Wiring Introduction

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1 Introduction

Wiring is an essential skill area for both Razorbotz and any other robotics team. Even with an impeccable mechanical design, a robot cannot function without wires and a functional electrical design. This is an area that we have consistently failed to focus on and allow future students to grow in. By neglecting to train future students, we have created a situation that could cause the team to fail, despite the good efforts of the mechanical students. To prevent this, we have created a series of training materials to introduce students to this needed area.

1.1 Motivation

This document was created to serve as an introduction to the world of electrical wiring in robotics. Many students are inexperienced with both electrical concepts and wiring for robotic applications and are hesitant to start. Although some caution is a necessary part of wiring, an excessive amount of fear can be counter productive. We will cover the safety information needed to allow students to wire in a safe manner in this document. This document is intended to allow students with no electrical background to both understand and be able to perform the essential skills of wiring and electrical design.

2 Background Concepts

2.1 Tools Used

When wiring robots and other electrical devices, we commonly use a variety of tools. There are many different types of pliers, as seen in Figure 1. Shown in the image are needle nosed pliers on the left, lineman's pliers right middle, and slip joint pliers on the right. These are all used to grip objects, but differ in their size and how large of an object they can hold. In Figure 2, there are several cutting implements shown. The left three are all various wire cutters, while the red-handled object on the right is tin snips. These snips are used for cutting sheet metal and other larger pieces of metal and shouldn't be used to cut wires.

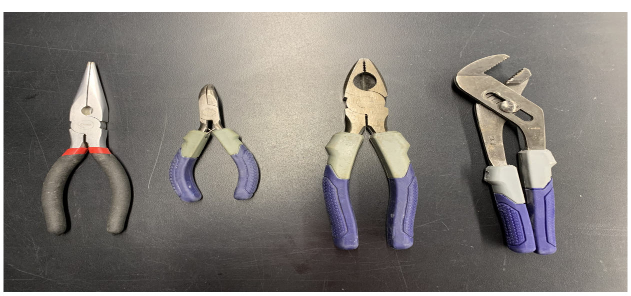

Figure 1: Various Pliers

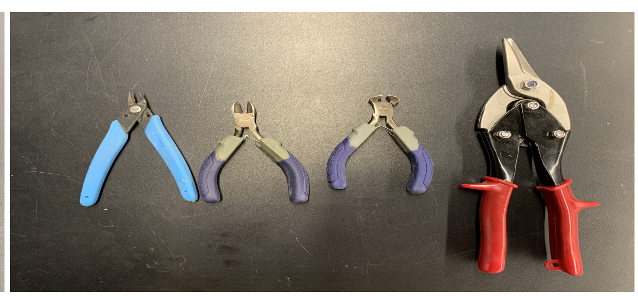

Figure 2: Various Cutting Tools

One of the most commonly used tools in wiring is the wire stripper. Wire strippers can be used to cut wires, remove insulation, and even create bend the wire for use in receptacles. Screwdrivers primarily come in two different types: Phillips heads and flat blade screw drivers. Phillips head screwdrivers have the appearance of a + on top, while the flat blades look like -. We primarily use the screwdrivers on small electrical components, such as the Jetson Nano Wi-Fi shield.

Figure 3: Wire Strippers

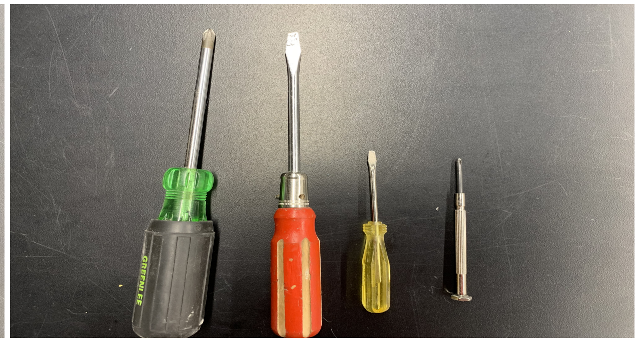

Figure 4: Various Screwdrivers

2.2 Essential Components

The Razorbotz team uses several key components in our robots, including motor controllers, motors, and other electrical components. The Power Distribution Panel (PDP) distributes and regulates the voltages to components attached to it. There are several 30 and 40 amp fuses that prevents over-current issues. The watt meter is mandated by NASA as a method of tracking the amount of power used by the robot. We have one watt meter per circuit, which allows us to monitor the voltages for both. The Emergency Stop (E-Stop) is also needed to comply with the NASA rules and allows users to shut down the robot if needed. All circuits MUST run through the E-Stop.

