AC 2007-1417: WEAVING THE CAPSTONE TAPESTRY

James Everly, University of Cincinnati

James O. Everly is an Associate Professor of Electrical and Computer Engineering Technology at the University of Cincinnati. He received a BSEE and MSEE from The Ohio State University in 1969 and 1970, respectively. He is a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE) and a registered professional engineer in the state of Ohio. He is currently Chair of the IEEE Cincinnati Section, and in 1997 he received the IEEE Professional Achievement Award. He has held several research and management positions in industry working for such companies as Battelle's Columbus Laboratories, Rockwell International, and Claspan Corporation. He joined the University of Cincinnati in 1985.

Laura Wilson, University Cincinnati

Laura Wilson is a Field Service Instructor at the University of Cincinnati's College of Applied Science. Her main focus is Humanities, specifically English composition and Technical Writing. She holds a Master of Arts from Bowling Green State University in Scientific and Technical Communication.

Weaving the Capstone Tapestry

Abstract

This paper focuses on bringing together the technical and humanities threads that comprise the first two years of a baccalaureate degree in Electrical and Computer Engineering Technology (ECET) at the University of Cincinnati. College students often view courses in English as well as analog and digital electronics as stand-alone course sequences or separate “threads” taken during the first two years of their baccalaureate educational experience. A junior-level course in Topics of Applied Design offers the opportunity for interdisciplinary teaching with the principal focus on a controlled capstone experience wherein interdisciplinary topics are woven into a capstone tapestry. One goal of the Applied Design course is for students to clearly identify various pre-junior level coursework threads and weave them into a successful capstone experience. The pre-junior humanities component of the course is re-introduced via technical report writing, project poster board development, and PowerPoint presentations. Similarly, the associate degree level of Electrical Engineering Technology coursework is re-introduced via a pressure sensor project comprised of a collection of analog and digital circuits studied during the first two years of college. The paper presents the "project philosophy" together with specific technical and humanities project components. Students can work independently or in teams composed of two or three students for the purpose of cost sharing. However, each student is required to build a project prototype and write a project proposal. In addition, a project notebook is maintained by each student and used to record ideas, data, test results, and experiences throughout the project.

Introduction

The course Topics of Applied Design is offered autumn quarter of the junior year for baccalaureate students in Electrical and Computer Engineering Technology. Prerequisites for the course include three course sequences in electronics, electric circuits, and digital electronics. In essence, students have completed the major technical sequences required for an associate degree in Electrical and Computer Engineering Technology. The primary focus at the beginning of the junior year is to introduce students to a course in applied design that utilizes a capstone project as a learning vehicle to bring together concepts previously introduced in both analog and digital electronics. In addition, the junior capstone course is used as a stepping board toward Senior Design. This paper focuses on

- Bringing together the technical and humanities threads that comprise the first two years of a baccalaureate degree in Electrical and Computer Engineering Technology.
- Employing interdisciplinary teaching with the principal focus on a controlled capstone experience wherein interdisciplinary topics are woven into a capstone tapestry.
- Having students clearly identify technical coursework threads by using the technique of annotated bibliography.
- Teaching students how to author a project proposal using a well-defined project and reverse engineering the proposal to give a desired outcome.

- Learning techniques that allow for an easy transition into the senior capstone experience (Senior Design) by allowing students to experience the capstone process using a well-defined technical example.
- Introducing students to the use of a research journal to record ideas, data, test results, and experiences throughout the project.

The next section introduces a technical project (The Pressure Sensor Project) that, through the use of an annotated bibliography, incorporated all of the relevant technical and humanities course threads. The annotated bibliography allows students to clearly appreciate the relevance of their previous technical course work. In addition, it allows students an opportunity to view how familiar circuits are combined into a working practical project. Subsequent sections of the paper are project independent. In fact, it is the goal of the authors to have a "collection of projects" that can be inserted into the "capstone project framework" introduced later in the paper. After the introduction of the capstone project in the technical discussion, which includes a project overview, design changes that lead to a successful project, project modules, packaging concepts and suggested future enhancements to the project, this paper focuses on weaving humanities threads throughout the technical completion of the project. The humanities discussion will detail the concepts of reverse engineering and technical writing, covering the main humanities outcomes of this course: project poster; PowerPoint presentation; project proposal; abstracts, introductions, and conclusions; annotated bibliography; and the ongoing project notebook. The final student assessment attests to the success of this junior capstone course in preparing students for their senior capstone course.

Technical Discussion

The project presented in this paper is a slightly adapted version of a project presented in a paper entitled "The Pressure Sensing Project" by Professor's Nghia T. Le and Terry O'Conner of the Purdue University School of Technology, New Albany location, and given at ASEE 2004 in Salt Lake City, Utah [1]. This project is ideal for a junior year capstone experience because of the circuits it uses to accomplish the tasks outlined in Figure 1, the block diagram for the analog section of the project. The individual circuits have all been covered in previous courses. Students should recognize these circuits from Electronics I, Linear Electronics, and Circuit Analysis I and II. This is also an excellent opportunity to review and enhance the students' understanding of electronic test equipment normally used in the first two years.

