ECE 4950 – Research Project 1
Team Bode, Bode, Bode, Bode Plotting Everywhere (W8)
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Executive Summary

Project 1 required us to become familiar with the real-time control workstation in lab as well as the laser cutter and the corresponding software for each. Software used throughout the experiment included xPC, Simulink, MATLAB, C++, and AutoCAD. When working with the equipment, as seen below in Figure 1, there are three major components: the host laptop, the target PC, and the Quanser Q4 interface board. In order to test that all of these will work together properly, we ran a series of loopback experiments diagrammed in Figure 2. These experiments required a signal be sent from the host PC into both analog and digital outputs on the Q4 board. To facilitate the required connections, three cables were soldered. The outputs were fed back by these cables to the board's analog and encoder inputs. The loops created verified the board's outputs could correctly send signal, the soldered cables could carry signal, the board's inputs could receive signal, and the target and host machines could transfer signal. Since the control workstation is real-time, we were able to monitor the results received by the host PC to ensure they were close to the original input waveforms. The specific signals used to test our tools include sine and square waves, which are seen below in Figures 3 and 4 respectively.

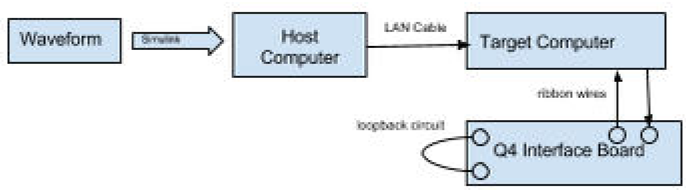

Figure 2: Feedback Diagram [1]

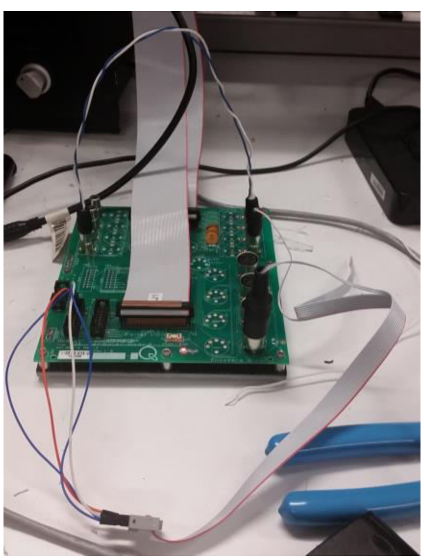

Figure 1: Q4 Interface Board

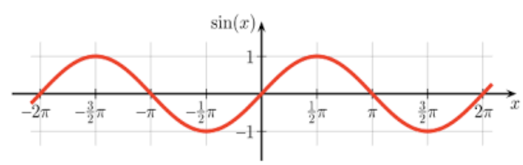

Figure 3: Sine Wave

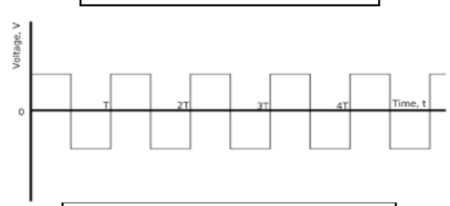

Figure 4: Square Wave

Materials and Methods

Host Laptop	Ryan Barker's laptop was used as the host computer. The IP address of the host computer's Ethernet port was changed to the same subnet as the target PC allow the host computer to interface with the target computer.
Target Computer	The designated team computer in the lab, booted up with xPC software from a boot disk. The disk was created on the host computer in xPC. Use of this software allowed communication between the host and target computers.
MATLAB	Mathworks 64 bit MATLAB 2015a, Simulink, and xPC were used on the host laptop to control the feedback loops created.
Q4 Interface Board	This was the hardware under test for the first five parts of the project. In each part, a waveform was sent from an output to an input on the Q4 board. Part 1: 100 hertz sine wave from analog output 0 to analog input 1. Part 2: 2000 hertz sine wave from analog output 0 to analog input 1. Part 3: 100 hertz square wave from digital output 0 to analog input 0. Part 4: 100 hertz square wave from digital output 1 to encoder input 0. Part 5: Encoder input 0 was connected to a provided US digital encoder. This verified the potentiometer in the board could correctly count the number of times the encoder turned.
RCA-RCA Cord	A connection cord of two male RCA plugs soldered to loop the analog input 1 and analog output 0 ports of the Q4 board. It is seen below in Figure 5.
Digital In/Out Ribbon Cable	Two segments of 10 pin digital IO ribbon cable were soldered to pins and used to connect DO 0 to AO 0 and DO 1 to EO 0. Figure 6 shows the cable. Because the Q4 board was built for 16 pin ribbon cable, four single pin digital IO cables were to connect this cable to the Q4 board.
Wiring Convention	All wires used were soldered by an engineer in our group. Blue wires were used to represent signal lines. Orange or white wires were used for ground.
Acrylic Glass	The material used to cut a design from the laser cutter.
AutoCAD 2015	AutoCAD was used to draw a schematic for an acrylic glass part, which was cut with the assistance of the lab TAs using a laser cutter.

