The Evolution of an EET Program's Introductory Course in Electricity/Electronics

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Introduction

A new course (EL 110) was developed in 1999 for first-semester students entering our four-year baccalaureate programs in electronic and audio engineering technology. In recent years we had noticed that very few of our entering students had experience with technical aspects of electricity and electronics, and we realized that students found the traditional first-semester DC circuits course both daunting and uninteresting. This phenomenon, and different approaches to addressing the problem, have been reported by others.[1,2,3,4] Our students didn't do well in the fundamental electronics courses (DC and AC circuit analysis, solid-state devices) which are prerequisites for the "fun" courses involving amplifiers, oscillators, filters, etc. Our faculty felt that giving students a "survey" course in first semester to give a broad overview of and an appreciation for the electronics, and moving the DC circuits course into the second semester, would improve retention and motivation. We felt that it was critical to the success of EL 110 that the lab experiences be interesting and enjoyable. An additional benefit to our students is that they get to complete the first math course (college algebra) before taking the DC fundamentals in the second semester.

A complete description of the new course, including a detailed syllabus and examples of innovative laboratory experiences, was presented at the 2000 ASEE Annual Conference.[5] Since then, a new population of students has been added: those majoring in Interactive Information Technology (IIT), which is not a technical major. For IIT students, whose math skills, technical background and interests are quite different from the electronic and audio ET students, EL 110 is the only course in electronics they will take. In fall 2002, fully half of the 70 students in EL 110 majored in IIT. Adding this new population of students required that we make some significant changes to the course, particularly the laboratory portion. In a like manner, Biswajit Ray describes how his college created, and then updated, a three-credit course for non-science majors.[6]

This paper will focus on the changes that were made to the laboratory portion of EL 110 for the fall of 2002, when a large percentage of the students were IIT students, and when for the first time a newly-created laboratory project board was used.

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About the EL 110 Course

Of necessity, the three-credit EL 110 is a survey course, because of both the wide range of topics covered in the time available and the background and math level of the students (first-semester). But these students have PCs, cell phones, electronic keyboards and sound systems of every description; they have a strong awareness of and interest in learning about the technology they possess. It is this interest that contributes to the success of the course in meeting its goals. The new experiments that were created for fall 2002 were designed to provide meaningful educational experiences for the students that could be completed in a two-hour laboratory class.

Course Lecture Topics: (2 hours per week for 14 weeks)**:**

Humankind's awareness of electricity/scientific understanding	1.3 hour
Types of electricity - static vs. dynamic, DC vs. AC, terminology & units	1.3 hour
Generation of AC power, distribution	1.3 hour
Electrical safety, hazards	1.3 hour
Basic electrical circuits & devices, schematic diagrams, notation	2 hours
Ohm's law, power law	2.7 hours
Cost of electrical energy, batteries vs. commercial electric utilities	1.3 hour
Block diagram approach to electronics, examples of familiar devices	1.3 hour
Power supplies, diodes as rectifiers	1.3 hour
Amplifiers	1.3 hour
Oscillators	0.7 hour
Other building blocks (mixers, detectors, hardware, connectors, cables)	1.3 hour
Radio systems	1.3 hour
Television systems	1.3 hour
Satellite-based communications	2 hours
Cellular phone technology - present and future	1.3 hour
Global positioning system	1 hour
Computers and their applications	2 hours
Examinations in class	2 hours
	Total lecture contact time = 28 hours

Laboratory Experiments - Summary

The experiments in EL 110 are quite varied: some are traditional and concentrate on elementary theory (e.g. Ohm's law, use of test equipment, series circuits, calculating power consumed by a load), while others are inherently more interesting to first-semester students (e.g. the cost of electrical energy; sound levels, speakers and their frequency response; dissection of a disposable flash camera; audio relaxation oscillator; looking at audio with a digital oscilloscope; using switches as control devices). Whenever possible, student interest is paramount. For example, even in traditional experiments power is calculated, not for a resistor, but for a glowing LED, a rotating motor, a sound-producing Sonalert or a palpably hot ceramic power resistor, so the student can experience the results of electrical energy in many forms.

For each experiment below, a very brief objective and a description of the laboratory equipment and supplies are presented. The original experiments are more completely described in the original paper,[5] and most of the newly developed experiments will be explained in detail in the next section.

