Session 2548

Sophomore Project/Capstone Course

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abstract:
This paper describes a new project course in ECET at Purdue University. It is a course taken by students in their 4th semester of the 2+2 ECET program, and may be considered a capstone course for the AS degree. In it the students must work with a time plan, and must follow a design guide that has them combine both analog and digital course concepts resulting in a finished project. They must use the principles of design for manufacturability (DFM) and design for testability (DFT), and must include the use of both active and passive surface mount technology (SMT) components. In addition to the circuit design, they must also use electronic computer aided design (ECAD) to design and lay out a printed circuit board (PCB), have the PCB made by a commercial PCB fabricator, test it, then populate the PCB and test the resulting printed circuit assembly (PCA). The design also includes a test port, which allows the instructor to add problems to the circuit, which the students must then troubleshoot and identify. The course culminates in both a written report and an oral report.

body
As part of a curriculum redesign in the late 1990's, the Purdue Electrical and Computer Engineering Technology department incorporated into the curriculum four required project courses:

- ECET 196, a 2 credit hour first semester freshman course that required students to build an already-designed 3-output power supply, and use basic time plan techniques to maintain control of the project work.
- ECET 296, a 2 credit hour sophomore course that required the students to design and construct an audio power amplifier while closely following both performance and hardware/circuit specifications.
- ECET 396, a 4 credit hour junior course that required teams of 3-4 students to design and build a project based primarily on performance specifications, using time management and creating both oral and written reports.
- ECET 496 &497, a 2-semester senior design sequence that requires the students to propose a project of their choosing, define the specifications, then design, construct, and test it. Final presentation of the project is to a group of faculty.

For a number of years, the Purdue EET/ECET program has also included a required sophomore course a 2-credit hour course in electronic troubleshooting, EET276. In recent years, the curriculum team responsible for the project courses, after discussions with both the faculty and the ECET Industrial Advisory Board (IAB), came to the conclusion that the 2 credit hour project course and the 2 credit hour troubleshooting course were not robust enough to properly serve their purposes in the curriculum. Additionally, it was felt necessary to add into the project courses the concepts of design for manufacturability (DFM), design for testability (DFT) and design including surface mount technology (SMT).

With these thoughts in mind, the projects team proposed, and the curriculum committee and faculty agreed, that the two 2 credit hour sophomore courses, ECET 276 and ECET 296, be combined into one 4 credit hour course, ECET 297, Electronic Prototype Development. The ABET outline for that course is at the end of this paper. Students who take this class meet prerequisites of 3 analog circuits courses, 2 digital circuits courses, the freshman project course, and a computer graphics technology course that includes AutoCad.

From the topics in the ABET outline, the syllabus developed for the course included these learning objectives:

- Completely understand the circuits in the project.
- Learn a concurrent engineering approach to PCB design
- Apply basic principles of design for manufacturability (DFM) to a project.
- Apply basic principles of design for testability (DFT) to a project.
- Successfully use ECAD software for circuit design and circuit board layout to meet the performance goals of the project.
- Successfully design, assemble, and test an SMT-based printed circuit assembly.
- Be able to demonstrate hand soldering techniques with surface mount devices (SMD's)
- Successfully use basic failure analysis techniques to analyze the circuit and predict voltages that would be present in both a properly operating circuit and a non-operating circuit.
- Be able to test both an operating and a non-operating circuit based on your analysis, and determine any circuit failures to the component level.

As can be seen from both the ABET outline and the learning objectives, the new course combines design and troubleshooting topics from each of the two prior courses. The ABET outline has several lecture/lab course patterns, primarily to allow flexibility in teaching the course at both the main West Lafayette campus and at Purdue's 2-year statewide sites.

