Abstract

This paper details the techniques and workflow methodology used in the instruction of an Electronic Circuit Design course. This course requires students with little to no design experience to select a project, plan the work to be accomplished and then complete several key milestones until a complete, packaged product is the end result. This course is targeted for sophomore and junior level college students.

Of primary emphasis with this type of course is not the complexity of the circuit, but the ability of the student to learn and execute the steps of the design process that include project network analysis, computer based circuit simulation, prototype construction, circuit board design and fabrication, product packaging, project assembly and demonstration.

Students in this learning environment work individually throughout the semester, being responsible for all aspects of the project including selection of a suitable project. This course also emphasizes oral and written communication skills through a project proposal, oral presentations, demonstrations of prototypes and finished projects and a final report detailing the lessons learned during the semester.

I. Introduction

The challenge of selecting and building an electronic project over the course of a single semester can be overwhelming for sophomore and junior level college students, especially for those who have never been exposed to a detailed design environment. The Elements of Design, Analysis and Fabrication by Machine Methods (EET 3124) course at Oklahoma State assumes that most students fall into this category. As such, this project design course has been developed to bring inexperienced designers to a skill level required to be able to plan and execute more complex projects that will be expected of them in advanced electronics courses. What is presented in this paper is a proven and successful roadmap to teach students how to plan and execute an electronics project through hands-on experience.

The primary goals of the course are:
   A. Teach students elementary program planning and management techniques
   B. Introduce students to the concept of requirements analysis and proposal development
C. Show how computer simulations can be used early in the design process to proof and debug electronic projects and the pitfalls of the same.
D. Introduce different circuit prototyping techniques
E. Use integrated design environment software packages for schematic generation and printed circuit board layout.
F. Apply the appropriate style of packaging given influential factors such as environment, ergonomics and maintenance.
G. Improve written and communication skills through written reports and oral presentations.

II. Project complexity/Group Size

The first decision that had to be made for the course was to determine the best student group size for the class. Since team building was not one of the primary goals of the course, it was determined that students could work by themselves. Baduru and Pulat have indicated that communication problems between individuals can be attributed to most program failures. With this in mind, and the desire to improve the class success rate, it was decided to make each student select and build projects individually. There are no project teams using this method. This also means that external sponsorship of the project was not recommended. In fact, it is suggested that the projects be kept simple for the purposes of the class. With most projects having fewer than 30 components and no required interaction between team members or customers, most failures in this class can be directly attributed to students simply procrastinating during the course of the semester. It is easy to underestimate the amount of work that goes into a project, even one that would be considered simple.

III. Project selection and planning

All students are required to select their own project. Project selection usually ranges from building simple devices such as logic probes to more complex circuits such as power supplies and communication circuits. The only requirements levied by the instructor are:

1. There must be at least two integrated circuit packages on the finished project.
2. There must be at least ten discrete components on the printed circuit board.
3. The printed circuit board size shall not exceed 6” x 6”.
4. The circuit board can be either single sided or double sided.
5. The project must be feasible in terms of time allowed and cost.

The selection process requires each student to prepare a proposal providing the instructor with the following information:

1. Detailed description of the project including theory of operation.
2. Why the project is important to the student.
3. The requirements for the project and how the requirements will be met.
4. Preliminary schematics/block diagrams as available.
5. Preliminary bill of materials.
6. Schedule with associated critical path method analysis (see figures 1 and 2).

Each proposal is examined by the instructor to verify compliance with class requirements. In some cases, students, who can be too optimistic, select projects that are too complex for the time frame. If the projects are deemed too complex, it is recommended but not required that the student select a simpler project.

Figure 1: Example Critical Path Analysis

Figure 2: Example Project Schedule
Once the project proposal is approved, students are officially authorized to start purchasing parts for their project. Students are responsible for finding sources and purchasing the parts for their project. Project costs have ranged from as low as $25 in parts to as high as $1200. No price limits are set for the projects.

IV. Project Simulation

One aspect of the class is to teach students how we can employ computer simulations in the design process. Electronics Workbench (EWB)™ from Interactive Image Technologies², is used in this class because it is very simple to learn and it uses the industry standard SPICE models. Students are given several assignments using EWB in preparation for the project simulation. Students are introduced to the standard simulation techniques of DC, AC, Transient and Fourier analysis.