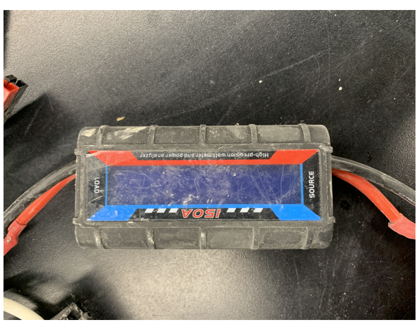

Figure 5: Watt Meter

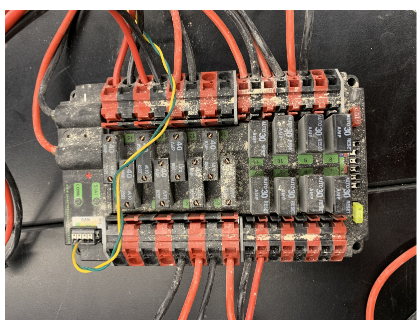

Figure 6: PDP

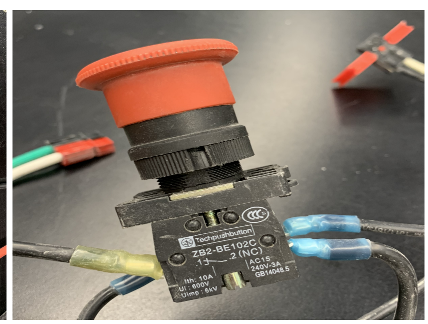

Figure 7: E-Stop

We use several motors and motor controllers on the robots. The Falcon 500 has an integrated Talon FX motor controller. The Talon SRX motor controller is used for a variety of motors, including the linear actuators and the mini Cim motors. The Rev SparkMax is used to control the Rev Neo Brushless motor. The linear actuators are typically used for moving components on the robot, while the Falcon 500 motors are used for the drive train. The Neo was used on the 2023 bot to spin the bucket ladder.

2.3 Wires

There are several types of wires, but the main two categories are solid and stranded. Solid wires have a single piece of metal running through insulation, while stranded wires have many tiny pieces of metal that are woven together. Different sized wires can carry different levels of current. Typically, the larger the conductor, the higher amperage that can be safely carried. Smaller numbers on the wire gauge indicates the wires are larger and are able to carry higher currents. On the Razorbotz project, we use 12 gauge stranded wire because it is very flexible and able to carry the currents needed.

Figure 8: Types of Wires [2]

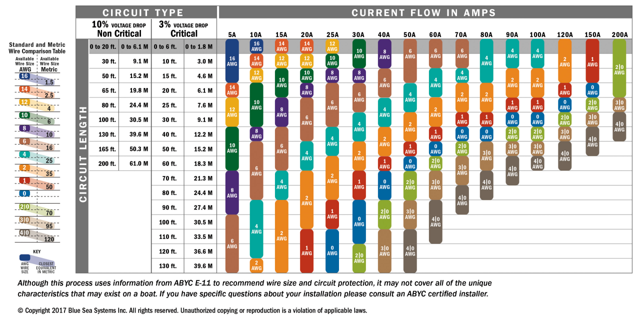

Figure 9: Amperage Chart [3]

2.4 CAN Bus

The Controller Area Network (CAN) protocol is typically seen in automotive applications. It is a serial communication protocol using differential voltage on two wires. It allows nodes connected to the wires to communicate. We have used the CAN protocol to control the motor controllers and other electrical components on the four previous Razorbotz robots. It allows the computer to receive data from the components and send commands to the motor controllers. The circuit consists of two wires: CAN_H and CAN_L or high and low. The high wire is typically yellow 28 gauge wire, while the low wire is typically green 28 gauge wire.

