AC 2010-119: CAPSTONE COURSE SEQUENCE FOR ENGINEERING TECHNOLOGY STUDENTS

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Capstone Course Sequence for Engineering Technology Students

Abstract

This paper discusses the capstone experience for the students of the Applied Engineering Technology (AET) program at Drexel University. AET was introduced at Drexel University in 2002 as a five-year co-op-based program with a mission to "provide contemporary students with an academic foundation and practical education in engineering technology through an outstanding curriculum and applied research program, and the participation of our students in one of the nation's most successful cooperative educational programs." The Senior Design Project provides major evidence in demonstrating how well the program meets its mission. Program Educational Objectives (PEO) are consistent with the AET mission and the general ABET outcomes.[1] The three-term nine-credit course sequence of the senior design project during the senior year is discussed term-by-term in detail. Groups of three or four students pick the topics of the project recommended by the faculty, industry representatives, or chosen by the students based on their experience during co-op cycles. This capstone experience allows students to demonstrate their knowledge and skills at a professional level. The course sequence is finalized by the completion of a working prototype and a presentation of the project to the Senior Design Project Committee, AET students and faculty, and general audience during the third week of May.

Introduction

> *The* <u>*mission*</u> *of the Applied Engineering Technology program is to provide contemporary students with an academic foundation and practical education in engineering technology through an outstanding curriculum and applied research program, and the participation of our students in one of the nation's most successful cooperative educational programs.*

The structure of the paper consists of the description and analysis of each of the three courses in the capstone sequence.[2] General discussions and conclusions are presented with suggestions for further development and improvement of this sequence. Special attention is focused on how each element of the capstone sequence contributes to accomplishing the mission of the AET program. The project emphasizes the team approach to solving multidisciplinary problems in real-world industrial environment.[3] Each team is assigned a faculty advisor based on the topic of the project and mutual interests of the students and faculty.[4] State-of-the-art laboratories of the AET program are utilized by the students for prototype development, design, and evaluation. Students apply their previous knowledge and experience gained during the laboratory-based courses and co-op cycles. In addition, during the three-term capstone experience students develop skills in making professional presentations and writing technical reports.[5] Specifically, the capstone sequence for AET students during the 2008-2009 academic year is described in detail.

Senior Design Project I

Senior Design Project I (MET 421) starts in the fall term of the senior year. At the end of the course, a written proposal and an oral presentation of the proposal are completed. To achieve this goal in ten weeks, the following schedule is executed (Table 1). Each week, the students meet with the faculty advisor and present the progress of the project.

Week 1

During the first week the students are introduced to the idea of the project (definition: To form in the mind, contrive) and specific features of the products to be developed. In addition, the students are introduced to the rules and regulations required for utilizing AET laboratories, including safety requirements. Students discuss their interests based on their experience, skills, and concentrations and present their proposals for forming teams. The students must realize at the beginning of the project that the project design results in reports, numerical analyses, prototypes, and /or drawings that describe the implementation of the design.

Table 1. MET 421 Senior Design Project I Schedule

Week 1:	Introduction
Week 2-3:	Brainstorming candidate proposal topics, resources, funding
Week 4:	First draft of written pre-proposal, request/select faculty advisor
Week 5:	Written pre-proposal (advisor assigned)
Week 6-7:	Proposal development
Week 8:	Hard copy – rough draft
Week 9:	Practice presentation and final written proposal (6 hard copies and 1 electronic CD or DVD preferred)
Week 10:	Full proposal presentation at Main Campus

Weeks 2 and 3

The main effort during this period is the development and selection of project ideas with the ultimate goal of forming teams to tackle the selected topic. Theses ideas are generated by the process of brainstorming; exploring ideas suggested by the industrial collaborators and AET faculty and students. During the brainstorming process, all suggested topics or ideas are listed along with the name of the person or organization who suggested the proposed topic or idea. In other words, the object is to demonstrate different suggested topics without criticizing on neglecting any of them. Examples of proposed topics including the proposers' names are presented in Table 2.

