Mecnaum/SMP Design Document

SDSMT Robotics Team

Ian Carlson

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Purpose

It should be noted above all that the SMP type robots are capable of indoor and light outdoor use, while the Mecanum is unsuitable for outdoor use. Beyond that, the SMP and Mecanum robots are intended for three primary uses:

- Learning and Research
- Functional Examples
- Demos

1.1 Learning and Research

One primary problem with building a student-led team based around a complex and competitive field like robotics is the long ramp-up time for new members and the perpetual attrition of more experienced members. To put it another way, by the time a new member learns enough to start pushing the limits on what the team can do, it is already time for them to graduate. In addition, the loss of conceptual understanding is devastating in a field where we generally are more focused on algorithms and integration than producing a physical deliverable. Add to that how quickly the field changes, and the cyclic nature of academia becomes crippling. The SMP and Mecanum robots are to provide three good examples of a functional, yet simple implementation of basic robotics principles including mechanical design (sort of), two types of kinematics, electrical design, and - principally - ROS architecture.

The hope is that having these examples readily available will allow new members or senior design teams working toward a robotics-related project to get up and running quickly. So often, a new group will get bogged down in the details of building and wiring their robot, that they run out of time before they get a chance to actually deal with the more "interesting" problem that they had actually intended to tackle from the beginning. Having working robots available allows the teams and/or new members to skip right to their intended topic of interest, whether it be modifications of the mechanical or electrical design, control systems, vision, navigation, or autonomy.

1.2 Functional Examples

ROS itself isn't fundamentally all that complex, but robots are. Another intent when working on these robots was to provide a "minimal working set" of ROS packages that can be used as a spring-board for future ROS development. It doesn't take *that* many pieces to make a robot in ROS, but knowing what exactly those pieces are is a daunting task when starting from nothing. By using the very simplistic design of the SMP and Mecanum robots as an example, the task of dealing with a robot in ROS becomes much more approachable.

This is doubly true with mechanical and electrical design. A lot of parts have to come together to make a robot, and a novice to robotics design will inevitably feel overwhelmed when attempting to design a robot from nothing.

1.3 Demos

One of the Robotics team's main responsibilities as good citizens of the MCS department is making a good showing at presentations or demos for the department. In the past, this has usually been the domain of between one and three robotics team members who knew enough about the robots to cobble something together at the last minute before the demo. With three readily available robots on hand, these demo days should be more interesting, more reliable, and less stressful for everyone involved. In addition, having multiple demo robots means that the presenters have backups in case one fails, and can attempt more interesting demonstrations knowing that they have a fall-back plan.

1.4 Not Competition

The intent of the SMP and Mecanum robots is not that they will be used in robotics competitions. They should always be kept in working condition, and not overhauled unless for the express purpose of providing a more robust application of the three goals mentioned above. The team should go through the entire design process - even if that means buying a new chassis - rather than skipping it in favor of a pre-existing robot. Even though it means more work and a larger risk of failure, the design process - and the occasional failure - are invaluable learning experiences.

2

Requirements

As demonstration and research robots, the SMP and Mecanum robots don't have any specific external requirements. However, there are several more subjective internal requirements for this iteration of the robots.

The Mecanum and SMP robots shall:

- Provide a Stable Research Platform
- Be Good Examples of ROS Design
- Separate Electrically Noisy Components
- Be Easily Re-configurable
- Be Easily Maintainable and Accessible

2.1 Provide a Stable Research Platform

This requirement states that this iteration of the robots shall be useful for demos, research, and general learning by the members of the robotics team or MCS department senior design teams. One important aspect of fulfilling this requirement is supplying a versatile platform. This means the robots shall be designed in such a way that various sensors can be mounted in multiple useful positions. The typical sensor payload for the SMP and Mecanum robots includes:

- ASUS RGBD Vision Sensor
- LiDAR
- IMU

In keeping with the spirit of versatility the robots shall be over-engineered such that additional sensors can be added without requiring electrical redesign.

