ESET 359 M01
Electronic Instrumentation
Spring 2024
Multidisciplinary Engineering

Final Project

Project Report
DSTR Robotic Vehicle Motor Control
Using Electrocardiogram (ECG) Sensors

Author's Name:
Mark Perez

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IS THIS LAB LATE? No

All of the information contained in this report is my own work that I completed as part of this lab assignment. I have not used results or content from any other sources or students.

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Chapter 1: Introduction

In terms of the final project that was constructed as a part of the Electronic Instrumentation course, I made the decision to design a system that would allow for the user to control the direction of the DSTR Robotic Vehicle that was constructed in the Microcontroller Architecture course using the user's muscle contractions of their forearm. The main objective of this particular project is to use the various concepts learned over the course of the semester in order to read data from the sensor, and based on the data being obtained, would cause the vehicle to either be in motion or halt the motion of the motors. In terms of concepts from the course that would be used in this project, I used the concepts of data acquisition via the DAQmx Board, obtaining signals via sensors, outputting data to hardware, and the use of LabVIEW programming techniques. The idea for this project came from the real world applications that this project can be used for such as giving individuals with limited motor functions the ability to control their mobility devices such as their wheelchairs using the motor functions that are still available.

In terms of the theory behind this project, we can focus on the sensor that was being used in this project. For this project, the AD8232 Heart Rate Monitoring Sensor constructed by Analog Devices was used for this project, which is essentially used to monitor the user's heart rate by detecting the electrical pulses that this muscle emits when beating. Since the human forearm also contains multiple muscles, we would be able to attach the electrodes to various locations of our arm in order to read the voltage emitted from these muscles when they are contracted. It is this application that would allow for this sensor to be used when developing this idea into a working design. Another aspect about this sensor is that the chip we are using from Analog Devices comes with a built-in amplifier that would allow for the signal being captured from the muscles, which are relatively small voltages, to be amplified to a range that can be captured via our DAQmx Acquisition Board.

In terms of the time frame of this project, the project was started at the beginning of April and continued throughout the month until its completion on April 30th, in which I feel the project could have been correctly implemented in this timeframe if there would have been less setbacks during the completion of this project. Although the original project proposal for this project consisted of the robotic vehicle having complete forward directional control, the time frame of this project combined with some setbacks that were faced during the development of this idea caused a shift in this proposal. Instead of allowing the user to control the vehicle by making left and right turns, I was only able to develop the program that allowed for the robot to either stop or continue forward motion. One of the biggest advantages to my process of completing this project that led to its completion was through the use of testing, which allowed for me to ensure that each portion of our program and hardware setup was performing accurately before moving onto the next portion of the project.

Chapter 2: Description of System Design

In this portion of this lab report, I will be discussing a description of each of the two major components of the system design, which are the hardware and software components that work together to accomplish the project. In terms of the hardware system design, we will discuss each of the components that were used, their specific purpose in our design, as well as how the hardware components were interconnected. For the software system design, we will reference the LabVIEW Virtual Instrument (VI) programs to describe how the program works and how the hardware and software components relate to one another to accomplish our project's task of controlling the motors of the vehicle using a person's muscle contractions.

Section 2.1: Hardware System Design

In terms of the hardware of the system I have created, there were six major components that were used in order to implement the final design, which were as follows: the AD8232 heart rate monitoring sensor, the NI DAQmx 6002 acquisition board, the L298N motor driver, the DSTR robotic vehicle, a laptop running LabVIEW program, and a power supply. In order to better visualize how these components are interconnected in the system, Figure 1 shown below shows the block diagram of how each of these components were connected to one another in order to have the correct flow of data from obtaining the signal from the sensor to outputting the data necessary to either rotate or stop the motors on the vehicle.

