ECE 4950 Project 1

Team 7
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Executive Summary

This project consisted of two main objectives:

1. a series of experiments to test the Quanser Q4 Data Acquisition System and xPC Workstation along with the MATLAB and Simulink software, and
2. modeling a part to be cut with the laser cutter.

While there was not a specific product to be designed for this project, the work was very important. The simple tasks and experiments that the team performed here were essential in getting familiar with the main tools that will be used for the rest of the semester in future work.

The tests with the lab equipment consisted of a series of “loop-back” experiments. The MATLAB software was installed on a laptop, which then was used to interface with the target computer in the lab that connected to the board. The experiments involved outputting a series of signals to the board, and measuring the signal back with the input. For the final test, the team connected a motor to one of the board’s encoder inputs. As the shaft of the motor was rotated, the received data was recorded. The second component of the project was to create a part for the laser cutter. The team was allowed to use some creativity on the specific design, as long as the part met the requirements of fitting in the 4” x 4” cutting area and demonstrated both the cutting and etching abilities of the laser cutter.

Materials and Methods

A large component of this lab was configuring equipment and learning how to develop in Simulink. Our group struggled for a few days on getting all the software installed and booting everything up. We ultimately achieved a setup consisting of a Windows 10 Workstation to be used as a development environment with Matlab 2017a and Microsoft Visual Studio 2015 installed. This laptop was to act as a controller. Next an ethernet cable was used to provide a network connection between the laptop and our lab workstation, which was booted into the Matlab R2017a SRT from a USB flash drive. The workstation or “target” had a PCI card installed that interfaced, via ribbon cable, with the Quanser Q4 board (see Figure 1). A shortage of wires required for connecting the loopback tests was a point of concern, but we were early enough in working on the project that there wasn’t too much competition for the limited resources.

Banana cables were used in the analog sine loopback test, where a sinusoidal wave was outputted on one of the Q4 board’s analog outputs RCA output 0, and input to RCA input 0, forming a “loop”. The analog signals that were used in these loopback tests were first a 100 Hz sine wave (figure 5), followed by a 2 kHz sinusoid (figure 6).

Next we had to assemble a cable for the digital-to-analog test with a square wave signal, operating at a frequency of 100 Hz (figure 7). Our Quanser board has an issue where the first 8 DIO pins are clamped upwards one volt which was a process to debug. Fortunately, the next set of eight behaved properly and we were able to proceed onwards. The motors were fairly easy to work with and we were lucky enough to get the one motor module that properly recorded the number of degrees it was turned. A special RCA-to-jumper patch cable was constructed for this stage of the experiment (figure 2).

To design and create a part for laser cutting, a variety of software and a laser cutter were necessary. Initially, SolidWorks was used to produce a drawing of the desired part. This was chosen due to the team’s familiarity with the software. SolidWorks was convenient and it was easy to export files with the ".dwg" extension and import the result to AutoCad. A puzzle piece was decided on as a demonstration of the laser cutter’s ability to produce lines, curves and etch information such as letters. AutoCad then allowed for easy adjustment of the colors used in lines on the drawing. The final physical component was produced using clear acrylic.