2.2 Be Good Examples of ROS Design

This requirement states that the Mecanum and SMP robots are intended to be good examples of ROS design. Great care shall be taken to use as many ROS Good Practices as possible.

These Good Practices shall include but not be limited to:

- Utilitize the Systemd Services utility for auto-boot
- Utilize the udev utility for mounting devices

- Use dedicated driver nodes
- Use no custom message types
- Write highly generic nodes where possible

2.3 Separate Noisy Components

This requirement states that electrically noisy components shall be isolated from the rest of the system, particularly the Odroid and sensors. One of the problems these robots experienced in the past was a condition in which the motor controllers would unmount from the Odroid. The cause was ruled to be noise generated by either the motor controllers themselves or the motors creating voltage spikes that scared the Odroid hardware into unmounting the USB devices to protect itself. To mitigate this problem, two measures shall be taken. First, motor controllers will be selected which can be connected over serial lines. The big advantage in doing so is that putting an FTDI between the motor controller and the Odroid USB port adds a layer of electrical isolation.

2.4 Easily Re-configurable

This requirement states that the robots shall be designed in such a way that a minor reconfiguration does not require redesigning the entire robot. In particular, the robots shall be over-engineered with respect to torque, power requirements, and electrical connections such that additional sensors can later be added without requiring electrical redesign.

2.5 Easily Maintainable and Accessible

This requirement states that the robots shall be designed in such a way that routine maintenance, such as battery recharging, can be done easily. In particular, the robot shall be designed such that it can be opened for maintenance without requiring the removal of the sensor payload, computation devices, or wireless capability.

3

Mechanical Design

This chapter details the mechanical design, as well as the reason behind some of the decisions that were made regarding the mechanical design.

Unfortunately for this document's usefulness as a stylistic guide, the mechanical design was mostly just restricted to the chassis available in the lab. However, I will provide some pictures of the robots, as well as what information I can about the mechanical design.

3.1 Surface Mobility Platform

The Surface Mobility Platform "SMP" is a chassis developed by Gears Educational Systems. The design provides independent suspension for the left and right sides of the robot, allowing it to articulate surprisingly far while maintaining balance and traction.