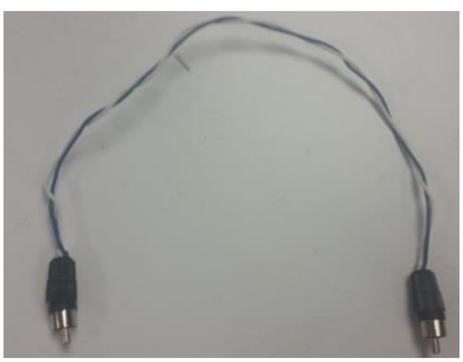

Figure 5: RCA Cord

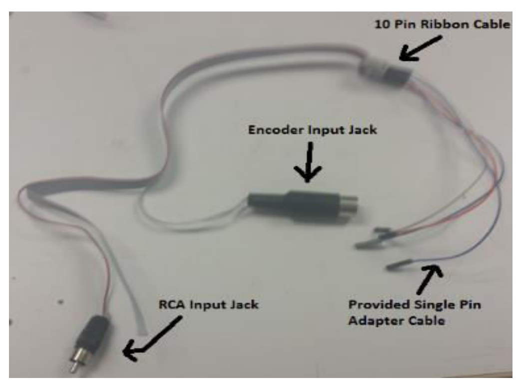

Figure 6: Digital Ribbon Cable

Results and Discussion

Our initial impressions after the first day of lab were that we entered this project too optimistically. Getting used to the new environment and diverse set of tools available to us proved to be a steep learning curve. Further, no one in our group had any prior experience working together. This only added to the challenge as we learned to communicate effectively with each other. The beginnings of this project provided perspective on how simple tasks can sometimes be surprisingly difficult when working with a new group of people.

The preparations for the loopback testing in lab one involved two parts: soldering the cables needed for the lab and setting up communication between the host and target PCs. Due to a lack of experience soldering across the team, the three necessary cables took an hour to create, but the process was straightforward. Connecting the PCs together involved creating a boot disk for the target PC from xPC on the host computer and changing the IP address of the host computer's Ethernet port to be in the same subnet as an IP configured for the target PC. Changing the IP on the host machine was easy, but getting a working boot disk proved to be a challenge. After burning two disks that caused the target PC to infinitely boot cycle, a setting for the target PC's RAM was discovered incorrectly set to zero in an additional menu of xPC. Changing this to be automatic and burning another disk allowed the machine to boot into the target xPC software. At this point, the host was able to ping the target, so the group proceeded with the loopback tests.

To produce the output for loopback experiment one, the new_analog_loopback_q4.slx demo file was modified by changing the frequency of the sine wave to 628 radians per second (100 hertz) and the analog input 0 block was changed to analog input 1. This was accomplished by changing the channel vector field for the input block from a one to a two. Note that MATLAB and C++ are zero-index based, and Simulink is one-index based, so analog input two in Simulink translates to analog input one on the Q4 board. Each scope was set to take 250 samples and had a decimation of 1. The default sample time of 1 millisecond was used on both pins. The cable from Figure 5 was used to connect the analog input and output pins and Figure 7 shows the output waveform in xPC. The output sine wave is smooth and fit the scope sufficiently, which was expected because the sample time on the input port was less than the sine wave's period.

Loopback experiment two was similar to loopback experiment one, except with a sine wave period of 12566 radians per second, or 2000 Hz. There were issues displaying this wave on the scope, however, as it initially appeared zoomed in on a small part of the wave and distorted. This was due to the sample time being 1 millisecond, but the wave's period only being half a millisecond: The wave was moving too fast for the scope to capture a complete period accurately. This was fixed in Simulink by changing the sample time on both pins to 0.1 milliseconds and increasing the number of samples on the host laptop's scope to 1000. Figure 8 shows the resulting wave, which again is smooth but at a higher frequency than the wave in Figure 7.

