Experiments on the Cheap: Using a Student Data Acquisition System

Christopher G. Braun
Colorado School of Mines

Motivation

The cost of operating a dedicated laboratory facility for student educational use is large in comparison to operating a general purpose lecture room. Laboratory uses require the setup of dedicated equipment, safety equipment and significant storage, often making the room unsuitable for other purposes. Additionally, hands-on laboratory projects require more time in class per credit hour than lecture – typically 3 hours in lab per week per lab credit hour compared 3 hours in lecture per week for 3 credit hours. Likewise, the costs for faculty and teaching assistants are far greater per lab credit hour than for lecture.

However, learning by doing is imperative for all engineering students. Just as I would never consider a surgeon competent without any hands-on experience, I believe that all engineers must have experience in the real-world skills to implement their designs. For many of our students, laboratory and capstone projects are where the book learning becomes active knowledge by understanding how to make use of their education.

The traditional engineering laboratory requires students to meet three hours a week in a room. There they work on a very focused laboratory project for one to several weeks and then move on to the next laboratory project. While labs often require outside work, most require students to spend the entire lab time in the laboratory classroom for instruction and use of lab equipment.

Taking the Laboratory Out of the Classroom

A completely different approach is to ***take the laboratory project out of the classroom*.** This approach is discussed by Hagler[1] who developed the term "hardware homework." The limiting feature is the need for an experimental setup, typically consisting of a system under test, some type of data gathering/control equipment, and, often, a computer. Many of these systems under test are (or could be) relatively simple, inexpensive and portable. Further, these days most students have access to or own their own computer. While typical data acquisition system are too expensive for wide use by students outside of lab, there are new alternatives, such as the CSM "Student Data Acquisition System."[2,3]

Issue	***Standard Lab***	***Take-Home Lab***
Learning	• Can take on completely new areas with sufficient instructional effort • Focused on specific aspect of overall system	• Promotes self learning and independent study • Must be familiar with topic / tools • Can focus on real-world systems and use
Cost ***Overall costs =>***	• Initial develop. time - moderate • Upfront costs - high • Space costs - high (indirect) • Operation costs - moderate • Labor costs - high • High	• Initial development time - high • Upfront costs - moderate • Space costs - none • Operation costs - moderate • Labor costs - low • ? Moderate to low
Major drawbacks	• Limited time to complete lab • Space often not adequate or new space not available • Multiple lab sections • Student scheduling problems	• Needs excellent documentation. • Computer & software at home • Lower speed data acquisition. • Systems must be simple, inexpensive & rugged • Availability of standard "real world systems" • Can't teach use of sophisticated test equipment
Major benefits	• Hands on learning • Controlled & scheduled • Get through complex material • Instructors to help overcome road-blocks	• Hands on learning • Can be when and where convenient for student • Connection to real-world • Makes independent learner
Best application	• Complex, difficult labs with special equipment or safety problems • Teaching specific skills or knowledge	• Easy to understand, but hard to master projects • Labs that allow creativity and exploration • Longer duration experiments

Table 1. A comparison between the merits of traditional vs. take-home laboratory projects.

As part of a long term change that began several years ago, we have developed an affordable data acquisition and control kit. Starting last summer, we required that all of our Division of Engineering Summer Field Session students (240 students, mainly Sophomores) build, test and learn how to use their own data acquisition system.[2] In addition, we also are in the process of writing interface libraries/modules in C, Visual Basic®, Qbasic®, Labview® and Simulink® as a means of easily allowing students to use standard high level software programs for acquisition, control and analysis.

These data acquisition systems are fully function with both analog and digital inputs and outputs as well as extremely portable though the use of a parallel port interface and a modular external connection board. A picture of the system is shown on Figure 1 and an example system configuration is shown on Figure 2. The first goal is to make this a standard part of our infrastructure so that subsequent classes can build on this functionality.

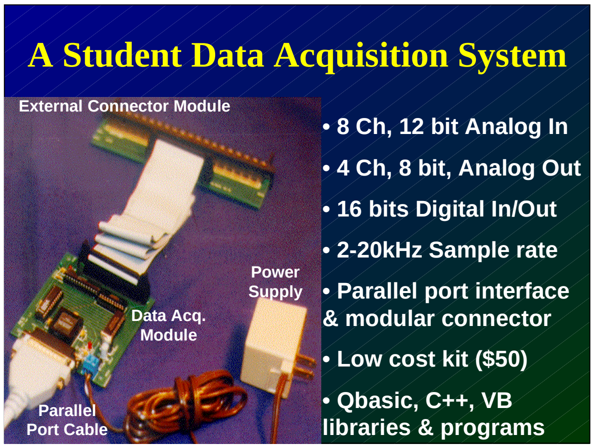

Figure 1. The "Student Data Acquisition System" used in the take-home laboratory.

