To: Team 6
From: Han Peng
Date: March 26, 2021
Subject: Testing Results Report

This is the memo page for our testing result report. In this report we are going over the testing phase of our project. We worked on multiple tests to verify that our project is working. The tests are based on the project requirements and how each part of that we are testing is vital in our project.

Introduction

Our client is Dr. Ventaka Yaramasu; he is an assistant professor at Northern Arizona University. He teaches electrical engineering courses and advanced classes about electric drives. Dr.Yaramasu has many interesting research types about power electronics, renewable energy, electric vehicles, and digital control. He published a book about Model Predictive Control of Wind Energy Conversion Systems. Furthermore, He published many different interesting research papers in IEEE transactions and conferences. Dr.Yaramasu currently teaches Electric Drives and Advanced Electric Drives courses at Northern Arizona University. These co-convened courses use dSPACE DS1104 and MATLAB/Simulink-based hardware labs that are designed and distributed by the University of Minnesota These hardware labs are quite expensive with dSPACE hardware costing $4000 per unit and software upgrades costing $300 per unit. The problem is that upgrading or adding hardware and software with this solution is very expensive. It is also extremely difficult for students to replicate this solution at home. This is a continuation project from AY19-20. The last year's students verified that all the dSPACE based experiments can be implemented with the Arduino control board which is cheaper than the dSPACE hardware. Also, to design the circuit diagram for the electric drive labs will need MATLAB/Simulink as software. The objective for this year's capstone team is to design a compact inverter board and combine it with the Arduino controller and make the kits ready for deployment at NAU. This work could be used as a prototype for using Arduinos in the Electric Drives class at NAU or any other university. This work could make the Electrical Engineering curriculum more accessible to universities that do not have expensive hardware to support an electric drives class.

This project aims to design and build a compressed inverter board (PCB) and syndicate the Arduino controller with the board to implement the Electric Drives lab experiments. A figure showing the idea of the project can be found in appendix i. The new design's goal is to make the electric drives courses labs easier and flexible for the students. The classes are using dSPACE hardware and control desk software for lab experiments. The dSPACE hardware and software are too expensive, and our project is to build a cheap instrumentation platform to do the electric drives labs. The Arduino is an affordable solution to replicate the dSpace functionality. Firstly, we must work on the dSPACE lab experiments to get familiarized with how the PCB and the motor are working. Therefore, we will implement the experiments and program them into the Arduino. A figure of a redesigned circuit can be found in appendix ii. We will still be using the MATLAB/Simulink with the Arduino to check the measurements and the results. The feedback can be shown on a plot. The project aims to lower the cost of the electric drives lab's equipment and make the student's experience with the electric drives labs easier to understand and less difficult to set up.

After familiarizing ourselves with the labs using the dSpace and getting the results to be our reference results. We started doing some research on how to use the Arduino linking it with the Simulink software. We needed to replace the current labs that are made of some dSpace Simulink blocks. So, we started with basic circuits including the digital to analog converter, analog to digital converter, and an encoder circuit to receive feedback.

