Teaching Instrumentation for MET and EET using LabVIEW™ software with Vernier® and National Instruments® hardware

Desrochers, M., Powers, M.

Michigan Technological University

Abstract:

Measurement, data collection and interfacing are a critical part of the everyday manufacturing and engineering world. It is important that today's technology students are exposed to measurement and data acquisition. This paper summarizes two courses, one from the Mechanical Engineering Technology curriculum and one from the Electrical Engineering Technology curriculum, where LabVIEW™ is taught as the programming language and interfaced with two different systems, sensors and controls. One system uses Vernier® instrumentation and data acquisition and the other uses National Instruments® PCI interface boards and a variety of discrete sensors and controls. These systems will be compared and contrasted to expose the reader to two approaches to teaching data acquisition systems. An outline of suggested laboratory experiments and related objectives is included.

Introduction:

While the Electrical Engineering Technology (EET) and Mechanical Engineering Technology (MET) curriculums are very different, we have found a common ground in our treatment of data acquisition and control. We both use LabVIEW™ to teach sensors, data acquisition and control primarily because it allows us to focus on sensors and controls, not on the mechanics of programming. It is also well accepted in industry and has led to job offers for our students.

LabVIEW™'s integrated data acquisition and control environment includes excellent information presentation capabilities. This allows students to easily see what's actually happening with an acquired signal and how applying various signal analysis tools affect it. This permits very rapid hands-on testing of signal processing routines to, for example, best reduce the effects of electrical noise on a desired signal.

Why teach LabVIEW™ ?[1,2,3]

- It is fun for both the students and the faculty
- It is an industry accepted standard that can translate into job offers
- The graphical nature of the program allows students to focus on the what is being taught and not the particulars of other command line languages allowing for accelerated application development

- It can be used for data acquisition, control (automation), presentation, simulation and analysis
- Labs can be controlled remotely (ideal for distance learning)
- Since the students write their own programs they are learning more about instruments, programming, and data collection and analysis than if the labs were offered as canned labs
- LabVIEW™ has the ability to talk with just about anything (instruments and devices)

EET needs:

Many Electrical Engineering Technology students will be involved with data acquisition and control systems during their careers. Therefore, a strong preparation in a variety of sensors is required. The basic physics behind transducers for temperature, position, and force sensing elements is covered both in theory and in the lab.

In addition, EET students need to work with and understand basic signal conditioning techniques in order to make effective use of various sensors. Prior coursework that is introduced in instrumentation circuits, including bridge circuits and signal amplification is applied in the laboratory.

The students need to understand how to process the data from the sensors. This includes noise reduction techniques as well as analysis of the acquired data.

Finally, the students need to learn how to that use the information collected to control an external process. They apply concepts learned in prior courses, such as how to condition output signals to drive relays and other actuators, to laboratory projects.

EET3353 Sensors, Data Acquisition and Control is a required course normally taken in the junior year of the Electrical Engineering Technology curriculum. The course meets three times a week for one hour and covers programming in LabVIEW™, basic concepts and types of control, elements of control systems, measuring instrument characteristics, and signal conditioning and data acquisition. The laboratory meets once a week for three hours and covers programming and data acquisition using LabVIEW™ as the programming language and the National Instruments® PCI-6024E for data acquisition.

MET needs:

Many of the MET students will be exposed to testing, data acquisition and analysis in some form during their careers. At the beginning of the term many of the students have some apprehension concerning the course material. They feel that this is "sparky stuff". This course is used to try and give exposure to instrumentation, control, programming, data collection and analysis. By the end of the course students are taking data using programs they have written (this is the only exposure to a programming course for MET students). The programming exposure the students gain (for, while, sequence, etc.) in this course can translate into any programming they encounter. This helps them to feel more comfortable with the material and get them over those initial fears. Our intention is for them to be able to write programs to collect, display and analyze data. During their experiences in the laboratory they also pick up some troubleshooting techniques. Using the Vernier® hardware and LabVIEW™ together allows us to concentrate on programming, data collection and sensors but not interfacing.

MET4131 Advanced Instrumentation is an elective for Mechanical Engineering Technology students during the senior year. This course is a continuation of a required course in the junior year (MET3131 Instrumentation – basic physics behind transducers is covered). The course meets two times a week for one hour and covers the following material: basic concepts and types of control, elements of control systems, Laplace transforms and transfer functions, measuring instrument characteristics, signal conditioning and data acquisition. The laboratory meets once a week for two hours and covers programming and data acquisition using LabVIEW™ as the programming language and Vernier® hardware.

<u>Lab Structure</u>:

Both of the fourteen week courses cover the teaching of LabVIEW™ during the first seven weeks and data acquisition during the rest of the term.