Based on each approved proposal, the instructor assigns each student with a circuit simulation task for his or her project. The simulation the student is required to perform depends upon the complexity of their project. It is up to the instructor to weigh the balance of fairness at this point. It would be much simpler for a student to simulate a logic probe than it would be to simulate a transmitter/receiver circuit. In such cases, the student building the logic probe may be required to simulate the complete project, while the student with the transmitter/receiver project may only be required to simulate the receiver. Again, the goal in this phase of the course is to show that circuit simulation can provide useful information as to the operation of the circuit without ever using real components.

Another major goal of this portion of the course is to show that circuit simulations are only as good as the models that describe the circuit. There are also many instances that the simulation package cannot converge to a solution. Verification of accurate device operation can be very tricky using computer simulations. This leads us to the next phase of the project design process of prototyping.

V. Project Prototype

Obviously, the next best thing to a finished product is the prototype. Prototyping techniques are discussed during the course of the semester. Use of proto-boards, cut-slash-and hook (CSH) and wire wrapping techniques are discussed in detail. Each student is required to build and demonstrate a working prototype of his or her project prior to circuit board fabrication. For their projects, the prototyping technique used is left up to the student. Most students opt to use proto-boards. Partial functionality is acceptable in some cases such as those that use microprocessors where all software coding may not be complete, but hardware functionality can be demonstrated.

VI. Circuit Board Creation

Once students have completed circuit simulation and prototype construction, they are tasked with the layout and fabrication of a printed circuit board. The software currently used is the
design suite of PowerLogic and PowerPCB by PADS Software Incorporated\textsuperscript{3}. Students create the project schematic and export the design files into the PCB layout software package. Although EWB also has a PCB layout package, it was felt that the students need exposure to other computer based design environments.

The printed circuit boards for the class are produced using a milling machine from T-Tech Incorporated\textsuperscript{4}. The milling process does influence the circuit board design due to the fact that only small areas around the traces and pads are milled away leaving large areas of copper on the pcb (see figure 3). This hinders the hand soldering process more than in an etched PCB because of the ease to which solder bridges can be created. Because of this problem, component placement is recommended to be as dispersed as possible. Students are given the option of creating a single sided or double-sided PCB.

![Figure 3: Milled PWB](image)

VII. Product Packaging

The aspect that most students overlook in electronic device design is the proper selection of a package for the project. Students are graded on labeling, ergonomics and appearance of their final project design. An example of a typical project is shown in figure 4.

![Figure 4: Typical Project Packaging](image)
VIII. Project Demonstration and Report

At the end of the semester, students are required to demonstrate to the class their functional project. Peer reviews of the presentation are performed. Their classmates evaluate students on their speaking abilities, preparation and ability to explain the subject matter. The peer reviews are completed anonymously with the instructor compiling the results into an overview of results for each student. One of the most surprising results is how often a fully functional project gets low marks for functionality by fellow classmates. This shows that the presenter did not convince the class that his/her project meets the design criteria.

IX. Conclusions

Students are taken through the basic steps used in the design and fabrication of an electronics project. The processes used are:

   A. Requirements analysis
   B. Preliminary planning and project scheduling
   C. Computer simulations
   D. Prototyping techniques
   E. Circuit board design
   F. Product packaging
   G. Project demonstration

With the students following the processes as defined, the class has continuously had success rates of over 95%, where success is rated as having a functional, packaged product at the end of the semester. Student feedback for this course is always high, with many students indicating that this course is the most beneficial ever taken and having a high degree of satisfaction with the completion of a project.

Bibliography
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Biography
Scott Baldwin (baldwis@okstate.edu) received his B.S. in Electrical Engineering Technology and his M.S. in Electrical Engineering from Oklahoma State University in 1988 and 1998 respectively. He worked as a Project Engineer for Frontier Electronic Systems Corporation and Raytheon Systems Corporation before coming to Oklahoma State University where he has taught in Electrical Engineering Technology since 1999. His primary teaching emphasis is in the area of electronic project design.