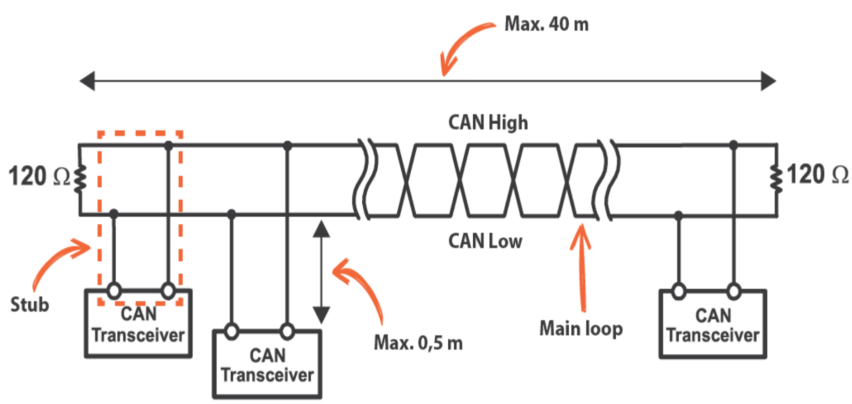

Figure 10: CAN Bus Diagram [1]

To wire the circuit, connect the yellow wire to the next yellow and the green to green. We use the

USB2CAN component, shown in Figure 11, to allow the Jetson to communicate with the bus. **To wire the CAN bus to the component, wire the CAN_H wire to the 7 pin and the CAN_L wire to the 2 pin.** Although you can connect the wires to other pins, they will not work and will cause the CAN bus to fail.

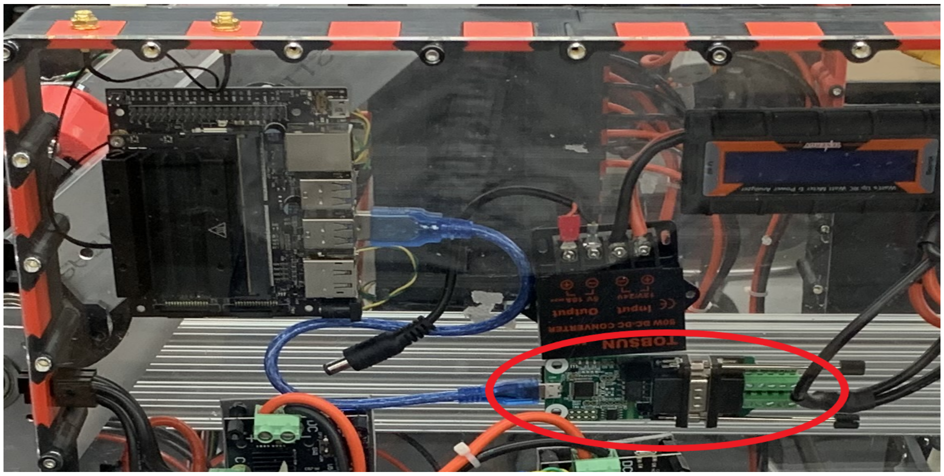

Figure 11: USB2CAN Circled in Red

2.5 Voltages

The electrical system uses Turnigy 4S 5000mAh Lithium Polymer batteries to power it. These batteries output between 14.5 - 16.8 volts. The batteries are wired into the power distribution panel and regulates the voltage to 12 volts. However, the Jetson Nano operates on 5 volts and requires a step-down voltage transformer to convert this voltage. The voltage converter is shown in Figure 12.