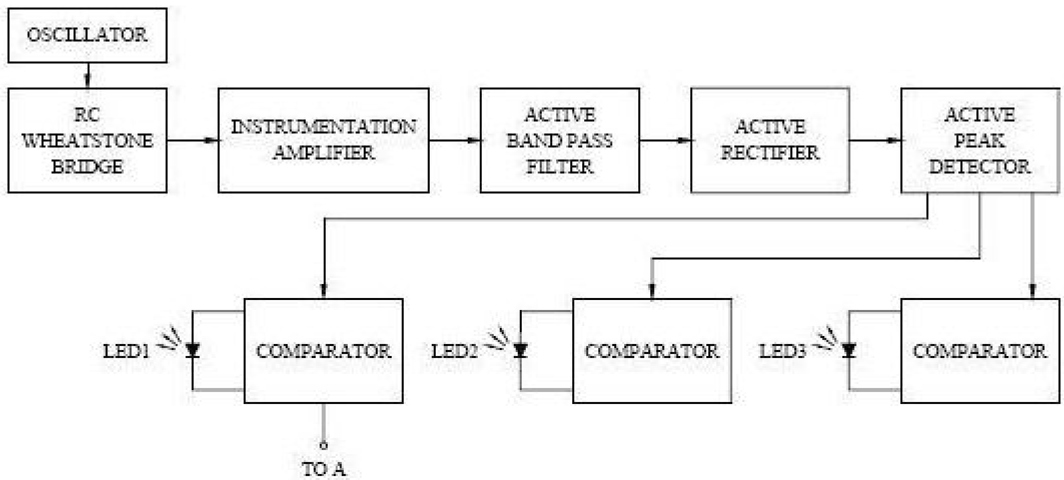

Figure 1 - Analog Section Block Diagram

Project Overview

The Purdue University Pressure Sensor Project operational concept employs both analog and digital concepts as illustrated in Figures 1 and 2. The system employs three different colors of light emitting diodes (LEDs) and a three-digit, seven-segment display. The LEDs are used as indicators to represent how much external pressure is being applied to the top plate of the capacitor C_5, in Figure 3, to compress the foam dielectric between the plates. A red LED1 is lit when the applied external pressure results in approximately 30% compression. The yellow LED2 and green LED3 are lit at external pressures resulting in approximately 60% and 90% compression respectively. At the instant the first diode, LED1, is lit a three-digit display shows, in seconds, the time that external pressure is being applied. When external pressure is released, the counter stops and the total time that pressure was applied is displayed in seconds.

The digital portion of the project requires less tuning, but is still an excellent review of material covered in Digital Systems I and II. Figure 2 shows the block diagram of the digital portion of the project. The circuits that make up the modules provide a combination of familiar technologies to accomplish a practical task. The project's complexity makes it a thorough project, but one that can be completed in an academic quarter.

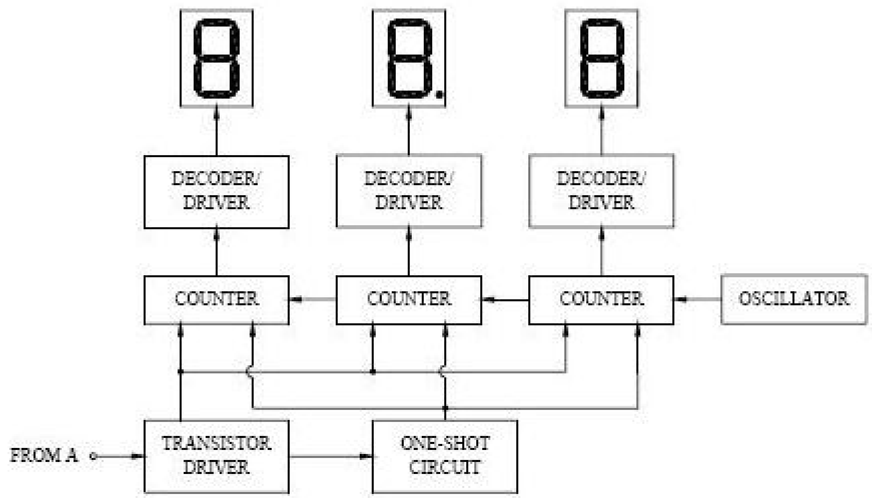

Figure 2 - Digital Section Block Diagram

Pressure Sensor Design Changes

The audio oscillator employed in the analog section is a standard Wien-Bridge designed to operate at 4.82 kHz and produces a 26 volt peak-to-peak sinusoid. The output of the oscillator, denoted as V_{OUT1}, serves as a reference voltage for the RC Wheatstone bridge circuit shown in Figure 3.

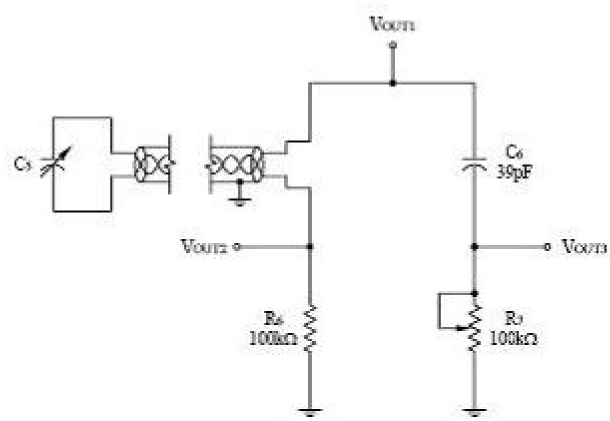

Figure 3 - Wheatstone Bridge with Variable External Capacitor C_5

The external sensor portion of the "pressure sensing" circuit, C_5, is shown in Figure 4. The figure illustrates a simple generic parallel plate capacitor containing a foam dielectric. The variable capacitor is intended to act like a "pressure switch." By applying pressure to the top plate of capacitor C_5, the foam layer collapses, causing an increase in capacitance. Note that the physical dimensions together with the intended value and range of capacitance is unspecified in the Figure 4 and associated technical article [1]. This made it difficult for students to reproduce the capacitor. Several attempts to construct this capacitor concept were attempted without success. Also, hand-induced capacitance varied from student to student and, during compression, the capacitor plates were difficult to maintain parallel to each other. Hence, the capacitance value was uneven and unpredictable.

