A NEW DESIGN-ORIENTED APPROACH FOR FRESHMAN ENGINEERING

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Introduction

In this paper, we describe a new approach in developing a design-oriented, first year, interdisciplinary experience for freshman engineering students under a Department of Education FIPSE grant. The new course, *Introduction to Engineering Methodology,* represents a broader set of goals course than the old course, *Engineering Problem Solving,* which was originally intended as an introduction to engineering problem solving. This existing course was based on traditional engineering topics such as circuit analysis, thermodynamics, and computing, and students learned basic skills in a conventional lecture-recitation format. The existing course was found to be lacking as a motivating and exciting experience for first year engineering students. Since these two factors play strong roles in student retention and persistence, an interdisciplinary team of faculty decided to develop a course that would be attractive to today's students, who bring with them a set of expectations that could not be met by the traditional textbook-oriented introduction to engineering course.

Basic Principles of the Course Design

Several basic principles were developed for guidance in the design of the new course. These principles will be used to guide the faculty team through the course development process. The basic principles are the following:

1. The course must excite and motivate students to pursue a degree in engineering.
2. It must expose students to real-world engineering instead of textbook engineering.
3. It must integrate professional CAD software so that students can perform professional- quality design.
4. It must include industrial linkages so that students will be exposed to the industrial world early in the curriculum.
5. It must integrate principles of cooperative learning.
6. It must include material of an interdisciplinary nature.
7. It must be pedagogically sound.

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Developing the Course

In designing the course, the team decided to build on the trend toward design-oriented freshman engineering courses. In addition, the team decided to introduce students to real-world engineering by designing the course around the actual manufacturing of a high quality electronic product, where students will use professional CAD software to design a product, lay out the printed circuit board, and assemble the circuit on professionally-manufactured boards. Students will work in state-of-the-art laboratories on professional CAD software, including PSpice, PADS Logic and PADS Perform. The final product can be taken home at the end of the semester.

The selection of course contents is made straight-forward by the establishment of the basic principles. To make learning more relevant to students, course contents will be selected on an "as needed" basis so that students would not be asked to learn something just "because you will need it later in the curriculum." Thus, course contents for the course will be selected because they are directly applicable to the final project--the manufacture of a high quality electronic product. A description of the course contents is discussed later.

Since our institution has only electrical engineering and mechanical engineering, the design and manufacture of an electronic product was selected as an ideal basis for an interdisciplinary course. This would allow the development team to cover a wide range of engineering topics that satisfy the principles, including computer-aided design, thermal sciences, mechanics, electric circuits, analog / digital electronics, computer simulations, and computer-aided manufacturing. In addition, industrial manufacturing processes can be simulated in our robotics laboratory and through industrial linkages with a local facility, the Electronic Manufacturing Productivity Facility (EMPF).

In additional to the selection of technical course contents, the team will work on developing instruction in communication skills, team skills, human factors aspects of design, and innovative ways of introducing design principles into the freshman year, before they have taken technical courses to build on.

The Course Contents

The course contents are designed to simulate a job experience. Students begin with a basic overview of engineering careers (Engineering as a Profession), progress to technical skill building (Problem Solving and Computing), and finally tackle the engineering of a product (Basic Circuits and Electronics, Mechanical Engineering Aspects, Electronic Manufacturing, and Testing.) Throughout the course, students are given workshops on interpersonal skills (Cooperative Groups.)

Engineering as a Profession

The course begins by introducing students to the engineering profession, including a discussion of different engineering disciplines, licensing, post-graduate education, and professional societies. This provides students with information on careers in engineering and how engineers interact with other engineers, scientists, engineering technologists, and management. Freshman engineering students are usually unaware of the different kinds of careers and advanced degrees that an engineer can pursue. Often, their perceptions are colored by their experiences, drawing from interactions with friends and relatives and from the media. Some see engineering in terms of inventions and patents. Some see engineering simply as a means toward a salary without considering that people have choices, and some see it as an opportunity to repair and maintain high-tech equipment.

In this part of the course, students are given information about other sources of information on engineering careers and are asked to write a report on career paths for engineers.

Problem Solving and Computing

Students are then introduced to general engineering problem solving and ways of approaching the process. To that end, we introduce students to the mathematical computer tools that students will need throughout the semester. Since the course emphasizes engineering applications at the freshman level where students may not have yet taken very many courses in math and computing, strong emphasis is placed on integrating MATLAB and MathCad into the core of the course. In this way, what would normally be taught in a pre-requisite course becomes an integral part of the course, and students will be able to handle instruction in the electronic manufacturing of an electronic system design. Students are introduced to elementary matrix-based mathematics, derivatives and integrals, curve fitting, polynomials, and vector calculus. Students are informed that this phase of their CAD experiences in the course will serve them well other courses in the curriculum.

