Development of Courses in Consumer Electronics

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The Department of Electrical Engineering at the University of Washington has established an undergraduate educational project for Consumer Electronics[1]. The goal of the educational project is to introduce students to electronic design by the disassembly, analysis, and redesign of consumer electronics products.

As part of achieving this goal, a regular electrical engineering course in Consumer Electronics (EE 498) and a Consumer Electronics version of the college honors course (ENGR 498) have been introduced into the curriculum. The Consumer Electronics version of the honors course was first taught Winter 1994 (Kuhn), and the regular Consumer Electronics course was first taught Autumn 1994 (Hannaford). Mixed courses (EE 498 and ENGR 498) were taught Spring 1995 (Kuhn) and Autumn 1995 (Hannaford). Another section of EE 498 is scheduled for Spring 1996.

The course has evolved and stabilized into a successful format. This format is characterized by classroom lectures early in the quarter, a series of organized laboratories (with a scheduled 3-hour laboratory section), and a three week final design project with a written component implemented on World Wide Web.

One outstanding success of the course has been the implementation of the student final reports on World Wide Web. This results in a dramatic baseline shift from quarter to quarter -- as students read past student work and learn from the successes and failures of their peers. The World Wide Web site for the entire project is located at:

http://isdl.ee.washington.edu/CE/ConsElectHome.html

This paper will focus on the laboratories which we have developed for the courses. Both a "CD-audio only" version and a "multiple consumer products" version of the class have been taught and found to be successful. Both versions of the class have five laboratory sessions and three of the five laboratories are identical. The various laboratories are summarized in Table I.

1. Manufacturing - Disposable Camera product dissection

In this laboratory students dissect and study a flash disposable camera. Emphasis is placed on discovering how much functionality can be obtained with extremely cheap and very cleverly designed parts. The laboratory also serves as an outstanding ice-breaker for students uncomfortable with mechanical dissection.

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CD-audio emphasis	Broad product coverage
Manufacturing - Disposable Camera product dissection	same
Product cost estimation - Coffeemaker product dissection	Magnetic Recording - Cassette Tape Player product dissection
not implemented in this version	Audio Engineering - Soundcards (demonstration of a facet of human audio perception)
CD optical train: Investigate the properties of a large "scale model" of the CD optical train.	same
Oversampling and 1-bit D/A Conversion: Investigate the operating characteristics of a 1-bit D/A converter.	same
Focus tracking control and mechanization: Measure and model the electro-mechanical properties of the lens positioner.	not implemented in this version

Table I - A summary of the laboratories used in the consumer electronics class

This laboratory is based on the work of Vipin Kumar and John Lamancusa, as independently implemented by Richard Storch and Robert Smith[2]. This laboratory leverages off the fact that disposable flash cameras are actually designed to be recyclable, and are fabricated from snap-together injected molded plastic pieces. A disposable camera can be easily disassembled by a student using only a small screwdriver. The mechanical operation of the camera can largely be inferred by observation. The electrical operation can be deduced from the structure of the circuit board. (As a warning, if the flash is not discharged prior to disassembly, students can get uncomfortably shocked!)

Flash disposable cameras range in price from $7 - $15. We have found that the laboratory is most successful when each student purchases a camera and the students do the laboratory in teams of 3 or 4. The experience is especially valuable if the student team has a variety of cameras to study and this can be readily accomplished by some method such as awarding bonus points to the students with the most unusual cameras.

2. Magnetic Recording - Cassette Tape Player product dissection

In this laboratory students dissect and study a cassette tape player. Emphasis is placed on deducing electro-mechanical functions by observation and test.

[2] We had originally heard of the idea of using disposable cameras as educational tools from Richard Storch, who had learned of it from Robert Smith. However, upon digging into the history, we learned that Vipin Kumar and John Lamancusa had independently arrived at the idea and were using it as the basis for an education module for minority students. There is also the rumor of a Kodak brochure discussing the disassembly of the disposable camera as an education tool. Unfortunately, we have been unable to locate this brochure.

Cassette tape players are somewhat more complex than disposable cameras. Thus, the laboratory is most successful when preceded by one or two classroom lectures covering the fundamentals of magnetic storage. However, once the fundamentals have been covered, much of the mechanical operation of the tape recorder can be inferred by observation. This laboratory typically requires a much larger tool assortment, including large and small Philips and standard screwdrivers, as well as a selection of wrenches or nutdrivers.

Cassette tape recorders suitable for this laboratory can be purchased at Goodwill or similar thrift shops. Garage sales also offer an excellent source of cassette players suitable for the laboratory. Used audio equipment stores and pawnshops are somewhat poorer choices, as they tend to price the equipment higher. Cassette players purchased at a thrift shop will range in price from $5 - $15. We have found that the laboratory is quite successful if one cassette tape recorder is purchased for each team of 3 or 4.

3. Product cost estimation - Coffeemaker product dissection

In this laboratory students dissect an electric coffee maker. Emphasis is placed on studying some of the factors which determine manufacturing costs in a simple product.

This laboratory is based on the work of K.T. Ulrich, S.A. Pearson[3] in which the authors dissected 18 coffee makers and used a detailed methodology for deriving an estimated manufacturing cost for each product. An abbreviated version of this methodology is used in this lab.