Experiment 1 - Familiarization with Lab Equipment, Circuit Construction
Objective: To become familiar with laboratory equipment and construction of circuits from schematic diagrams. Equipment Needed: Small 12 V incandescent lamp, "hobby" motor, Sonalert (tone generator), light-emitting diode (LED), 50 Ω 7-watt resistor, DMM (voltmeter and ammeter).

Experiment 2 - Use of Ohmmeter, Resistor Color Code
Objective: Use of ohmmeter, resistor color code. Equipment Needed: Assorted Ω, kΩ and MΩ resistors, digital multimeter (ohmmeter only).

Experiment 3 – Motors: Measuring Voltage, Current, Power, Efficiency
Objective: To measure voltage and current, and calculate power and efficiency for DC motors. Equipment Needed: Three DC Motors (permanent magnet, low power), analog voltmeter, DC ammeter, 1 cm of sleeving from #18 AWG stranded wire, one LED.

Experiment 4 - Ohm's Law Verification, Calculating Power
Objective: To verify, by measurement, all forms of Ohm's law: V=IR, I=V/R and R = V/I. Equipment Needed: Assorted kΩ resistors, voltmeter, ammeter, ohmmeter.

Experiment 5 - Electricity on Campus – A Walking Tour of Watt's Up
Objective: To become familiar with electrical distribution systems. Equipment: Feet (1 or 2), eyes, pencil or pen, pad or clipboard to write on, a curious mind. Description: Students follow the path taken by electrical energy, from the point where 3-phase power at 23 kV enters the campus, is then stepped down to 4.8 kV by a 5,000 kVA transformer (the size of a faculty office), is fed underground to the campus buildings, and is finally transformed again down to 3-phase 208 V/120 V, through a circuit breaker panel box and finally to an outlet in the laboratory.

Experiment 6 - Series Circuits
Objective: To verify voltage, current and resistance relationships in series circuits. Equipment: Assorted kΩ resistors, voltmeter, ammeter, ohmmeter.

Experiment 7 - Energy, Power, Cost of Electrical Energy
Objective: To examine the current and power of a tungsten lamp at the instant it is turned on, and again in steady state, to learn how to use the power supply "current limit" feature, and to compute the cost of running common household electrical loads. Equipment: Digital multimeter, DC power supply with adjustable current limit, 6 V incandescent lamp, assorted resistors, calculator.

Experiment 8 - Speakers, Ears, Electro-Acoustic Transducers
Objective: To explore the frequency range of human hearing and the electrical characteristics of permanent magnet speakers, including their frequency response. Equipment: Two digital multimeters, function generator, oscilloscope, two small permanent magnet speakers.

Experiment 9 - Relays: Electromechanical Tools
Objective: To learn about relays as devices for switching, for isolation of the load circuit from the controlling circuit, and for latching. Equipment: Digital multimeter, DC power supply, relay

with 12 VDC coil and 3PDT contacts, Sonalert sound generator, 12 V incandescent lamp, 12 V cooling fan, magnetic reed switch, small permanent magnet.

Experiment 10 - Relaxation Oscillator Using 555 Integrated Circuit
Objective: To construct an oscillator circuit on an op-amp designer board and examine its output using an oscilloscope. Equipment: Digital multimeter, DC power supply, 555 integrated circuit, op-amp protoboard, assorted resistors & capacitors, CdS (cadmium-sulphide) photoresistive cell, speaker, 10 kΩ variable resistor, small speaker.

Experiment 11 - Dissection of Disposable Camera With Electronic Flash
Objective: To take apart a used disposable camera, examining the mechanical parts and electronic circuitry, including seeing how a 1.5 volt "AA" cell voltage is stepped up to 300 volts for the flash tube. Equipment: Digital multimeter, used disposable camera with flash.

Experiment 12 - Sound Levels, Speakers and Their Frequency Response
Objective: To learn about sound levels in decibels of a wide variety of sounds by using a sound-level meter, and to use the meter to explore frequency response of a speaker. Equipment: Inexpensive analog movement sound-level meter, function generator, small speaker.

Experiment 13 - Looking at an Audio Amplifier with a Digital Oscilloscope
Objective: To construct an audio amplifier with microphone input and speaker output, to learn about excessive feedback causing oscillation, and to see voice waveforms on an oscilloscope. Equipment: Digital oscilloscope, digital multimeter, DC power supply (+ 5 volts DC), LM 386 integrated circuit amplifier, op-amp protoboard, electret microphone, 10 Ω resistor & assorted capacitors, 3-inch PM speaker.