Week	Topic	Chapter[4]
1	Introduction	1 & 2
2	Editing and Debugging	3
3	Structures and sub VI's	4 & 5
4	Arrays and Clusters	6
5	Charts and Graphs	7
6	Strings and file I/O	9
7	Analysis, Curve Fit, FFT	11
8	Review as necessary	
9	Sample Data Collection	
10	Penny Counter Program	
11	Temperature Control	
12	Temperature Control	
13	Project	
14	Project	

During the first part of the term all students are at their own computer with the instructor using a projector screen and a computer. Since each student is able to follow along and build their own programs it seems to help them learn the material better. In the second portion students are in groups of two to complete the data acquisition. We could move much faster through the LabVIEW™ instruction portion (National Instruments does provide information to teach the basics in a 6 hour course[5]), however we feel that it is the best interest of the students to move through the initial material at a slower pace. When we reach the data collection portion the students are confident in their use of LabVIEW™ and can concentrate on data collection.

<u>Labs:</u>

<u>Acquire Voltage – (EET)</u>

This first data acquisition program introduces the student to using LabVIEW™ and the PCI-6024E DAQ board for acquiring and analyzing voltage signals. In the first part, a DC voltage is acquired both with and without proper grounding. This clearly demonstrates the impact of improper grounding in signal acquisition. In the second part of the lab, an AC signal is acquired and analyzed using LabVIEW™'s FFT (Fast Fourier Transform) capabilities. The AC waveform is varied to show the frequency components of sine waves, square waves, and triangular waveforms.

<u>Output Voltage – (EET)</u>
In the first part of this lab students use LabVIEW™ and the PCI-6024E DAQ board to generate a simple stair-step output voltage signal. The second part of the experiment involves acquiring a sinewave and changing the sampling rate to demonstrate the effects of sampling signals at rates below the Nyquist frequency (i.e. sampling at less than twice the frequency of the input signal).

<u>Penny Counter Program – (EET)</u>
A locally fabricated cantilever beam wired with four general-purpose strain gages is used for this program. Two of the strain gages are configured to be in compression under load, with the other two in tension. The gages are wired into a full bridge configuration with excitation provided by a DC power supply. The goal is to determine the number of pennies placed in a basket attached to the beam. The students need to adjust DAQ board settings for proper gain and appropriate voltage levels, follow proper grounding practices, and use LabVIEW™ to effectively process the voltage signal to reduce the effects of electrical noise.

<u>Heating Temperature Control Program - (EET)</u>
In this program, students read in the temperature of a small confined space and activate a heating element to control the temperature of that space within assigned tolerances. A thermocouple board is used to read the temperature of the confined space and an electrical power relay board controls the heating elements (two low wattage light bulbs). Both of these boards are locally fabricated. The students address issues with signal conditioning, sensor calibration, control routines, and presentation of information.

<u>Acquire Temperature – (MET)</u>
This first data acquisition program is to acquire temperature using the stainless steel temperature probe from Vernier®. It is used first because the students are familiar with the instrument from a previous course and they have a conceptual understanding of temperature. The students use one of the sample LabVIEW™ VIs provided from the Vernier website to acquire the temperature. After studying the components of this program (initialize the hardware, collect data, end sequence) they are able to build their own programs. They can also use the software provided by Vernier® (Logger Pro®) to verify the results of the program that they have written. They can do that for any of the programs that they write where they use Logger Pro® and a Vernier® sensor.

<u>Penny Counter Program – (MET)</u>
This program utilizes the force transducer from Vernier®. The objective is to determine the number of pennies placed in a basket attached to the transducer. In this program the students need to do a five point calibration curve and then use that curve to determine how many pennies are in the basket.

Heating and Cooling Temperature Program – (MET)
Input and output are both used in this program. The stainless steel temperature probe is placed on the side of a heater. The program monitors the temperature of the heater. When the temperature is above the limit entered by the user, a signal is sent to the fan using the digital control unit from Vernier®. When the temperature is below the lower limit set by the user, a signal is sent from the digital control unit to turn on the heater. The students must also include a cool down scenario for safety purposes.

Projects (MET)

- Voltage FFT analysis – Using the voltage probe the students acquired a voltage signal (produced by an external function generator) and determined the FFT. The students verified the signal they analyzed using an oscilloscope. They were able to input multiple signals and show the FFT and also by changing the sampling rate show aliasing. (This program used non-real time (NRT) data collection. The data is actually collected in real time but is different from real time (RT) collection in that once the data collection sequence is initiated no other processing will take place. For all of the other programs RT data collection was used.)
- Motion sensor – Using the ultrasonic motion sensor the students set up a system to indicate to a driver how far from the garage wall a vehicle is. Depending on the distance form the motion sensor to the wall different lights were activated on the computer screen.
- Light sensor – Using the light sensor, students took different readings from different light bulbs to determine the wattage associated with each light bulb.