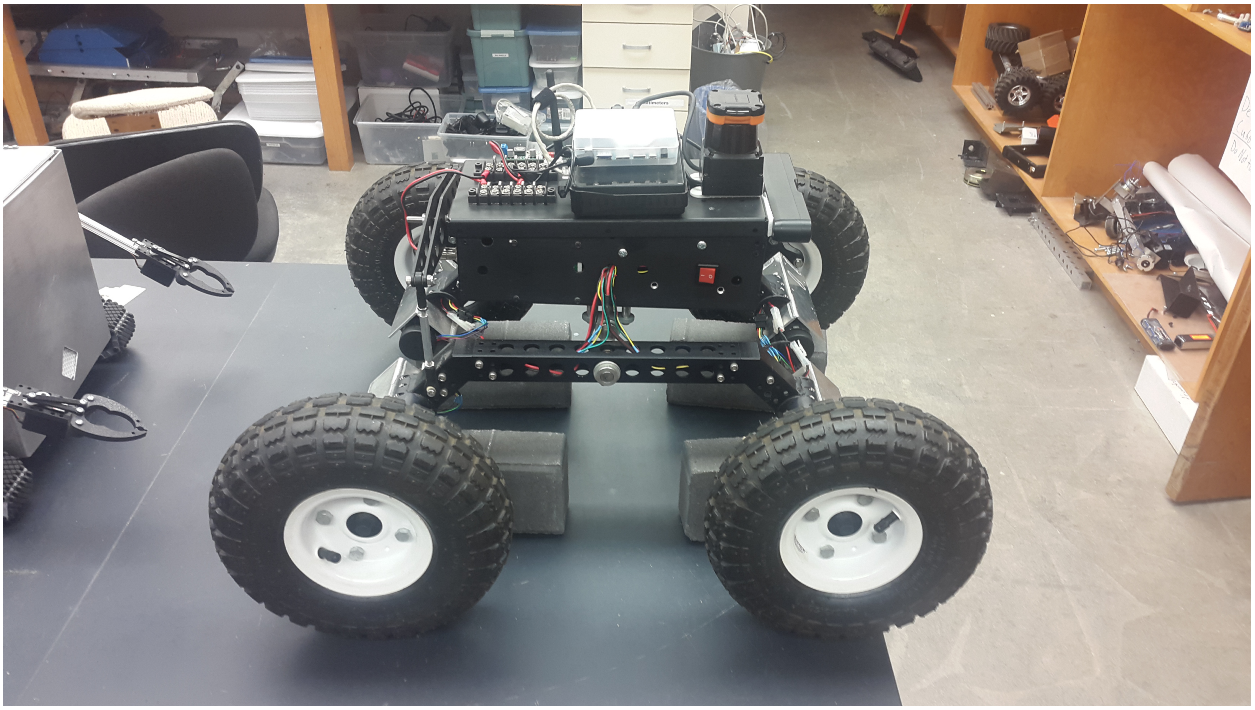

Figure 3.1: The Suface Mobility Platform "SMP"

The silver motor-housings are not part of the original platform. It was determined (at some point in the past) that the stock motors were undesirable for some reason or another. It was a good idea conceptually, but could have used some work in implementation. The screws are difficult to reach, and the housings themselves are not very square. This makes the robot slightly lopsided, which is unfortunate because the rest of the frame is actually really cool.

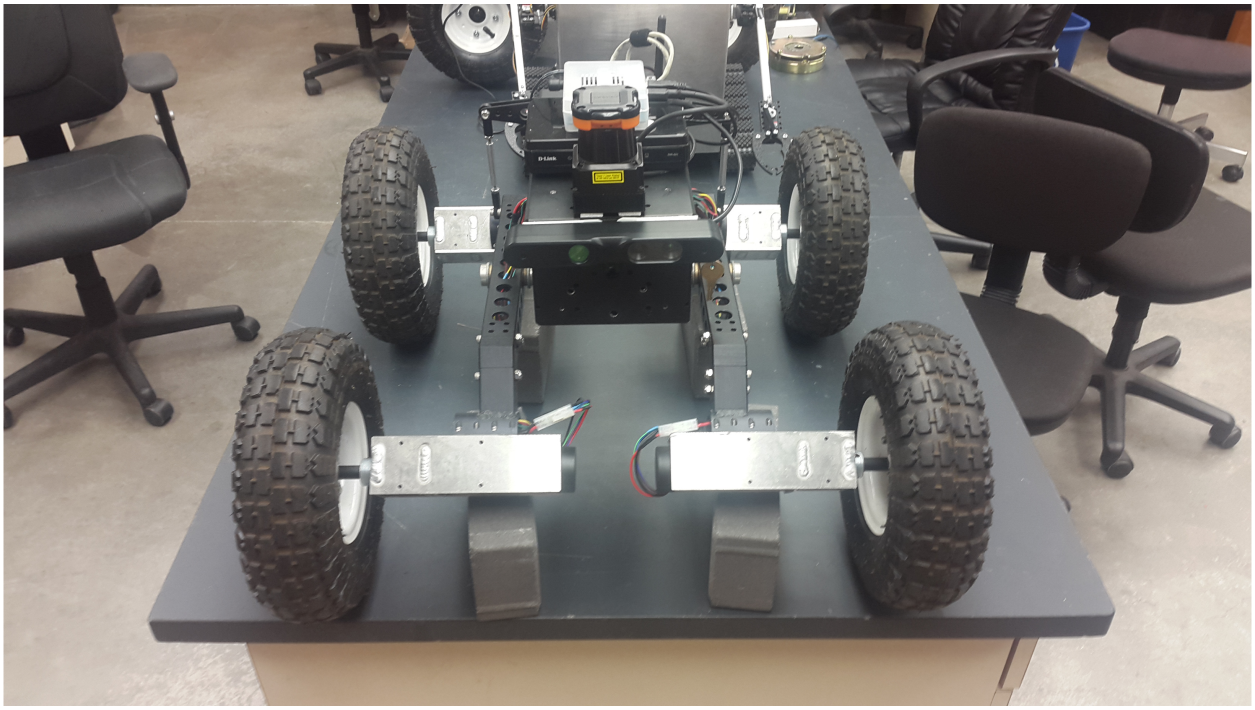

Figure 3.2: The Suface Mobility Platform "SMP"