Experiment 14 - Using Switches as Control Devices
Objective: To learn how a variety of switches can be used to turn loads on and off, including from two or three different locations. Equipment: DC Power Supply (adjustable), PBNO (push-button normally open), SPST knife switch, SPDT knife switch, DPDT knife switch, incandescent lamps, motor, Sonalert.

Highlights of the New and Revised Experiments

Experiment 7 - Energy, Power, Cost of Electrical Energy
This experiment used to be one of calculation only. Students calculated the cost of running common household electrical loads, and in doing so learned that the University of Hartford pays about $200 per year for each PC that is left running for an academic year. The new version added the measurement of "cold" and "hot" resistance of a tungsten lamp, and the realization that the power the lamp dissipates at the instant it is turned on is about 800% larger than the power when the lamp filament is hot (which is why lamps nearly always burn out at the instant they are turned on). Also added was a graphic example of how proper use of the current limit control on a power supply can minimize damage to circuits: a 51 Ω 1/4 watt resistor is sacrificed in the process, giving clear visual and olfactory evidence of the effect of too much current.

Experiment 10 - Relaxation Oscillator Using 555 Integrated Circuit
Students construct an oscillator circuit at a fixed frequency, shown on a Protoboard in Figure 1 below, connect it to a speaker, and use a digital oscilloscope to measure the output waveforms. A variable resistor, and then a cadmium-sulphide photocell, are used to change the frequency of the oscillator. The "autoscale" button on the oscilloscope allows students to get a useful display of the output waveform with little help from the instructor. Visual and aural information, and automatic measurements on the oscilloscope, help students correlate the period and frequency of a waveform with the perceived pitch.

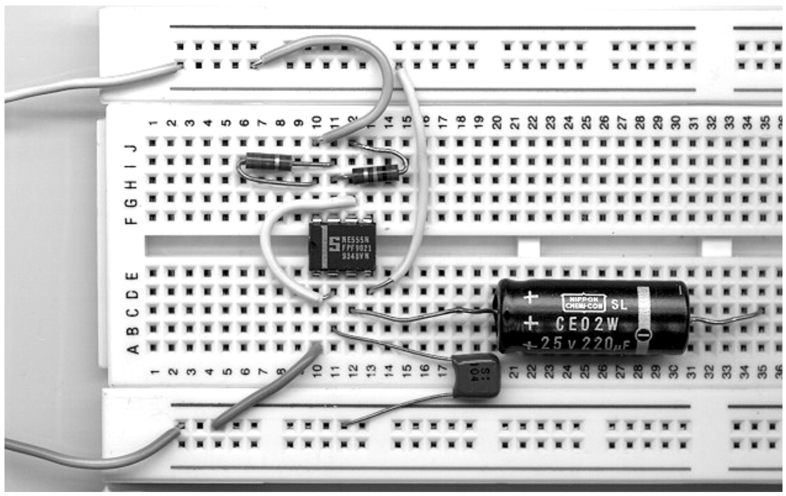

Figure 1 Oscillator circuit using 555 I.C.

Experiment 11 - Dissection of Disposable Camera With Electronic Flash
This can be a dangerous experiment, and instructors should offer it only to students who have demonstrated they will follow written directions. Even then, instructors must supervise the students very carefully; the camera's capacitor (see Figure 2 below) can be charged, up to 300 volts, even when it is turned off. The disposable camera, with film removed, is taken apart step-by-step. The mechanical features (film transport mechanism, lens and shutter assembly, and flash circuit board) are examined. The flash circuit is then turned on, and the voltage across the energy-storage capacitor is measured. Then the flash tube is "fired", using the camera's shutter system.