The initial project for the course was a low-power digital DC voltmeter with three input ranges, using standard CMOS ICs. The Intersil 7106/7136 ICs were used, along with their secondary sources from Maxim and Microchip. These ICs incorporate input signal controls, dual-slope A/D conversion, and direct LCD drive. In the development of the project the students complete these tasks throughout the semester in the order listed:

- Receive the performance specifications for the project
- Receive the hardware specifications for the project
- Design the circuits for the project based on the hardware specifications, using both through hole technology (THT) and SMT parts
- Design into the project the required test port, allowing the lab instructor to add "troubles" to the circuit, which the student must then find and define.
- Layout the printed circuit board (PCB) following accepted practice
- Create the industry-standard Gerber files for PCB fabrication by a commercial PCB vendor, and have their boards fabricated

- Acquire all parts and specialty tools necessary for the project
- Perform standard bare-board tests and parts tests
- Assemble the project using appropriate soldering techniques
- Perform in-circuit tests prior to applying power to the project
- Apply power to the project and perform functional tests
- Determine all signals and voltages present in a properly operating circuit
- Determine signals that would be present when certain failures were present in the circuit
- Identify problems added to the circuit by the lab instructor

The lecture material supports the project topics noted above as necessary. The lecture also covers topics that relate to the successful completion of larger projects that the students may be involved with in industry. Central to the support of the project is a discussion of both the basic circuitry used in the project , the internal functions of the IC used, and the additional circuits used in a particular semester. The basic circuit is shown in Intersil application note AN023:

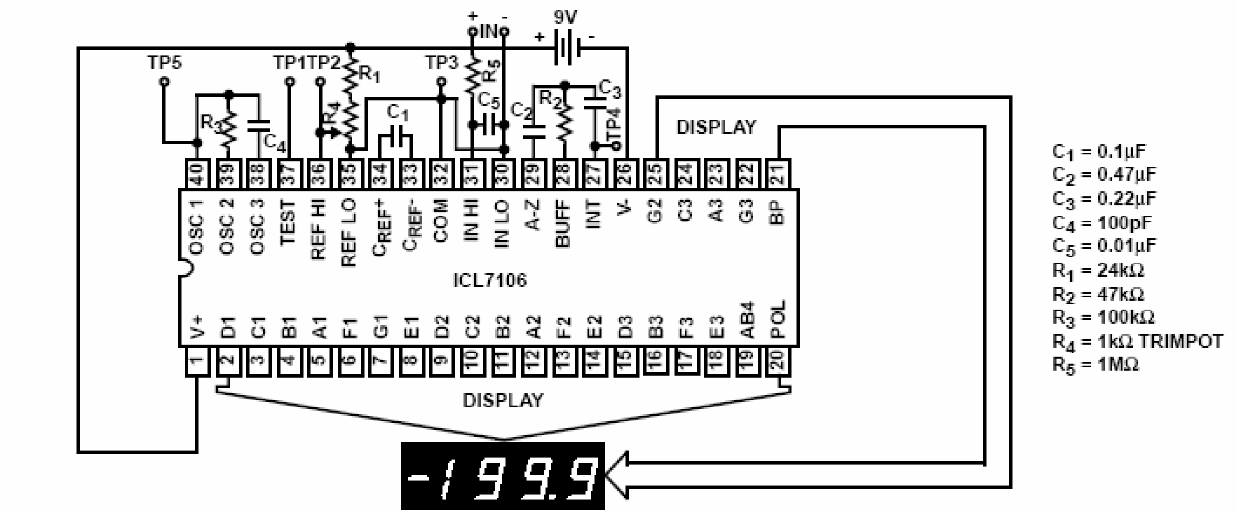

Figure 1. LCD Digital Panel Meter Using ICL7106 [1]

Circuitry that can be added to the above basic circuit includes:
- Multiple DC voltage ranges
- AC voltage ranges
- Autoranging
- Current ranges

An example of the finished project will be displayed at the ASEE conference presentation. Test results will also be presented. As a result of the first semester student efforts, it was determined that no significant changes need be made in scope of the project. The nature of the project and the 7106 are such that the project can be changed each semester by changing the supporting circuit without redesigning the 7106 section. As can be seen in Figure 2, the 7106 IC itself is fairly complex, and the course requires that the students understand its operation, rather than just use it. As is typical of any device incorporating an A/D converter, there are separate analog and digital grounds, and correct use of them is required during the troubleshooting labs in the course.