Hardware Descriptions:

The following equipment was used in the Electrical Engineering Technology LabVIEW™ classroom and laboratory:

PC:

- Windows XP professional, Version 2002, Service Pack 1
- 2 GHz AMD Athlon ™ XP 2800+ with 512 MB RAM
- LabVIEW™ 7.1 Express with the LabVIEW™ 7 Express Learning Directory of VIs installed < http://www.ni.com/labviewse/lvse.htm > insert ref here

National Instruments®:

- PCI-6024E Multifunction DAQ, 200,000 samples per second, 12-bit, 16 analog inputs, 2 analog outputs, and 8 digital I/O lines. Price: $575. (see note)
- CB-68LP I/O Terminal Block. Price $70.
- R6868 Ribbon I/O Cable. Price $40.

Note: National Instruments® recommends a newer DAQ board, the PCI-6221, in place of the older PCI-6024E. It offers improved capability over of the PCI-6024E for less money!

Test Equipment:

- Agilent® 54621A Oscilloscope
- Exact® Model 121 Sweep-Function Generator

- Tektronix® TM 506 frame with:
    - PS503A Dual Power Supply (2)
    - DM502 Digital Multimeter (2)
    - FG503 Function Generator

Penny Counter
This experiment uses a locally fabricated cantilever beam wired with four general-purpose strain gages. Two of the strain gages are configured to be in compression under load, with the other two in tension. The gages are wired so the student has access to each one, allowing the gages to be wired in single, double or full bridge configurations. This system is also used in other courses. Est. price $60.

Thermocouple Board
For temperature sensing and control experiments, a locally fabricated thermocouple board is used. Type J thermocouples are connected to Analog Devices ™ AD594 Thermocouple Amplifiers. The amplifiers were powered directly from the CB-68LP connector block. This board is also used in other courses. Est. cost $50.

Electrical Power Relay Board
Used for control experiments, this locally fabricated board consists of two relays controlling 120VAC power to two standard sockets. The relays are powered and controlled from the CB-68LP connector block. Est. price $30.

The following equipment was used in the Mechanical Engineering Technology LabVIEW™ laboratory:

PC:
- Microsoft Windows 2000, Service Pack 4
- 128 Mb RAM
- LabVIEW™ 7.1 Express

Vernier®:
- LabPro® ($220)[6,7]
    - Four analog data collection channels
    - Two digital data collection channels
    - Maximum sampling on one channel 50 kHz
    - Compatible with over 40 sensors ranging in price from $9 – $249 [8]
    - Compatible with user built sensors
    - 12-bit A/D conversion
    - Internally stores 12,000 data points
    - One analog channel can be used as an output channel, ±3 volts, 100 mA (with function generator)
    - Both digital lines can be used as output (8 TTL, 4 per port)
    - Serial computer connection
    - USB connection
    - Calculator I/O port
- Digital Control Unit (DCU)[9]

- Plugs into one of the LabPro digital channels
  - Controls six output lines (not all independently)
  - Used to run 6 volt devices
  - Allows currents up to 600 mA
- Vernier® sensors (Stainless Steel temperature probe, Force Transducer, Light sensor, Voltage probe)

Test Equipment:

- Agilent® 54621A Oscilloscope
- Tektronix® TM 506 frame with:
  - PS503A Dual Power Supply (2)
  - DM502 Digital Multimeter (2)
  - FG503 Function Generator

Power Relay Box

This locally made box uses solid state relays that are powered by the 6 V signal from the digital control unit. There are six 120 V outlets that are controlled.

Conclusions:

We have found that the students really enjoy programming and data collection using LabVIEW™ (and the instructors enjoy teaching the course). Some of our students have been offered jobs based on the programming experiences from these courses. When LabVIEW™ is paired with Vernier® hardware it is an economical way to equip a laboratory for data collection. The support from both Vernier® and National Instruments in the academic areas is terrific; we would recommend that you contact them if you are considering teaching a similar course.

Future Plans:

In the future, we plan to expand the number and types of data acquisition labs to demonstrate additional types of sensors, including TEDS (Transducer Electronic Data Sheets) sensors. In addition, experiments will be added to exploit LabVIEW™'s instrument control capabilities for both data acquisition and control and data display and analysis. Finally, it is planned to include more sophisticated control scenarios, including proportional-integral-derivative (PID) control situations.

References:

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Biographical Information:

MARYFRAN DESROCHERS is an Associate Professor in Mechanical Engineering Technology at MTU. She earned her BSME from MTU and her MS in Applied Science from the University of Arkansas at Little Rock. Prior to pursuing her MS degree, she worked as an engineer for Kimberly-Clark Corporation. She teaches Machine Design, Instrumentation, Mathematics and serves as the academic advisor for MET students.

MICHAEL POWERS is an Assistant Professor in Electrical Engineering Technology at MTU. He earned a BS in Mathematical Sciences from the USCGA in New London, CT and his MSEE from the Naval Postgraduate School in Monterey, CA. With the U.S. Coast Guard, he worked in electronics, telecommunications and information technology support when ashore and on icebreakers. He teaches electronics, communications, and control systems.