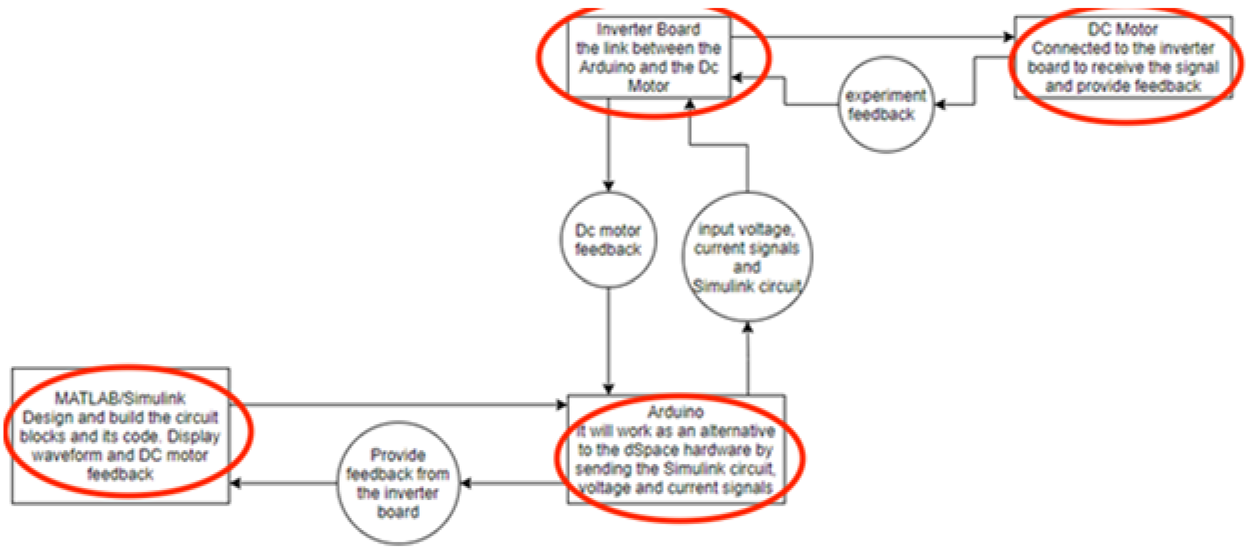


Figure 1: System architecture. The red circles represent the parts tested.

Instructions: List all of your requirements, and use a numbering system.

Type of Test	Status	Req #	Requirement
		1	Arduino integration
		1.1	Establish the connection between the arduino and Computer.*
Integrate		1.1.1	Connect the Arduino into the inverter board and the DC Generator encoder.
Inspect		1.1.2	Get feedback from the encoder and display the results on Simulink. *
UTM		1.2	Display the current and voltage from the inverter board connected to the Arduino.
Inspect		1.2.1	Required the DB37-M2 connector to connect the Arduino in the inverter board and firgure out the PWM pins in both inverter board and DB37 connector. *
		1.2.2	Place an order for the inverter board component for next year group because it's a continues project for next group.
UTS		1.3	Display the required units based on what the lab is asking for i.e Voltage,Speed, and current
		1.3.1	Compare the results from the Arduino with the dSPACE results we got from last semester.

Figure 2: Our requirements excel spreadsheet.

Most important requirements

On our excel spreadsheet, we chose three requirements that we deemed important to our client. The first requirement is establishing a connection between the Arduino and the computer which is the MATLAB/SIMULINK software. It is a vital part of our project because not being able to connect the Arduino to the computer means that we can perform the experiments. the labs are performed using the SIMULINK software for circuit design and code generation. Our client made it clear to us that we must perform the labs using the Arduino and the SIMULINK software. failing to meet that requirement means that we cannot move on with our project and start implementing the labs. The second requirement is to connect the Arduino to the dc motor encoder. This is also an important step in our project because it will provide us with feedback from the motor showing the encoder's position and the speed of the motor. Most of the labs require feedback from the dc motor's encoder hence why this an essential part of our project. like the first requirement, our client urged us to focus on this requirement for it being such a huge part of our project. The final requirement that we have identified is connecting the Arduino to the inverter board using a DB37-M2 connector also figuring out the pulse-width modulation pins in the inverter board so that we can use connector pins and attach wires to them connecting it to the Arduino. It is important for the Arduino to be connected to the inverter board because it will enable it to send PWM and digital signals to the board. Those signals are the signals that should control the DC motor. Going back to the two previous requirements, our client stressed the importance of connecting the inverter board to the Arduino for us to be able to finish all the labs. failing to meet these requirements will result in the failure of completing this project.