The SMP uses an aluminum box - now with far too many holes drilled in it - for the main body. The interior of this box is used to house all of the electrically noisy components, creating a sort of Faraday cage to protect the more sensitive electronics, mounted on the top.

To my eternal regret, we decided at the last minute that 3M velcro-tape would be a good mounting solution, as it was easy, didn't require drilling more holes, and made reconfiguration painless. It works ok, but the tape was far more sensitive to vibration and shear stresses than our original tests led us to believe. That being said, it was basically the only way we were able to get everything to fit. Even just putting a few bolts into the box took away too much space inside.

We considered replacing the box currently used for the main body with a larger one, but the articulating bars worked against us. Making the box any wider will cause it to collide with the bars during even fairly low levels of articulation. Making the box longer would both require redesign of the swing arm and pivot joints, as well as looking a bit odd. Making the box taller would raise the center of gravity and put any reasonable mounting points for a LiDAR too far up to be of any real use.

The LiDAR is the piece of main concern with the current mounting system. The wireless router and Odroid are long, wide, and short, meaning they experience very low sheer stress from the robot's motion. The ASUS is fairly light, and so its mass doesn't cause too much of a problem. The LiDAR, though, is both tall and heavy, meaning it experiences relatively high pivoting and shear stress from the robot's motion, and has the most inertia of any of the sensors.

New wheels and potentially new motor housings should be the most imminent upgrade, however. The current set allows the wheel hubs to slip within the wheels during sudden acceleration. The wheels also deform very easily. Both of these conditions are hindrances to accurate odometry using wheel encoders. Of course, it's still a skid-steer drive system, so the odometry will never be all that great.

Only two cables connect the top of the unit with the noisy components within. This is good for two reasons. First, it limits the noise that can pass from the cage to the sensitive electronics. Second, only two things must be unplugged to remove the upper layer.

3.2 Mecanum

The Mecanum frame was built custom in house (or at least in town, it has existed since before I was on the team) from aluminum. The main body is two 2" square aluminum tubes with a sheet of aluminum welded to the bottom of the tubes. The Mecanum robot is also unique in that is uses 4 45°Mecanum style wheels allowing for omni-directional travel.