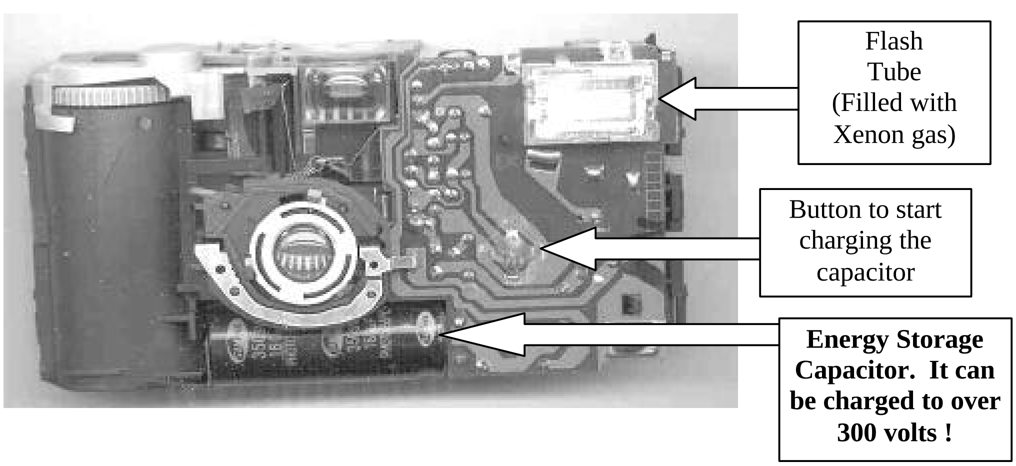

Figure 2 Disposable Camera with Case Removed

Experiment 12 - Sound Levels, Speakers and Their Frequency Response

Students measure the sound levels in decibels of a wide variety of sounds (voice, hand clap, scream, flushing toilet, etc.) using a sound-level meter. Then a speaker and function generator are used to explore the relationship between sound levels (in dB) and applied voltage, and the frequency response of the speaker. Lastly, the decrease in sound level as the sound-level meter is moved away from the speaker is studied.

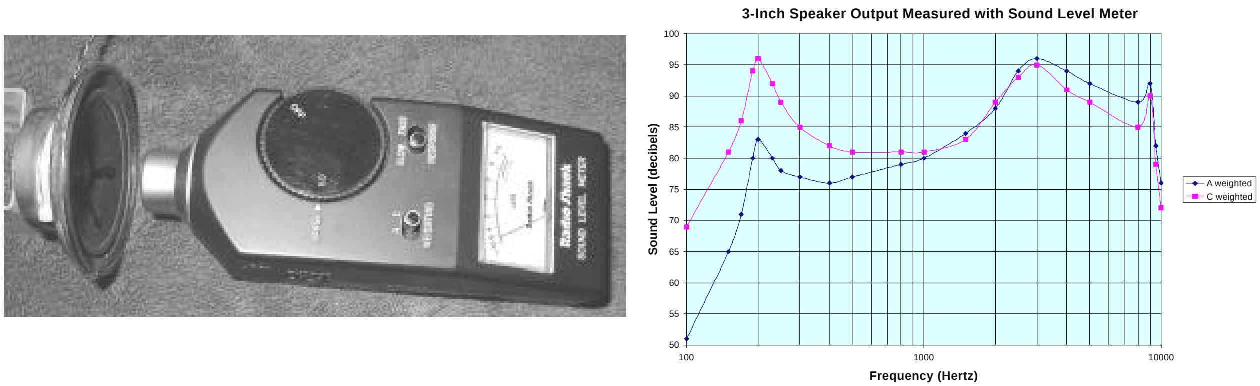

Figure 3 Sound-Level Meter (left), Frequency Response of 3-Inch Speaker (right)

Experiment 13 - Looking at an Audio Amplifier with a Digital Oscilloscope

An LM 386 audio amplifier IC is used with an electret microphone and a speaker to construct an amplifier system. Students always enjoy hearing their voices amplified, and then they use a digital oscilloscope to see their voices. The effect of too much feedback (by bringing the microphone close to the speaker) is studied, including measuring the frequencies of the resulting howls using the oscilloscope. Finally, the oscilloscope sweep speed is lowered to 500 ms/division, and the students capture (using digital storage) the envelope of their voice saying a phrase (e.g. "rubber baby buggy bumper"). The attack and decay of each syllable can be clearly seen.