Types of tests:

The first type of test we wanted to perform a step-by-step unit test. The parts that are involved in this test are the dc motor, Arduino, and the inverter board. For this test we wanted to input different voltages from the Arduino to the inverter board so that we can change the speed of the motor. The second type of test is the integration test. The part that is involved is the Arduino. We want to connect the Arduino to the inverter board, and the dc motor encoder. The third type of test is the matrix unit test. The parts that are involved are the Arduino and the computer. We wanted to establish a connection between the Arduino and the computer software SIMULINK.

Major tests

The first major test we did was we wanted to establish a connection between the Arduino and Simulink. We start with a few simple circuits to gain an understanding of how to create a circuit on Simulink and generate its code to be sent to the Arduino. We started with turning on a single LED light using the Arduino and then we moved on to turning on the LED light by using a button. Both tests were successful. After completing those simple tests, we wanted to see how we can build a circuit to the PWM signals from the Arduino. The PWM signals are important for our project because most labs contain them. For us to control the speed of the motor we must be sending PWM signals to the inverter board so that it can deliver them to the dc motor. On the inverter board there are three phases that control the motor, phase A, B, and C. For our testing we connected phase A to Arduino digital pin 9 phase B to pin 8 and phase C to pin 7. All of them are set to be outputs so that we can connect them to the oscilloscope for us to see if the signals are being sent. We did 6 total tests. Each test we have a different PWM signal that is being sent to the digital outputs and the oscilloscope should display a digital graph showing the PWM signal. All our 6 tests passed, and we established the PWM part of our labs.

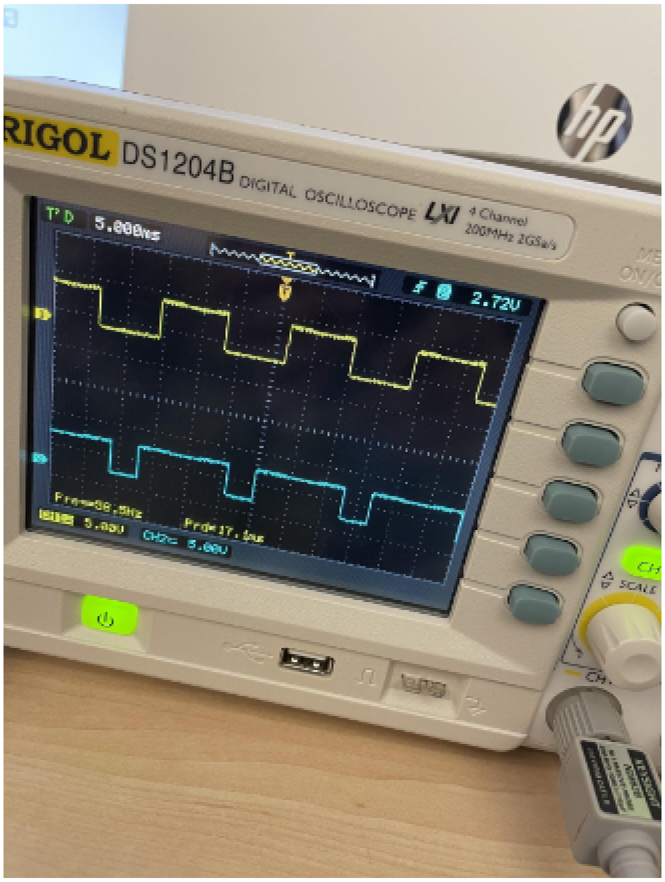


Figure 3: One of the test results that we ran. Phase A is 0.5V and Phase B is 0.25V and Phase C is 0V

The second major test that we did was connecting the Arduino with the inverter board and the dc motor encoder. The first connection we wanted to make is connecting the Arduino to the inverter board. We used a DB37-M2 connector to establish that connection. We started off by figuring out where each PWM pin on the inverter board can be found. Searching the internet for the user manual of the inverter board we successfully found and connected the pins on the DB37-M2 connectors. Then we connected the encoder to the Arduino using a DB15-M2 connector. Like the one before we had to look up its user manual so that we can identify what each wire function. We successfully completed the connection. Finally, we had to connect a PNC cable from the board to the Arduino so that we can get a measured current of the DC motor. We failed to do so and that derailed our project progress.

