Battery Management

General Description

The battery management subsystem is primarily concerned with the operation and charging of the battery. The battery and battery charger supply power to the power PCB which supplies power to the robot.

Equipment, Parts, Software Used

Lithium Iron Phosphate Battery	https://www.digikey.com/en/products/detail/power-sonic-corporation/PSL-SC-1270-F2/13577482
Lithium Iron Phosphate Battery Charger	https://www.digikey.com/en/products/detail/zeus-battery-products/PCCG-LFP14-4V10A/9828828
Panel Mount 3-Prong Receptacle	https://www.digikey.com/en/products/detail/schurter-inc/6100-3300/569903
12 Foot 3-Prong AC Power Cable	https://www.digikey.com/en/products/detail/tripp-lite/P010-012/1533391
IEC 320 C13 - C14 Power Cable	https://www.digikey.com/en/products/detail/assmann-wsw-components/AK500-OE-11-5/821664
C13 - C13 Adapter	https://www.newegg.com/p/2VH-0003-00029

Schematic

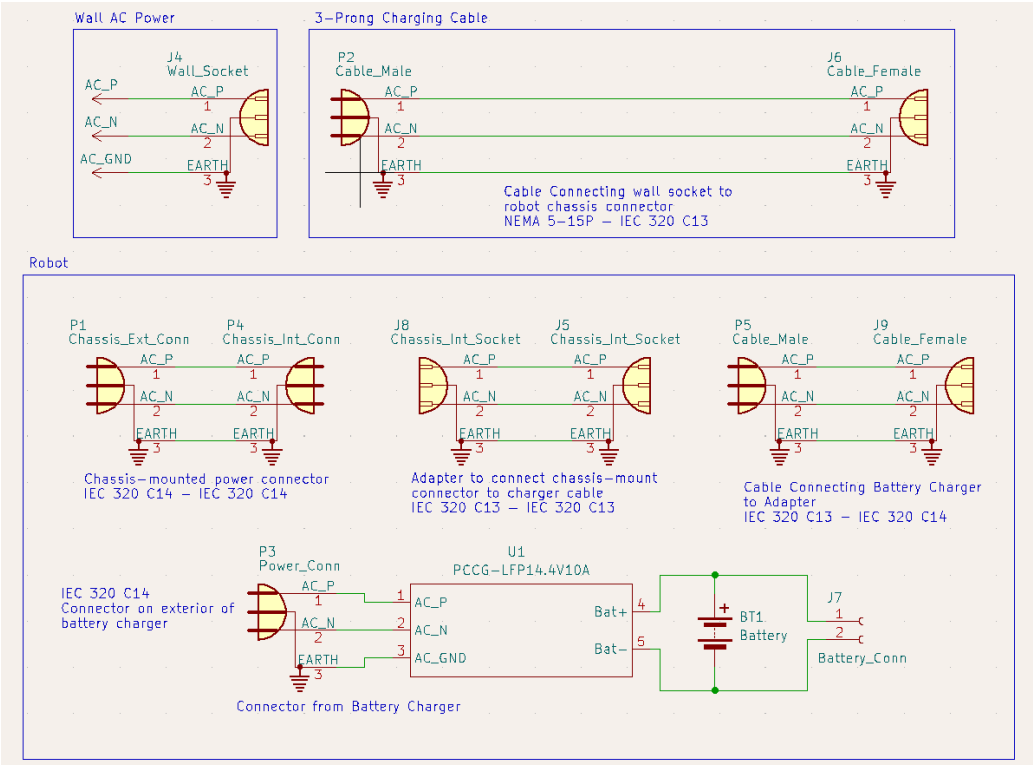

Figure 1. Schematic of Battery Management System.

Logic, General Notes, Reasonings

The original goal for runtime was for the robot to be able to have 2 hours of continuous runtime. Using the current estimates shown in Tables 1-3 of the Power Distribution Manual and Table 5 below it was estimated that this would require a 20 Amp-Hour (Ah) battery. When investigated, the size and weight of such a battery would inhibit robot operation, and so a smaller battery was chosen that could still source enough total current.

Table 1. Current Requirements.

Item	**Part Number**	**Quantity**	**Max Current Draw (mA)**	**Item Current (mA)**
Line Sensor	Pololu QTR-8RC	1	100	100
Ultrasonic Distance Sensor	SKU 101020010	4	8	32
Jetson Nano*	SKU 101020010	1	2000	2000
Compass	LIS3MDL	1	0.27	0.27
Accelerometer	ADXL345	1	0.14	0.14
Motor	Metal Gearmotor 37Dx73L mm 12V	4	720	2880
Motor Driver	L298N Motor Drive Controller Board	2	2000	4000

Arduino Mega	A000067	2	500	1000
Total Current				10012.41

The above current requirements with a 7.2 Ah battery gives a worst-case battery life of 0.72 hours = 43 minutes. Note again that this is the worst case and the true runtime may very well be several hours. With these requirements a battery was chosen.

A battery charger was also chosen. The charger was chosen such that the entire robot could potentially run off of the charger alone. To charge the battery, simply connect the two alligator clips to the terminals of the battery. The battery charger takes a standard 3-prong cable for its power supply and has two alligator clips for its output. To extend the range of the battery charger so that it is easier to charge the battery while the robot is in use, the easiest method will be to use a longer 3-prong cable and possibly hang the charger from something overhead to keep the cable from dragging or needing to be held as the robot moves. Using a twisted pair cable connected between the alligator clips and the battery was investigated for extending charging range, but seems to at best be much slower to charge than without, sometimes not charging at all.