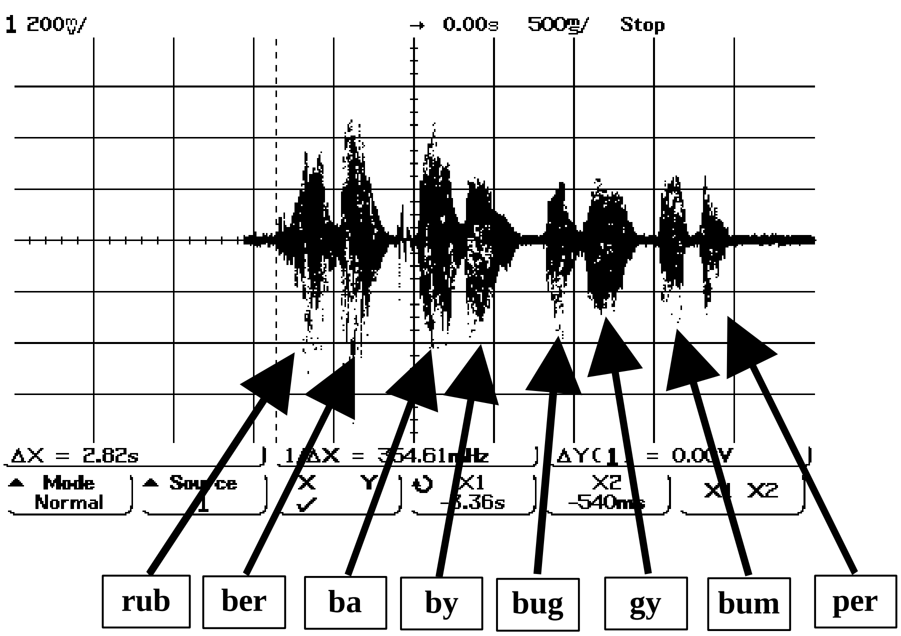

Figure 4 Digital Oscilloscope Envelope Display of Voice

Experiment 14 - Using Switches as Control Devices
Students use the switches on their boards (PBNO [push-button normally open], SPST knife switch, SPDT knife switch, DPDT knife switch) to switch on and off loads (see Figure 5 below). Progressing from the simplest (one switch controls one load) to an amateur electrician's nightmare [two "3-way" switches and a "4-way" switch, to control one load from three locations], students are challenged to determine all the wiring needed to accomplish a variety of switching situations. Unlike the other lab experiments, students are given little guidance except for being given a functional description of the control circuit (e.g. a SPST knife switch AND a PBNO must both be "on" to turn on the lamp).

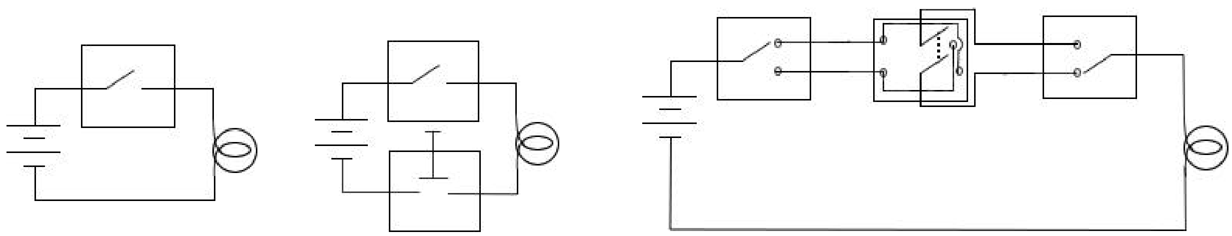

Figure 5 Three Progressively More Challenging Switching Circuits

Design and Construction of the Laboratory Project Board

The original laboratory experiments were developed during the first semester the course ran, and students were given the individual parts needed for one experiment at the start of each two-hour laboratory period. This turned out to take an inordinate amount of time for students and instructor, particularly for those experiments that took longer than one week and where the same components should have been used (e.g. Experiment 3, using DC motors, and experiments using incandescent lamps). The motor experiment (# 3) proved troublesome for many students; they had to mount two small electric motors to a wood beam, and then couple the motor shafts together in a way that was mechanically rigid. Because of the time required to do this properly, many students took more than one lab period to complete the experiment; this meant they had to perform the motor mounting twice, and spend additional time finding the same two numbered motors out of a large group.

During a sabbatical leave in spring 2002, and the following summer, the laboratory project board shown below in Figure 6 was prototyped, with the assistance of a senior EET student who "debugged" the initial design concept and made major contributions to the success of the final design.