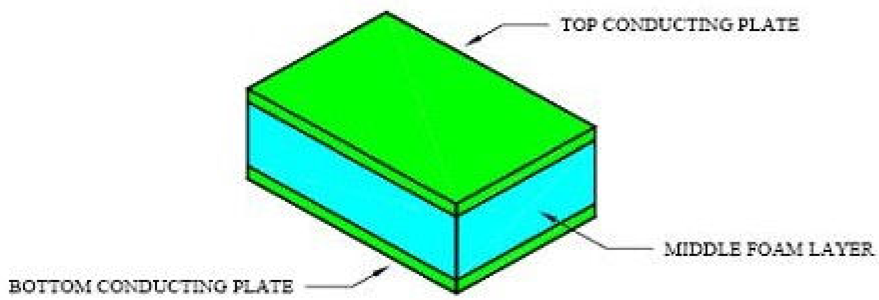

Figure 4 - Parallel Plate Capacitor C_5 used as Pressure Switch

An alternative solution for the variable capacitor was proposed and is shown in Figure 5. The three-element variable capacitor is marketed by Fair Radio Sales [2] and is available on eBay. The capacitor is formed by three aluminum plates and is designed to produce 180 pF of capacitance when fully meshed. This capacitor is used with a loop antenna to form a parallel resonant circuit and is designed to tune the Amplitude Modulation (AM) broadcast band as part of crystal radio set. The plate dimensions are approximately 57 mm by 91 mm. A small piece of dielectric material is inserted between the two outer plates at the screw insert on the right side. The two outer plates are electrically isolated from each other and must be tested with a continuity tester. A nylon screw and nut are used to secure the assembly and to insure electrical isolation of the outer plates. Operationally, the external three parallel plate "variable capacitor" capacitance value is increased when the inner-plate is pushed in and decreased when it is pulled out. The resultant capacitance of the substitute C_5 capacitor ranges from 5-90 pF. To allow the new variable capacitor to operate over its maximum range, a capacitance of 18 pF is placed in series with C_5, and a 39 pF capacitance is placed in shunt with this series combination prior to entering the bridge. This technique is similar to "band-spreading" which is used in RF tuner design.

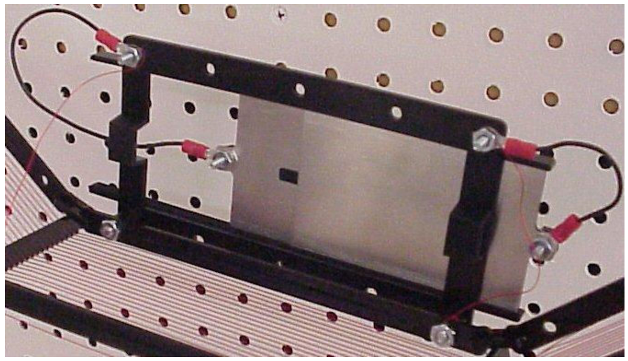

Figure 5 - New C_5 Variable Capacitor Contains Three Parallel Plates

One additional adjustment is required for the bridge circuit to operate properly. Resistor R_3 is replaced with a 1.0 MΩ potentiometer. This will allow the peak voltage output from the instrumentation amplifier, V_{OUT4}, to be adjusted to the required nominal 300 mV peak value.

During prototype construction and testing, it was discovered that the second order active band-pass filter, shown in Figure 6, was unstable and produced an oscillation. Hence, an alternative design was implemented and tested.

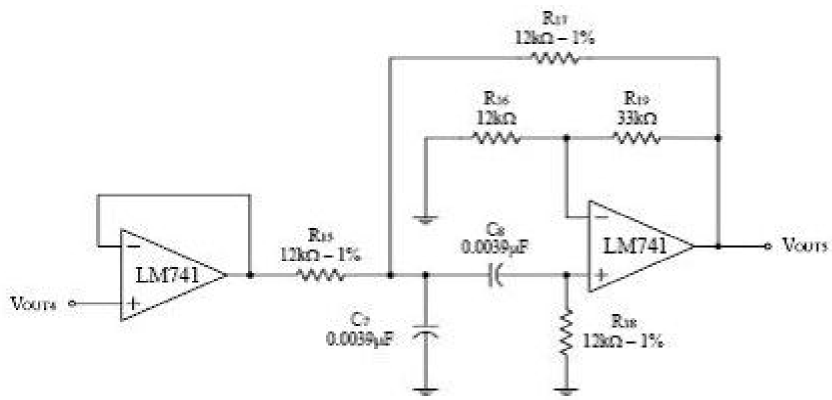

Figure 6 - Unstable Second Order Active Band-Pass Filter

The resistor values for the new filter are given in Table 1. Note that all capacitance values of the original filter remain unchanged.

