AC 2009-1976: A STUDENT-SELECTED TEAM-BASED CAPSTONE PROJECT IN RF COMMUNICATIONS

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A Student-Selected Team-Based Capstone Project in RF Communications

Abstract

This paper presents the results of a capstone project in an elective RF communications course. The course is third in a series of upper-division communications courses in an Electrical and Computer Engineering Technology program. Students were allowed to select the type of project, create specifications and develop test plans. Students were then grouped into teams that were maintained throughout the course.

The project initially progressed slowly as students selected overall specifications, determined functional blocks and developed block designs. Weekly project team meetings required teams to communicate their progress and any discoveries to the remaining teams. As the project progressed, initial designs and test criteria were updated to reflect student discoveries relating to components, manufacturing and measuring capabilities. All specifications, test procedures, and designs for the entire project were completed individually by each team and submitted to all other teams. Submissions were reviewed in design review sessions in which all teams voted on the best submission, which then served as the standard for all teams. Upon determination of all circuit designs, the project was equally divided among all teams. Each team was solely responsible for the layout, fabrication and testing of their project block.

Course instructors facilitated project progression through comments on the advantages and disadvantages of proposed approaches. Course lectures and laboratories were designed to provide instruction in concepts relating to the project which were not covered in previous courses. The project, a 915MHz, multi-channel FM audio transmitter and receiver, was successfully constructed and operational by the required delivery date.

This paper presents student results for key project milestones, results of student interviews relating to their project experiences and preferences, and instructor observations. Additionally, comments regarding the suitability of this type of capstone project method for engineering technology students are provided.

Introduction

Providing meaningful laboratory experiences to electrical engineering technology students becomes increasingly challenging as they advance through a curricula. Early fundamental labs are often highly structured, but as students advance in their experience and education, the need for independent inquiry learning emerges. Students nearing graduation face the future prospect of working or studying in an environment with substantially less oversight and direction. Additionally students will need to develop self-confidence in their abilities and decisions to allow for the level of independence desired by employers.

Background

This paper examines the implementation of a team-based capstone project in an undergraduate communications course. The elective course in RF circuit design is the final in a series of three RF communications courses. Prerequisites to the capstone course include a course in RF communications from a systems perspective and a course in transmission lines, antennas and fundamental electromagnetic theory. Additionally, previous laboratory exercises familiarized students with the use of RF benchtop sources, measurement tools and simulation software through the construction of a discrete FM broadcast receiver[1]. Incoming students have been immersed in a curriculum of structured laboratory experiments which typically provide a detailed list of specifications, deliverables and instructions for both the construction and testing of a circuit.

The open-ended nature of this course project represents a significant paradigm shift from previous course and laboratory experiences in the curricula. Students nearing the completion of their undergraduate education are poised to shortly face work or graduate school environments where the ability to self-start and perform with minimal instruction is desired, if not required. Positive experiences in previous laboratory exercises, designed to be bulletproof to support instructional goals, often leaves students with unrealistic expectations. This produces a naivety of the resources necessary to complete the iterative cycle of design, construction, test and modification required to develop a prototype of a practical circuit or system. The primary goal of this capstone project is to instill an awareness of real world considerations which must be addressed in practical designs, with particular emphasis on those issues encountered in RF design. A team project was selected over individual efforts as most students in the course have minimal experience with project design and the scope of the design effort requires that students work at a greater level of efficiency than necessary in previous courses.[2,3] Team projects allow for a collaborative learning environment in which each student has access to and can utilize the discoveries of their classmates to advance their designs without having to repeat the mistakes of others.[4]

Implementation

The project was undertaken over a fifteen week semester. The course was structured to have three one-hour lectures and a two-hour laboratory session each week. Throughout the course, lecture and laboratory activities were synchronized to assist in meeting the requirements of project deliverables. Fifteen students were assigned to project teams comprised of 3-4 students early in the course. These project teams were maintained throughout the course of the project.

Lectures and laboratories in the first half of the semester were primarily focused on the presentation of additional content relevant to the project and the reexamination of prerequisite topics critical to the project. One lecture and approximately 15 minutes of laboratory were devoted to the project each week. Project effort was directed to the development of specifications, circuits, material lists, layouts and test procedures. During the second half of the semester project effort shifted to construction, test and modification of prototype circuits. At this time two lectures each week and all of laboratory were strictly devoted to the project.