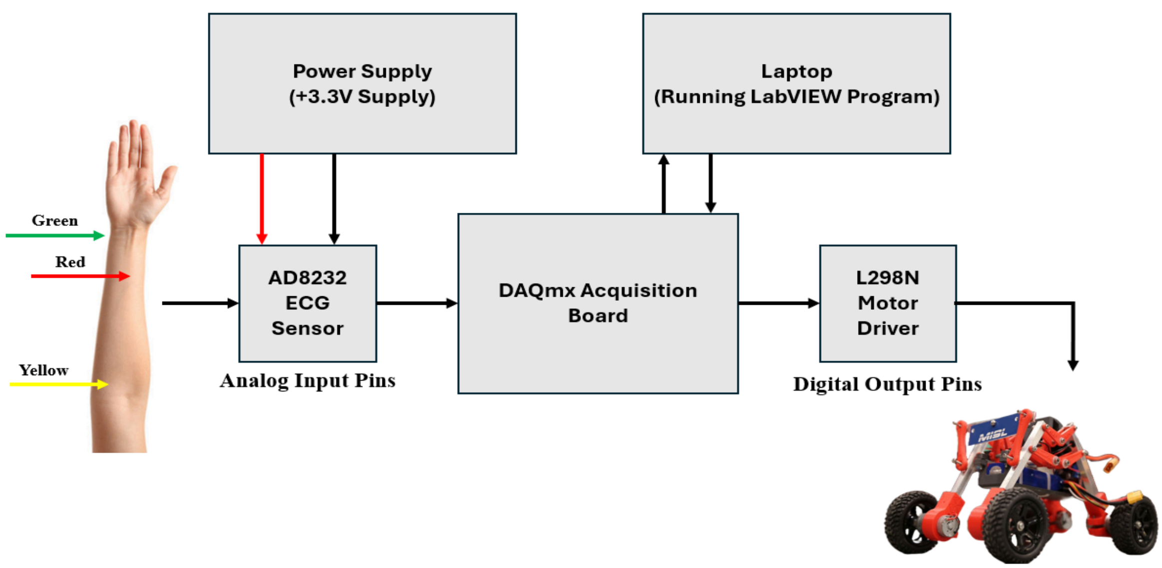

Figure 1: Block Diagram of Robotic Vehicle Control System using ECG Sensors

In order to gain a better understanding of each of the hardware components, we will now take a look at how each of these components and their uses in our system. The AD8232 heart rate monitoring sensor, as mentioned previously, is the sensor component that we will be using in order to obtain data from the user's muscle contractions in order to maneuver the vehicle. This component consists of connecting electrodes to various regions of the forearm, in which you can find the position on the block diagram as well as in Figure 2 shown below, which are then connected to the chip. This chip is powered using 3.3 Volts from our power supply, which is the power supply's sole use, and outputs an amplified signal to our DAQmx Board. The DAQmx Board is one of the central components of our design, in which its use is to obtain analog signals from our sensor, convert those signals to digital data to be processed on our LabVIEW program, and output digital data to our motor driver found on the robot. Our laptop is another key element to this project since it interacts with the DAQmx Board to supply our software found on LabVIEW to the hardware components. Lastly, the L298N motor driver is found mounted to our robot and acquires the signal from the digital output pins of the DAQmx Board and amplifies the logic signals to be able to power the motors and wheels located on our DSTR Robotic Vehicle. In order to visualize how these hardware components look when they are interconnected, Figure 3 shows the setup of the hardware components done when testing the system.