Table 1 - New Resistor Values for Band-Pass Filter

Resistors	**R_{15}**	**R_{16}**	**R_{17}**	**R_{18}**	**R_{19}**
Old Value	12kΩ-1%	12kΩ-1%	12kΩ-1%	12kΩ-1%	33kΩ-1%
New Value	8.45kΩ-1%	10kΩ-1%	8.45kΩ-1%	16.9kΩ-1%	18kΩ-1%

Project Modules

The circuit subsystems described in the block diagrams shown in Figures 1 an 2 have been translated into practical analog and digital modules via ExpressPCB [3] software. The printed circuit boards (PCB) measure 3.8 inches by 2.5 inches and can be purchased in groups of three boards for $51. Two PCB's namely, the analog and digital circuit boards are required for each student. Normally three students work together as a team to develop the PCB and have it manufactured in a cost effective manner. The cost per student is approximately $20 per board when return express shipping is utilized. The analog and digital PCBs are shown in Figures 7 and 8, respectively.

Packaging Concept

The packaging concept for this project was chosen by the authors, who have an outside interest in K-12 education outreach. The SpongeBob lunch box container was purchased at a local department store, and is tall enough so the printed circuit boards can be turned on their edges. The seven-segment display is placed in the section containing SpongeBob's teeth. The power distribution connectors are attached to the side panels of the rectangular opening as shown in Figure 9. The front view of the SpongeBob lunch box is shown in Figure 10. Overall, the packaging concept was fun and provoked many student comments. Moreover, it encouraged students to use their imagination to address their intended audience.