Loopback experiment three involved deleting the sine wave and analog input blocks and replacing them with pulse generator and digital input blocks, respectively. The pulse width, or duty factor, of the input was changed to 50 percent and its period was set to 0.01 seconds to obtain a 100 hertz frequency square wave. Analog input 0 and digital output 0 were connected by the analog half of the cable in Figure 6 for this phase. Because the wave was only 100 hertz, the default sample time of 1 millisecond was set on both pins, and the scopes were set to record 100 samples with a decimation of 1. Figure 9 shows the square wave on the host scope in xPC. Note that this waveform is reasonably smooth, but the sharp corners of the wave are rounded off. This is expected, since the real world is analog and the digital output pins cannot output a wave with an instantaneous change in voltage. They can, however, output something that is close enough to be interpreted as instantaneous change in digital circuits, which is exactly what was observed in Figure 9.

Loopback experiment four involved changing the analog input block from experiment three into an encoder input block and adding a numerical target scope at the end of the circuit. This engaged the potentiometer in the Q4 board's encoder, which caused the numeric target scope to count down by one for every pulse in the input square wave. The encoder input portion of the cable in Figure 6 was used for the feedback, with signal being carried over encoder pin A. This is why the wave counted down rather than up. As seen in Figure 10, the host scope connected to the encoder and showed its current value, producing downward stepping behavior over time.

The fifth experiment was an extension of the fourth, which did not involve feedback. Instead, the input wave portion of the circuit was deleted in Simulink and a supplied encoder shaft was connected to encoder input 0. Once the model was built and running, the numeric target scope on the encoder could be manually manipulated by turning the encoder shaft. Turning the shaft right caused the scope to increment, while turning the shaft left caused the scope to decrement. This verified the ability of the board's encoder to react to manual changes.