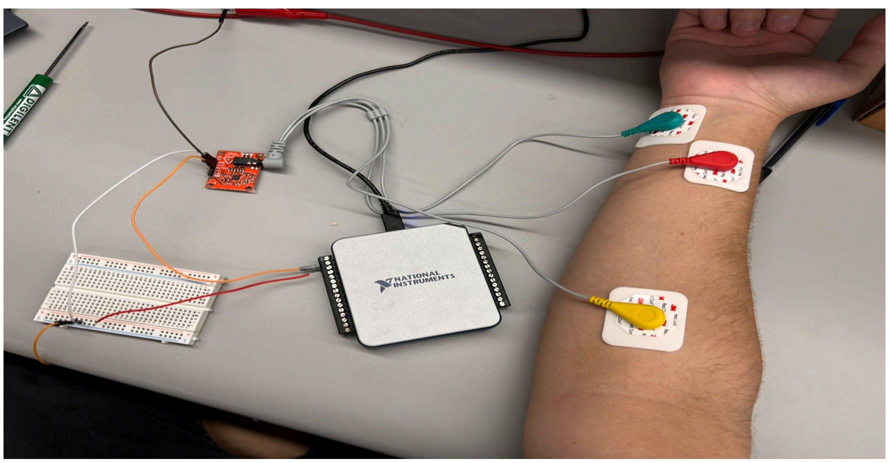

Figure 2: Electrode Placements for Forearm Muscle Contraction Readings

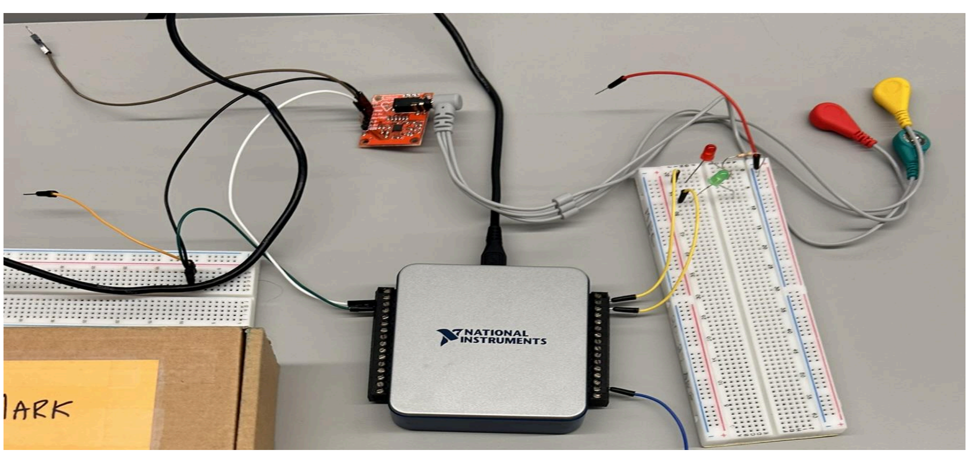

Figure 3: Hardware Connections for Data Acquisition and Motor Control

Section 2.2: Software System Design

In terms of the software design for this system, the program can be broken down into two main components: the data acquisition from the sensor and the case structure for outputting the data to the motor driver. Each of these components were developed separately to ensure that each of them were functioning before implementing them together in order to test the system. For the first component of acquiring data from the sensor, you can refer to Figure 4 shown below, which shows the Virtual Instrument (VI) program that was developed in LabVIEW. In order to consistently obtain data, we used a while loop to enclose the program components, in which the majority of the components are used together to acquire the data from the DAQmx Analog Inputs. The four functions that were used to obtain data via the DAQmx Board were the Physical Channels, Create Virtual Channels, Start, and Read Functions. The Physical Channel function allowed for the choice of the channel in which our data will be inputted from, and the Create Virtual Channels was used to choose the type of data, analog or digital, and measurement that would be taken, which in our case was Voltage. The Start Function would start the process of reading data, and the Read Function allowed for the choice of the type of data, the number of channels, and the rate of samples taken. Lastly, we had two indicators used to quantify and visualize the data, which were the Voltage Output indicator, which showed us the voltage value of the sensor, and the Sensor Data waveform that showed the waveform obtained via the sensor data.

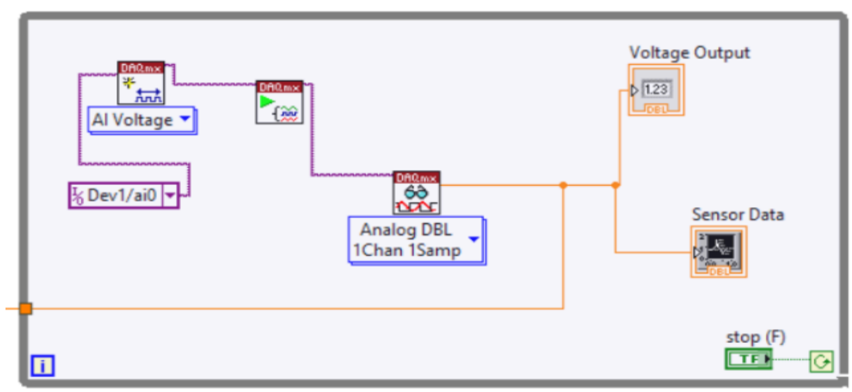

Figure 4: LabVIEW VI Program for Acquiring Data from AD8232 Sensor

After this stage was completed, the next portion of the program to develop would be the case structure that would determine whether a muscle contraction was detected or not in order to decide whether or not to turn on the motors. Based on the data acquired from our acquisition program, we determined that the amplitude of the data never rose above 0.8 V to 0.9 V when no muscle contractions were present, which led us to develop our case selector to be a comparison with the sensor from the data and the value 0.9. If the data obtained from the sensor was greater than 0.9 V, then the program would determine that a muscle contraction was detected, and would run the true portion of the case structure. The true case would send true logic out of the digital output pins thus turning the motors on. In order to have the robot's motors move for an extended amount of time as soon as a muscle contraction is detected, a for loop was used within the true case of the case structure, which would allow for the program to turn the motors on for an extended amount of time depending on the value that was set as the number of iterations, which in the case of my program was 500 iterations. If the value obtained via the sensors was less than 0.9 V, then the program would determine that there has not been a muscle contraction and the program would output false logic via the digital output pins of the DAQmx board thus keeping the robot's motors in its initial off state.