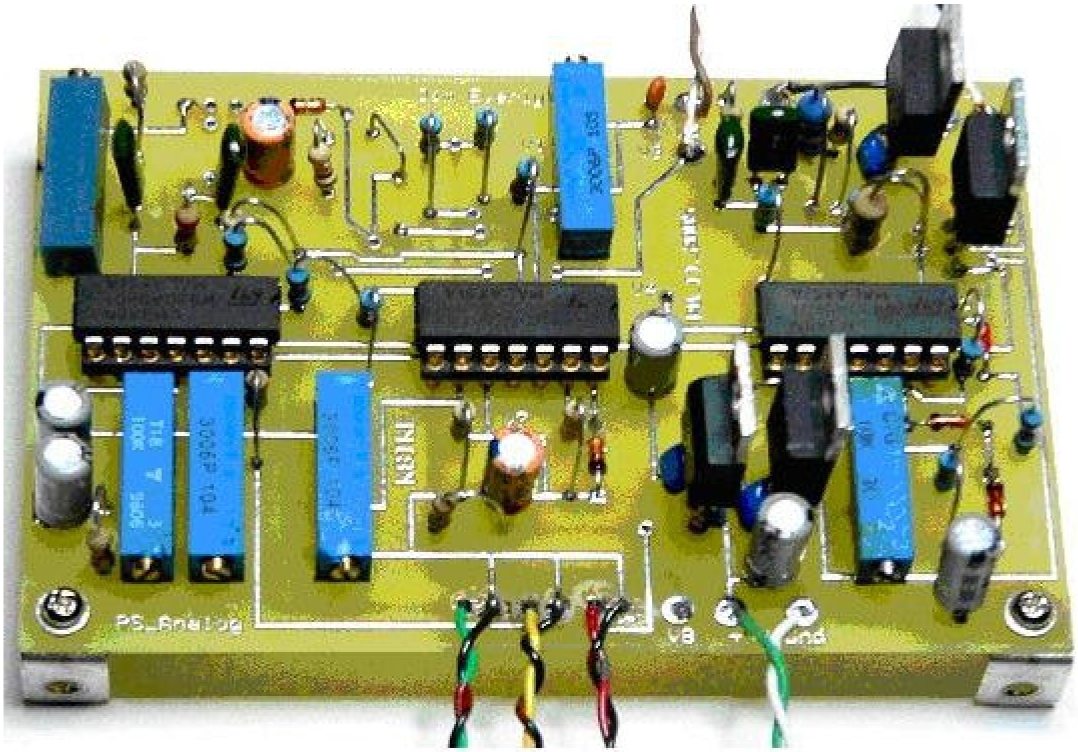

Figure 7 - Analog Section Printed Circuit Board

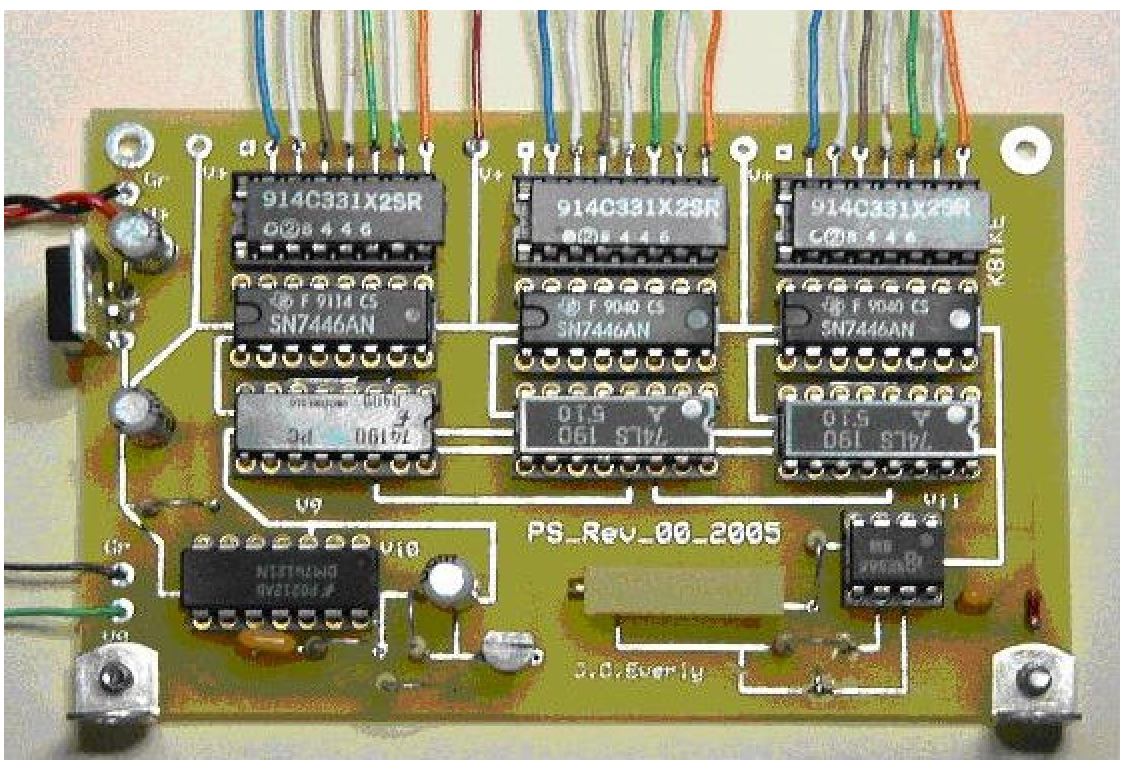

Figure 8 - Digital Section Printed Circuit Board

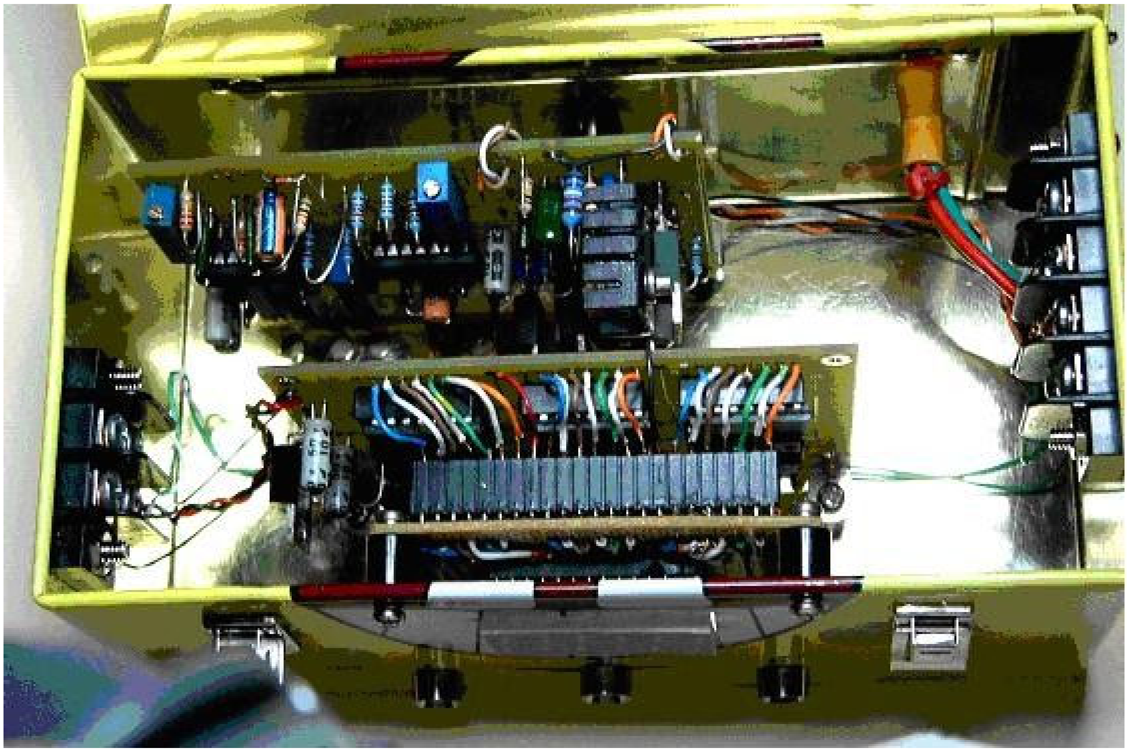

Figure 9 - Inside View of Final Packaging

Figure 10 - Final Packaging Concept for the Pressure Sensor Project

Future Pressure Sensor Project Enhancements

Recent changes in the Computer Engineering Technology curriculum now introduces embedded systems concepts in the first two years. For the next iteration of the Applied Design course the digital section of the project will be replaced with a microprocessor, programmed in a higher order language, as well as a liquid crystal display. In addition, the three op-amps used to form the instrumentation amplifier will be replaced with an actual instrumentation amplifier integrated circuit chip. It should also be noted that the concept of a "pressure switch" should be restored to the project by employing a mechanical device that when squeezed will provide a change in capacitance.

The previous sections of this paper discussed a project concept that fits nicely into the "project philosophy" required of the Applied Design course. The next section of the paper presents the core concepts of the paper together with the humanities component.

Integrating the Humanities Component into Technical Projects

Weaving a junior level capstone tapestry, as the authors of this paper have succeeded in doing in the Applied Design course, requires many varying threads. The weaving concept will be successful regardless of degree program or skill level, provided that the master weavers, the faculty, are able to provide a successful well-defined project, similar to the one outlined in the previous sections of this paper, for the students to work through.