The connectors of the battery are meant for slide connectors, also referred to as F2 connectors. For the main battery-board connections, slide connectors were put on the end of 16 AWG wire and crimped onto wire and the other side connected to the battery screw terminals. This provided a secure but removable connection to the battery.

The other connectors and adapters shown above were meant to be used to show that a connector could be mounted on the chassis for easier charging without battery removal. The chassis mount receptacle was meant to be mounted on the chassis and there would be a cable connecting this receptacle to the wall, and one connecting it to the charger inside the robot. The current version of the robot does not have a chassis, so this was just for future teams to use. However, it was found that the male connector of the chassis-mount receptacle does not fit the female connectors of the cable or adapter. Because of this, if a chassis connector is to be used, a different receptacle will need to be chosen.

Testing

The testing done for the battery management subsystem centered primarily around the battery life. The battery functioned with not issues supplying power to the robot, so here the testing done for battery life will be discussed.

Initially, the battery life was going to be tested completely, by running the robot's motors in short bursts until the battery was depleted. This was done originally by driving the robot back and forth in place every second in 2 or 3-minute increments, but it was found that this caused too much power to be sent back into the motor driver (caused by the constant changing motor direction) and caused a driver to overheat and fail. When switching to a continuous rotation of the robot, driving the robot in place in a circle, this problem was solved and could be run in increments of over 12 minutes with no issues.

Using this continuous rotation, the robot was run for a total elapsed runtime of over 3 hours with the battery still showing no signs of depletion. Instead, how the final estimate of battery life was made was by running the robot in the same way, but recording the battery voltage over the time while the motor was running.

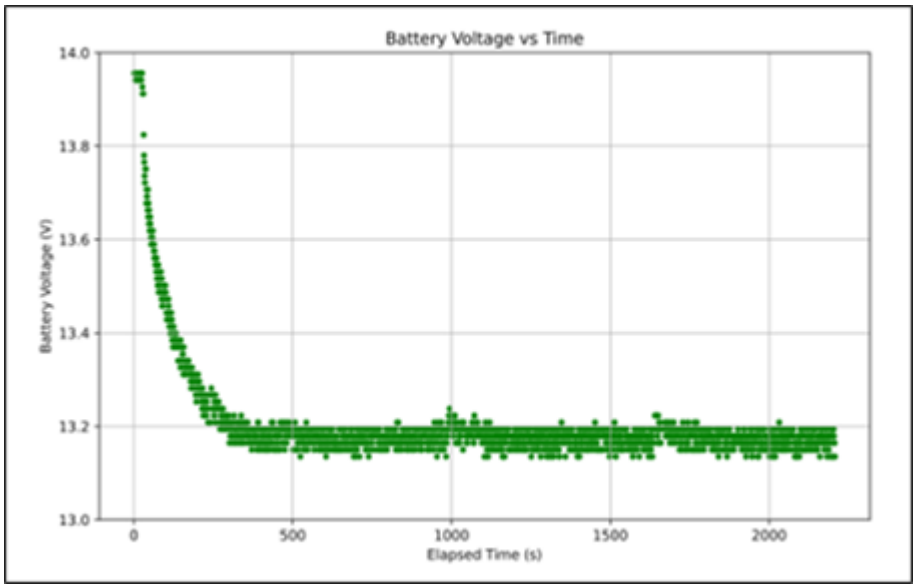

Figure 2. Battery Voltage vs Elapsed Continuous Runtime.

The data gathered in this test is shown in Figure 2. This data is from about 38 minutes of motor runtime. Using the graph of this data and the graph of the battery discharge curve provided by the manufacturer, the battery life could be estimated.

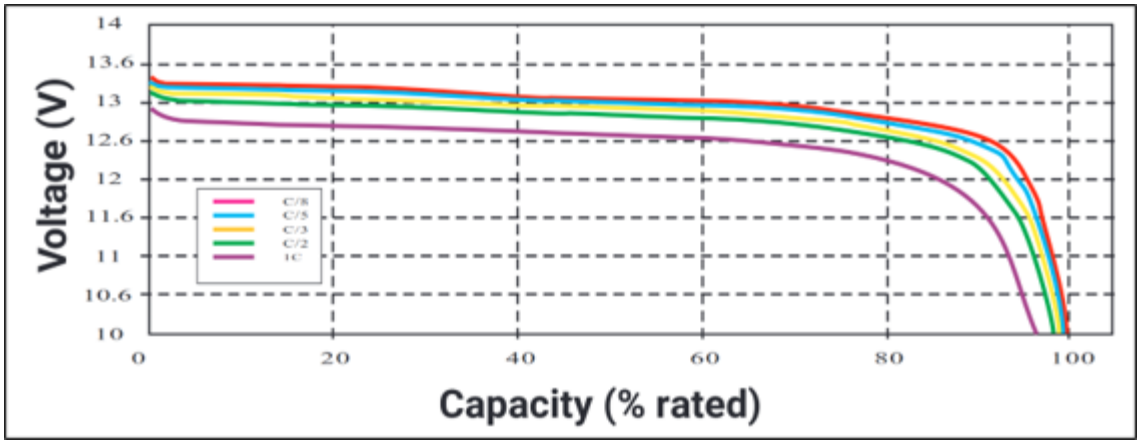

Figure 3. Manufacturer-Provided Battery Discharge Curve.

Using an image manipulation program, the measured discharge curve was scaled to match the provided discharge curve scale and overlaid on top of the manufacturer's plot. By adjusting the length of the measured data plot to fit the manufacturer, the elapsed time recorded was found to end at about 10-12% battery capacity (i.e. 38 minutes usage corresponds to 10-12% battery depletion). From here, the battery life was estimated to be between 3 hours 56 minutes and 4 hours 55 minutes. Far more than the goal of 30 minutes proposed.