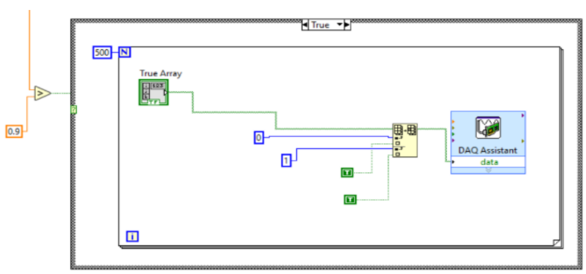

Figure 5: LabVIEW True Case Structure Program

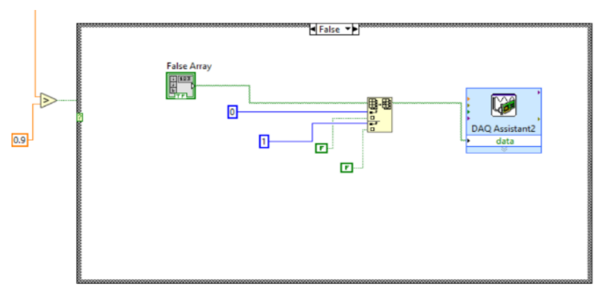

Figure 6: LabVIEW False Case Structure Program

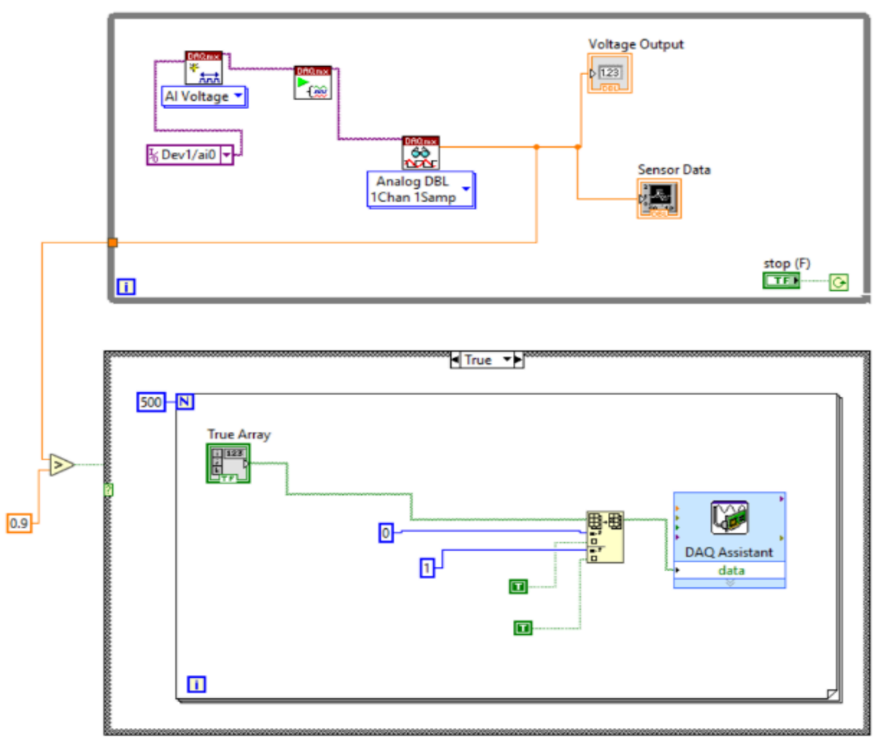

Figure 7: Complete LabVIEW Program for Motor Control System

Chapter 3: Test Plan & Results

In this portion of the lab report, I will be discussing how the hardware and software components were tested, how the overall system was tested once the design was completed, as well as the outcomes of the project as a whole. In terms of testing of the hardware and software in this project, one could not be tested without the other, so the main testing that was done was based on the constructing the hardware and testing our software on the hardware in order to determine if each of the software components were functioning correctly, which we will dive into in this section.