This portion of the paper follows a reverse engineering methodology, allowing readers to see how each aspect of the humanities curriculum is woven into each project element in the Applied Design course. Ronald Barr, Philip Schmidt, Thomas Krueger, and Chu-Yun Two support the idea that reverse engineering is an effective way of introducing engineering students to new concepts in their field [4]. Although usually used in the re-creation of a design, this paper used reverse engineering to re-introduce the students to the humanities threads that would take them through the junior capstone experience. By starting with the end result, the students were able to see how all of the humanities threads came together in the end.

During the students' first year, the English Composition sequence teaches students to write annotated bibliographies and follow a specified style guide, such as MLA or APA. The Speech Communication course ensures that they are prepared to present their findings confidently. Finally, the Technical Writing sequence, taken generally in the students' second year, provides them with the threads needed for report writing. Despite the completion of these course sequences, many students find it difficult to transfer these skills into their major fields of study. In addition, many engineering students resist writing assignments in their major classes, "unconvinced of writing's importance" [5]. According to E.D. Wheeler, G.G. Balazs, and R.L. McDonald, engineering professionals set an example for their students. As professors and professionals in the engineering field, students will follow the lead if the importance of writing is stressed in each class [5]. The newly developed junior Applied Design course is designed to facilitate the connections among the students' previous coursework in technical and humanities threads as well as stress the importance of writing.

To this end, students are provided with algorithms, or templates, for writing technical report introductions, conclusions, and abstracts. Project posters are developed using the same guidelines as Senior Design, the final step in their degree coursework. Each student project, poster board, and presentation is judged using the same rubrics as those used for Senior Design capstone projects. As an ongoing project in the junior Applied Design capstone course, the students keep a project notebook or journal in which they record their progress throughout the entire experience. Ultimately, success in this junior level course will ease the students' transitions into Senior Design as well as enhance the quality of their performance in their final capstone experience.

In the junior Applied Design capstone course, the following threads are presented in reverse chronological order, starting with the final outcome of the students' capstone experience, the project poster. By starting with the end product, the project poster, students are able to see how the various skills from each humanities course completed to date will tie together with their technical knowledge. Ultimately, the goal of teaching through reverse engineering is that the students weave a pattern among the courses they have taken in both the technical and humanities fields. However, it is the authors' experience that students do not necessarily relate their courses unless the pattern is made clear to them: only then do the individual threads become apparent to the students. The introduction of the project poster at the beginning of the Applied Design course outlines the main assignments of the course: abstract, proposal, presentation, and annotated bibliography.

Project Poster

One of the most important skills that a technical person must develop to become successful is the ability to communicate effectively the essence of his/her technical work in an extraordinarily short time and /or small space. Designing and producing a project poster provides the mechanism for each student to enhance presentation proficiency. In addition, posters serve to showcase the breadth and depth of the ECET department junior capstone design experience.

This assignment is introduced first during the junior capstone experience, though it is completed last. By introducing and detailing the requirements of these assignment first, students become effective reverse engineers. The students see how each thread – each humanities and technical element of their education thus far – contributes to the overall tapestry of the capstone course.

The four-page assignment clearly details the requirements for the poster. These requirements include the following elements:

- project title;
- names of the project advisor, project sponsor (if applicable), and project presenter;
- abstract;
- introduction, which is a condensed version of the project proposal (adhering to the mechanics of reverse engineering) that should include the Problem/Need, Users and Uses, and Assumptions/Limitations;
- design requirements section, also condensed from the project proposal, which should include design objectives and design constraints;

- technical approach;
- testing approach;
- budget effort;
- final product/project results; and
- references used (if applicable).

By introducing all of the components necessary to complete a successful project poster, the students can see the finished tapestry for themselves. Each component of the poster represents a different thread to be addressed, whether from a technical or humanities background. This preview forecasts the work necessary to complete the capstone experience.

The poster is judged on the above requirements, as well as on aesthetic appeal. The students are taught four basic design criteria – proximity, alignment, repetition, and contrast. The completion of this junior capstone poster prepares students for their Senior Design poster presentation. The Senior Design poster is a staple of the Senior Design course, where the students' final projects are displayed at a college-wide Technology Exposition (Tech Expo) at a local convention center.

PowerPoint Presentation

The PowerPoint presentation is the second-to-last humanities requirement for the course. Students must take the following components from their project proposals and project outcomes and incorporate them into their presentation:

- introduction – title of project, student name
- project objectives
- project design
- project outcomes
- parts list
- future implications
- questions

This presentation strengthens the students' communication skills – both verbal and written. It also prepares them for the questions they may be asked at the final Tech Expo convention center display. In the junior capstone course, the presentations are judged only by the course instructors. At the senior capstone level, all ECET faculty judge the presentations based on delivery, content clarity and aesthetic appeal.

Project Proposal

The purpose of this junior capstone project proposal is to have the students analyze all aspects of an already-completed project. In the senior capstone, students have to propose a unique, individual project. Part of the appeal of this junior capstone course is the pre-selected project. The students do not have to come up with a project on their own – that is already done for them. This allows the students the time and creativity to master the skills needed to present the findings of their projects and tie all of the threads from their coursework together without the pressure of innovation. The proposal is broken down into three sections: introduction, discussion and conclusion.

The introduction covers:

- top-down strategy (introducing all components of the proposal for the reader, a skill introduced to the students in technical writing) [6]
- project scope
- project overview (brief problem and solution summary)
- student qualifications
- background information (technical information the audience needs to know to understand the proposal)

The discussion includes:

- problem
- solution
- implementation
  - time (Gantt chart)
  - budget (parts list, proposed budget)
- benefits/rationale

The conclusion is a very brief reiteration of the problem and need; this is where the students "sell" their project.