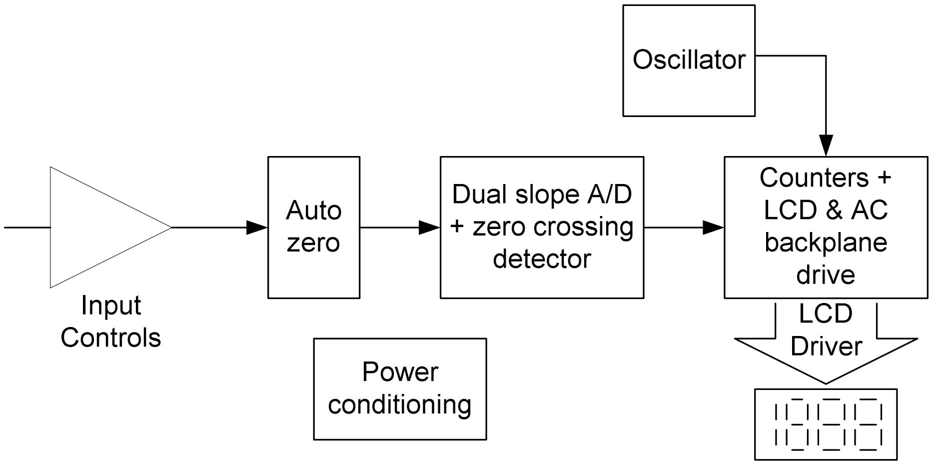

Figure 2. Basic block diagram of the 7106 IC.

The new course was first taught in the fall semester of 2003 with 14 students and the author as lecture and laboratory instructor, to work out the bugs that always exist in a new course. Of the 14 students, 10 had a successfully working project at the end of the semester, 3 had significant PCB design errors that were corrected and resulted in a semi-functioning project, and 1 student had several major PCB design flaws that prevented his project from functioning. The author considered this a successful first run, and many of the issues that occurred in the first run allowed corrections to be made to course materials. In the spring semester of 2004, 65 students will take the course, and the ASEE presentation in June will report on the results of their efforts.

Unlike many ECET courses, the lecture and lab were not tightly coupled. While the lab concerned itself with the topics directly related to the project, the lecture covered both lab-specific topics and more generally topics that the faculty and the ECET Industrial Advisory Board (IAB) felt would be of value to graduates in industry. For example, the DFT discussion included topics necessary to allow proper design and use of 10 test points in the ECET 297 project, as well as industry-oriented topics such as:

- DFT topics that would be used in much larger projects in industry
- Automated testing techniques used in industry
- failure analysis techniques used in industry

Other industry-oriented topics include:

- The formal prototype development process such as that used by a contract PCB design house
- SMT automated assembly and test issues
- Secondary source considerations for parts
- Timing of semiconductor manufacturing
- Professional ethics
- International nature of industry

While this course results from the faculty's desire to improve the ECET curriculum at Purdue's main campus, the author feels it would serve equally well as a capstone course for an AS program. The Purdue School of Technology has a number of 2-year AS ECET program sites across the state of Indiana, and the course will be implemented in those programs starting in the spring or fall semesters (depending on the site location) of 2004. Those sites will treat the course as a capstone course and will hopefully find it serves well for that function.

The results of the course and the responses from the first group of students as a result of the initial course offering are such that the author feels the change has been positive for the students, the program, and in the future for companies that will be hiring the students upon their graduation.

references

1. ------; "Low cost digital panel meter designs". Application note AN023, Intersil Corp, Milpitas, CA, 1999.

ABET Outline for ECET297

Catalog Data: **Electronic Prototype Development** **Class 3, Lab. 3, Cr. 4, or Class 2, Lab. 4, Cr. 4.**
Prerequisites: ECET 159, 196, 207, CGT 120

This course introduces basic concepts in the development of an electronic product prototype. The student develops an electronic device by utilization of: electronic design automation (EDA), design for testing (DFT), surface mount technology (SMT), design for manufacturability (DFM), component characteristic selection techniques, and basic failure predictions. New construction and testing techniques are introduced. The final prototype is presented in a written and/or oral report.

Required Text: Electronic Prototype Development, Blackwell, Learning Systems, 2003.