The first phase of the project began with a laboratory session devoted to the completion of a laboratory equipment audit to determine the testing capabilities available to the students in the laboratory. This exercise was designed to focus student attention on the practical limits that capital equipment poses on a project. The idea of a course project was introduced the following week and students were tasked with brainstorming project ideas and were reminded to consider the capabilities determined in the previous equipment audit. Over the course of the next two weeks students submitted their lists of project ideas and descriptions, which were subsequently discussed in open design group sessions during lecture sessions. Throughout the process, the anonymity of the idea's author was maintained to encourage honest assessment by their peers and to prevent any embarrassment from criticism. A range of ideas emerged covering the spectrum from unchallengingly simple to impractically difficult. The course instructors served to facilitate discussions by suggesting, but not explicitly stating, factors deserving consideration at this stage. The pros and cons of each approach were illustrated by the instructors in a non-judgmental and highly interactive discussion. Students were encouraged to research these factors and use them as a basis in their decision-making process. Ultimately, the list of project ideas was reduced to five possible candidates with the final project idea selected through a single vote process. The course instructors did not participate in the voting process. The selected project was a 915MHz, multi-channel FM audio transmitter and receiver.

The second phase of the project focused on the determination of functional blocks, block specifications, circuits, component selection, test and measurement procedures and layout and design of printed circuit boards. At this point, project teams were assigned by the course instructors (3 teams of 4 students and 1 team of 3 students) and all project activities were completed as a team effort. Student interaction was low and typically had to be prompted in the early stages of this phase. Later interviews yielded comments indicating that students assumed that if they waited long enough, the answer would be given. "We just figured that you would tell us what you wanted… It got pretty boring. I finally just said something so [course instructor] wouldn't keep asking the same questions over and over." After a slow initial week, student involvement slowly increased upon realizing that solutions would not be provided by the course instructors. Over the course of the next week designs evolved rapidly. Once again, a voting process was used to determine the most feasible block design and specifications and the selected specifications became the standard for all teams.

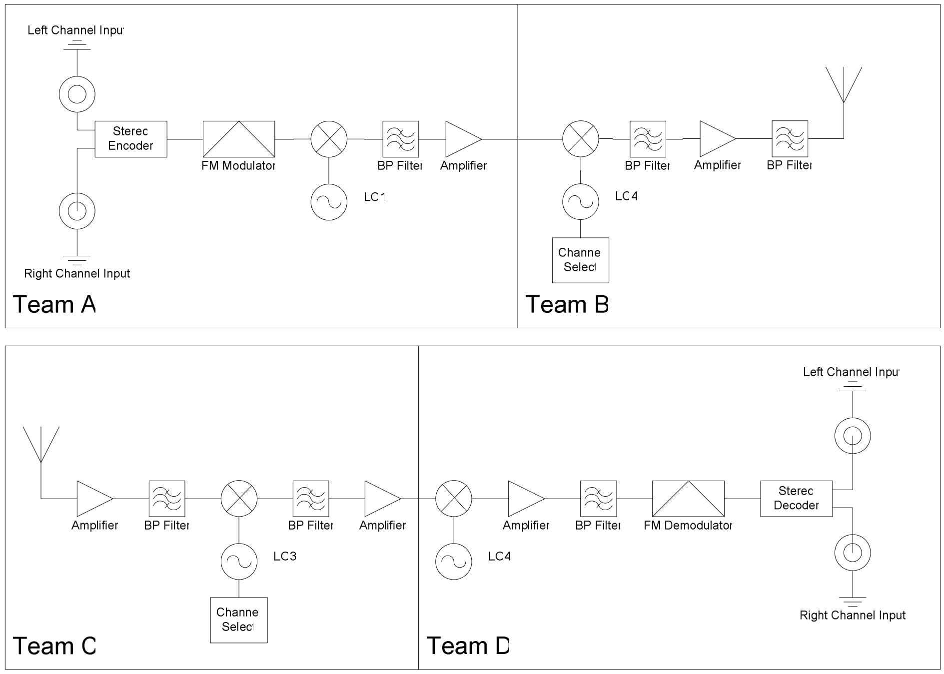


Figure 1 – Project Block Diagram

The project was divided into four sections which were assigned to each team. Each section required an equivalent work effort and contained a number of components common to each section, including mixers, filters and amplifiers. Each team was required to create and present designs for the entire project. Block designs were voted on at an individual level and the winning design became the required standard. In some cases, the winning design was produced by a project team not assigned to construct that portion of the project. This stage of the project required approximately three weeks as students learned the challenges of procuring feasible RF components. Rapidly conceived initial designs were modified several times as discoveries that components were too expensive or small, unavailable in small quantities or required a substantial lead time forced students to reconsider their choices. Prompting one student to comment in a post-project interview, "I just thought that if I find[sic] a datasheet, I could get the part and somehow make it work. I never really paid any attention to that stuff…." As final designs were presented, modifications of the previously generated block specifications were required and accepted by a vote of those students impacted by the changing specifications.

