Hardware Homework using a Student Data Acquisition System

Christopher G. Braun
Colorado School of Mines

Overview

A project developed by a student team under close guidance of a faculty member is underway to build a very affordable yet highly functional data acquisition system. Our plan is to introduce this system to our students in the Engineering Division's six week long Summer Field Session for students between their Sophomore and Junior year. Each student would buy and build their own data acquisition system. In conjunction, other Field Session modules would teach C++ programming and interfacing, and then use this data acquisition system in a motor control application.

The following semester, students will return with their own data acquisition system which will be used in their laboratories, at home, or for their own projects such as their Senior Design. Once each student possess their own data acquisition system, then the faculty here foresee dramatic changes we can make in the curriculum to take advantage of this new capability.

Motivation

Students in engineering and science classes use computers and data acquisition systems for measurement and control in many, if not most, of their laboratory classes. The type of measurements/control range from chemical processing to materials fatigue testing to PWM motor control. In many instances, however, the students and faculty are forced to make do with a limited number of laboratory stations and time. This constricts projects to be narrow, focused and often simplistic in order to finish in the allotted time.

An alternative approach has been discussed by Hagler[1] to give the students the tools so that they can do "hardware homework." This allows the students to do some of their laboratory work outside of the laboratory class. There are several significant benefits from this approach. These include:

- Giving the students a higher level of understanding
- Allowing the students the flexibility to explore different ways of accomplishing the same task
- Allowing them to work more at their own time and pace
- Reducing the resources needed to outfit a laboratory
- Allowing the students to apply their classroom knowledge to situations outside of class
- Providing a higher feeling of control and overall enjoyment

The key to this approach is providing the students the tools and training to accomplish these tasks. The essential item is thereby the data acquisition system since most students have access to computers -- both at home and at school. There are many excellent data acquisition systems on the market. These range in cost from about a couple of hundred dollars to many thousands of dollars (including software and external modules). Even at the lower price range, it is unreasonable to suggest students purchase their own data acquisition system.

Our approach has been to develop a highly functional, yet very affordable data acquisition system. A student senior design team under the close supervision of their faculty advisor has been working toward a system with the following specifications:

- Affordable -- under $50 per kit (student assembled)
- Parallel port interface to make portable, yet with high throughput
- Sufficient channels and resolution for analog inputs and outputs
- At least 8 digital inputs and output lines
- Single voltage power supply
- All inputs and outputs connectorized to enhance "plug in" concept
- Software libraries and system to run from any common computer
- Fully documented system with user manual

The rationale for these specifications comes from our experience in teaching/taking laboratory courses. The driving element is the price -- it must be affordable so that each student can be required to buy and use this system. Another, less obvious element, is that we needed to connect the data acquisition board to an expansion terminal strip to be able to move the system around as needed. Any dedicated/fixed wiring would be connected to an inexpensive, dedicated terminal strip.

The are many possible choices in implementing this system. Because we need to consider fabrication as well as cost, one of the major constraints was to minimize the number of different integrated circuit packages. After considerable design work, we have produced a working prototype that is shown on Figure 1. A block diagram of the internal system functions is shown on Figure 2.

We were led to the use of an Altera programmable logic device (PLD),[2] even at a relatively high cost, to handle the bus control and parallel port interfacing. This approach greatly simplified the hardware, reduced the board size and allows changes in the control logic as the project continues. We selected Maxim parts for the analog data acquisition (DAC, ADC) chips.[3] This is due to their generous sample supply policy as well as the high level of chip functionality.