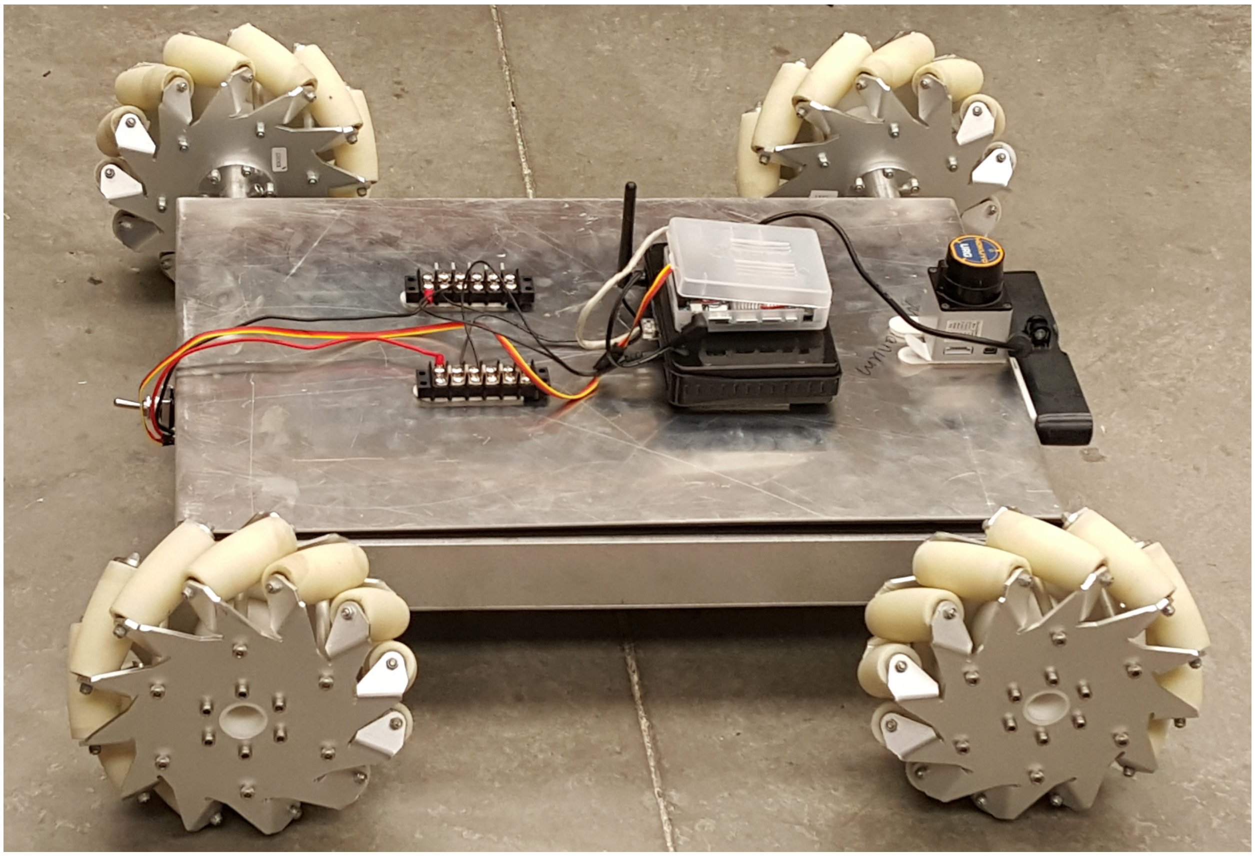

Figure 3.3: Mecanum

One really nice feature of the Mecanum is that it provides a large amount of interior space. We used the 3M velcro tape solution with Mecanum as well because it was (so we thought) working so well with the SMPs. One addition we did make was the bent lid piece of aluminum. Using a single piece of metal with 90°corners actually increases the rigidity of the structure. Before we added the lid, the entire frame would flex. The addition of the corners reduced that flexibility considerably. Corners are, in general, a good way to increase rigidity, but they do act as focal points for stress.

Like the SMP, the interior of the Mecanum acts as a Faraday cage for the motors, motor controller, batteries, contactor, and other high voltage or high noise elements.

4

Electrical Design

This chapter details the electrical components used in the design, and includes logical connection diagrams.

4.1 Parts List

Both the SMP and Mecanum robots used nearly identical parts for the electrical system. This was by design to reduce the number of different parts the lab would need to keep on hand for replacements. It also simplified the build process because we were able to prototype with a single robot, rather than going through the prototyping phase for each one. The items marked with (*) varied between the SMP and Mecanum designs.

- DC Motors with Encoders (4)*
- Motor Controller(2)*
- 11.1V LiPo Battery(2)
- Contactor(1)
- DC-DC Converter(1)
- Power Switch(1)
- Terminal Blocks(4)
- Odroid XU3 Lite(1)
- Wireless Router(1)
- LiDAR(1)
- ASUS(1)
- IMU(1)

4.1.1 DC Motors With Encoders

Each robot uses four (4) Brushed DC Motors with quadrature encoders mounted on the back shaft. Both use a 42mm motor made by Shayang Ye Industrial Co., Ltd.. The Mecanum robot uses the 24:1 gear ratio, while the SMP robots use the 49:1 gear ratio. The relevant datasheets should be included with this document:

- Motor
- Gearbox
- Encoder

4.1.2 Motor Controller

SMP

The SMPs each use two (2) SDC-2130 RoboteQ motor controllers. We never quite got the serial communication working with these guys, so they are currently still connected through USB. This is undesirable as it violates one of our requirements from Chapter 2. I'm still not sure why the serial communication didn't work. Kudos to whoever figures out what I missed. It's probably something simple. Most problems turn out to be simple.