Table 2. Typical Listing of Senior Design Project Ideas

Name	Idea Description
Student 1	Solar Preheater
Student 2	Magnetic grappler for police
Student 3	Solar recharging panel in a hat
Student 4	Backpack solar charger
Student 5	Hydro Activated Survival Locator
Student 6	Race engine improvements - various
Student 7	Regenerative braking hydraulic system - bicycle
Student 8	Car baby seat monitor

After approving the list of all project topics (ideas), the students develop a set of criteria presented in Table 3 to be used for testing if the idea has a high probability of resulting in a successful senior design. For example, during the 2008-2009 academic year, 56 topics were presented and discussed.

Table 3. Criteria for Selecting Suitable Idea for a Senior Design Project

1. Project must be appropriate for team member's concentration and skill set.
2. Project should be financially viable.
3. Project should be senior level.
4. Project should fit scheduled time frame.
5. Project should be useful.
6. Project should be original and creative.

When the criteria were applied to the proposed topic/idea list, several topics were immediately rejected. Next, the students expressed their willingness to participate in particular surviving projects. Teams of three or four students were formed and possible required funds were discussed. This process resulted in the formation of eleven teams, including eight at the Drexel University (DU) main campus and three at the Burlington County College (BCC) campus. It is worth mentioning that BCC has a 2 + 2 articulation agreement with DU. Each team needed to discuss the project with the AET faculty who was willing to serve as an advisor for the particular project.

In addition to selecting projects and forming teams, three other areas important to ABET outcomes were promoted:

- Ethics in engineering was discussed and students were provided with the NSPE (National Society of Professional Engineers) Code of Ethics for Engineers. They were tested on the NSPE Ethics Quiz and were graded to the scale provided. The quizzes were scored and contributed to the grade each student earned at the end of the course.
- All students had to write a brief essay in which they would relate a diversity problem that they confronted during their experiences at Drexel or during their cooperative education experience. This essay contributed to the grade each student earned at the end of the course.
- Each student was surveyed to learn what professional organizations he or she joined that related to their area of technology. Special value was given to students who demonstrated leadership. This information was scored and contributed to the grade each student earned at the end of the course.

Week 4

At this stage, the students were introduced to the **Report and Grading** document, a 60-page document that explained the details of the course sequence, including the formats for each of the three reports, the grading scheme, scoring rubrics for each course, and the pre-proposal requirements. The following questions had to be addressed and comprehensively answered in each pre-proposal:

1. What are the objectives of the project?
2. What are the elements of engineering design involved?
3. What are the specific deliverables you will produce?
4. What are the resources, funding or external support for the project?

Week 5

After completion of the pre-proposal, each team member signs and dates the document. The group advisor and co-advisor, if assigned, also sign and date the pre-proposal. The co-advisor is included if the team works on a project that is sponsored either by a company or a student organization. This event signals that the teams are ready to start working on a written proposal and an oral presentation. The advisor helps the teams clarify the ideas of the design and possible solutions of the proposed project. At this stage, the Report and Grading documents are reviewed. The general outline for the proposal with formatting instructions is presented below:

Components of a Written Project Proposal

Title Page
Abstract
Table of Contents
List of Figures
List of Tables
Body of the Proposal
Reference
*Appendices

*****Optional component

The students should follow the following structure of the report:

Page Format:
Line Spacing: single to 1 1/2 spacing
Font Size: 12 point for the body text, maximum of 14 point for section headings
Left/Right Margins: 1.0 inches
Top/Bottom Margins: 1.0 inches

Descriptions of each of the components of the written proposal are detailed in the Report and Grading document. The grading for the course consists of three main elements, consisting of the written report, the oral presentation, and the student contribution. Each element has assessment sheets that are used to assess to the performance criteria that are related to the appropriate ABET Outcomes.[1] For example, performance criterion 3 of outcome a (a. 3.) is assessed.[6,7,8] The performance is scored using clearly defined rubrics and the assessment sheets are shown to the students in the Report and Grading document.[9] Each performance criterion is weighted with either a 2 for high importance or 1 for moderate importance. A performance criterion may be assessed in both the written and oral assessment sheets. The students understand what is expected from their teams and from their individual contributions.