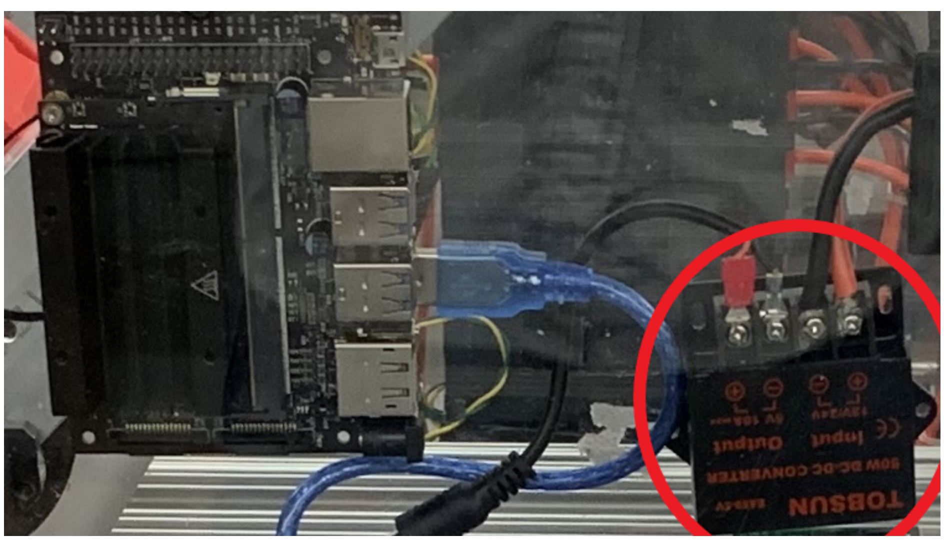

Figure 12: Voltage Converter Circled in Red

3 Key Skills

3.1 Wire Stripping

Wire stripping is the act of removing portions of the insulating material from a wire, exposing the conductor inside. By removing the insulation, we are able to use the wires to create a functional circuit. To strip the wire, we use the wire strippers. The holes on the wire strippers are labelled with the respective gauges. Most of these are sized for solid conductor wires, while stranded wires are slightly larger. If the gauge of the wire isn't known, use the largest size and move down as needed. To strip a wire, place the wire in the corresponding hole in the wire strippers. Ensure the wire strippers are perpendicular to the wire and pull the strippers towards the end of the wire. If the tool isn't perpendicular to the wire, some of the strands will be severed. An easy way to ensure that the strands won't be severed is to cut the insulation with the wire strippers, then pull it off the wire with your hand.

Figure 13: Well Stripped Wire

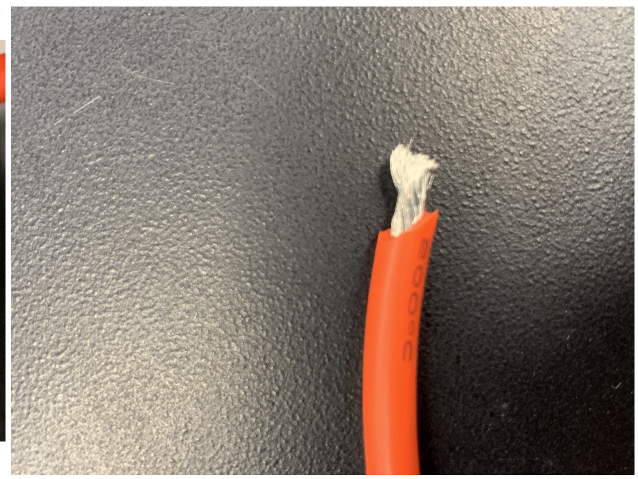

Figure 14: Poorly Stripped Wire

3.2 Splicing Wires

Splicing wires is used to combine two wires into a single, continuous circuit. To splice two wires together, remove around an inch and a half of insulation. Hold the two wires and form an X with the exposed ends. Wrap the two wires together, ensuring that the wires are equally wrapped, instead of one around the other. To ensure the spliced wires remain combined, they need to be soldered.

3.3 Soldering Components

Soldering components allows conductors to make a good connection. By heating up the components with the soldering iron, the solder will be able to adhere to the material. One of the keys to soldering is to heat the components and allow the heated metal to melt the solder, instead of melting the solder directly on the iron. If the metal is cool, the solder will bead up on the wires instead of connecting properly. To solder a component, turn on the soldering iron and allow it to heat up. Once to the proper temperature, press it to the components that need to be soldered. Allow them to heat up, then press the solder on the opposite side. Once the solder melts and is accepted, remove the soldering iron.