Lab Textbook: (same as required text)

Coordinator: Glenn Blackwell, Associate Professor of ECET

Course Objectives:
After completing this course, the student should be able to:
1. Plan and complete a prototype by the application of EDA techniques
2. Perform appropriate component selection based on the functional definition of the prototype
3. Respond appropriately to design criteria that emphasize DFM and DFT
4. Apply problem-solving techniques to predict PCB and component failures
5. Isolate and identify faults that will be applied to the completed prototype
6. Document and present the final prototype

Prerequisites by Topic:
1. Sketching of electronic circuits
2. ECAD schematic capture and simulation principles
3. Analog circuit analysis and design principles
4. Digital circuit analysis and design principles
5. Component layout and dimensioning of drawings

Topics Covered (3 lectures, 50 min. each week for 15 weeks):
Electronic design automation (4 hrs)
Project planning (3 hrs)
System analysis and design (3 hrs)
Component characteristics and predicted failure rates/modes (5 hrs)
Design of circuits (4 hrs)

Design for testability (DFT) (2 hrs)
Design for repair-ability (1 hrs)
Design for manufacturability (DFM) (1 hrs)
Fault prediction analysis (2 hrs)
Surface mount technology (SMT) fabrication techniques (4 hrs)
PC fabrication and commercial PCB standards (3 hrs)
Prototyping/construction/fabrication (3 hrs)
Circuit testing and documentation (4 hrs)
Fault isolation/testing (2 hrs)
Written/oral presentations and Examinations/Quizzes (4 hrs)

Relationship of course to program objectives: This course is required in the Associate program and contributes to Associate Program Educational Objectives 1, 2 and 3.

1. **Technical and Professional Skills.** Students are required to develop prototype electronic devices using guided-development principles. They use an industry-accepted ECAD program for this development, and must perform component selections to complete the design.
2. **Application of software simulation.** Simulation of the circuits in the design is performed using the ECAD software program.
3. **Communications.** The students must prepare and give a formal oral report on the nature of the project and their success in meeting the goals initially defined.

Laboratory Experiments and Related Activities (including major items of equipment): Lab meets once a week for three hours.

1. Project scheduling and reporting
2. EDA software and commercial standards
3. Schematic capture of the project circuits (2 weeks)
4. Printed Circuit Board (PCB) layout techniques (3 weeks)
5. PCB layout methodologies for manufacturability, testability and repair-ability (2 weeks)
6. Prototyping techniques, including PCB layout development and PCB fabrication
7. Testing and documentation (2 weeks)
8. Fault analysis and troubleshooting (3 weeks)
9. Project demonstration

Use and operation of analytic and measurement equipment:

Students use test equipment such as DMMs, signal generators and oscilloscopes to verify operation of their design, and to determine voltages and signals present during proper operation. They use the test equipment to find faults that are placed in the circuit by the instructor.

Student competence with design practices, tools, and techniques:

This course directly involves the student in a guided design project that requires them to design circuitry using an industry standard ECAD program for both circuit design and printed circuit board (PCB) layout. They must complete their PCB design in industry standard format so that it can be fabricated by a commercial circuit board manufacturer.

Capstone or integrating experiences

The students integrate their knowledge from previous analog and digital courses, with new knowledge in the areas of digital displays, printed circuit board layout and fabrication, component failure probabilities, design for testability, and troubleshooting. After completion of their project, and fault analysis and troubleshooting of problems, they present an oral report describing the results of their semester-long prototype project.

biographical information

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Glenn Blackwell currently is teaching in the areas of project courses, surface mount technology (SMT), and electronic manufacturing. To increase his knowledge in the areas of Surface Mount Technology (SMT) and electronics manufacturing , he spent the 92-93 school year on sabbatical leave at Delco Electronics, Kokomo, IN, as a Senior Project Engineer in their Powertrain Electronics Manufacturing Development Group. To increase his knowledge in controls techniques and automation software, he spent the calendar year 2000 on sabbatical leave to work with several contractors in the automation field. He supervises EET design projects in the sophomore year and previously has done so for project courses in the freshman, junior, and senior years. He is a registered Professional Engineer in Ohio and Indiana, and consults in the areas of SMT and UL compliance.