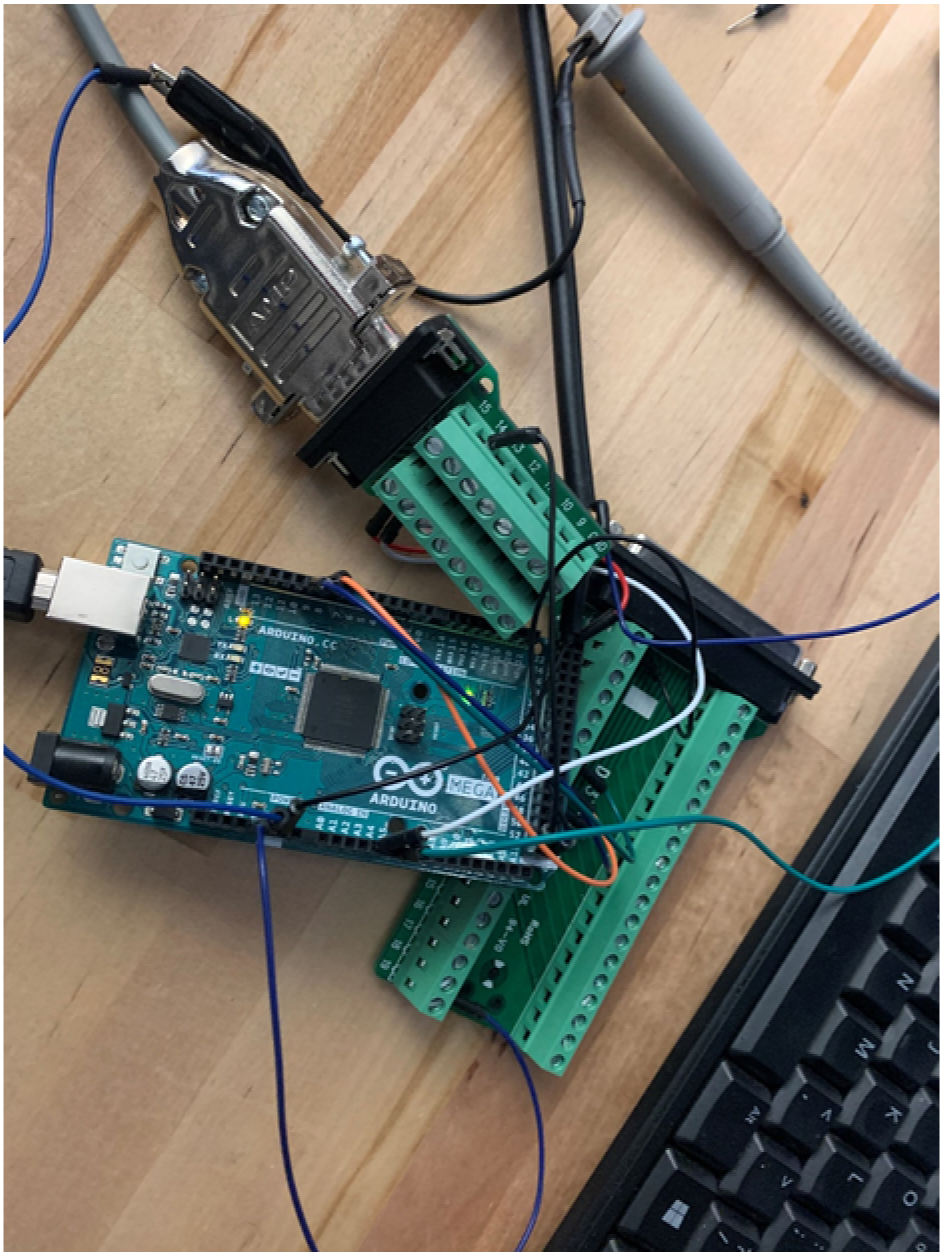


Figure 4: The two connectors connected to the Arduino with the correct wire from the user manuals.