Basic Circuits and Electronics

After the mathematical and computer tools have been introduced, the course switches to the fundamentals of circuits and electronics. Elementary circuit analysis is introduced, starting with Kirchhoff's Laws and basic procedures for solving circuits with one or two loops with dependent and independent sources. Students are also introduced to digital chips such as timers, memories, and DACs. They are introduced to PSpice for Windows and its library of components which they will use to design an electronic product. The students run computer simulation to validate the logic operation of the system. The Windows version has an advantage that it is capable of generating the netlist that is accepted by PADS Perform, a CAD tool for PCB manufacturing. The artwork files in Gerber format are used in two ways: for industrial manufacturing and to drive pick-n-placement machines to place the circuit components on printed circuit boards using the department's robotic laboratory to perform the modeling of the process.

Electronic Manufacturing

In this section, students are introduced to manufacturing and printed circuit board (PCB) design using the newest 'generation of appropriate software. In this section, we address issues involved with designing and manufacturing PCB using IBM-compatible computers. This section covers two principle phases of the manufacturing process: (1) the schematic capture to the finished board process and (2) PCB layout CAM for manufacturing. Specifically, we cover schematic capture, circuit design verification, design of the PCB, preparing board artwork, making the PCB, and board testing. By the end of this section, students are anxious and ready to learn about how the components are placed automatically on the board, which is covered in the next section of the course.

Mechanical Engineering Aspects

In this section we cover the mechanical aspects of manufacturing printed circuit boards and automated methods for component placement during the manufacturing process. In the first part, students are introduced to the thermal effects and mechanics involved in the soldering process, while the second part of the course covers automation concerns. In the latter, students will learn to do simple tasks with laboratory robots, programming them to pick and place components. Students also visit local industrial facilities to observe the actual automated pick and placement processes.

Testing

In this section of the course, students will be introduced to concepts of testing as they test the printed circuit board they designed. Students are required to check the board against design requirements.

Course Syllabus

1. Engineering Profession	1 lecture
2. Units, Dimensions, Engineering Approximation.	1 lecture
3. Math and Basic Computer Skills(Use of MathCad or Matlab)	4 lectures
4. Circuit Fundamentals and Digital Logic Circuits (pSpice)	5 lectures
5. PADS for Schematics and Performs	6 lectures
6. Mechanical Aspects of PCB Work	4 lectures
7. Human Factors in Design	3 lectures
8. Library Research, Plant Visitation	2 lectures
9. Manufacturing Products	2 lectures
10. Exams	4 lectures

Cooperative Groups

Approximately 80% of the work in this course will be done in cooperative groups. Students will be taught the skills which will help them function efficiently and effectively, such as time management, brainstorming, consensus seeking, and cooperation. In order to facilitate student acceptance of working in cooperative groups, one of the classroom exercises will ask students to brainstorm its advantages and disadvantages.

Sample Projects

Because the course is designed around professionalquality design software and professionally produced circuit boards, the projects for this motivational course will be carefully selected so that they do not pale in comparison with the software and hardware.

Magnetic Field Detector. In this project, students will design a magnetic field detector. With the current interest in the possible hazards to health due to the magnetic fields associated with high voltage power lines, this project should interest students. Using the circuit shown in Figure 1 as a starting point, students will design a magnetic field detector which uses a bank of LEDs to indicate different field strengths. They will also design the circuit board layout, build the circuit using professional manufactured circuit boards, test it, and take it home.

Music Synthesizer. Working in design groups, students will design the simple tone synthesizer shown in Figure 2 using the 555 multi-purpose IC to generate square wave functions in the stable mode of operation. PSpice for Windows will be used for the circuit design. Students begin with the circuit schematic and select the 555D IC timer and the switch component Sw-Topen from EVAL.SLB library from the PSpice Windows. They will simulate the operation by TRANSIENT ANALYSIS using final time of 2 to 10 ms. Students see the effect of varying the duty cycle and period on the synthesizer tones and modify the design for different tones in the musical scale. Figures 3 and 4 show the different waveforms for given resistor and capacitor values.

Human Factors in Design

Students will be introduced to the human factors aspects of product design. Through group brainstorming sessions, students will consider such factors as product safety, ease of use, and customer satisfaction. Students will also consider the human factors aspects that affect the manufacturing process, and they will be asked to search through industrial journals for case studies which describe how the consideration of human factors in the design process led to significant improvements in the product.

Student Satisfaction With the New Course

The new course was offered during the fall semester of 1995 as it was being developed. To assess the impact of the course on student satisfaction, we developed a survey form and asked students who took the old course and students in the new course to tell us how they felt about their first experience in their first engineering course. We will continue to collect data from both groups so that statistical analysis can be applied to determine if the new course has significantly affected student satisfaction.