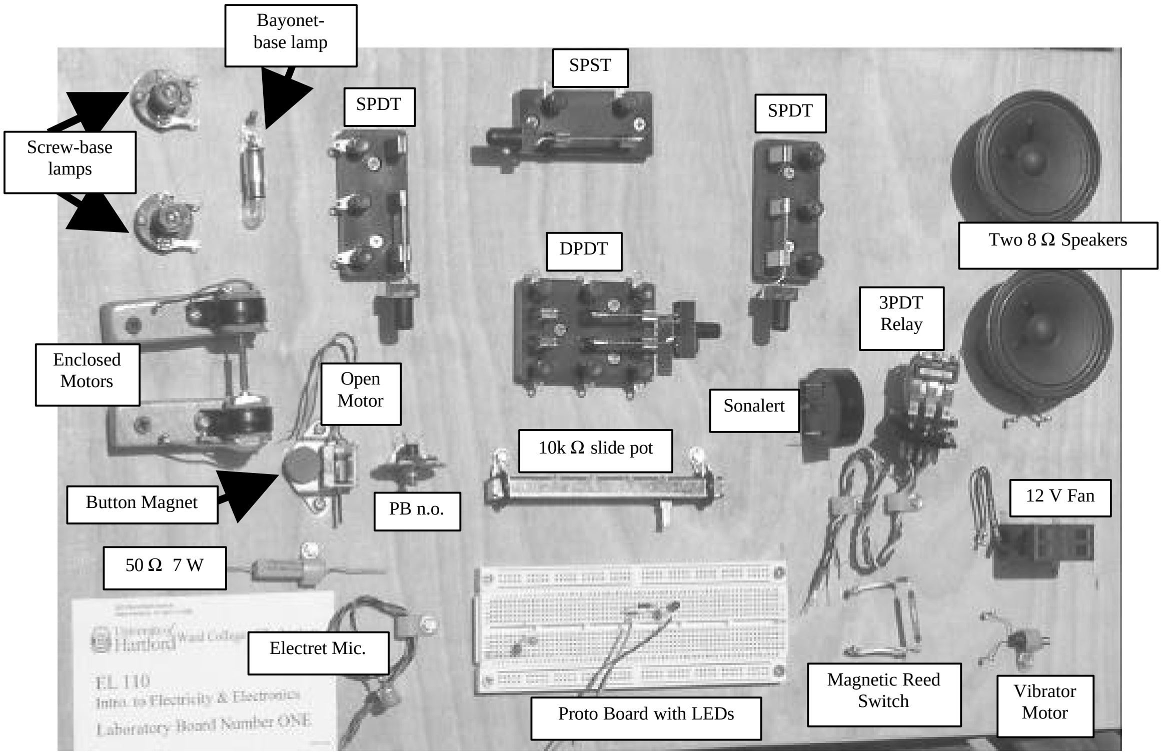

Figure 6 EL 110 Laboratory Project Board

The board is cabinet-grade plywood, coated on all six surfaces with four coats of water-based urethane to provide a surface highly resistant to smudging, staining or graffiti. Room was left between components to allow students to use alligator leads to make connections.

Some of the components are permanently mounted on the plywood: lamp sockets, 12- volt fan, magnetic reed switch, potentiometer, all switches, Protoboard and 7-watt resistor. Other components are mounted with Velcro to allow students to remove them: two three-inch speakers, and the Sonalert. The open-frame motor and the button magnet adhere (magnetically) to a steel plate. The two enclosed motors are mounted on wood blocks to allow the two motors to be coupled, and their positions adjusted, when a rubber sleeve is used to connect their shafts together. The electret microphone and three-pole, double-throw relay are attached using their wiring harnesses. This allows students to remove them and inspect or position them as needed for the experiment.

Results

The laboratory project boards were successful in reducing setup time for students, simplifying lab management for the instructor, improving the ease and speed of building circuits, and ensuring that students used the same components from week to week. Each board was numbered, and a lab group of two students used the same project board each week.

No student is expected to perform all the experiments. Students must do experiments 1-7; thereafter they are free to choose the experiments that interest them or most closely relate to their major.

For each lab report the students are required to use the Internet to research "related information" and to include some of it in their reports. A brief demonstration showing how to use the search engine **www.google.com** is all that is needed. Most students have indicated they find the research to be interesting and helpful in understanding the topics of the experiments.

Instructors are conscientious about stressing laboratory safety, in every lab session. This teaching ranges from reminding students to remove their "electrodes" (rings and watches) and reinforcing the use of the "one-hand" rule for working on live circuits, to a demonstration of stored energy during which a 15 μF capacitor from a defibrillator is charged to 5,000 volts, disconnected from its power supply, and minutes later quickly discharged with a shorting bar.

In the future we will incorporate a separate lab lesson or tutorial on using Protoboards at the beginning of the semester, so that they can be used efficiently as a circuit building tool.