Weeks 6 - 9

The drafts of the final reports are written and practice oral presentations are conducted. The advisor provides the students with guidance and opinion but the responsibility entirely rests with the students and the team. During this stage, the advisor will provide help and advice in any reasonable way. Nevertheless, the final decision of design is made by the students. The written report must be completed by the week 9 deadline so that the report can be distributed to the faculty and outside assessors. Outside assessors are co-advisors or other qualified professionals who are assigned to assess team performance.

Week 10

The final oral proposal is presented. Assessment sheets with scoring are assembled by the course advisor and grades are determined. The grading scheme is described in the Report and Grading document and is shown in the box below.

The senior design project is a capstone course sequence. The content and structure of the sequence are designed to establish that the Applied Engineering Technology Program is meeting its Program Educational Objectives and Program Outcomes. The AET students are expected to know learning outcomes and apply this knowledge during their undergraduate education. To demonstrate that these outcome expectations are achieved, team reports and oral presentations are measured based on teams meeting specific performance criteria. In addition, individual students are evaluated based on their meeting specific performance criteria. Each performance criterion is scored and grades are reported. For each course, team and individual scores are added together to obtain the total score.

Determining the grade is explained in both the Report and Grading document. An example of MET 421 (Senior Design Project I) course grading is presented below in the box.

Grading for MET 421: Each assessor scores either the team (written report and oral presentation) or the student (average of the advisor and co-advisor scores). All assessors' scores are averaged for a final score for the particular Criterion. For each Criterion of an Outcome that is assessed, the Value number times the Score number is listed in the Points column in the table that follows. The Points column is totaled and the grade is determined from the Grading Table for MET 421.[6,7,8]

The following two tables are used to tally the scores into a Total Point Score (Table 4). The Total Point Score directly translates into a grade for each student (Table 5). Table 4 shows the performance criterion as referenced to the ABET outcome and the assigned value to that performance criterion.[1] The product of the value and score results in a point value.

Table 4. Score Tally Sheet

Outcome	Criterion	Value	Score	Points
a	3	3		
b	1	4		
b	3	2		
d	1	3		
d	3	3		
e	1	2		
e	2	4		
e	3	2		
f	1	4		
f	2	4		
g	1	4		
g	2	2		
g	3	1		
g	4	3		
h	1	2		
h	2	1		
i	1	2		
i	2	1		
i	3	2		
j	2	1		
j	3	1		
k	1	2		
k	2	1		
			Total =	

Table 5. Translation to Grade

Point Total at or above	Grade
213	A
196	A-
179	B+
162	B
145	B-
128	C+
94	C
77	C-
61	D+
54	D
Below 54	F

Senior Design Project II

Senior Design Project II (MET 422) starts in the winter term of the senior year. At the end of the course a written progress report is completed. Much of the development and design work of the working prototype is carried out during this course. Weekly meetings with the advisor are used to generate “to do” lists and other tracking mechanisms. Typically, during the beginning of the term planning starts with conceptual drawings or statements. Material and parts availability; and potential costs are explored. Lead times are determined. Orders for parts, components, and necessary software are placed. Upon receiving the ordered material, the construction and assembly of the prototype starts. Revisions to the design may be required. When assembly is completed, testing and validation of the design commences. The prototype design and development are considered to be completed when the test results correspond to suggested functionality and performance of the prototype. These events can extend into the next course (MET 423) of the sequence. Nevertheless, the progress report must be submitted to the advisor at the end of the ten-week period of the winter term. The following Components of a Progress Report, presented in the box below, must be included in the report. Details of each of these components are discussed in the Report and Grading document.