The last major test we tried to do is the input of different voltages in the inverter board to change the speed of the DC motor. A few of the labs require us to change the speed of the motor while it is running. It asks us to do so by sending in different voltage inputs into board and with that the speed will increase or decrease depending on the voltage being sent in. We did not finish the prerequisites for this test, so we failed attempting it. We did not have enough time to reach that level in our project so we could not perform the tests. You can refer to appendix iii for the flow chart for this test.

Analysis of results:

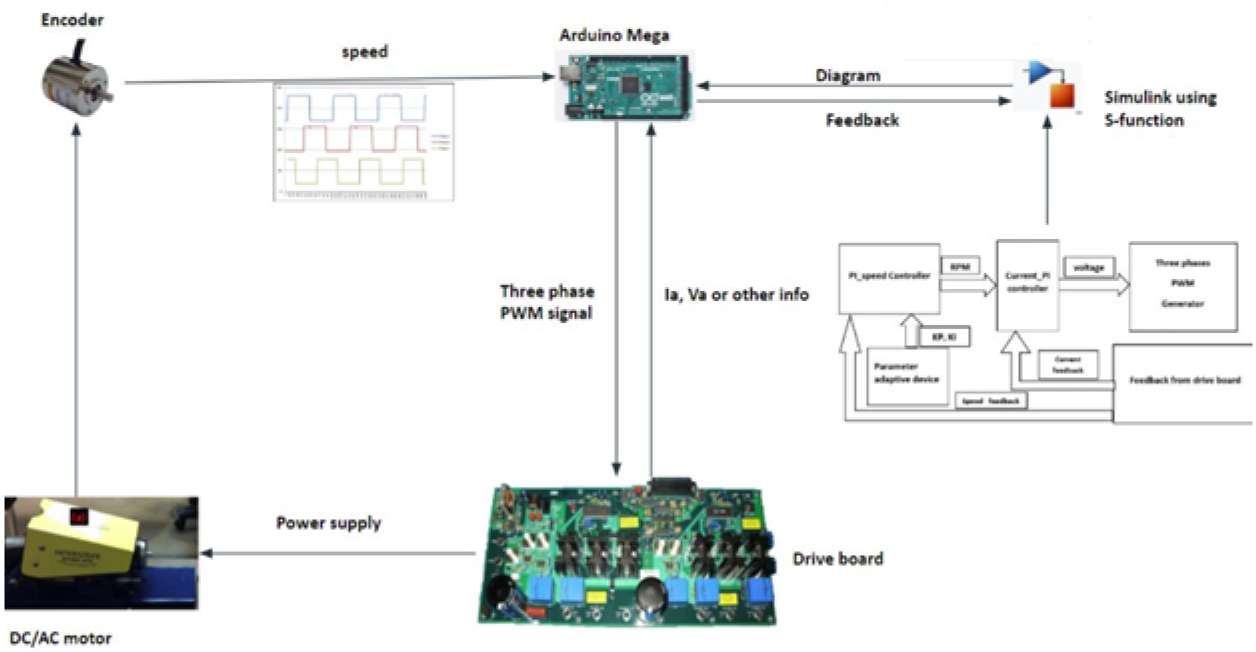
After performing these tests the results went as we expected them to go. We were unable to complete the entire project but the tests that we performed were successful and up to expectations. We met most of our requirements but not all of them. From what we built the project performed well under the test conditions.

Lessons Learned:

We ran out of time to complete the building of our project which affected some of our tests that we wanted to do. One way to improve our project's performance is to work on it earlier than we did and have each member contributed equally. Not completing every test, we could not change the requirements on our project. one lesson we learned in the testing procedures is that you have to test each part of the project even if it's a small part.