Future Directions

It is clear that we need to explicitly teach troubleshooting skills, perhaps using defective motors, lamps, LEDs, and even alligator leads, to save student and instructor time. For example, a simple test to see if an alligator lead is defective (i.e. an open circuit) can be done in a few seconds using the power supply's current limit feature.

We will create a booklet of specification sheets for many of the components (lamps, motor, LED, Sonalert, relay, slide potentiometer) to familiarize students with extracting from manufacturers' data those parameters they need for an experiment.

One goal of EL 110 is that all students taking this course will be better prepared to live, vote, work and thrive in their digitized, networked, computer-controlled wireless 21st century. Towards this end, every semester the lecture and laboratory content of EL 110 will be reviewed to keep it as current technologically, and as relevant to first-semester students, as possible.

What Did the Students Think of This Course?

55 students completed anonymous course/instructor evaluation forms at the end of the fall 2002 semester. Relevant statements, and the responses, follow:

ITEM: For this course ...	Strongly agree	Agree	Disagree	Strongly disagree	Don't know-doesn't apply
1. I had little knowledge of electricity/electronics before this course.	18	18	13	5	0
2. I learned a significant amount in this new course.	24	26	3	0	1
3. The lab experiments illustrated the theory discussed in lecture.	23	25	4	0	0
4. Overall, the labs were a valuable experience and helped me learn.	13	33	9	0	0
5. Overall, the lectures were a valuable experience and helped me learn.	23	28	3	0	0

The evaluation revealed that 18 of 55 (33%) students disagreed with statement 1 (i.e. they disagreed that they had only "little knowledge of electricity/electronics before this course"), yet only 3 of 55 (6%) disagreed with statement 2: "I learned a significant amount in this new course". Apparently, the breadth and depth of material learned satisfied 91% (50 of 55) of the students, even those who said they had significant background in the field coming into the course.

Statements 4 and 5 reveal that 46 of 55 (84%) felt the labs were valuable and helped learning, while 51 of 55 (93%) thought the lectures were valuable and helped learning.

These results from fall 2002 are similar to the evaluation results from the fall of the 1999 and 2000 semesters, except that overall a greater percentage of students were satisfied with the revised course.

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Walter Banzhaf, Professor of Engineering Technology at Ward College of Technology, University of Hartford, is a registered professional engineer and amateur radio operator (WB1ANE). Now in his 26th year of teaching EET, he specializes in RF communications, antennas, fiber optics, linear integrated circuits, and the first-semester course described in this paper. He received the B.E.E. and M.Eng.E.E from Rensselaer Polytechnic Institute in an era when all EE students knew the filament pins for a 12AX7. A senior member of IEEE, Banzhaf is the author of two books on computer-aided circuit analysis using SPICE.

AARON GOLD
Aaron Gold just graduated with B.S.E.E.T. and A.S.C.E.T. degrees from the University of Hartford's Ward College of Technology with a minor in Computer Science. While taking courses himself, he taught laboratory sections of courses in both algebra-based physics and electronic engineering technology, including three sections of the EL 110 course described in this paper. Gold was a president's list student for all eight semesters, and plans to pursue a graduate degree as well as a career in Information Technology, while likely continuing to teach at the University.

2 Introduction Electrical Systems â€“Diagrams Block (system) PictorialSchematic â€“Components SourcePathControlLoadIndicator. 3 Energy, Work and Power Energy â€“Kinetic Energy â€“Potential Energy â€“Chemical Energy Work â€“Conversion of Energy Power â€“Rate at which work is done.Â 8 Electrical Current Movement of electrons â€“ current flow Potential for electrons to flow â€“ voltage or electrical potential Conductors â€“Single electron in valence layer Insulator â€“Full valence layer. 9 Other material Semiconductors â€“Exactly four electrons in the valence layer Superconductors â€“The Holy Grail of electronics â€“No resistance AT ALL. 10 Electrical Circuits Conventional Current Flow Electron flow Charge â€“1 coulomb = 6.25x10 18 electrons Rate of electron flow â€“1 Ampere or 1 Amp = 1 Coulomb per second. EET 112 (3) Elementary Electricity and Electronics The basic elements of electricity and electronics are explored in an internet enabled, self-paced course. Laboratories make use of a Virtual Laboratory environment to provide experience with issues in wiring, power, circuits, and digital electronics. Fall, Spring GE-3. EET 113 (3) DC Circuits A study of DC electrical circuits, Kirchhoffâ€™s laws, series and parallel circuits, inductors, capacitors, circuit response to RL, RC and RLC circuits.