Components of a Progress Report:

Title Page
Abstract
Table of Contents
List of Figures*
List of Tables*
Body of the Progress Report
Reference
Appendices*

* Optional component

The progress report is scored by the advisor, the co-advisor, and one additional AET faculty member. Only the advisor and the co-advisor score the student performance. The scores are tallied in the same manner as in Senior Design Project I. Results are translated into grade similarly to MET 421 course for each student and presented in the table as the Total Point score.[6,7,8]

Senior Design Project III

Senior Design Project III (MET 423) starts in the spring term of the senior year. At the end of the course, a written final report and a final oral presentation are completed. Weekly meetings with the advisor continue and necessary modifications and debugging of the prototype are completed by week 5 of the term. A preliminary draft of the final report is due during week 6. The final report deadline is week 7. The Components of a Written Final Report are presented in the box below. Details of each of these components are discussed in the Report and Grading document.

Components of a Written Final Report:

Title Page
Abstract
Table of Contents
List of Figures*
List of Tables*
Body of Report
Appendices*

* Optional component

The final report is submitted to the advisor and other assessors and faculty who are assigned to assess the written report. The example of the portion of assessment of the written report is presented in Table 6. The assessment forms were developed based on ABET Outcomes and Performance Criteria.[1] Table 6, presented below, describes a portion of the assessment form of the written report that maps Outcome a and Performance Criteria 1 and 2.

Table 6. Assessment form of the written report

MET 423 Senior Design Project III – Goodwin College - Drexel University
Performance Evaluation Sheet –
Spring Term

Project Title: ____

Team Number: ______________________

Advisor: ___________________________ **Evaluator:** ____________________

Instructions: Circle one description that best represents your evaluation of each Outcome/Performance Criterion. Descriptions are found in either the **Exceeds, Meets, Minimally Meets, or Fails to Meet** columns.

Outcome/Performance Criteria	Exceeds (5)	Meets (3)	Minimally Meets (1)	Fails to Meet (0)	Score
Outcome a./Performance Criterion 1 – Team demonstrates mastery of the skills of their discipline.	Can demonstrate exceptional mastery of all skills of their discipline.	Can demonstrate mastery of nearly all skills of their discipline.	Can demonstrate mastery of some skills of their discipline.	Unable to demonstrate mastery of most skills of their discipline.	
Outcome a./Performance Criterion 2 – Team applies techniques used in their discipline.	Applies and explores new techniques used in their discipline.	Applies techniques used in their discipline.	Sometimes needs help when applying techniques used in their discipline.	Often needs help when applying techniques used in their discipline.	

The final presentation occurs during week 8 of the spring term. The Final Oral Presentation completes the student participation in the capstone course sequence. The assessment sheet scores are tallied in the same manner as for MET 421 and MET 422 courses and the Total Point score is translated into a course grade for each student.[6,7, 8]

To demonstrate that our program is achieving its mission and program outcomes based on ABET requirements, we have established that an average score of 3.00 be attained. The assessment material for this course series was examined for the academic year 08-09. The overall assessment score for the series was 3.94 and was above the established threshold of 3.00. Specifically, the assessment score for each course was achieved as follows: MET 421 = 3.83, MET 422 = 4.04, and MET 423 = 3.94. Since our assessment data met our goals, teaching and learning was effectively achieved.

Example Projects

To illustrate the kinds of projects developed by the students, two projects from the previous year are described. The first is the Hydro Activated Survival Locator (HANSL), which was listed in Table 2 (Student 5). This project was aimed at the problem of locating a person who has fallen overboard from a boat or a pilot in the water. This person could be incapacitated and unable to deploy standard visual distress systems (VDSs), such as dispersive dyes. The project was conceived by one of the four students on the team, who was a member of Drexel's Sailing Club.