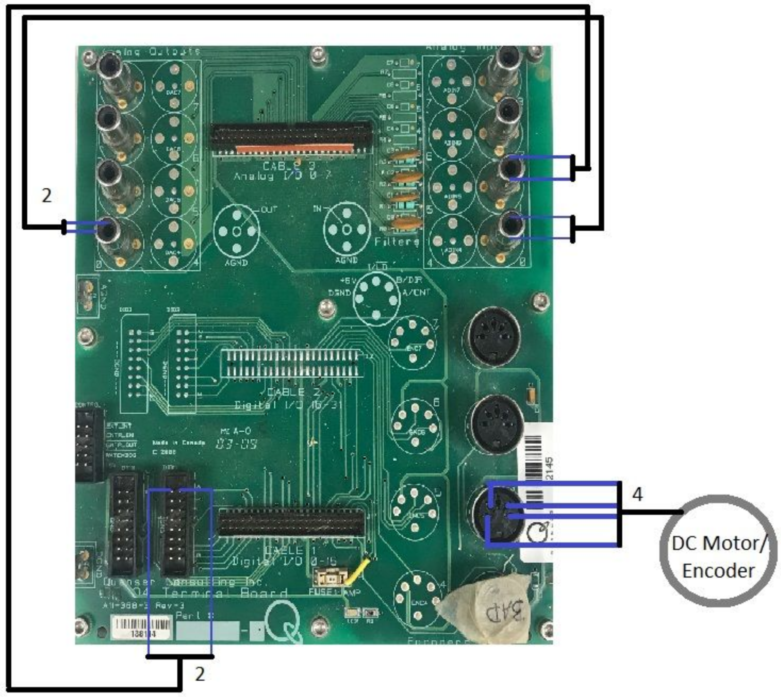

Figure 1: Quanser Q4 Experimental Wiring Diagram

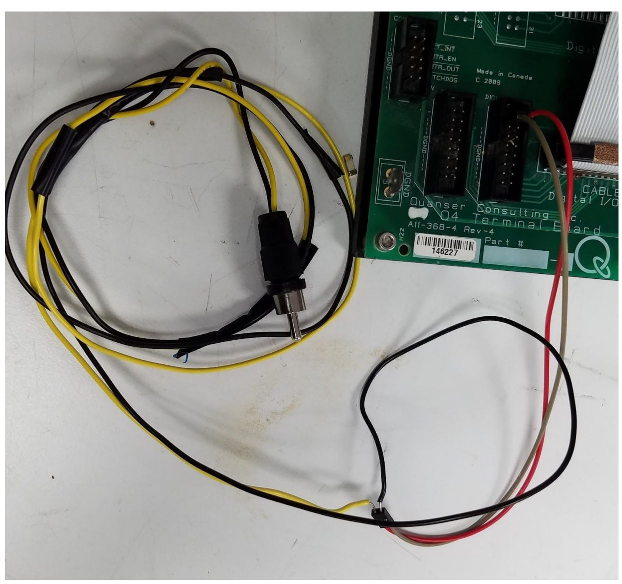

Figure 2: RCA-to-jumper patch cable for digital-to-analog square wave test

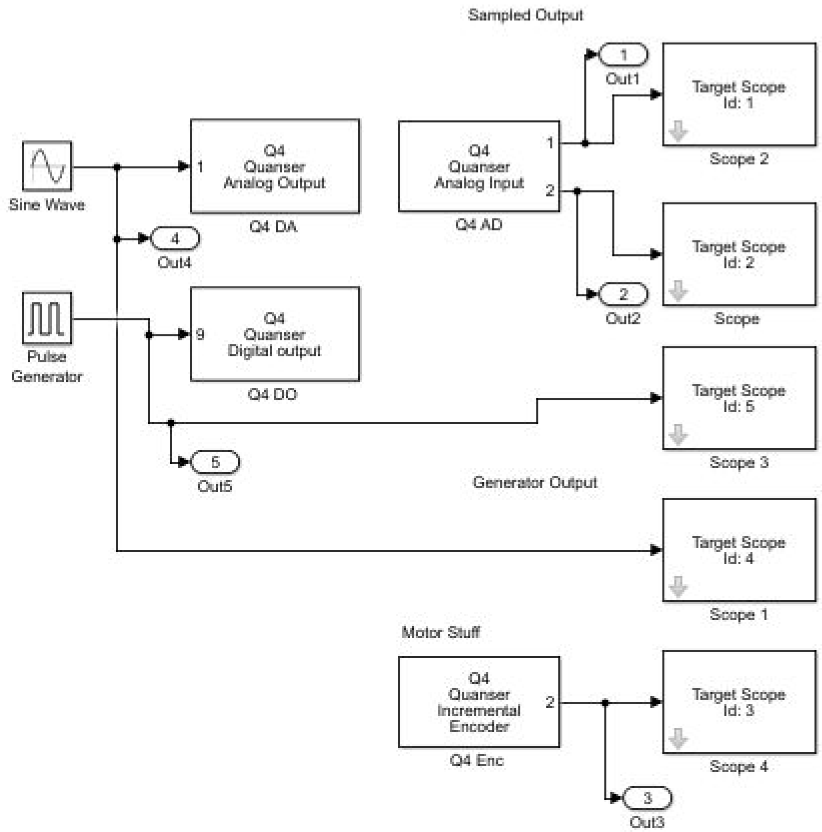

Figure 3: Simulink Block Module Diagram of the System

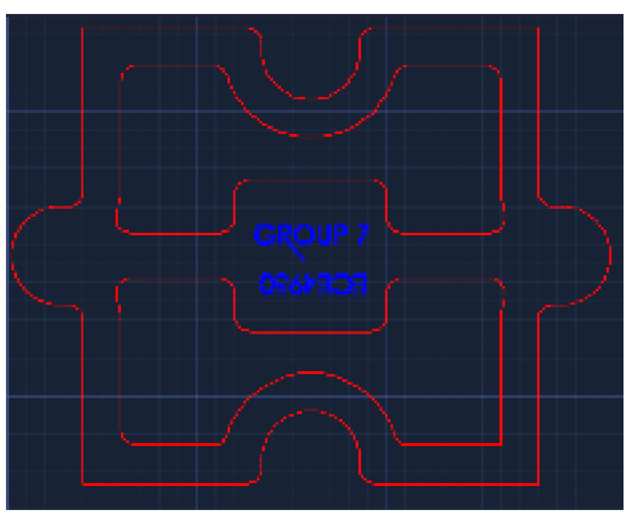

Figure 4: AutoCAD drawing of component to be cut

Discussion of Results

The loop-back experiments gave the correct results after some minor troubleshooting. Errors in the output that existed prior to this troubleshooting include incorrect frequencies of sinusoids, as well as incorrect sampling rates. When entering the frequencies of the sinusoids in the appropriate Simulink module, we failed to convert the frequencies from Hertz to radians per second. Simply converting and re-entering these values fixed this issue and the output waveforms were correct. The sampling rate that we were using allowed the system to identify the 100 Hz sinusoid and record it as expected. When transitioning to the 2 kHz sinusoid, however, the system could not sample the signal enough to accurately display the sinusoid. After increasing the sample rate of the system and converting the units of frequency all outputs behaved as expected. Each of the signals we were generating and then reading had a small delay between the signal being input to the board from the workstation and the analog signal that was looping back into the board. This is due to the signal having a propagation delay traveling from the slave pc to the board and back again before being read. Another quirk we noticed is that the motor doesn't read in degrees. Instead there are 400 increments along a single rotation. While this does increase the precision it can be controlled with and divide a single revolution into 400 quanta that is a multiple of 10, we did have a concern that it might create problems while calculating rotations.

Producing a drawing ready to be cut by the laser cutter was straightforward. Future changes may include the use of Adobe Illustrator for cutting in the Clemson Makerspace. Adobe Illustrator has the advantage of easier scaling of drawing sizes, along with easier cutting using the Makerspace's software. Additionally, the Makerspace allows for easier reservation of time without the need for assistance by a TA for lab access. The produced drawing had slight scaling issues whereby the AutoCAD component was slightly smaller than desired. This was an easy correction to make within AutoCAD, thus the issue was not present in the final piece.