Electric coffeemakers suitable for this laboratory can be purchased at Goodwill or similar thrift shops. The coffeemakers can also be purchased new at stores such as Bartells, Payless, and Costco. Used electric coffeemakers can be obtained for $10- $15 and new coffeemakers are approximately $35. We have found that the laboratory is quite successful if one coffeemaker is purchased for each team of 3 or 4.

4. Audio Engineering - soundcards

In this laboratory students use a computer soundcard to explore some of the features of digital audio. There are two major aspects to this laboratory. In the first part of the laboratory, students use commercially available soundcards and software to explore the tradeoffs between sampling rates, number of bits per sample, and aliasing. In the second part of the lab, students relate this material to human audio perception by using the soundcard to develop an experiment which illustrates some anomaly in human hearing.

We chose to implement this laboratory with a Creative Labs Inc. Soundblaster AWE-32. This card comes with a wide variety of software for sampling and modifying audio signals. The soundcard can also be coupled with Matlab. We typically operated the sound card with one channel driving a speaker and the other channel driving an electronic spectrum analyzer. Thus, students could both hear the signal and see the frequency response. We also explored a shareware program called Cool Edit which extends some of the sampling and Fourier transform capabilities of the soundcard software[4].

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[3] K.T. Ulrich, S.A. Pearson, "Does Product Design Really Determine 80% of Manufacturing Cost?" Sloan School of Management Working Paper, MIT, WP#3601-93, August 1993.

[4] Cool Edit can be downloaded from WWW at http://www.ep.se/cool/ at one of the ftp sites listed.

5. CD optical train

The very small size of the CD optical train makes it difficult to perform significant experiments on the optical head. However, a large model of the CD optical train can be fabricated from conventional optical components. This model can be exceptionally useful in displaying the optical and polarization properties of the CD optical head.

In the laboratory, students assemble and align the optical train. Then, they alter the polarization properties of the beam path by removing and adding quarter wave plates. This allows them to visualize the beam path during operation of the CD player as it hits "pits" and "land".

6. Oversampling and 1-bit D/A Conversion

One-bit D/A conversion is the most common D/A conversion technology used in low-end CD-audio players. However, most students have not seen one-bit D/A or A/D converters in their undergraduate curriculum. Thus, we elected to create a laboratory test fixture which illustrates the principles of single and multi-bit D/A conversion.

Two inputs are provided to the test fixture. One is a digital signal derived by using a commercially available 8-bit A/D converter (ADC0803) to convert the analog signal from a function generator. The second input is a simple digital signal derived from a DIP switch. These signals can be switched into either a 1-bit D/A converter (our design) or an 8-bit D/A converter (based on a 4053). The output from the conversion stage can then be switched into a filter.

The test fixture allows students to observe and compare single-bit and multi-bit conversion, before and after filtering, and with a variety of input signals.

7. Focus tracking control and mechanization

In this laboratory, students study the dynamic model of the focus tracking system, measure the parameters of this model, and calculate its performance. The basic model includes resistance, inductance, mass, damping, and spring constant. In this laboratory, each group is issued a surplus laser readout unit[5]. Students locate the focus coil and measure the resistance and inductance directly. The spring constant measurement is made by placing tiny weights on the coil, measuring the deflection versus weight, and estimating the spring constant from the results. The actuator motor constant is measured by adjusting the current I so that $x = 0$, measuring the current as a function of weight, and estimating the actuator motor constant from the results. Mass and actuator damping are measured by tapping the coil and observing the amplitude and frequency characteristics of the damped oscillation on an oscilloscope.

[5] Philips Electronics has been kind enough to donate units to us each time we have run this laboratory.

8. Suggestions for implementation

The most difficult part of teaching a consumer electronics class is obtaining sufficient background information[6]. We found that the minimum set of information is probably K. Pohlman's book[7], IEC 908 and 10149[8], and a subscription to IEEE Spectrum, CD/ROM Professional[9] and PC magazine[10].

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10. Additional resources

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B. Thompson, "What's in a CD/ROM Drive", CD ROM Professional, December 1995, pp 91-102.

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[6] Literature in the field of CD-audio and CD/ROM frequently mentions the "color books". Most frequently mentioned are the Red book (CD-audio), Yellow book (CD/ROM), and Orange book (CD-R). These are co-developed by Philips and Sony. They are confidential documents intended for licensed manufacturers of CD players. Obtaining an CD information agreement to use these documents costs US $5000. Setting up an CD information agreement is negotiated through Bert Gall in the same way that IEC documents are obtained. Needless to say, we did not pursue this beyond discovering the proprietary nature ... and price.

[7] K. Pohlmann, *The Compact Disk Handbook*, A-R Editions, Inc. ISBN 0-89579-300-8 (paper).

[8] Copies of IEC specifications can be obtained from Bert Gall, Philips Consumer Electronics, Coordination Office Optical and Magnetic Media Systems, Building SWA-1, P.O. Box 80002, 5600 JB Eindhoven, The Netherlands. Phones: +31-40-736409 (regular) +31-40-732113 (FAX). For US $200 you receive IEC 908 + amendments, IEC 10149, CD-ROM XA, ISO 9660, and ECMA 168.

[9] CD ROM Professional is available from Pemberton Press, 462 Danbury Road, Wilton, CT 06897-2126, at 1-800-222-3766. A year subscription is $55.

[10] PC Magazine can be obtained from P.O. Box 51524, Boulder CO 80321-1524.