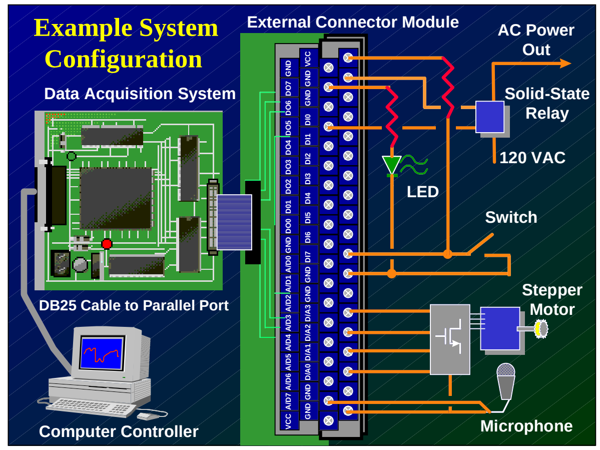

Figure 2. A conceptual drawing showing the wiring of typical sensors and actuators to the "Student Data Acquisition System."

The next step in our process of changing the way we teach laboratories, is to develop take-home projects for our mainstream labs. Clearly, some projects are unsuited for taking out of the laboratory room for reasons ranging from complexity and cost, to size and safety. However, a large number of laboratory projects can be done at any location and any time desired with the use of inexpensive sensors and system components. Examples range from a motor/controller setup used to teach feedback control techniques, to a suitcase sized process control (water pumping) system, to stress/strain measurements of materials, to thermodynamic and (safe) chemical reactions.

Another category of laboratory projects comes from realizing ***that take-home projects do not (and perhaps should not) be the same as in-class projects***. Because take-home labs are not governed by the same time or space constraints as standard, we can imagine new possibilities where data is collected over an extended period. An example of this might be to monitor air, noise or water quality over several weeks.

There are many, complex, real-world systems and processes that directly affect our everyday life. Another innovative approach is to focus on using these systems as the basis for an experiment to better understand the fundamental engineering principles on how they work and how they can be improved. Examples of these systems include automobiles, cooking processes, structures, bio-organic processes, traffic flow, house appliances, human performance and behavior. A take-home laboratory might focus on the heating and cooling system for a house. It could take data on the operation as well as allow the student to implement control strategies to turn on, for example, a space heater only when needed to save energy.

The First Take Home Laboratory – A Refrigerator Energy Monitoring System

The first take-home laboratory project we are developing is to monitor, analyze and improve the energy efficiency of a refrigerator. A concept picture is shown on Figure 3. This was chosen for several reasons:

- Students have access to a nearby refrigerator
- They consume considerable power and often are not working at peak efficiency
- It is a understandable yet fully interdisciplinary system with aspects of heat transfer, fluid mechanics and electronics.

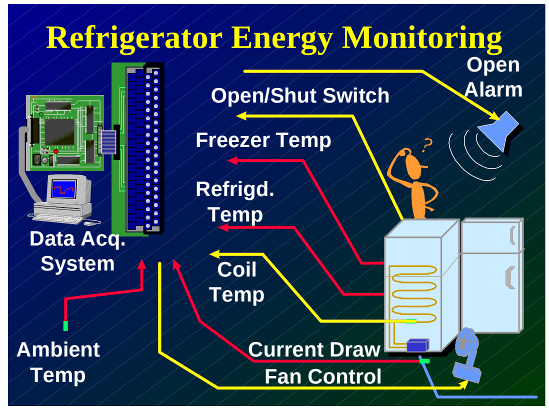

Figure 3. An overview diagram of a take-home laboratory project .

The focus of this laboratory project is to understand the operation of a refrigerator and use the data to help improve operation and make a real-world economic decision. Shown on Figure 4 and Figure 5 is an example of some of the data and analysis we expect from this laboratory.

The students check out a kit with sensors and instructional material. They take it home and setup the system layout to take power and open/shut readings, as well as several temperatures. They also connect output actuators to an alarm, indicator light, and (possibly) to a solid-state relay to power a fan. Using Labview®, C or Qbasic®, they construct the data gathering and control program from high-level existing software modules. The next step will be to calibrate the sensor reading. Data will be taken over several days for a baseline operation. Students calculate the efficiency and cost of operation. They then conduct experiments to focus on improving the efficiency by cleaning the heat exchanger coils, de-frosting the freezer, using an active alarm to remind users to close the door, etc.