As students were working on producing block circuit designs, they were concurrently tasked with creating test and measurement plans to detail how each specification would ultimately be verified. This proved to be significantly challenging, as students claimed to have no previous experience in this area. After some prompting and the creation of a sample procedure for one of the project blocks by the course instructors, the students were able to make reasonable, though incomplete test and measurement plans for the blocks. During the voting process, it was apparent to the instructors and the students that a widely varying range of efforts and results existed, with one team ultimately producing nearly all test plans and others openly admitting a poor performance on the task.

With the mid-semester break approaching, teams were tasked with producing circuit board layouts for their assigned portion of the project. These layouts were presented and discussed over the course of two lectures leading up to the break. In these sessions teams provided comments and suggestions on all layouts. Teams were required to consider these suggestions when producing their final board layouts. A significant project milestone was the requirement that project teams produce their layouts, a receipt that the layouts were being produced, a bill of materials and a receipt that indicated all project components were purchased before the mid-semester break.

The third phase of the project commenced after the mid-semester break. All available lab time was devoted to the construction and fabrication of the project component blocks. Two lectures a week were devoted to project reports from every team detailing their proposed progress for the coming week, their level of success at meeting their progress goals from the previous weeks and discussions of any problems or discoveries encountered during the week. The laboratory was open for additional time to allow the teams to work on project items and was utilized to a higher degree than expected by the course instructors.

During this phase of the project, teams faced the challenges of manufacturing prototype boards with smaller components, component failures and non-ideal performance. Teams with all project blocks integrated onto a single PCB discovered the difficulties of performing test plans which required the isolation of individual blocks.

Throughout this phase, project block specifications were continually modified as project teams discovered parts which performed better or worse than initial expectations, failed to receive ordered parts in a timely manner or destroyed their entire stock of a particular component. An observable appreciation of the necessity to communicate both within and between teams became most evident during this phase. As each team began to achieve working project blocks, the motivation of the entire class improved, as no team wished to be responsible for failing to produce working blocks when others were successful. Individuals within teams began to emerge as leaders and took ownership of their blocks and served to motivate lagging teammates.

In the final week of the course, the teams were able to each complete their project blocks and in the final allotted day, the project blocks were successfully integrated into a working transmitter and receiver. While the quality of the prototype was sufficiently adequate from the perspective of the course instructors, the highly motivated teams continued to work to improve performance even after all course requirements were met.

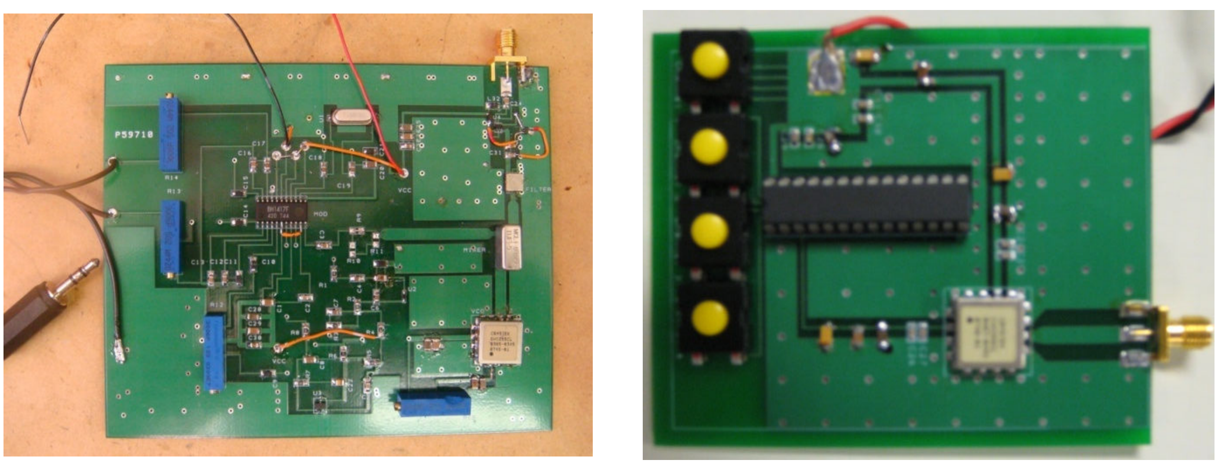
During the final four lecture meetings, project teams were required to deliver a formal presentation of their team's efforts, results and conclusions to the class. Each presentation filled an entire lecture slot and typically produced a surprising number of follow-up questions and comments. A final project report was assigned to cover the scope of the team's efforts in detailed version of the final presentation. The presentation and paper were required in lieu of a final exam.