Without the project proposal, students will struggle to complete the other components of the course. The writing of this proposal, based on a completed project, helps students understand the scope of what they'll be asked to do in senior capstone as they develop a project of their choosing. The writing of this proposal is also the gateway to completing the presentation and the project poster.

<u>Abstracts, Introductions & Conclusions</u>

It is apparent to the authors that, at the graduating level, students still need help writing abstracts, introductions and conclusions. Students are successful in explaining the "content" of their projects, or the body of their ideas, but it is hard for them to summarize, introduce, and conclude. These skills need honing. In the junior capstone course, the authors developed algorithms for creating these pieces. The authors produced handouts that depicted the need for abstracts, the types of abstracts, and an equation for the writing of abstracts. Students used these handouts to create their own abstracts based on the provided project.

<u>Annotated Bibliography</u>

Students are introduced to the annotated bibliography in first-year composition. However, it was clear that the connection of creating an annotated bibliography did not transfer into other fields of study. The purpose of weaving this capstone tapestry all started with this assignment. Students were asked to compile a list of course texts; these texts were a large part of forming the threads for the capstone tapestry. Each text listed on the annotated bibliography had to be relevant to the knowledge the students used while completing the assigned project. If the course fulfilled the authors' expectations, these annotated bibliographies would reflect the incorporation of knowledge from all previous technical and humanities-related courses. Organizing material and creating a model to understand the students' level of comprehension were two main goals of this assignment. Larry Yore and David Treagust's discussion of creating a unified model in students' work to enhance the students' metacognition is really supported in this model junior capstone class [7].

Requirements of this assignment include:

- a citation of each text, following the style of their choice (MLA, APA, etc.);
- a brief annotation (approximately 200 words) that covered the text's main point, arguments, and findings; and
- a brief closing annotation (approximately 50 words) that covered what knowledge the text provided the student in relation to the completion of the assigned project

The junior capstone annotated bibliography is a brief example of the extended annotated bibliography completed during senior capstone, which includes not only textbooks, but outside sources and primary research as well.

<u>Project Notebook</u>

The project notebook is an ongoing assignment in the junior capstone course. It is used to record the students' journey through the course with emphasis placed on recording events and ideas as the prototype concept develops. Many students also use the notebook as a journal and often record their frustrations as well as their successes. As cited by Susan Hawkins, Mary Coney, and Karl-Erik Bystrom, this is a type of "incidental writing," which improves metacognitive abilities and domain knowledge in engineering students [8].

Laboratory time is used to form discussion groups which deal with problems encountered during the building and testing phase of the project. The final packaging concept is often discussed and students share ideas during group discussions. In addition, each student is required to develop a Gantt chart to show project progress during the course. A handout is given in lecture that describes the Gantt chart technique for implementing the project schedule, but the actual development and updating of the chart occurs outside of the classroom. The chart must be included in the student notebook. In Topics of Applied Design, the project is weighted at 30% of the lecture grade. The components of the project scoring are highlighted in Table 2.

Table 2 - Research Notebook Project Scoring

Topic	Points
Journal entries complete	5
Component data sheets	1
Parts list	2
Sketch of packaging concept	2
Gantt chart	2
ExpressPCB layout	5
Does project work as intended	2
Schematic diagram	1
Prototype construction	5
Construction & soldering	2
Actual product packaging	3
TOTAL	**30**

Student Assessment

To date, qualitative and quantitative student feedback on the course structure and project has been very positive. Representative selections of student comments are presented in the following student assessments.

The following comments are extracted from course assessment forms developed by the authors. The student population is drawn from Electrical and Computer Engineering Technology students at the onset of their junior year. Five questions were presented to the students during the last class of Topics of Applied Design during Autumn Quarter of 2006. Overall, the comments are very encouraging [9]:

1.0 Did the class project illustrate the concepts presented in the course?

- "This project covered most concepts presented in the course. We explored design considerations, in testing circuits to find current draw, so that overall power consumption could be considered. We developed testing procedures for step by step project assembly. We learned troubleshooting skills for a complex multi component circuit and redesigned aspects of the circuit for greater stability. Abstracts, proposals, annotated bibliographies, poster board and PowerPoint presentations were presented and required as part of the project."

- "The Pressure Sensing Project succeeded at illustrating the concepts presented in the course. The project incorporated several different circuits which had been covered in previous courses. This provided a great review of earlier coursework, and the complexity of the circuit allowed for an excellent troubleshooting experience. The paper outlined the project in block diagram and schematic form, and provided all of the necessary equations. Since this project was already laid out, we could concentrate on the work that was necessary to complete a capstone project. The concepts of abstracts, annotated bibliographies, proposals, PowerPoint, and poster boards could all be illustrated effectively using this existing project. ExpressPCB software, project cost, and planning with the use of Gantt Charts were also introduced."

2.0 Was the class project effective in enhancing your technical skills?

- "The project introduced the soldering onto printed circuit board, which I had no prior experience with in the past. In addition this project allowed us to work on design improvements for the project to overcome some small problems in the circuit. We were able to get the Wheatstone Bridge to balance properly and we also devised a scheme to allow a sliding parallel plate capacitor with a large range in capacitance to be used in place of the as specified parallel plate pressure capacitor."