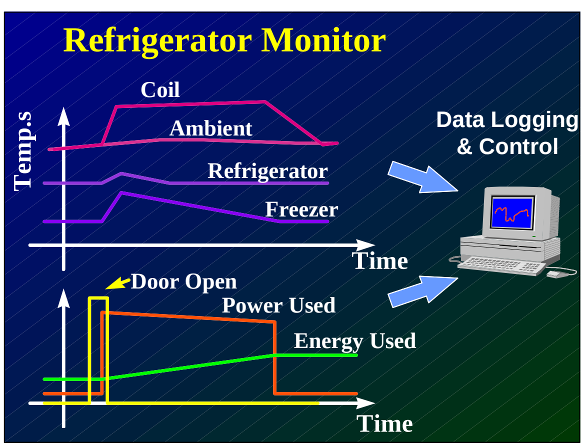

Figure 4. Conceptual data from the refrigerator monitoring take-home lab.

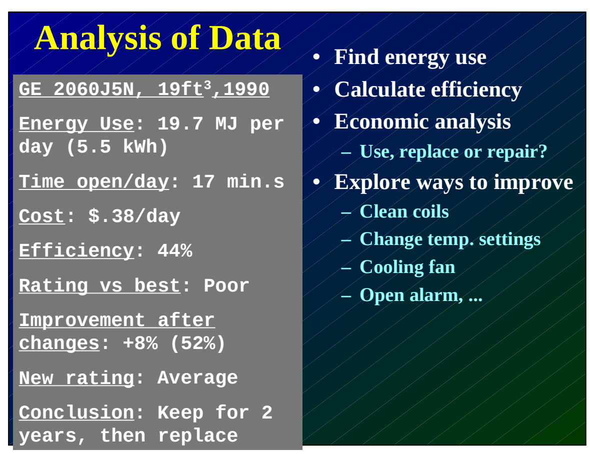

Figure 5. An example of the type of analysis for the take-home lab.

The last part of the laboratory will be to then use this data and analysis to make an economic tradeoff analysis on whether to keep or replace this unit.

The learning objectives & benefits of this laboratory project are to:

- Understand in detail the operation of an everyday, real-world system
- Be able to setup an experiment and gather data to make system-level decisions
- Become more self-directed and able to gather the necessary information
- Create a high quality, interesting laboratory experience outside of the classroom

Summary

Computers are wonderful tools for calculation and visualization, but limited without the means to interface to our physical world. With the addition of a data acquisition module, interfacing electronics and software, a computer system can be transformed into a powerful tool for acquiring data, making complex real-time decisions and implementing control loops. Although there are countless educational applications, schools are often limited in application of these systems due to their limited availability and cost.

For the students at CSM, we have developed and produced in quantity a “Student Data Acquisition System.” Since this system is designed for educational uses and not for commercial/industrial applications, we are able to fabricate a fully functional system for exceptionally low cost. This low cost allows us to require that all of our Division of engineering students, about 250/year, build and keep this system for later use.

We are working towards being able to step away from the laboratory classroom and have the students check out “suitcase” experimental setups to conduct their labs where and when it is best for them. The expected costs for these types of labs should be far less than that for traditional laboratory experimental setups. We are in the process of implementing a new take-home laboratory module for “Refrigerator Energy Monitoring” that is the first step in changing the way we teach laboratories. The promise of this new student acquisition system and the developments underway here in integrating it into our curriculum are just the beginning of an exciting new process.

References

[1] M. Hagler, "Hardware Homework for Courses in Circuits and Electronics," Proc. of 1994 FIE Conference, pp. 557-561, 1994.

[2] C. G. Braun "Hardware Homework using a Student Data Acquisition System," Proceedings American Society of Engineering Education (CD ROM), 1996

[3] C. Braun, "Transforming the Way we Teach Laboratories: A Student Data Acquisition System," Proceedings of the 1996 Frontiers in Education, (CD ROM), 1996

Biographical Information

Dr. Christopher G. Braun received his S.B. from MIT in 1982 and M.S. and Ph.D. from USC in 1984 and 1987, respectively. Since 1992 he has been a professor at the Division of Engineering at the Colorado School of Mines. Dr. Braun is very active in developing new approaches in teaching electronics. He can be reached at cbraun@mines.edu.