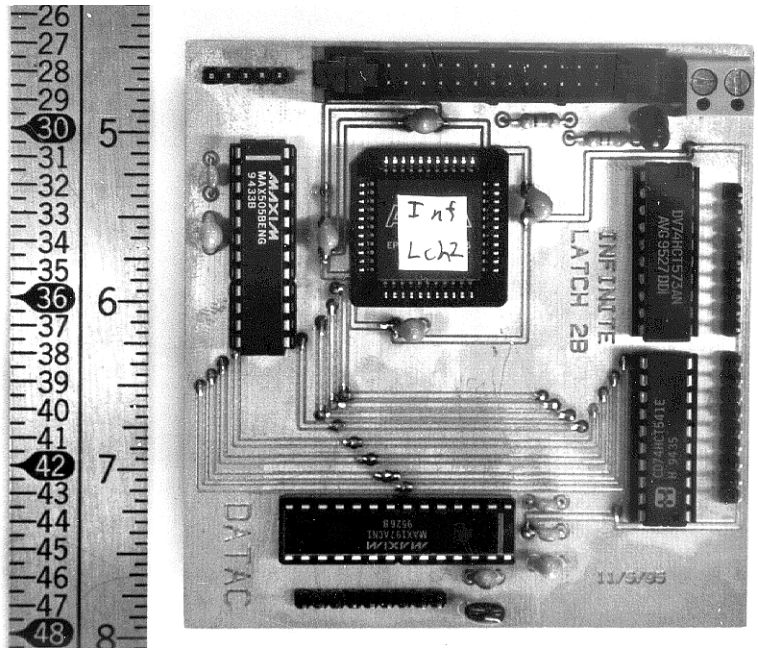

Figure 1. Shown is a working prototype of the student data acquisition system. This system costs less than $50 and is fully functional for student/laboratory uses.

The final system has the following detailed specifications:

- 8 input analog channels, 12 bit, bi/uni-polar, internal clock, 100 ksps, +5 V power, analog to digital converter (Maxim 197)
- 4 output analog channels, 8 bit, digital to analog converter (Maxim 505)
- 8 digital input channels (74HCT541)
- 8 digital output channels (AVG 573)
- 5 VDC wallplug power supply
- Complete software libraries and data acquisition system for input, output and on screen graphical display
- Technical, assembly and user documentation

Educational uses of this data acquisition system

A data acquisition system as described above would make an immediate impact in the effectiveness of the students' continuing education. In our interdisciplinary Division, comprising about 40% of the CSM undergraduates, we provide a general engineering background with options in electrical, mechanical and civil engineering. This data acquisition system will become a major factor in our ongoing development of a set of interdisciplinary laboratories for all students. In addition, our existing laboratories, dealing with subjects from fluids to electrical motors, will be able to use this data acquisition system to augment their existing setups. Working toward the concept of hardware homework, we anticipate beginning to move parts of our laboratory experience out of our laboratory classrooms.

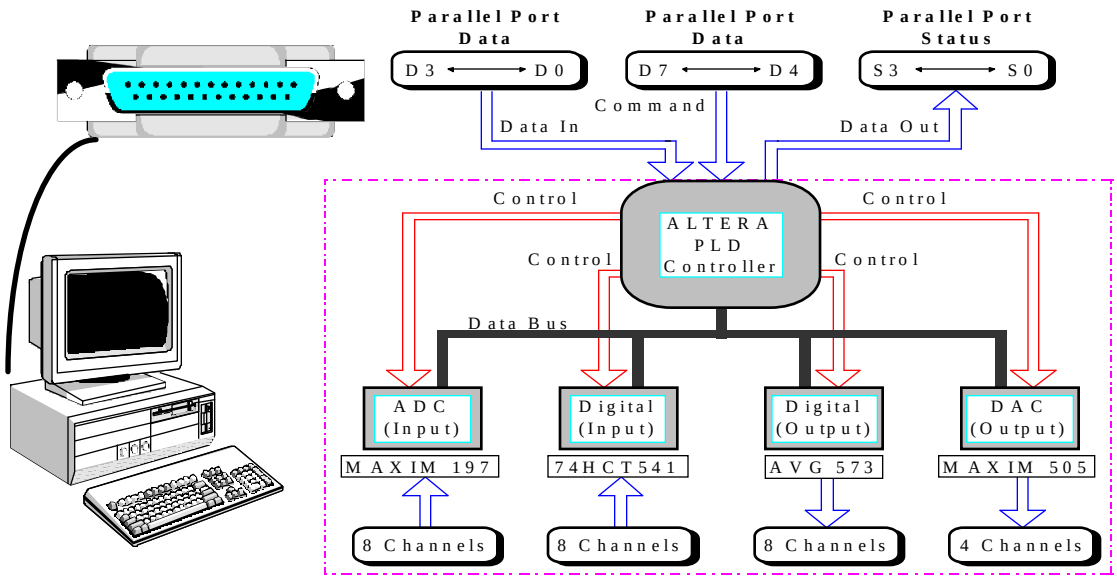

Figure 2. A block diagram of the student data acquisition system.