Data for the new course was collected at the end of the fall semester. Data from students who **took the** old course was obtained by contacting students who completed the old course. Thus, data from students who took the old course did not include all students who took the course, and the time delay between the time that they took the course and responded to the survey could have distorted their responses. Table 1 shows the percent of students who **agreed** with each statement in the old course and in the new course.

Table 1. Student Satisfaction Survey Results

	Old Course (% agree)	New Course (% agree)
1. I chose electrical engineering as my major before taking the course.	83.0% (n=24)	70.6% (n=34)
2. My interest in electrical engineering increased after taking the course.	50.0% (n=24)	88.2% (n=34)
3. I enjoyed learning engineering math in the course.	70.8% (n=24)	88.2% (n=34)
4. I enjoyed working with PCs in the course.	65.4% (n=23)	100% (n=34)
5. I enjoyed working with application software in the course.	75.0% (n=20)	100% (n=34)
6. I enjoyed solving computational homework problems	70.8% (n=24)	82.4% (n=34)
7. I enjoyed learning electrical engineering principles.	75.0'% (n=24)	100% (n=34)
8. I enjoyed the hands-on parts of this course.	70.6% (n=18)	91.2'% (n=34)
9. I enjoyed working with other students in teams.	75.0% (n=16)	91.2% (n=34)
10. I enjoyed working on electronic design projects.	NA	88.2%
11. I enjoyed assembling and testing circuits.	NA	**88.2%**

Points of Interest

The results of the student satisfaction with the new course in comparison with a similar survey of students who completed the old course are extremely positive. Almost across the board, students who completed the new course reported a higher degree of satisfaction.

1. Item 1 shows that a larger percent of the students who enrolled in the old course chose to major in EE prior to taking the introductory course compared with the new course. This item is significant in light of the more favorable responses on items 3-9 from students in the new course. This strengthens the over-

all student satisfaction with the new course, a conclusion drawn from the fact that the students drawn to the first course were already more committed to electrical engineering but less satisfied.

2. In item 2, a larger percentage of the students in the new course reported an increase interest in electrical engineering at the conclusion of the course. Since a small percentage of students in the new course had already committed to electrical engineering as a major, this may not be a significant student satisfaction item.
3. Items 3 through 8 assessed student satisfaction with the course contents. For each item, a larger percentage of the students in the new course reported that they were satisfied.
4. Item 9 assessed student satisfaction with working in groups. A higher percentage of students in the new course reported that they were satisfied.
5. Items 10 and 11 assessed student satisfaction with their experiences designing, assembling, and testing real, functional circuits using professional software and professionally produced circuit boards. Since these experiences were not a part of the old course, students who took that course were not asked the same questions. Student responses in the new course indicated that they were highly satisfied with the **experiences.**

Concluding Remarks

Based on the preliminary survey of student satisfaction, the course development process appears to be on the right track. The percentage of students who were satisfied with their experiences in the new course indicate a greater satisfaction compared with the old course, even though it is being developed as the materials are being taught. Anyone who has developed a course “on the run” knows how things can go wrong with newly prepared course notes and experiments.

To summarize, we feel that student satisfaction has risen because the course is more exciting. Students work with the latest computers and professional design software, design a functioning electronic circuit and printed circuit board layout, and assemble and test the real circuit. Course topics were selected as required for the design project. Rather than including topics that might be of general interest to freshman engineering students, they are selected so that students would immediately see a relevance to the project. At no time did the instructor have to say, “You will use this material in later semesters.” Perhaps if other courses in the curriculum were to follow this course design philosophy, students would see more relevance in their education and become more satisfied and motivated.