The situation of a person-in-water (PIW) is an extremely dangerous one because it is easy to quickly lose sight of the person due to the continued motion of the vessel, particularly in choppy or foamy seas. Once visual contact is lost, a successful recovery is difficult. Dye markers are an excellent aid to maintaining or reacquiring visual contact. Presently, no systems are available that automatically deploy dye. The problem is further complicated by the fact that the dye material disperses rapidly, requiring frequent redeployment.

Two technical issues were addressed in the early stages of the project. First, the amount and frequency of deployment of the dye had to be determined. Second, a reliable deployment mechanism had to be developed. To determine the frequency and amount of dye to be deployed, the students performed sea tests at both a nearby lake and a river. One of these tests is shown in Figure 1. From these measurements, it was determined that about 2 oz. of dye should be deployed every 30 minutes. The target coverage time was 3 hours, so six deployments would be required.

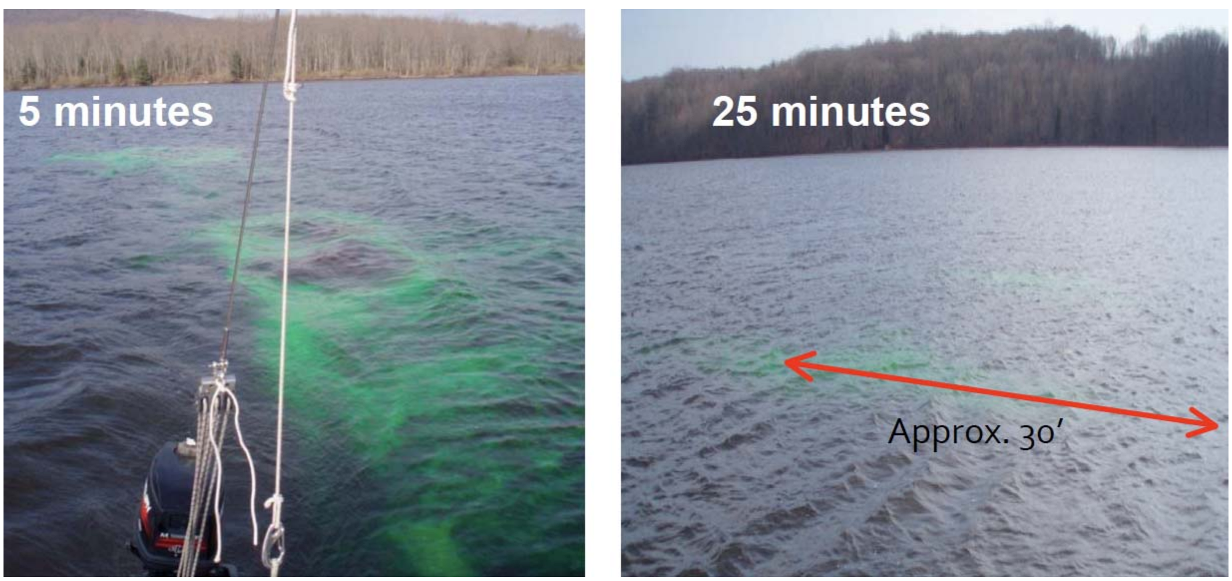

Figure 1. Dispersion of dye marker after 5 and 25 minutes.

The second technical issue was the deployment mechanism. This mechanism must be completely reliable with a shelf life of several years. An important consideration was electrical power drain because it impacts the size and cost of the battery pack.

The technical approach developed by the students is shown in Figure 2. The design employs a "stacked cartridge" configuration comprising six canisters of dye. The system uses two constant force springs as its main source of energy to deploy the cartridges. The spring force also maintains pressure on the cartridge lids, which are not otherwise attached. The cartridges are deployed by activating two solenoids that act as stops. This design effectively transfers most of the energy required for the dye ejection sequence from electrical energy to more reliable and longer shelf life mechanical potential energy. In this way, the batteries are used only to activate the solenoids, sensors, and microcontroller. These springs provide the necessary force to eject each cartridge from the muzzle of the bore tube. Once released each cartridge floats just at the water line releasing the dye. Fluorescein is used as the dye because it is highly visible and has no environmental impact. In fact it is used to dye the Chicago River green on St. Patrick's Day.