One of our most glaring needs is in our Senior Capstone Design sequence. Currently, students propose and build a system to address a real-world need. Very often they request data acquisition/control resources that the Division cannot supply. Leaving them stuck with making due with less and, generally, achieve less. Further, in some cases it is important to keep their system together and operational for future work -- something that is not possible if they must return their data acquisition system at the end of the semester.

There are numerous specific ways this type of data acquisition system can and will be used. For example, a Civil engineering student could interface the data acquisition system directly to a strain gauge on a concrete caseon while acquiring personal, hands-on experience rather than passively watching an instructor perform a demonstration, as is currently done. A student Mechanical engineering student could attach an optical tachometer to a flywheel on our Hybrid Electric Vehicle and gather information about the efficiency of power transfer. And a student in the Electrical specialty could use the data acquisition system as part of motor control experiment to close a feedback loop.

Every aspect of engineering and science that uses data acquisition and control may reap a benefit from this dramatic change. One of the major tasks we face here at CSM is redesigning laboratory projects to take advantage of this new capability. However, there are a number of situations where it is impractical to even try to move the laboratory project outside of a laboratory classroom -- safety, cost, complexity of equipment, etc. are all important considerations. We will target opportunities where students, armed with their data acquisition system and additional interface modules, can perform meaningful hands on experiments. Some specific examples are discussed later.

Summer Field Session

CSM, as different from most universities, conducts a required summer Field Session. In the Division of Engineering this 6 credit hour (6 weeks, full time) sequence starts after the end of the Sophomore year. The purpose of this field session is to introduce the students to their major and give them a set of practical skills they will take forward into their Junior year. Engineering Field Session is used to teach basic skills in areas including surveying, machine shop techniques, C++ programming, electronics and data acquisition.

The previous version of our one week long, electronics module taught basic electronics hands-on skills. All students learned how to solder, read resistor codes, use the multimeter, and so forth by analyzing, assembling and testing a mutimeter kit. Our plan is to update this module by having the students build and test their own data acquisition system instead of this multimeter. This data acquisition system will be used in another Field Session module that teaches C++ programming/data acquisition techniques. The result will be that each of our engineering students will possess their own data acquisition system and the skills to program and use it. The students will then take this data acquisition system into their Junior year classes.

Use in standard laboratory courses

Our Division of Engineering continually strives toward a greater interdisciplinary education, trying to eliminate the segregated, rigid division of disciplines. One ongoing reform is the integration of our Fluids lab, Strengths lab and Electrical Linear Systems lab into a single, multi-disciplinary laboratory. One of the unifying element between these areas will be this common, student data acquisition system. Because funds for new equipment as well as laboratory space are limited, the adoption of this student data acquisition system enables us to inexpensively build new experimental stations as well as allowing the students to do meaningful interdisciplinary experiments outside of our laboratories.

Another place where this system could make a strong impact is in our Controls class/laboratory. Due to equipment limitations, only a electrical option students are allowed to take the laboratory along with the course. The introduction of this student data acquisition system would allow us to open this laboratory to teach practical skills that are important for all our students (going from 40 students per semester to over 100).

To accomplish this change in our Controls laboratory, we would have the students rotate through a set of projects. Some would require the students to work outside of our Control laboratory using their data acquisition system and portable check-out controls module. Other projects, typically the more complex/equipment intensive, would make use of our existing laboratory stations in our Controls laboratory.

Specific changes for our Controls class might take the following form:

* Keeping our existing 6 motor control experiments for the more complex, equipment intensive laboratory projects

* Developing portable check-out modules consisting of two coupled +12 VDC motors (motor/ generator), a motor controller (PWM), various sensor and interfacing modules, a variable load and a small power supply (Figure 3).