Results

Students in the course were able to determine a feasible project with minimal instructor guidance, determine appropriate specifications, design circuitry to meet those specifications, procure parts, layout and construct printed circuit boards, test and integrate component blocks into a functional RF design, meeting, and in some cases exceeding, the goals of the course. In subsequent semesters the students participating in this project continued on to complete the program's final capstone project, often indicating a belief that this RF capstone project provided them with a substantial advantage over other students. Student motivation at the inception of the project was low, but continually increased as the realization that their, and not faculty, decisions were driving the project.

During the design stage of the project, it became evident that two key concepts, mixing cross-products and linear and logarithmic power conversions, covered in prerequisite courses, were poorly understood by the majority of students. This prompted subsequent changes in the presentation of this material in prerequisite courses which appear to have addressed these problem areas.

Each project team's prototype used a varying level of integration, ranging from an individual circuit board for each project block to all blocks on a single board. Teams who selected to create multiple boards were able to test and troubleshoot circuit problems in a more efficient manner; however each team noted the impracticality of this approach for a final design. Teams with a high level of block integration on their circuit boards faced difficulty in testing individual blocks and troubleshooting circuit failures. Group presentations helped to demonstrated the contrast in results and allowed course instructors to revisit the differences between prototype and final designs which are spanned by the closed-loop, iterative design process.



Figures 2a,b – Multiple Block and Single Block PCBs (Team A, C)

This project has been adopted as a permanent fixture in the course with minimal modifications from this initial effort.

Conclusions and Recommendations

A capstone project of this nature provides students with exposure to real considerations which exist in practical designs while providing a means to advance their understanding of underlying concepts in RF design. At the conclusion of the project, several students commented on their enjoyment of this type of approach and the desire for a follow-up course which expands the RF communications curriculum in a similar project format.

The development of thorough test and measurement plans proved to be the most difficult aspect of the project for most students. While students were capable of performing the necessary measurements and had done such in previous laboratory exercises, they were at times unable to adequately determine which methods were most appropriate or how those methods should be employed or considered in the circuit design and layout process. A number of measurements were proposed but unable to be taken as a result of failure to reconsider these during the board layout stage of the project. While course instructors repeatedly mentioned the need to make accommodations for test in circuit board layouts, few teams realized the scope of changes required or appreciated the importance of this step. Subsequent offerings of this course project will require an additional focus on the importance of test and measurement in the design process.

While most teams eventually were productive and capable of interacting and performing in a constructive manner, there were exceptions. It was these cases which prompted the adoption of the weekly progress reports mentioned earlier. After the adoption of these presentations, the performance of underperforming teammates increased and the dissatisfaction of performing teammates significantly decreased as it became evident which team members were completing their assigned tasks and brought attention to those whose efforts were beyond the requirements.

Bibliography

[1] Denton, J. and Richards, G. (2006, June). Review of an Engineering Technology Graduate Course Project to Develop Undergraduate Course Laboratory Curriculum. *The 2006 ASEE Annual Conference and Exposition, June 18-21, 2006, Chicago, IL.*

[2] Bohmann, L. J., B. A. Mork, et al. (2004). Power engineering design projects: capstone team projects versus topical design courses. I*EEE Transactions on Power Systems*. 19(1): 152-156.

[3] Vorst, A. V. (1985). Integrated Team Projects as Part of the Undergraduate Curriculum. *IEEE Transactions on Education*. 28(3): 138-142.

[4] Wikstrand, G. and J. Borstler (2006). Success Factors for Team Project Courses. *Software Engineering Education and Training, 2006*, Turtle Bay, HI.