"COOL!" – A PEDAGOGICAL ARGUMENT FOR DOWNGRADING YOUR LAB EQUIPMENT

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ABSTRACT

Labview software, combined with National Instruments hardware, provides a powerful and seamless package that makes turnkey data acquisition almost foolproof in undergraduate labs and facilitates the implementation of complex measurement systems for research and production applications. Other suppliers provide similar functions. The very strengths that make them excellent production tools hide measurement system functional details from students and reduce their sense of accomplishment in making a successful measurement. This paper details a single lab experience, delivered with much more primitive instrumentation, to measure the steady and transient performance of a strain gauge load cell weighing system. Students made their own decisions about measurement system configuration and parameters for testing, generally failed on a first attempt, did debugging and troubleshooting, and succeeded in acquiring physically interesting data. Observation showed a higher level of engagement in the lab compared to more turnkey instrumentation. Students demonstrated frustration, followed by accomplishment, literally pointing to their results on the screen and exclaiming "COOL!" in voices that could be heard across the lab.

KEYWORDS

Lab, Arduino, Active Learning, Strain Gauge, Standards: 1, 6, 8

INTRODUCTION

MECH 216 is a lab course aimed primarily at the physics and practice of the measurement process, rather than at the physical systems being measured. One of the segments explores the performance of a strain gauge cantilever beam load cell, similar to the load cells used in a wide variety of industrial systems and consumer products for weighing and force measurement. These load cells are larger, with more visible strain gauges, and within the range of fabrication skills developed by our second year students in the machine shop.

LAB PROCESS

Students start with components, build, program, calibrate and test their own weighing system in a single hands on session. They are responsible for advance preparations, tested with an online quiz, and post lab reporting. In the lab they mount the load cell, verify its function, configure an instrumentation amplifier to increase the signal voltage, do a deadweight calibration and program an Arduino to display load as a function of time. Each of these tasks takes place at an intentionally primitive level to minimize the hidden information in the system. Students need to develop a working understanding of all the components in order to succeed.

To provide a design basis, the students are asked to determine if the load cell is suitable for distinguishing between a hen and a fox at the entry to a chicken coop and the application details are left open for them to assess.

Load Cell Configuration

Wiring the load cell is described for students in videos (https://www.youtube.com/watch?v=2-qIaecxUdg https://www.youtube.com/watch?v=0d_xWLeBPRk) however they make the actual connections themselves in the lab, connecting four resistance strain gauges in a full bridge configuration.

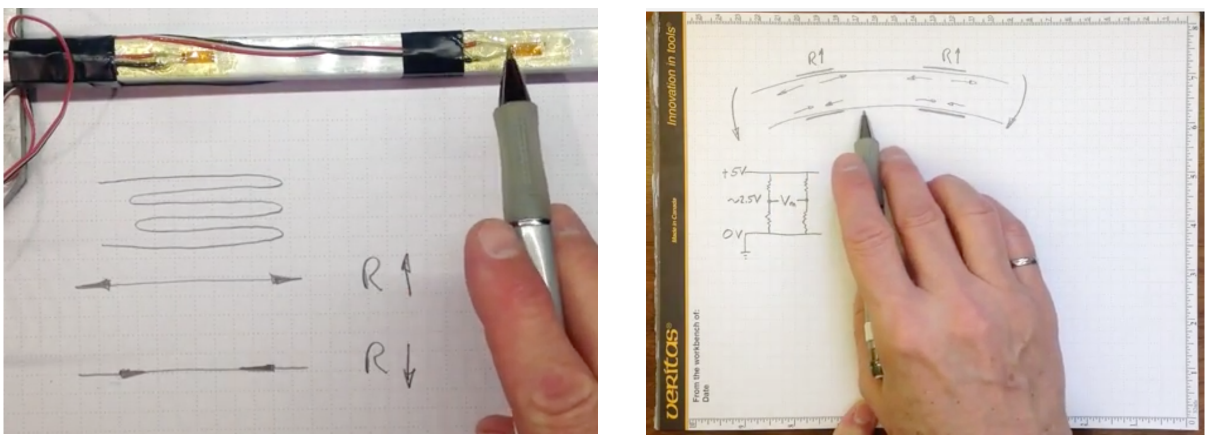

Figure 1. Clips from explanatory videos showing the load cell and the full bridge configuration concepts.

Amplifier Configuration

Students use an INA 125 instrumentation amplifier chip on a breadboard, choosing their own gain and offset and configuring it with resistors and wire jumper connections. A good amplifier gain selection will vary from group to group depending on the load cell zero offset they have measured.