Appendixes:

i.



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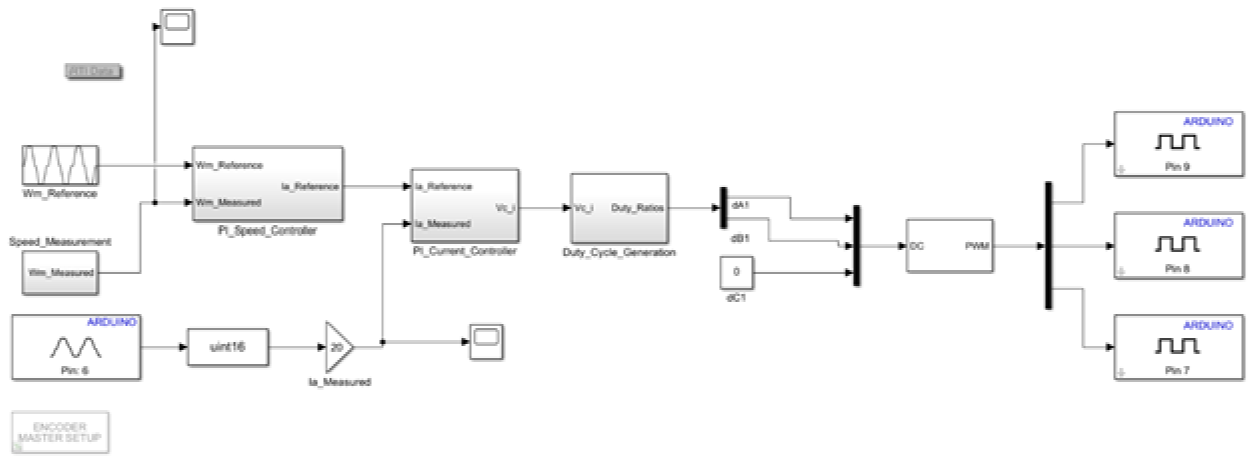
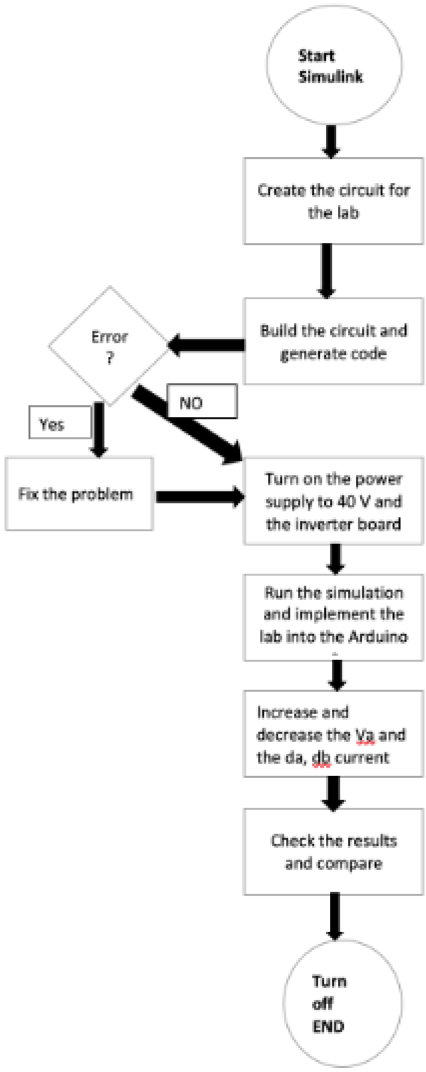
This figure shows how our project should be functioning and how each part is connected to the other.

ii.



This figure shows the lab 1 circuit redesigned to work on the Arduino instead of the dSpace.



iii.

This is a flow chart that explains how we wanted to perform the third major test for our project. That we failed to do so.