The electrical system was designed for low-cost low power operation. A PIC16F882 microcontroller was selected to control the system due to its low operating power and ultra-low-power sleep mode. Three ruggedized waterproof pushbuttons allow the user to manually deploy the dye and to pause or reset the deployment sequence. Commercially available water immersion sensors were found to be both expensive and power hungry, so a low-cost low power alternative was designed and fabricated using a simple two-electrode system connected between the battery and a digital input to the microcontroller. The sensor system was tested in water from a variety of sources including filtered, de-ionized water and found to work in all conditions. A piezoelectric buzzer was also included to provide an audible cue to the operator.

The prototype (Figure 2) was thoroughly tested including pressure testing to 68 ft of water.

An economic analysis performed by the students showed that the startup cost for mass-producing the HANSL would be about $120,000, primarily for producing injection-molding dies. The production cost per unit would then be about $50 in quantity of 100 and more. The target sale price can be chosen in the range of $300 - $350 (comparable to other marine safety devices), making the break-even point in the range of about 400 – 480 systems sold.

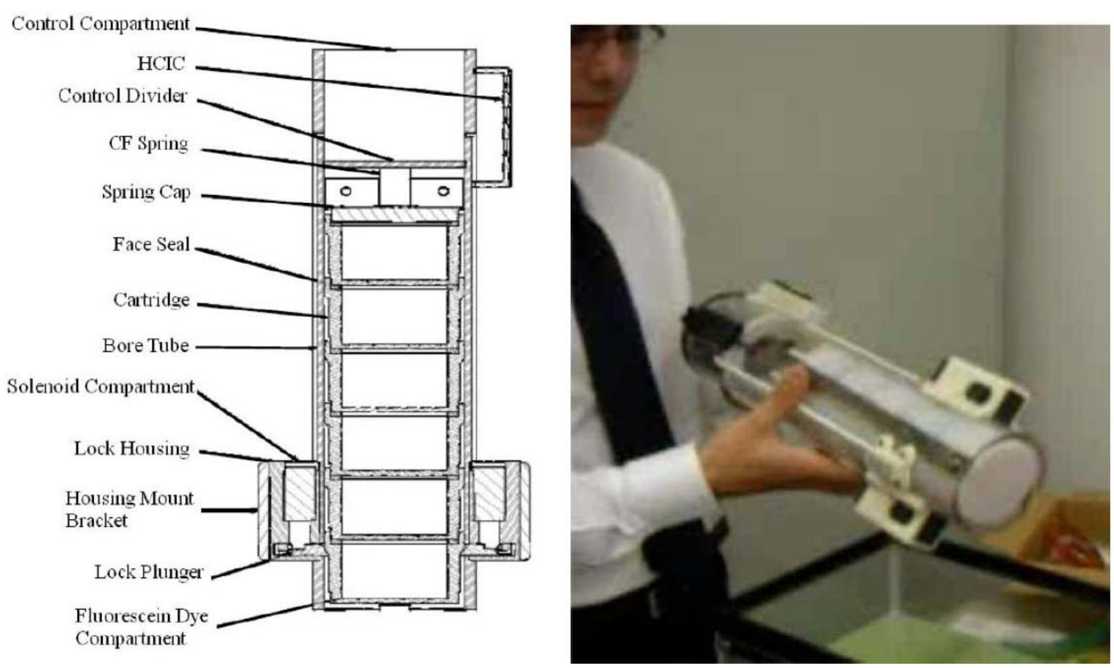

Figure 2. Diagram of the HANSL visual dye device (left) and testing of the prototype (right).