Section 3.1: Testing of Hardware & Software Components

As mentioned above, the testing of the hardware components was dependent on having software developed, so in a way both components were being tested at the same time, and it was my responsibility to determine in which area the errors, if any, were found. The first portion of the project that was constructed were the hardware components to acquire data, which were tested using the VI program that would acquire data. In order to test whether or not the data acquired from LabVIEW was consistent with what the sensor was outputting, we used two methods, which were creating graphs from the Excel Data obtained from the LabVIEW program and using the LabVIEW waveform graphs in our VI. Both of these methods were compared to the waveform output on the oscilloscope, which was connected straight to the sensor to ensure our program was not altering the data in any manner. In Figure 8 and 9 shown below, you will find the waveform obtained via our Excel Spreadsheet and the graph obtained via the LabVIEW waveform indicator respectively.

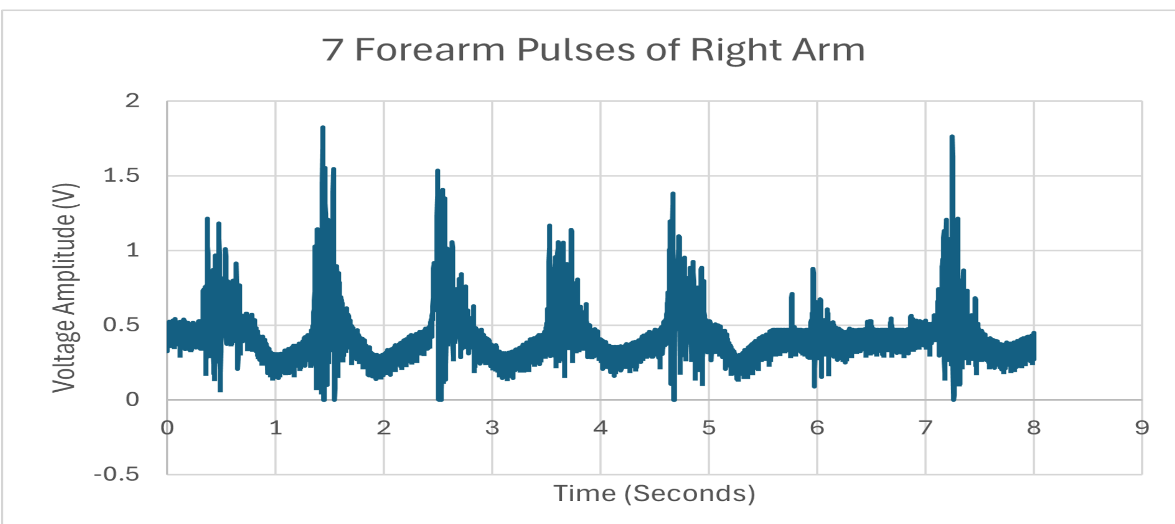

Figure 8: Waveform Obtained via Excel Spreadsheet Data of 7 Arm Pulses

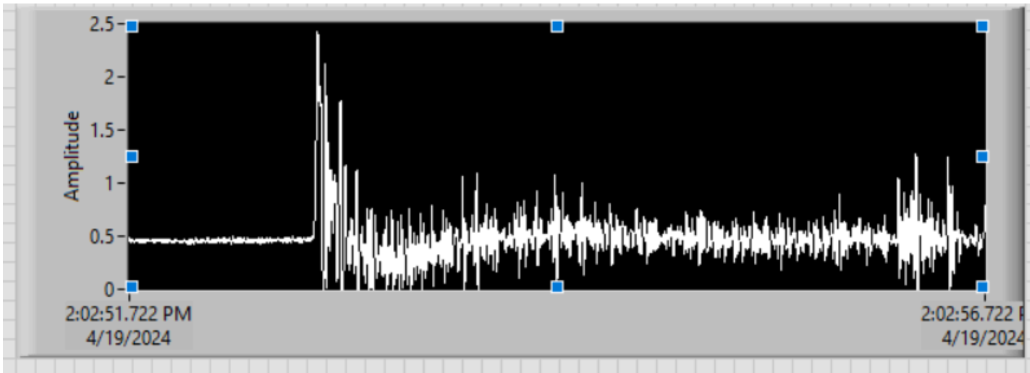

Figure 9: Waveform Obtained via LabVIEW Program Waveform Indicator

Once the testing had been completed for obtaining data via the ECG sensor, the next portion of the project, which is the case structure VI, was developed via LabVIEW. In order to test that the case structure was working properly, we used numeric controls that were connected to the 'X' portion of our comparison to test the functionality of our case selector. In order to test that the correct values were being output via our two digital output pins, we created a simple LED circuit using two LEDs and two 470Ω resistors to test the output of the case structure. If the numeric control was higher than 0.9 V, then the True case would run and the LEDs would turn on, and if the value was less than 0.9 V, then the False case would run and the LEDs would stay in the off state. After it was tested with the test values, the controls were removed and it was tested with the actual data from the sensor to ensure that this portion was functional.

Section 3.2: Testing of Overall System

Once the hardware and software portions had been tested, the next step was to connect the digital output pins from the DAQmx Board to the motor driver that was connected to the robotic vehicle. In order to do this, the data sheet for the motor driver was used to find the pins to connect to. For the left and right motors there were two input pins for each side, in which we had one pin connected to the digital output pin and the other connected to the 5V port of our DAQmx Board, which would allow us to send a low signal from our board to control the motors. When initial testing of the system was taking place, the program did not have the for loop within the true case structure, so when all these connections were made and the program was run, the motor would turn on and off rapidly when arm contractions were made since the values were coming in instantaneously. The way this issue was combated was to include the for loop that would consistently supply the output pins with a high value for a specific number of iterations when a muscle contraction was sensed in order to have the motors run for a specific amount of time before returning to the off state. Once this was tested and the motors behaved in the correct way, the sensitivity of the sensors were tested by having the arm contract with various strengths whether it be by having a rapid movement or a slight pulse of a finger movement.