Mecanum

The Mecanum uses two (2) Roboclaw 2-15A motor controllers. There is one odd caveat of the Roboclaw motor controllers I want to document here. The Roboclaw allows up to 8 contollers to be networked on one serial line. All of the receive (rx) pins from the motor controllers just tie together and lead to the one transmit (tx) pin on the Odroid. However, because we can't have multiple units attempting to "talk" on one transmit line, a diode is required on each individual motor controller tx pin, and a single pull-up resistor is required on the line. This diode will prevent problems with collisions, because the line can only be pulled low by the motor controllers, but it cannot be pulled high. There's some serial arbitration magic in there as well, which I don't fully understand, but I do know that without those diodes it will not work.

4.1.3 Contactor

Both robot types use one (1) White Rodgers 124-309 Contactor.

4.1.4 DC-DC Converter

Both robot types use 1 (1) Mean Well RSD-100B-5 DC-DC Converter.

4.1.5 Power Switch

Both robot types use simple mechanical switches to activate the contactors. The two SMPs use key switches from Chris Supply in Rapid City. The Mecanum uses a simple throw switch I found randomly in the lab.

4.1.6 Terminal Blocks

Both robot types use terminal blocks with screw terminals to distribute power. There is a +24V unregulated and 0V unregulated in the cage. There is also a regulated set of 5V and 0V terminal blocks on the top of each robot. These terminal blocks were from Chris Supply in Rapid City.

4.1.7 Odroid XU3 Lite

Documentation on the Odroid XU3 Lite exists, but it's sort of spread out all over the Hardkernel website, so there isn't an easy way to just link to a .pdf. Sorry about that.

4.1.8 Wireless router

Each robot has a wireless router to allow connection and programming wirelessly. I stole three routers from the turtle-bots and can't remember any actual information about them other than that they worked.

4.1.9 LiDAR

There are two Hokoyu LiDARs currently floating between the three robots. These LiDARs are good both indoors and out, but perform best indoors.

4.1.10 ASUS

Each robot has an ASUS RGBD sensor. This allow for depth sensing as well as color vision. The ASUS also has a built-in microphone. There isn't a readily available .pdf to present with this document, so online will be your best resource.

4.1.11 IMU

The two SMP robots currently have one (1) YEI 3-Space Motion sensors that allow them to infer their pitch, yaw, and roll, as well as measure accelerations.