Arduino Programming

The amplifier output is manually connected to an analog input on the Arduino and code written to read the input and display time series data.

Calibration

A two point calibration of the load cell / amplifier / Arduino system allows them to calculate kilogram load as a function of analog (0-1024) conversion value, then test the linearity of the system with other loads.

Data Display

Their time series data can then be copied from the serial monitor in the Arduino IDE and pasted into a spreadsheet for graphical display.

Student Results

Students are able to complete this sequence of events, including iterations of troubleshooting both hardware and software in about 2 hours. Taking actual results takes about 5 minutes at the end of the lab.

A sudden change in applied load is achieved by dropping an additional weight in the suspended load bucket and measured load recorded as a function of time. Unsurprisingly (to us) the results are second order, damped oscillations as shown below.

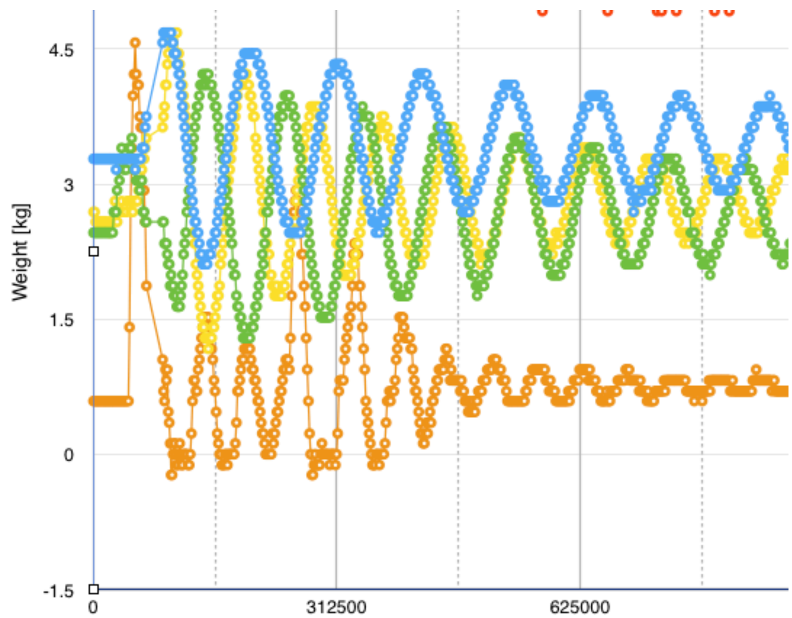

Figure 2. Sample data recorded using the lab equipment. Note the second order response with initial chaos associated with bouncing weights in in the bucket.

When this graphical data finally pops up on their screen, we hear explanations of “Cool!” Catching students in this moment provides a real opportunity to link their differential equations course to something measured in a real system, without needing to do complicated analysis.

DISCUSSION AND CONCLUSIONS

These measurements could be achieved much more quickly, much more accurately and much more reliably using research quality tools and software, with automatic gain selection, minimal zero offsets and connectors that only fit together in one possible way. Students could be in and out of the lab in a very short time, or spend longer accumulating a large dataset for detailed analysis.

Faculty members (who are often absent from actual lab sessions) are biased towards making the best possible measurements in labs by using high quality equipment and software.

Lab technicians are biased towards protecting the high quality equipment from the students who are likely to break it.

Lab teaching assistants are biased towards getting the lab finished as quickly and easily as possible by helping students get data, rather than letting them have a bit of a struggle.

Lab students are often delighted to have TAs do the lab for them.

All of these biases tend to limit the Active Learning of our students by protecting them from making mistakes along the way and having to deal with the consequences. Using low cost, simple equipment that is rugged and replaceable gives the students a hands on opportunity to fail on the way to success and enhances their engagement.

Having a faculty member in the lab sessions helps keep the focus on active learning, rather than student / TA collaboration to get the data and get out.

The learning experience leads to more student engagement and enthusiasm than was seen in similar labs completed with more expensive, higher precision equipment and feature rich software that insulated students from the data acquisition details.

All of these conclusions are from observation of the labs and direct feedback from students in winter 2015. A survey of student opinions on the experience has been carried out and results should be available for presentation at the conference.

BIOGRAPHICAL INFORMATION

Rick Sellens is an Associate Professor in the Department of Mechanical and Materials Engineering at Queen's University. His research background is in Fluid Mechanics and more recently in Biomechanics. He has been actively involved in facilities and curriculum development to support active learning, including the Integrated Learning Centre at Queen's.

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