Section 3.3: Results of System

As a whole, the system worked efficiently since, through testing, the system was able to react to various strengths of arm contractions. Since even slight movements such as the movement of a finger were able to have the correct output for the motors, we can relate this back to our real-world application of this being a system that can be implemented on wheelchairs for people with limited motor functions to use. In the video hyperlinked below, you can see the testing of the entire system, which shows the different strengths of arm contractions being tested on the robotic vehicle motor control system. The video starts with very exaggerated arm contractions and finishes by showing that even the movement of a single finger can provide the correct output on our motor control system.
Testing of DSTR Robotic Vehicle Motor Control via ECG Sensors

Chapter 4: Description of System Operations

In this particular section, I will be discussing a brief description of the system operations for the entire system. Specifically, we will be referring to the set-up requirements for the system as well as operating instructions and overall how the system will run when a user is using the system.

Section 4.1: Setup Requirements

In terms of setup requirements, the major setup requirements would be the use of the laptop with the LabVIEW VI program that is used to run the system. In order to set up the system, the USB connection used to power and transmit data from the laptop to the DAQmx Board would be connected to the laptop and the VI program would have to run continuously in order for data to be consistently transmitted between all portions of the system. The other setup requirement would be to have a power supply to provide the necessary 3.3 volts to the ECG sensor, but since we are going to be presenting this project at the CURE symposium, this will be taken care of by having a transformer connected to step down the 5 volts provided by the DAQmx Board to 3.3 V that can be used to power the sensor. This would ensure that we would not have to lug around a power supply to power one single component of the system.

Section 4.2: Operating Instructions & Overall Operation

In terms of operating the system, the procedures are relatively simple, and the user would first have to attach the electrode pads to their forearm in the locations shown above in Figure 2. Once the electrode pads have been attached to the user, the electrodes themselves would be attached in the following order: Red, Green, Yellow starting at the wrist and moving towards the bend of the elbow. Once the electrodes have been connected, the user would then have to flip the switch found on the robotic vehicle in order to power the motor driver using the battery pack found on the bottom of the vehicle. Once the motor driver has been powered on, the next step would be to press “Run Continuously” on the LabVIEW program in order to start the collection of data from the sensors that have now been connected to the user. Once this has been completed, the robot will now stay in its initial off state until the user performs a muscle contraction, in which it will now power the motors for a specific amount of time.