- "This project provided us with both an analog and digital portion, so a lot of the key concepts covered in Circuits and Digital Systems were reviewed. It was necessary to use a wide range of test equipment to accomplish the tasks that were outlined in the project, and troubleshooting skills were a must. I feel that the project provided an excellent review that spread across concepts which had been presented in several different courses. It was interesting to see a practical application of all of the concepts that had been covered. This was also my first experience with soldering PCB boards, so a lot was gained from going through the design and build process."

3.0 Was the class project rewarding?

- "The most rewarding part of the class for me was working on the revisions for the Wheatstone bridge and adapting the sliding parallel plate capacitor to the project. I was able to analyze where the problem might lay in each case and through some calculated trial and error I was able to get the Wheatstone bridge to balance by replacing the as specified 100 kΩ rheostat with a 1 MΩ rheostat. In respect to the variable capacitor the original design used a capacitor with a small range in capacitance. The alternative which we decided to use had a much larger range in capacitance, which had to be addressed in order for the circuit to function correctly with our new capacitor. By using a combination of parallel and series capacitance I was able to create a way for the large range capacitor to work in place of the small range one. These improvements were the most rewarding part for me."

- "I feel that this class project was very rewarding. It walked us through the senior design process and provided a review of earlier coursework. I feel that I am well prepared to start senior design next year. The only reason that I did not rate this class project with the highest score possible is that it would have been nice to have time to package the final project. Time constraints did not allow for packaging, so in my mind that project is not really complete. I also would have liked to learn about Microsoft Project which will be used for senior design. Again, time constraints did not allow for this software to be covered."

4.0 Did you encounter any areas of difficulty while completing the project?

- "There were really no difficulties with the project other than the issue of time. The general consensus from the other students is that the details of the project could have been spread out more evenly over the course of the quarter. As it turned out we spent a lot of time near the end of the quarter addressing the humanities end of the project, where these could have been covered earlier in the quarter. With this I would have liked to have seen Microsoft Project formally introduced and possibly even implemented which may have helped to alleviate the aforementioned problem."

- "The areas of difficulty were related primarily to the external capacitor and time. The capacitor presented in the original paper was designed to be two plates that had a foam pad between them. When the plates were squeezed together the capacitance would vary. This looked like a good concept, but when we tried to put it into practice it proved difficult. It was hard to balance the bridge that the variable capacitor was a part of. Hand capacitance and uneven pressure were factors that made the squeeze variable capacitor ineffective. The sliding cap that was used for the final project proved to work much better.

  Time was an issue because a lot of the work that was required for this course was not assigned until the last few weeks of the quarter. I think that the assignments could have been spread out more throughout the quarter. If more time was allowed for the humanities portions of this class I think the submitted work would have been of a higher quality overall than it was. Also, the final PCB boards did not arrive until the last week of the quarter. This made it extremely difficult to finish the project when there were other classes and exams that had to be taken into consideration. I would recommend getting an earlier start on the PCB build portion of the project. A lot of time was spent early in the quarter going over the concepts presented in the paper. This was a great review and it did demonstrate that each individual portion of the project would work. However, I think more time should have been spent on the actual project build. This would probably have eliminated the time constraints that we ran into at the end of the quarter."

5.0 Rate this course overall, based on its effectiveness and helpfulness in utilizing your past coursework experiences and preparing you for senior design.

- "This course proved to be quite enjoyable. Introducing PCB Express and printed circuit board design and soldering techniques was a high point of the class. Also this was the first large scale project or circuit that I have encountered, outside a previous Honors project that I completed. One of the nice things about the course is that once it is all said and done you are able to walk away with a completed circuit/project that has a certain level of professionalism that cannot be achieved in labs where simple breadboards and jumpers are used. Lastly by requiring us to submit abstracts, proposals, annotated bibliographies, etc allowed us to preview and prepare ourselves for Senior Design. With this when we are required to prepare such things for our Senior Capstone Project they will be something we have seen before and have had experience with, hopefully making our Senior Capstone Experience that much better."

- "I feel that this course provided a solid foundation that can be taken into senior design. The senior design process was presented in this course from concept almost to completion. It was demonstrated that several pieces of the final project overlap if done correctly. The writing and presentation portions of the project are all connected to each other, and the student should not be overwhelmed as long as the process conveyed in this course is followed.

  Also, a lot of the comments that I made were related to time constraints. It is understood that this course is going through some significant changes, so this quarter may not have went as smoothly as it will in the future. I hope that the suggestions that myself and the other students have made will help to make this course more valuable for future students."

Ultimately, this commentary proves that a successful capstone tapestry has been woven. Acknowledgements concerning the time frame of the course were the most helpful; the authors will make this change for the next Topics of Applied Design course by introducing the humanities component at the onset of the course. As practiced by Kolikant, Gatchell, Hirsch, and Linsenmeier, the feedback gained from the students in the junior capstone course will be used to modify the course for future applications [10]. The end result of this experience, this “apprenticeship”, is better prepared ECET students entering their senior capstone experience.

Conclusion

This junior capstone project relies heavily on knowledge and skills previously learned in both the analog and digital electronic sequences as well as those learned in the humanities courses. In addition, the capstone project provides a vehicle to introduce applied design concepts, construction techniques, printed circuit board layout techniques, and packaging concepts. Only a modest amount of construction, testing, and calibration skills are required for successful completion of the project. Finally, the humanities threads helped the students make connections between their course experiences and produce more critical thinking and collaboration between ideas and course sequences. Overall, the student attitude towards the course and subsequent feedback were the most rewarding, and the authors were very encouraged by the level of student involvement in the project.

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