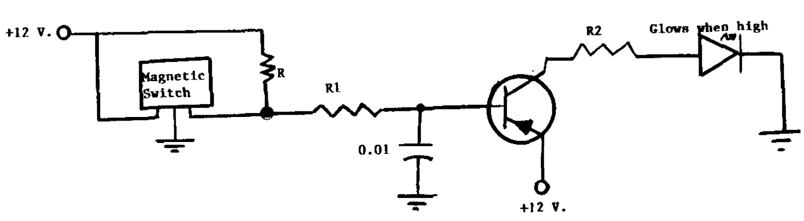

Figure 1: Basic Circuit for Magnetic Filed Detection

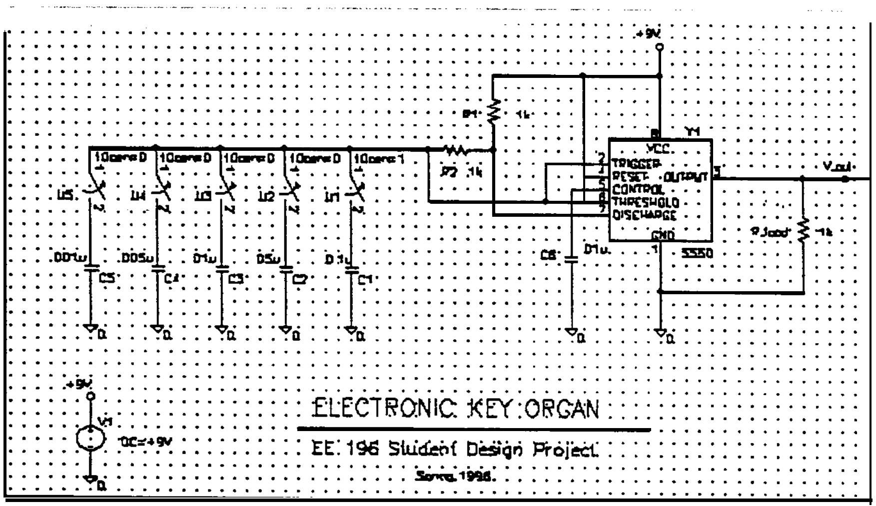

Figure 2: Schematics for the Electronics Music Synthesizer

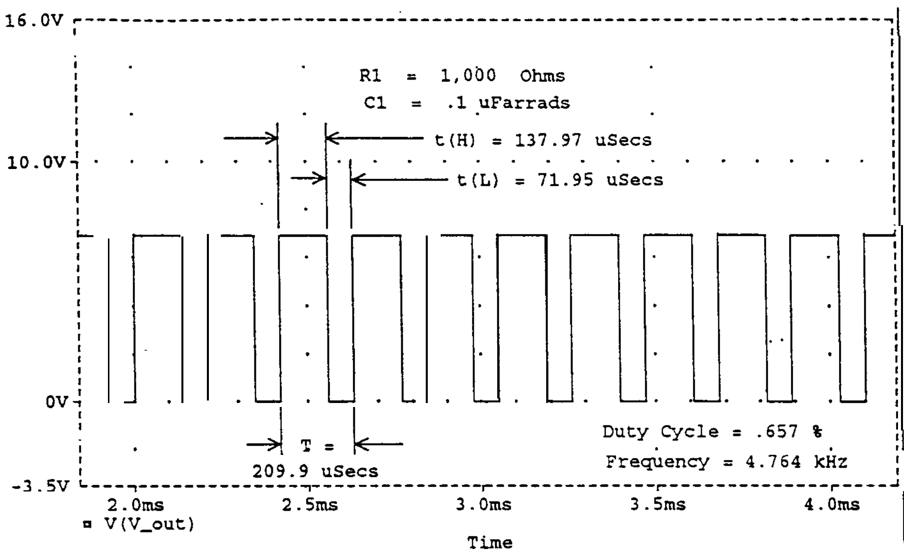

Figure 3: Output Waveform at R_1= 1 KΩ and C_1=0.1 μF

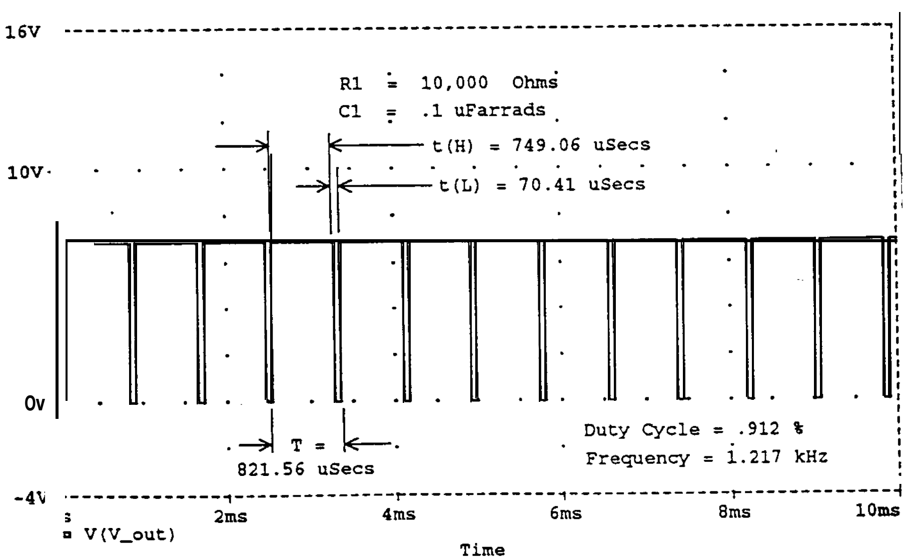

Figure 4: Output Waveform at R_1= 10 KΩ and C_1=0.1 μF