4.2 Wiring Diagrams

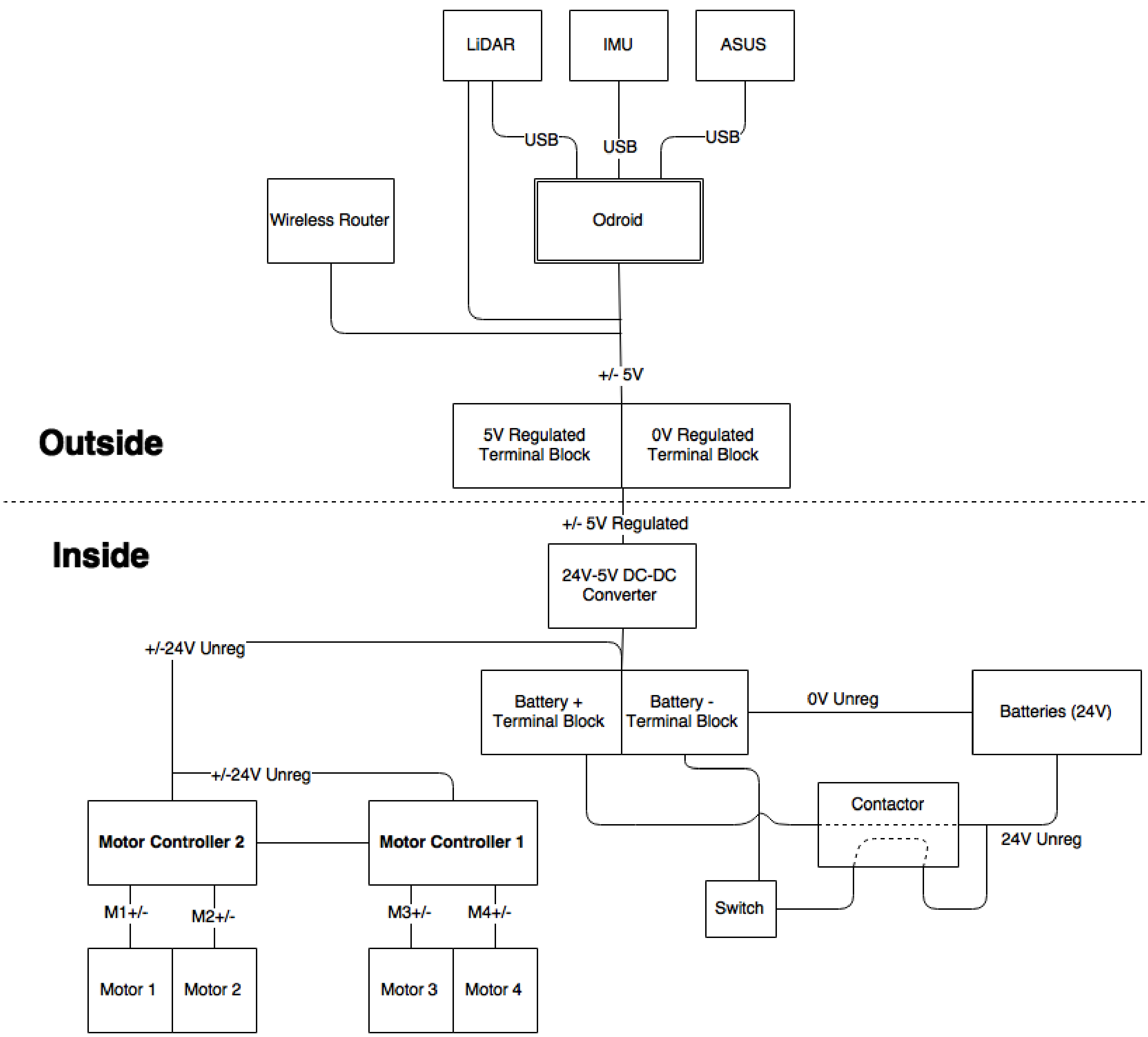

Figure 4.1: Power Connections

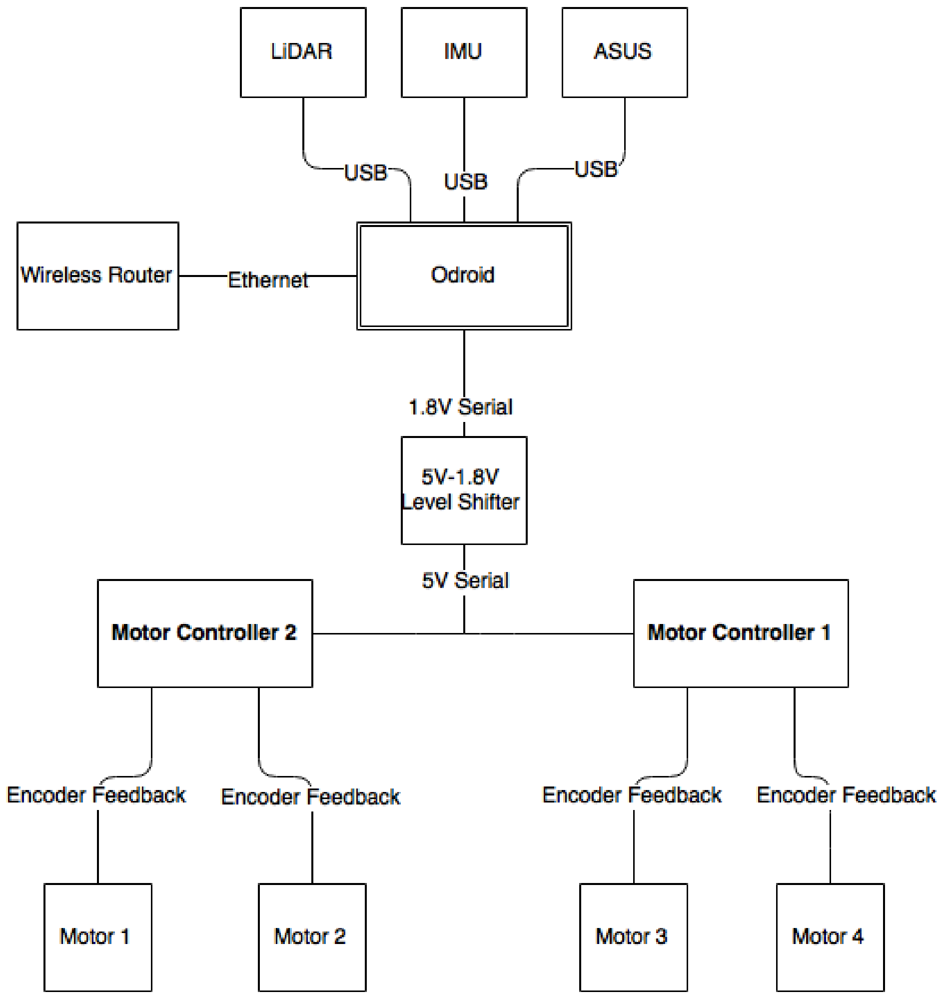

Figure 4.2: Logical Connections

5

ROS Architecture

The SMP and Mecanum robots have identical ROS architecture with the exception of the drivers used to control the motor controllers. With a more complex robot, this section would be considerably longer, but there isn't actually a whole lot going on to just make a robot drive under RC control.

5.1 Nodes

The following ROS nodes are running on the SMPs:

- joy_to_twist
- skid_drive_controller
- roboteq_nxtgen_controller

The following ROS nodes are running on Mecanum:

- joy_to_twist
- mecanum_drive
- orion_roboclaw_driver

5.2 rqtplot