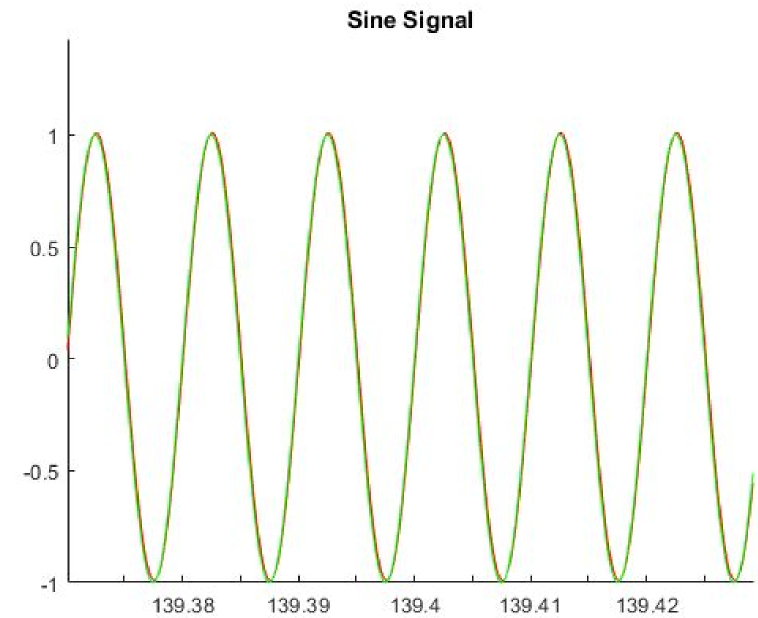

Figure 5: 100 Hz Sinusoid Signal with Feedback

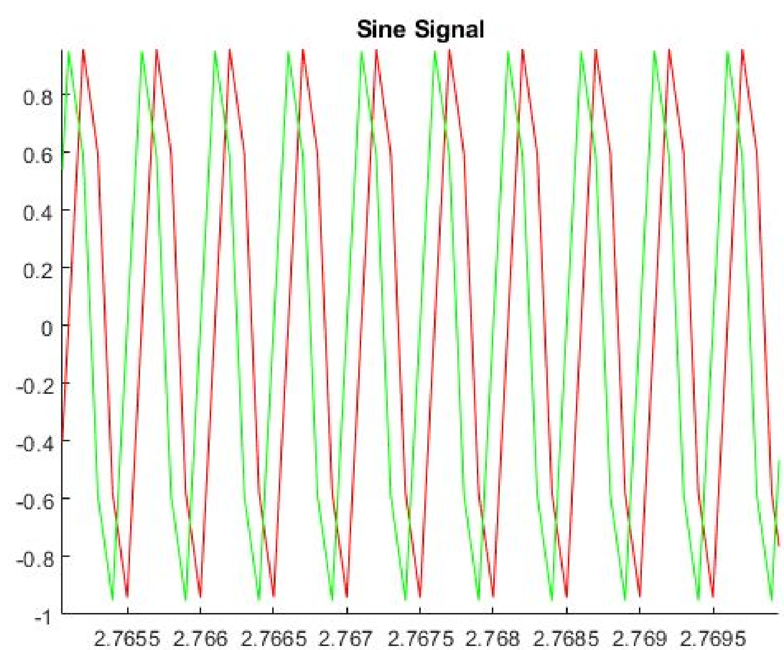

Figure 6: 2 kHz Sinusoid Signal with Feedback

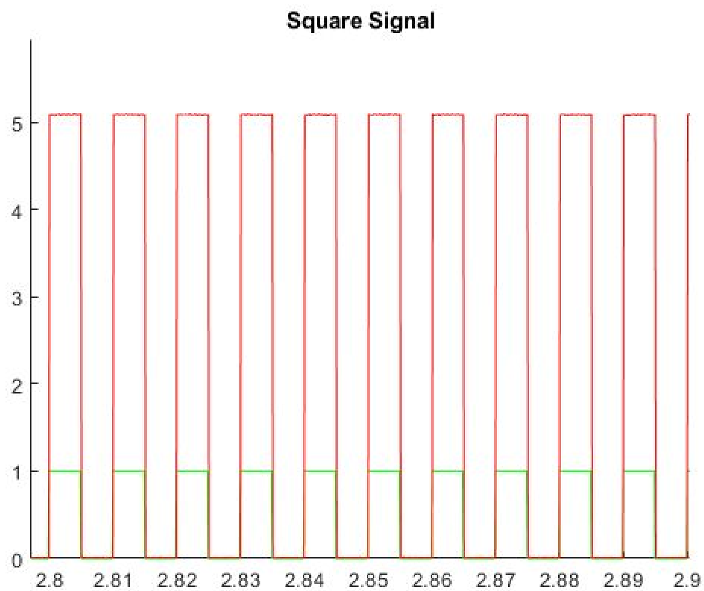

Figure 7: 100 Hz Square Waveform with Feedback

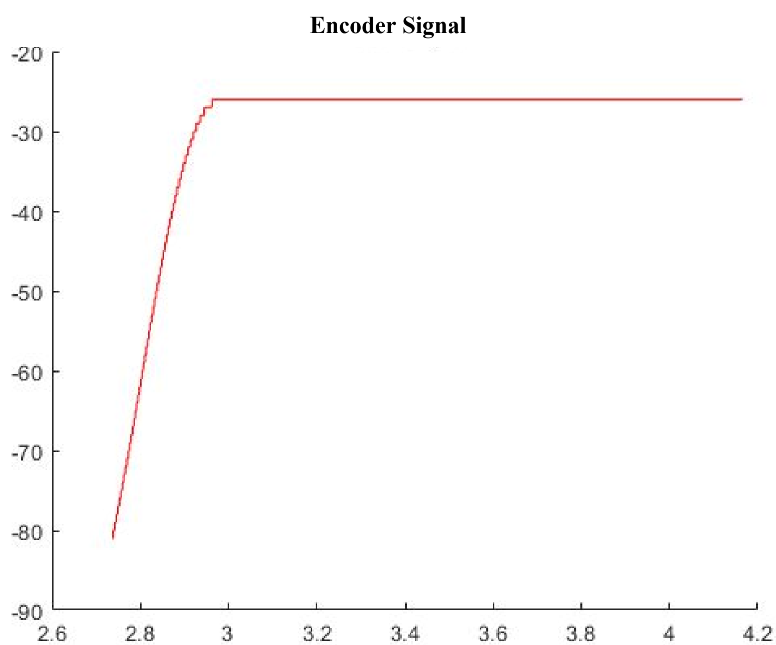

Figure 8: Encoder Output

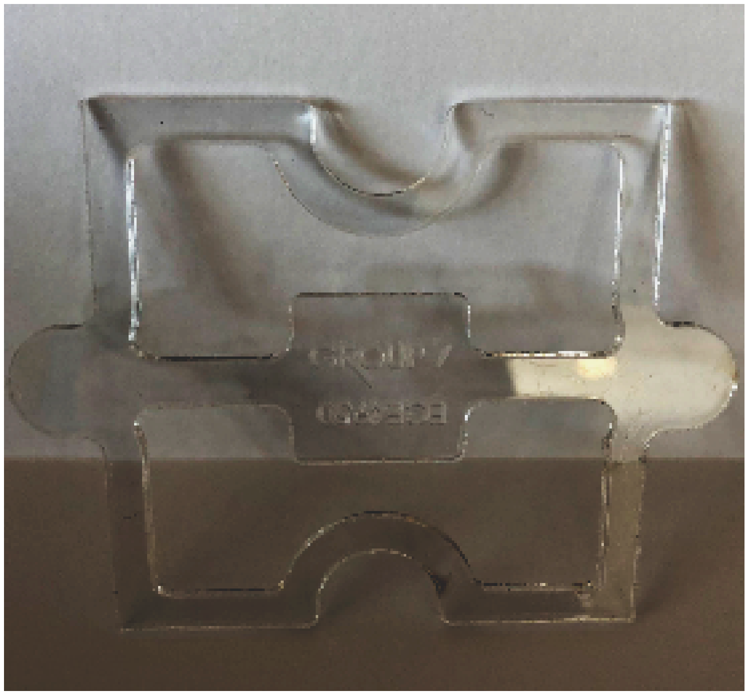

Figure 9: Final Laser Cut Piece

Conclusions

The Quanser Data Acquisition System, with its Hardware-in-the-loop structure, has proven well suited for certain robotics applications - specifically those involving stationary robotics elements that will be confined to a lab bench.

The Q4's single analog-to-digital converter (ADC), with 4 analog inputs, can provide real-time feedback. It can also control mechanical parts as well as input from a variety of transducers, particularly sensors. This system also includes: analog outputs, 16 channels of digital I/O interfaces (either input or output), encoder inputs, and Pulse Width Modulation output. These features make the system a suitable choice for electromechanical systems. The Q4, for our purposes, will serve as the equivalent of a microcontroller in an embedded system. Note, however, that any robotics system created with the Q4 would not be an *embedded system* by definition. This is because the target computer constitutes a standalone computer system that simply interfaces with motors and sensors through the Q4 data acquisition board.