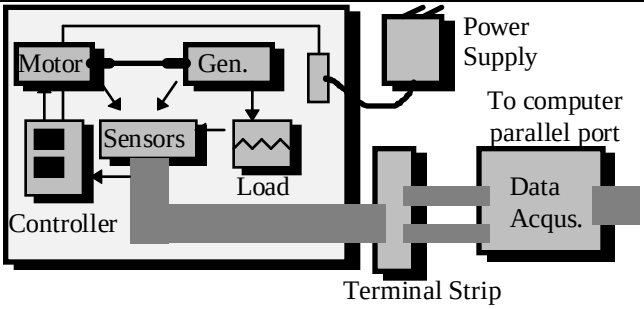

Figure 3. A (proposed) portable check out module for Controls laboratory experiments.

* Create sets of documentation/ software to lead the students through each "take out" experiment

* Add a general set of lectures to explain and means to access help for students doing the take-out projects

Shown on Figure 3 is Senior Design project developing an automated dynamometer teststand using the student data acquisition system. As is the case for many projects, there are a number of analog and digital sense and control lines. Without the development of the low cost student data acquisition system, this ongoing project would have been impractical due to the cost of the equivalent commercial system.

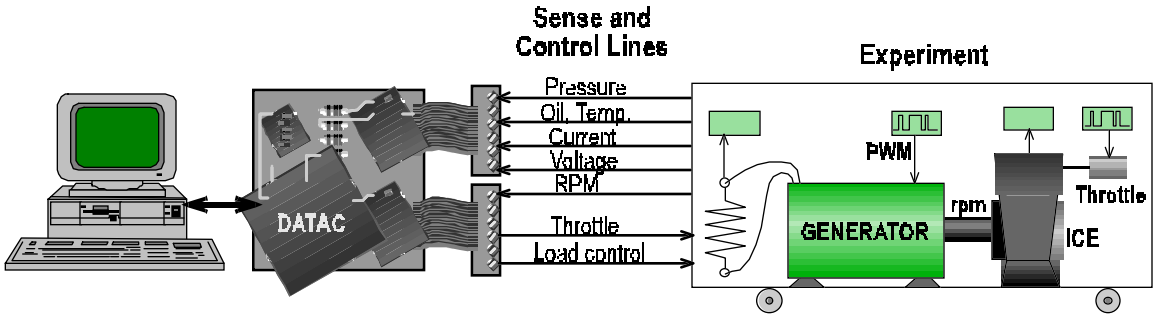

Figure 4. Shown is one example of the use of the student data acquisition system in a senior design project which automates the testing of an internal combustion engine. The data acquisition system is allows the computer to monitor and control the testing of an internal combustion engine.

Summary

The student data acquisition system we have developed and are beginning to use has the potential for changing the way we conduct laboratory classes. Because of the high level of functionality and very low cost, it is possible for each student to posses their own data acquisition system. We plan to use our Summer Field Session as the means to have every engineering students build and learn how to use their student data acquisition system. Other schools may use time during a basic electronics class to accomplish the same task.

Once we make that fundamental change, then our faculty will be able to redesign and rethink our many laboratory classes to take advantage of this personal data acquisition system. Some of the more major changes will come in three initial areas: expansion of our Controls laboratory, enhancement of our Senior Capstone Design projects, and use in our Interdisciplinary laboratory under development. The result will be a extension of the laboratory experience outside of the laboratory that will help the students make connections between their education and their professional work. Additionally, by giving the students this data acquisition tool, we are enabling them to learn more deeply and find new applications that are important to them. Thus, enhancing their learning and enjoyment at the same time. We look forward to continuing this development and working towards a new approach in teaching laboratory classes.

Bibliography

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

[2] Maxim data sheets for the MAX505 and for the MAX197

[3] MAX 7000 Data Book, Altera Corporation, February, 1993

Bibliographic Information

CHRISTOPHER G. BRAUN

In addition to his research in power electronics, Dr. Braun has been working for several years towards new approaches in teaching electronics to students. In this approach, students would acquire the practical skills they need to fabricate their electronic system designs. He can be reached at cbraun@mines.edu for questions or comments.