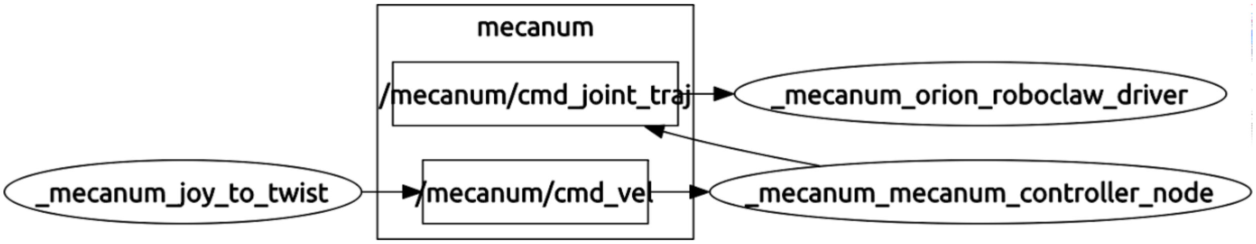

Figure 5.1: Mecanum rqtplot

I'll be adding one for the SMPs when I get a chance to do some remote work through someone at the lab. The one for mecanum isn't quite what I expected to see, so I'll have to look in to that as well.

5.3 Other Packages

The SMPs also require the smp_bringup package with contains the default launch file. Mecanum has no corresponding package, but does require a very similar launch file which calls for the different drive and motor control nodes.

5.4 Other Files

The SMP launch file, udev rules, and smp_bringup.service file are included with this document. The Mecanum variants will also be included once I get them from Dan and Joe, who currently have the robot.