Similarly, using Simulink and MATLAB as the logic/controller element of a robotics system, implemented with the Q4 Data Acquisition System, has the potential to effect a powerful and fault-tolerant robot. With MATLAB, our team will be able to create complex signal processing and control systems that rely on feedback. Another advantage of MATLAB is that the Time-to-Market will be as minimal as possible, and the design cycle will be most optimal.

Within the context of Team 7's Senior Design projects, laser cutters will serve as a powerful rapid prototyping and development tool. Mechanical components can be quickly generated with great precision. This will aid not only in the prototyping process, but in the realization of the final design. For future laser-cut components, it may be desirable to use another material, such as quarter-inch plywood, for the production of parts. This is a more cost effective material which is easier to source at local businesses, such as Lowes. If acrylic is to be used, it may be beneficial to raster a texture on the surfaces of components for visibility. This would produce components which are easier to work with and visualize at the expense of cutting time per piece.

The xPC system in conjunction with the Quanser Data Acquisition System provides a powerful and flexible (if a bit dated) platform for mechatronics applications.

References

[1] ECE 4950 Project 1Configuring a Real-Time Workstation / Introduction to the Laser Cutter
http://akapadi.people.clemson.edu/ece4950files/Fall2017Projects/Project1_2017.pdf

[2] Q4 Data Acquisition System Manual
http://akapadi.people.clemson.edu/ece4950files/manuals/quanser_q4_manual.pdf

[3] ECE 4950 Integrated System Design References
http://people.clemson.edu/%7Eakapadi/ece4950_references.html

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Score	Pts		Performance Indicators
	15	**General Format - Professional Looking Document/Preparation (whole document)** a) Fonts, margins (11pt, times new roman, single spaced. 1" margins on all sides). b) Spelling and grammar are correct c) Layout of pictures – all figures need numbers and captions and must be referenced in the text d) Follows the page limitations below. e) References. Use IEEE reference format. f) This grading sheet is included as the final page.	g.1
	20	**Page 1: Title, Group Name, Group Members, and Date** **Executive Summary** (~1/3 of the page) Provide a brief summary of the whole experiment. Use language that targets **a nontechnical audience**. An important skill for an engineer is to communicate complex technical information to a general audience that may be involved in decision making, e.g. marketing. Important criteria: a) Can a non-technical audience (~ high-school degree) read this section and understand your goals, procedures, and conclusions? b) Use simple words and graphics to help explain	g.1

	40	The next sections of the report follow the standard **laboratory report format**. **Page 2: Materials and Methods for the Loop-back Experiments (don't need to describe the laser cutter)** (< 1 page) You are establishing the credibility and usefulness of your results by providing all the details so that someone else could repeat your experiment. As an example, MATLAB 2011a may behave differently than MATLAB 2010b – the software version information which would be required to reproduce your result should be included. This section should answer the following: a) What equipment is used (i.e. real-time workstation), include software versions. b) How were the experiments conducted? How is the equipment connected and used? Describe the instrumentation, cables, connections, and experiments using diagrams and photos. You should have drawings (pin connection and connector part numbers) for any special cables, an RCA-RCA cable is well known and you would not need to make a drawing for this cable. **Pages 3-4: Results and Discussion for the Loop-back Experiments** (< 2 pages) Describe what you have done. Include plots (from MATLAB, not photos of the Target screen) for each of the four loop-back experiments and a brief discussion of how you interpret the result. Describe the results of the encoder experiment. Did you demonstrate (through your documentation) that the equipment has been configured and used correctly? **Page 5: Conclusions and References** (< 1 page) a) Based on this experiment, do you recommend this equipment for use in a robot control project? What are the possible limitations? Your results and observations should be the basis for your conclusions. (~1/2 page) b) What are the possible uses for the laser cutter in your projects? (~1/4 page) c) Use IEEE format [3], at least cite the class website http://people.clemson.edu/~akapadi/ece4950_references.html.	k.2 k.2 k.2
	5	**Page 6: Grading Sheet**	g.1
	20	**Laser Cut Part** (turn in with printed report) Grading based on:	k.2
		a) How well does this part demonstrate the capability of the laser cutter to make prototype parts for an automated (robotic) system? b) Originality and creativity	i.1