The second representative student project was aimed at the development of an active cooling system for the ExpressCard form factor. ExpressCard is the new laptop interface standard for peripheral devices that is replacing the older, slower PCMCIA (CardBus) interface. A major problem with ExpressCard is that power dissipation severely limits the types of peripheral devices it can support; the standard allows about 7 W of power to be supplied to the card through its connector power pins, but only specifies that the laptop case be capable of removing 1.3 W for the 34 mm version, and 2.1 W for the 54 mm version. This is a major problem if one wants to use high-powered devices, such as Field Programmable Gate Arrays or microprocessors. Passive external heat sinks were found to be only capable of dissipation an additional 2 W.

To address the need for greater power dissipation the students devised a novel active system. This system employs two micro fans to blow air into an enclosure containing the heat sink. The air then exits near the middle of the enclosure (Figure 3). These fans were originally developed for Palm Pilot applications and are available from Sunon, Inc.

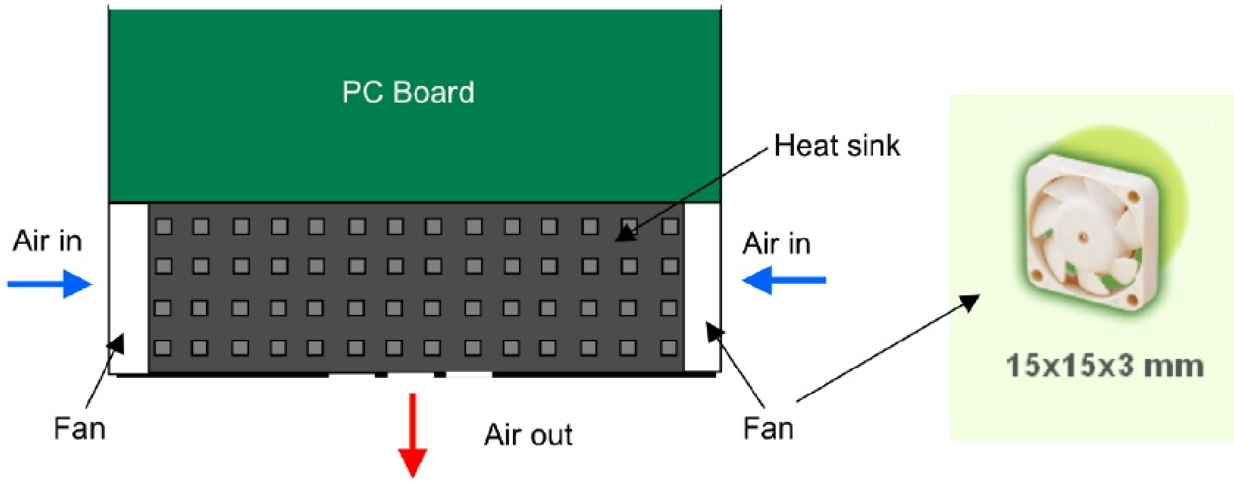

Figure 3. Functional diagram of the active cooling system and Sunon microfan.

Prior to fabrication the students simulated the airflow and temperature inside the module using the FloWorks computational fluid dynamics simulator from SolidWorks.[10] The results of the simulation are shown in Figure 3. The results show that the internal temperature does not exceed 82^{o}C, and the heat sink temperature was 44.9^{o}C. This is just below the standard heat sink temperature required for comfort and safety.

To test simulation predictions a test fixture, shown in Figure 5, was fabricated using a commercial ExpressCard case and power resistors to represent a high-power component such as an FPGA. Experimentally it was found that the active cooling system was capable of dissipating over 8 W.