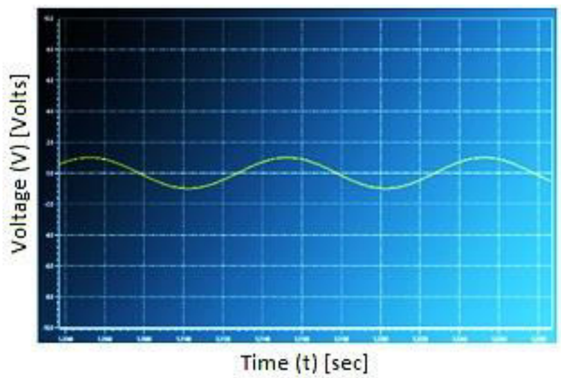

Figure 7: Host Scope 100 Hertz Sine Wave

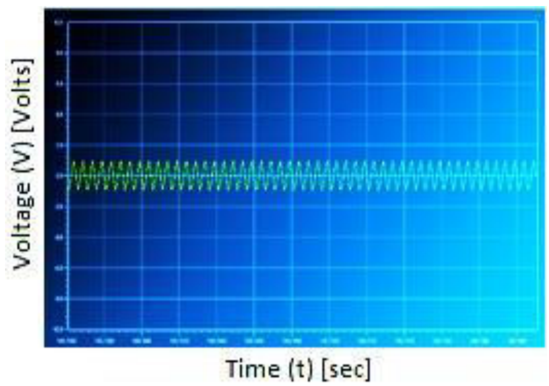

Figure 8: Host Scope 2000 Hertz Sine Wave

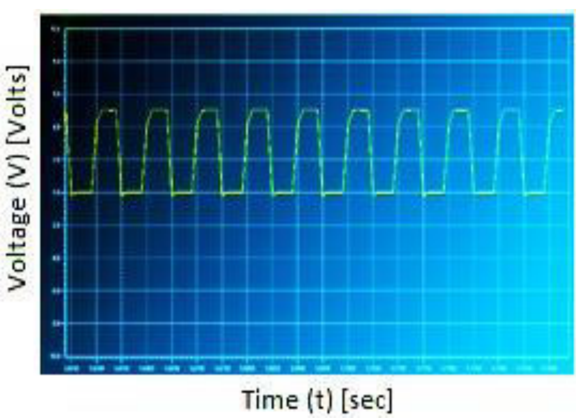

Figure 9: Host Scope 100 Hertz Square Wave

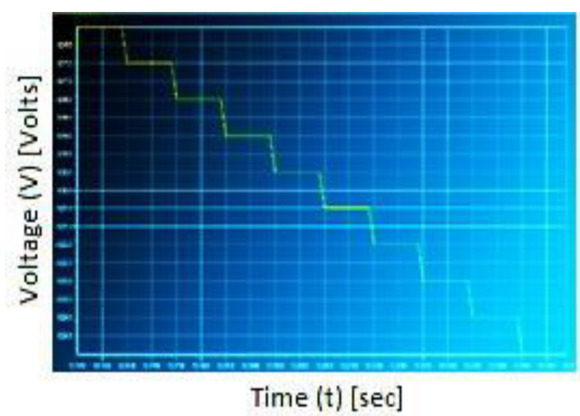

Figure 10: Host Scope Encoder Output

A quick note about the screenshots on the previous page: All data was taken as print screens in xPC because no one in lab could figure out how to transfer data from xPC or Simulink to MATLAB 2015a (not even the teaching assistants). We found a way to get data from Simulink into MATLAB (using the 'To Workspace' block), but the TAs confirmed that the time data did not correctly transfer, leaving rough and incorrect images for the waves. We did our best to enhance the images of xPC, but recognize that they are still difficult to see on printed paper (holding them in light helps). We apologize for the inconvenience, and please grade us accordingly, but we tried to do the best with the tools that we had.

Conclusions

Because all five experiments were successful, our team recommends the Q4 interface board, target PC, and host PC used for further use in the robotics lab. Since the waves in xPC (Figures 7 through 10) were nearly identical to the input waves, we expect a low distortion and high accuracy when transferring signals across the ports tested on the board. Due to this experiment, we know for certain that our board has two working analog inputs, one working analog output, two working digital I/Os, and one working encoder input. Further, if the reliability of any of the other ports on the board is ever doubted in the future, it will be easy to use the cables and Simulink files created in this lab to quickly test their functionality.

The main limitation on the Q4 interface board are the amount of voltage and current it can transfer across it. Hooking a 100 volt source to the board is certain to at minimum blow a fuse but also probably render an input unusable. Going forward, we need to carefully select the equipment and sensors we buy to ensure compatibility with the Quanser Q4 board.

The combination of MATLAB, Simulink, and the Quanser Q4 will be invaluable as we design our robot. Simulink will act as the brain control system for the robot and the board will allow us to interface equipment or sensors into the control system as necessary. Once we get the Simulink to MATLAB transfer working, we can use the vast array of powerful MATLAB functions to interpret and manipulate data from the system if needed.

The laser cutter was used to create an object, which was required to contain at least one etch and one cut. We designed, on AutoCAD, a pepperoni pizza with one bite missing to fit the criteria. The "bite" was extremely detailed in order to test the precision of the laser cutter. After transferring the pizza design file to the laser cutter, cuts and etches were made on a piece of acrylic by the laser. We were pleasantly surprised with the pinpoint accuracy of the machine, as can be seen by comparing our designs to the physical "pizza" which was made. This section of the project allowed us to grow accustomed to using AutoCAD and the laser cutter. Since the machine cut mirrored our design, we were assured that the laser cutter will be able to handle any intricate design we'll need it to cut for future projects (i.e. mechanical arm for a robot).

References

[1] A. Kapadia. ECE 4950 - Integrated System Design [Online]. Available: http://people.clemson.edu/~akapadi/ece4950_references.html. Cited: 9/03/2015.

[2] K. Azad. Better Explained [Online]. Available: http://betterexplained.com/articles/intuitive-understanding-of-sine-waves/. Cited: 9/03/2015.

[3] Square Wave Offset [Online]. Available: https://upload.wikimedia.org/wikibooks/en/e/ea/Square_Wave_Offset.svg. Cited: 9/03/2015.

ECE495 – Research Project 1

Group Name and Members: ____

Score	Pts		ABET Outcomes
	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. (5 pts)	g
	20	**<u>Page 1: Title, Group Name, Group Members, and Date</u>** **<u>Executive Summary</u>** (~1/3 of the page) Provide a brief summary of the whole experiment. Use language that targets **a non-technical 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
	40	The next sections of the report follow the standard **laboratory report format.** **<u>Page 2: Materials and Methods for the Loop-back Experiments (don't need to describe the laser cutter)</u>** (< 1 page) You are establishing the credibility and usefulness of your results by providing all the details so that <u>someone else could repeat your experiment</u>. 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. **<u>Pages 3-4: Results and Discussion for the Loop-back Experiments</u>** (< 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? **<u>Page 5: Conclusions and References</u>** (< 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 <u>http://people.clemson.edu/~akapadi/ece4950_references.html</u>.	k
		<u>Page 6: Grading Sheet</u>	
	25	**<u>Laser Cut Part</u>** (turn in with printed report) Grading based on: 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	k