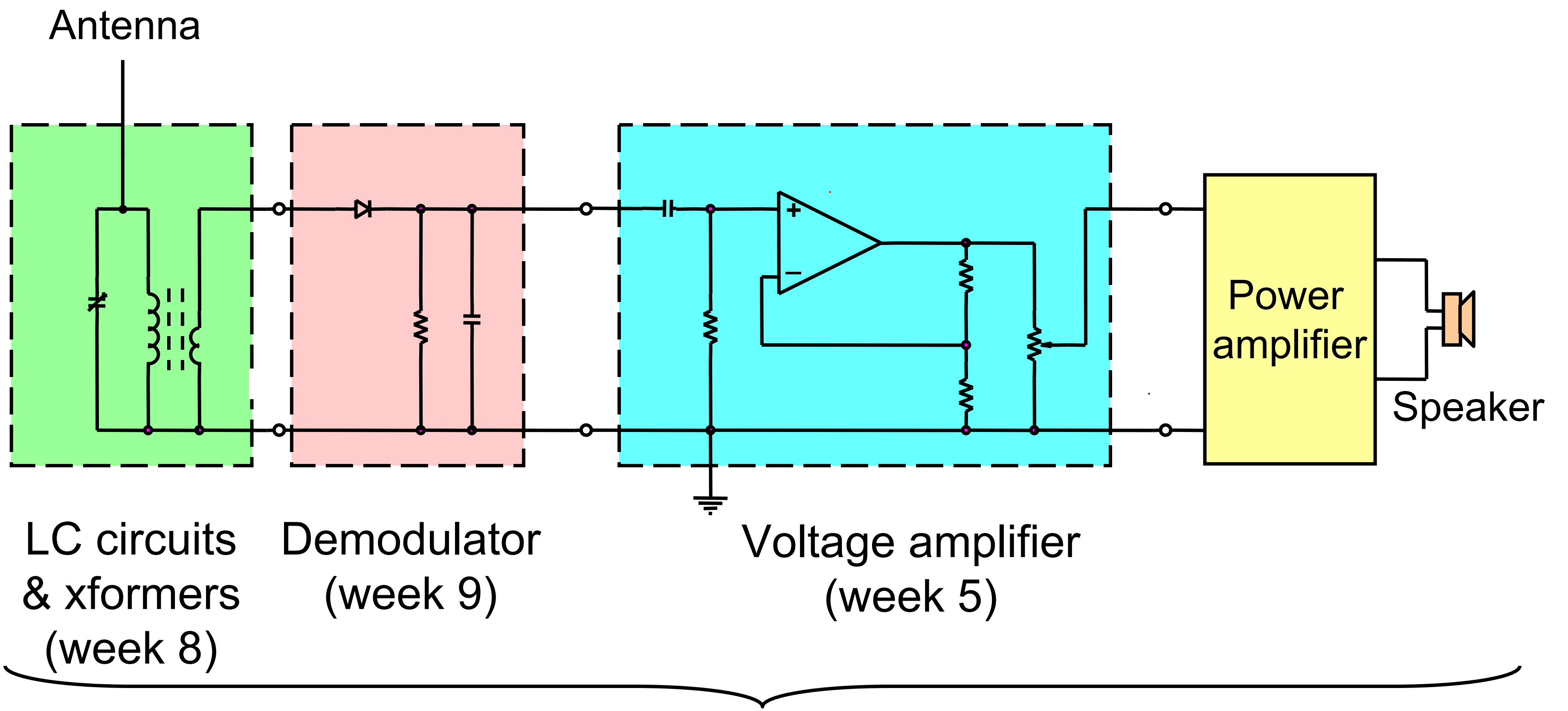
Finding out whether a loudspeaker can act as a microphone.

Example: 7th week
RC filters and frequency response



- Measure frequency response.
- Hear how circuit modifies music signals.
- Vary cutoff frequency and hear effect on music.