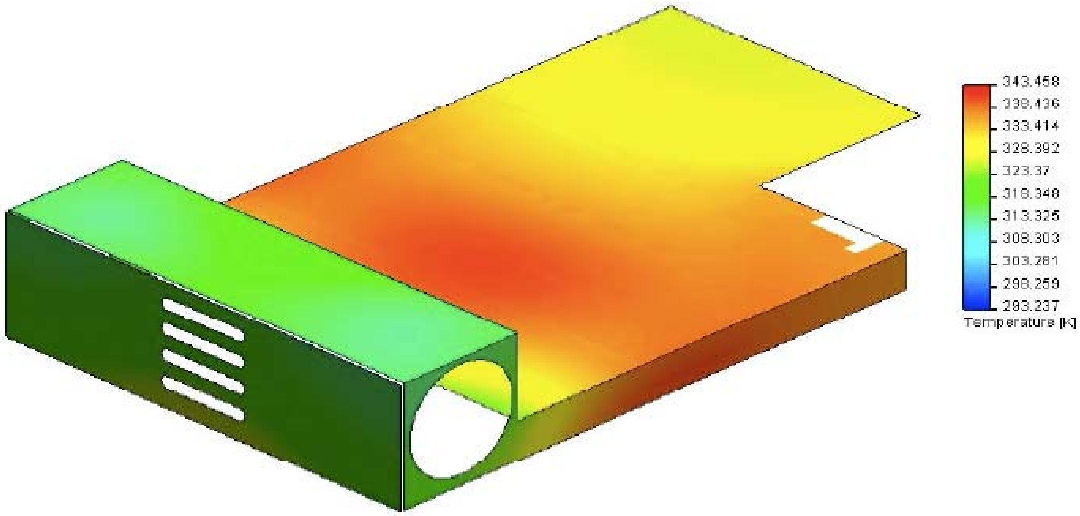

Figure 4. Predicted temperature profile for an ExpressCard/54 using active cooling (K).

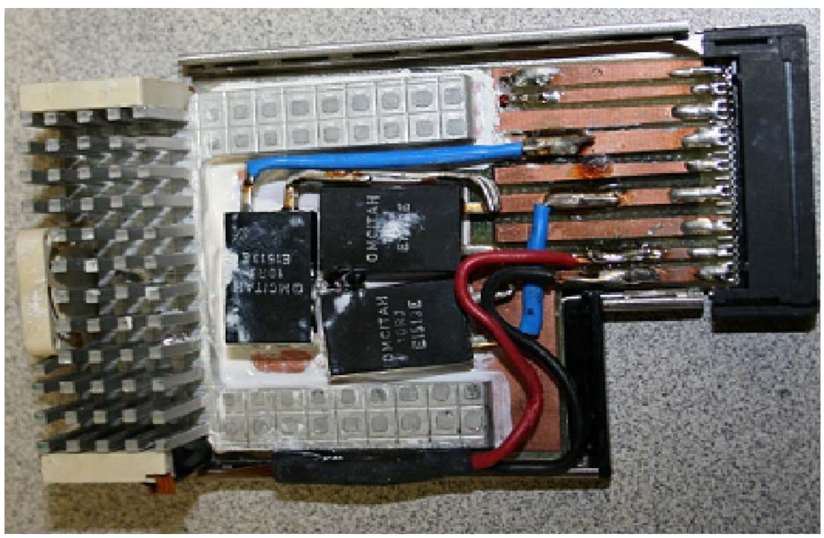

Figure 5. Test fixture with case lid removed.

Summary

The capstone course sequence presented in this paper clearly provides a process for students to demonstrate their performance at a professional level. The quality of the design is subjected not only to the AET faculty opinion but is subjected to reasonable scrutiny through outside assessment by qualified professionals. It is evidenced in the students' exit interviews that the capstone course sequence stimulates students' interest in engineering and engineering technology. In addition, it demonstrates students' technical competence and ability to work in teams and communicate orally and in writing on the progress and results of the project. Students learn how to share work fairly and solve personal relationship issues effectively. At the end of the senior design project, students generate and contribute knowledge and experience to their professional portfolio, which they will utilize throughout their life-long careers.

The capstone course series demonstrates that the AET Program Mission is being achieved and is consistent with ABET accreditation requirements.[1] The analysis of the performance results generated from capstone course sequence is an integral part of the continuous quality improvement for the AET Program. This analysis allows AET faculty members to provide evidence of the effectiveness of the developed processes and quality of the program. This analysis justifies necessary changes to keep the program relevant to the university and community.

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