Figure 15: Good Wire Splice

Figure 16: Bad Wire Splice

3.4 Wiring Anderson Connectors

Anderson Power Pole connectors consist of two components: the connector 17 and the contact 18. To use these connectors, the wire is placed in the contact and the contact is crimped to hold the wire. To ensure the wires don't slide out when they are pulled on, the wires need to be soldered to the contacts. Once the wire and contact pair is prepared properly, it will slide into the connector. These connectors are designed to snap together and allow wires to be easily disconnected when needed.

Figure 17: Anderson Connector

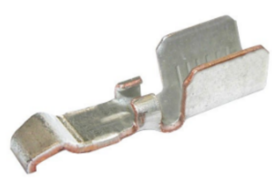

Figure 18: Anderson Contact

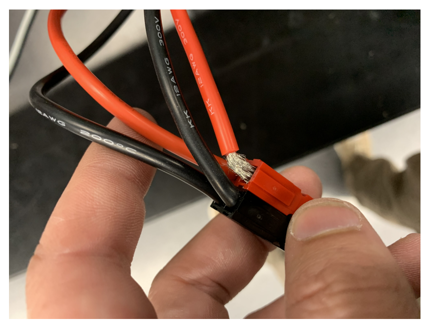

Figure 19: Wire Pulled Out of Anderson Connector

NOTE: To disconnect the connectors from other connectors, pull the connectors, not the wires. Pulling on the wires can cause the wires to slide out and will damage the connection.

3.5 Electrical Design

The design of the electrical system is often an afterthought to the design of the mechanical systems, despite its importance to the success of the robot. Some key aspects of the electrical system that have been forgotten in the past include wires running to motors, securing wires to the frame, and even placing the electrical boxes on the robot. These mistakes happened because the designers failed to have a good understanding of what was needed to allow the robot to operate, as well as a misunderstanding of the size of the wires needed for the motors. To have a good electrical design for the robot, we must consider the size of the wires that are being routed through the robot, where the wires will be run, and how we will secure them. **A good rule of**

thumb is to allow about half an inch per pair of wires. This will allow plenty of room to run not only the wires, but also the flexible conduit and the cable ties needed to secure it. Additionally, wires should never be run near spinning motors without being secured and should never be run through sharp metal frames without protection.

4 Task 1: Strip, Splice, and Solder

Tasks. Take two lengths of wire at least four inches long. Strip between an 1 inch and 1 $\frac{1}{2}$ inches of insulation off the wires. Make sure that the wire strippers are perpendicular to the wire. After having stripped the two wires, splice the two wires together. Ensure that the wires are wrapped tightly together, rather than one wrapped around the other. Once the wires are spliced together, use the soldering iron to heat the wires. Apply the solder to the wires and allow it to melt. Check to make sure the solder has made a good connection to the wires. **Show the soldered wires to the electrical team lead before starting Task 2.**

5 Task 2: Wiring a Robot

Although wire stripping and soldering are important aspects of wiring, they are not useful in isolation. For this task, we are going to wire a circuit that will create a fully functional robot. On the Razorbotz project, the most commonly used motors are the Falcon 500, Pololu linear actuators, and the Rev Neo brush-less motor. The motor controllers that are used are the Vex Talon SRX and the Rev SparkMax. The Falcon 500 has an integrated Talon FX motor controller, so it has the CAN bus wires going directly to it. The voltage converter steps the voltage down from 12V to the 5V necessary for powering the Jetson Nano. We will use the USB2CAN component to allow the Jetson to interface with the CAN bus.

Tasks. We need to wire the various components together to complete the circuit. First we will wire the motors and motor controllers to the PDP. Next, we will wire the voltage converter to the PDP. Connect the USB2CAN to the Jetson and connect the CAN bus wires together, with the wires terminating at the PDP. Finally, we will connect the E-Stop to the XT-90 connector WITHOUT connecting the battery to the circuit. Ask the electrical team lead to check your circuit. **DO NOT CONNECT POWER TO YOUR CIRCUIT WITHOUT GETTING IT APPROVED FIRST.** After getting approval, connect the battery to the circuit and turn the E-Stop on. The finished circuit should look like the one shown in the Wiring Diagram below.