Similarly:



Radio receiver (week 10):

A simple introduction to systems

Radio receiver experiment

Experiments
(Pick according to lab objective and length)

- Measuring DC voltages and currents.
- Simple DC circuits; resistors and resistive sensors.
- Time-varying signals and the oscilloscope;

- Op amps and comparators; LEDs.
- Amplifier design using op amps; a sound system.
- RC circuit transients.
- Filters, frequency response; tone control.
- LC circuits, resonance, and transformers.
- Diodes; rectification, AC-to-DC conversion.
- Modulation and radio reception; a radio receiver.

Experiments – cont'd

- MOSFETs; analog switching and sampling.
- Amplification using MOSFETs.
- Bipolar transistors and amplifiers.
- Digital logic circuits; open-door alarm.
- D flip-flops, shift registers; circulating light.
- JK flip-flops and ripple counters.

Design projects

- 5^{th} week: Mini design project
  - E.g., night lamp.
- Last two weeks: Final design project
  - Students propose, or choose from list.

- Can beginning students handle all this?

- *Yes* – It's impressive what they can do if they are well-motivated.

- Suitability of this lab for beginning students has been proven again and again in a variety of settings at several schools.

- Yet, it doesn't necessarily have to be the first EE lab; it can be used whenever circuits are studied in the curriculum.

Balance between freedom and guidance

- Too few instructions: Students get stuck.
- Too many instructions stiffle learning and creativity.
- Balance found after much experimentation.
  - Give them enough, but don’t give them the whole story.

Lab development and testing

- During development, students filled in detailed questionnaire at end of each lab session;
- Based on that, lab handouts were revised and tested again;
- Process repeated until lab became smooth, and a proper balance between freedom and guidance was achieved.

Results

- When lab was introduced, our EE enrollment doubled within two years.
- Motivation of students to take subsequent courses increased significantly.
- Performance in subsequent classes increased.
- Dean required other engineering departments to establish courses along the same lines.

Several schools have adopted this lab in a variety of settings – Examples:

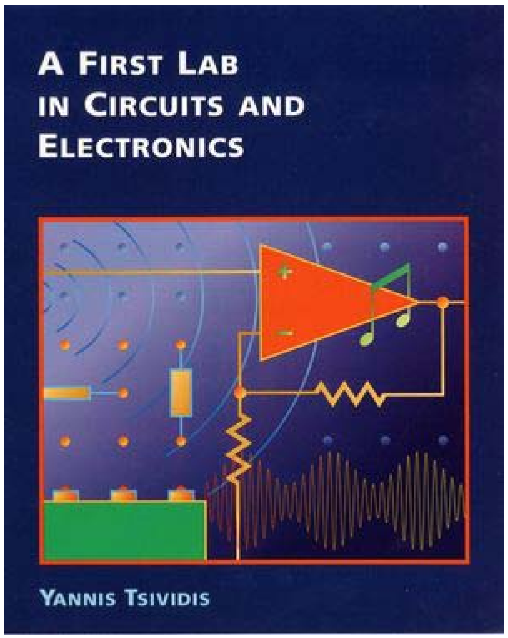
- With first circuits class, sophomore year (*E.g., Princeton, U. Connecticut*).

- With first electronics class, junior year (*E.g., San Diego State*).

- With circuits and electronics class, first year (*E.g. Columbia; Caltech starting this winter*).

If you would like to consider offering this lab:

- Lab manual:



Wiley 2002

INSTRUCTOR'S MANUAL

PUTTING THE LAB TOGETHER

Give this to your technician and forget it.

Available on the Web

Offering this lab, cont'd

- Electronic School Supply Co. (ESS) provides parts and equipment for this lab.
- Write to me:
  tsividis@ee.columbia.edu
- Visit our lab!

This presentation is based on the article by Y. Tsividis, "Turning students on to circuits", *IEEE Solid-State Circuits Society Newsletter*, Winter 2008, www.ieee.org/portal/pages/sscs/08Winter/Tsividis.html