Chapter 5: Conclusion

All in all, the development and implementation of this project has helped me not only solidify my knowledge of the concepts taught in this course, but it did so in a hands-on manner that allowed for me to develop my own ideas into a working system. By working on this project, I was able to relate both theoretical concepts to their real world application counterparts. In doing this project, I was also able to learn about consistency and finding solutions to issues that may arise when developing an idea into a working prototype. Over the course of this project, there were multiple setbacks that occurred, but each setback was followed by a solution. Some of the setbacks included time constraints, scrapping ideas based on their functionality, and issues during hardware construction. In terms of time constraints, I had to decrease the functionality of my design in order to complete the project by the deadline, which led to the single directional control. In the initial proposal, the use of the Fast Fourier Transform (FFT) along with filtering signals were to be used, but after several trials, the idea was scrapped, and the raw data would be used in our final implementation, which led to wasted time that could have been used on other applications. Lastly, there were wiring issues where some wires were not functioning properly, and led to wasted data and loss of time due to having to find the faulty wires and replacing them, but even through the hardships, the final implementation was successful.

Just as with any design, there are always improvements that can be made to a design, in which there were some major improvements that are worth noting. One of the biggest improvements would be to add multidirectional control, in which the robot would be able to make left and right hand turns along with possibly moving in both the forward and reverse directions. Other improvements that can be made to this project would be to include Pulse Width Modulation to the design, which would not only allow for the direction to be controlled via the design we have already constructed, but would also allow for the speed of the motor vehicle to be altered to allow for a more user friendly design. Lastly, an improvement can be made on how the data is transmitted to the vehicle’s motor driver, which would hopefully be to make the transfer of data wireless through the use of WI-FI or Bluetooth transmission. All in all, the development of this project has taught me valuable lessons that can be applied to any other projects I will be developing as well as when I eventually end up working in the industry.

Chapter 6: Experience

In order to conclude this final project completed for ESET 359, I would like to highlight how the experience of working on this project has been. Just as with all projects, there were ups and downs, but even throughout the negative aspects, I persevered through it and completed the project.

In terms of the positive aspects of this experience, I can first discuss how working on a major project individually positively impacted my experience. Since this is the first semester where I am the sole designer, it allowed me to choose my own project idea and work on an idea that truly interests me, which allowed for me to be more passionate about working on the project both in and outside of the classroom. Along with being able to choose my own idea that interests me, the aspect of working individually on this project also allowed for me to get better at asking for help, which has always been one of the challenges I have faced. I have always been one to not ask questions or ask for help at the fear of being wrong, but since I was the only person working on this project, it made it easier to ask questions since these questions would lead to positive outcomes for this project. This project has also allowed for me to learn a valuable lesson about engineering in the real world, which is persevering through difficult situations. There were many points in the development of this project where I faced various obstacles in terms of errors in the programs I was developing or obtaining data that was not consistent with the ideal data I should be obtaining, but after looking into my work and finding my errors, you can learn from your mistakes. Lastly, one of the biggest positive aspects of this experience has been watching my progression of this project go from an idea to a working system. Although this project has been one of the most involved projects, the fact that this project was functional at the end of the semester definitely makes you feel proud of all the hard work that was put into this project.

In terms of the negative aspects of this experience, I would say that working on the project individually also had some negative aspects just as it had positive aspects. The only negative aspect of working on this project individually would have to be the fact that the entire project was dependent on my own work although I received immense amounts of support from my professor. After completing this project, I would say that the positive aspects of working individually clearly outweigh the negative aspects, but at the beginning of the project, the work did seem very daunting since it was dependent solely on my work.

Chapter 7: References

Below you will find several links to the references that were used over the course of the implementation of this system. Most of the links that are provided include the data sheets to the major hardware components that were used in the implementation of the project. These include the data sheets for the AD8232 Heart Rate Monitor Sensor, L298N Motor Driver, and DAQmx Acquisition Board. Also linked below are forums that were referenced during the completion of the VI program in order to aid with any errors that occurred during the creation and testing of the VI programs.

AD8232 Data Sheet Analog Electronics
L298N Motor Driver Data Sheet
NI DAQmx 6002 Data Sheet

Chapter 8: Appendix

Linked below you will find the documentation for the initial proposal for this project as well as information pertaining to the pinouts of the L298N motor driver. Along with these documents, you will also find a link to a Zip file that contains all the Virtual Instrument (VI) programs that have been developed over the course of this project. This includes the VI program that would allow for interfacing two sets of AD8232 sensors, which was started but not completed due to time constraints.

ESET 359 Final Project Proposal
L298N Pin Out Diagrams
ESET 359 Spring 2024 Final Project VI Programs