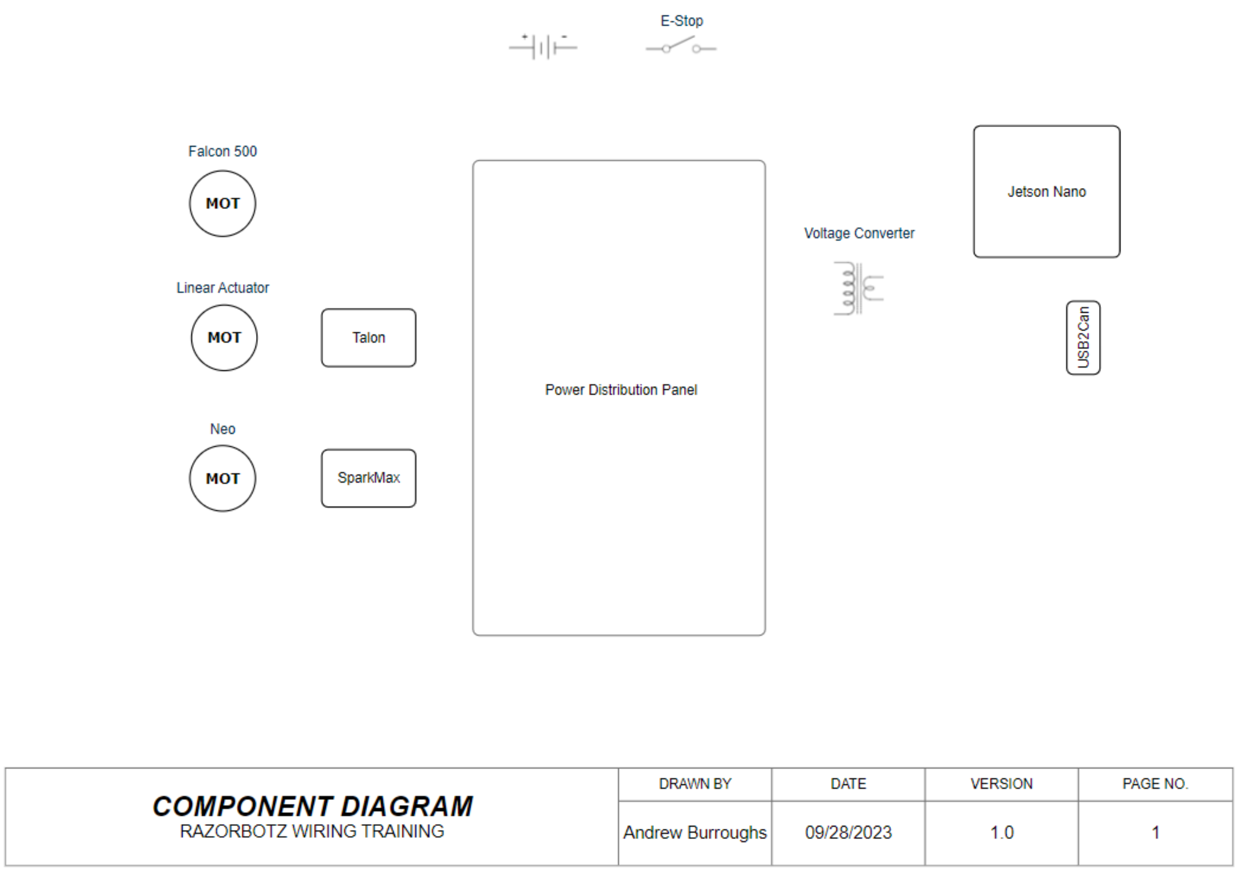

Figure 20: Component Diagram

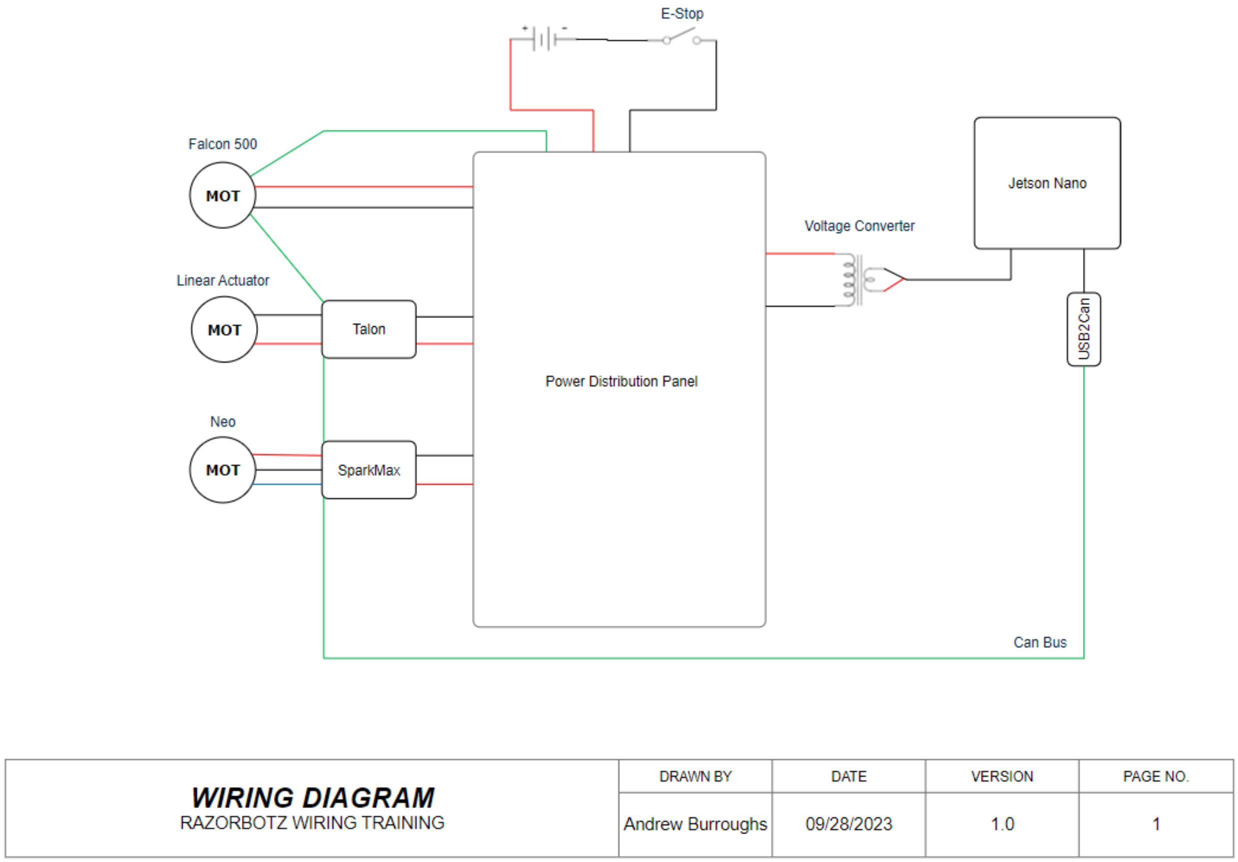

Figure 21: Wiring Diagram

6 References

[1] Alferink, T. (2017, August 31). Practical tips: Can-bus. KMP Drivetrain Solutions. https://www.kmpdrivetrain.com/paddleshift/practical-tips-can-bus/

[2] What is the difference between solid and stranded cables?. Universal Networks. (2020, March 18). https://www.universalnetworks.co.uk/faq/what-is-the-difference-between-solid-and-stranded-cables/

[3] Part 1: Choosing the correct wire size for a DC Circuit. Blue Sea Systems. (n.d.). https://www.bluesea.com/support/article