Carnegie Mellon University

16-681

MRSD Project I

Task 11 Power System Design
Team C - COBORG

Teammates:
Husam Wadi, Feng Xiang, Jonathan Lord-Fonda, Yuqing Qin, Gerry D'Ascoli

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1. Power System

1.1. Power System Needs

The Coborg platform is a backpack robot that assists aircraft and automotive factory workers with their production tasks. To achieve this goal, the robot we design must be mobile (untethered), power a robot arm (motors), and power a main compute unit. It would also be beneficial to have a method to switch between tethered, charging, and untethered to allow greater flexibility with the platform.

Our goal is to create a power distribution platform that can sense what the power source of the robot is (tethered to the wall, or battery powered) and select the best source, with a bias towards tethered power. This means if both the battery and a power cable is plugged into the robot, it will choose to source power from the cable.

1.2. Loads

The loads of our current system are as defined below *Table 1*. Note that the input range for the motors is between 24-48 volts, however we will choose the nominal voltage of 36 volts to calculate amp draw and power requirements:

Table 1 - Current Loads

Load Source	Required Voltage (V)	Continuous Current (A)	Peak Current (A)	QTY	Peak Power Required (W)	Connector Type
HEBI X5-9	24-48 | (36)	0.5	1.6	3	173	Molex Mini-Fit Jr.
Zotac EN51050	19.5	9.25	-	1	180	DC Barrel (5.5 mm x 2.1)
GL.iNet N300 Router	5	1	-	1	5	Micro USB Type A
Total					**358**	

However, if we design to these loads, then we negate the ability to expand in the future. We want to have the ability to expand to this configuration for future iterations of the platform:

Table 2 - Expansion Loads

Load Source	Required Voltage (V)	Continuous Current (A)	Peak Current (A)	QTY	Peak Power Required (W)	Connector Type
HEBI X5-9	24-48 | (36)	1.3	3	6	346	Molex Mini-Fit Jr.
ASUS-ROG-i7-10750H	19.5-20	9.25	-	1	180	DC Barrel (5.5 mm x 2.5) USB-C (20V-65W)
GL.iNet N300 Router + Misc Peripherals	5	1	5	1	25	Micro USB Type A
Total					**529**	

1.3. Sources

Our power sources currently consist of these potential sources to match the loads of the system:

Table 3 - Power Sources

Supply Source	Voltage (V)	Continuous Current Output (A)	Peak Current Output (A)	Nominal Power Output (W)	Energy Capacity (Wh)	Connector Type
Wired Power Supply	24-48 | (36)	20	20	720	-	Anderson Powerpoles
Grin LiGo Battery (1)	36	5	10	180	98	Anderson Powerpoles
Grin LiGo Battery (2)	36	10	20	180	196	Anderson Powerpoles
Grin LiGo Battery (3)	36	15	30	180	294	Anderson Powerpoles

We also want to estimate the amount of time available using our battery configuration with our nominal load and future expansion load. Since each battery can only handle 5A of continuous current nominally, we need at minimum 2 batteries to power the current configuration, and 3 batteries to power the future configuration:

Table 4 - Battery Life

Total Battery Load (W)	Voltage (V)	Continuous Current Draw (A)	Required Battery QTY	Energy Capacity(Wh)	Total Time Capacity (Minutes)
358 ~(360)	36	10	2	196	32.6
529 ~(540)	36	15	3	294	32.6

Our primary advantage is the use of “Grin LiGo” batteries in our design. These batteries are designed to be modular units of 98Wh, and can be configured in series or parallel to suit the end user’s needs. We can use these batteries in parallel to expand our continuous amp capacity to deliver the same powered time with higher expansion loads:

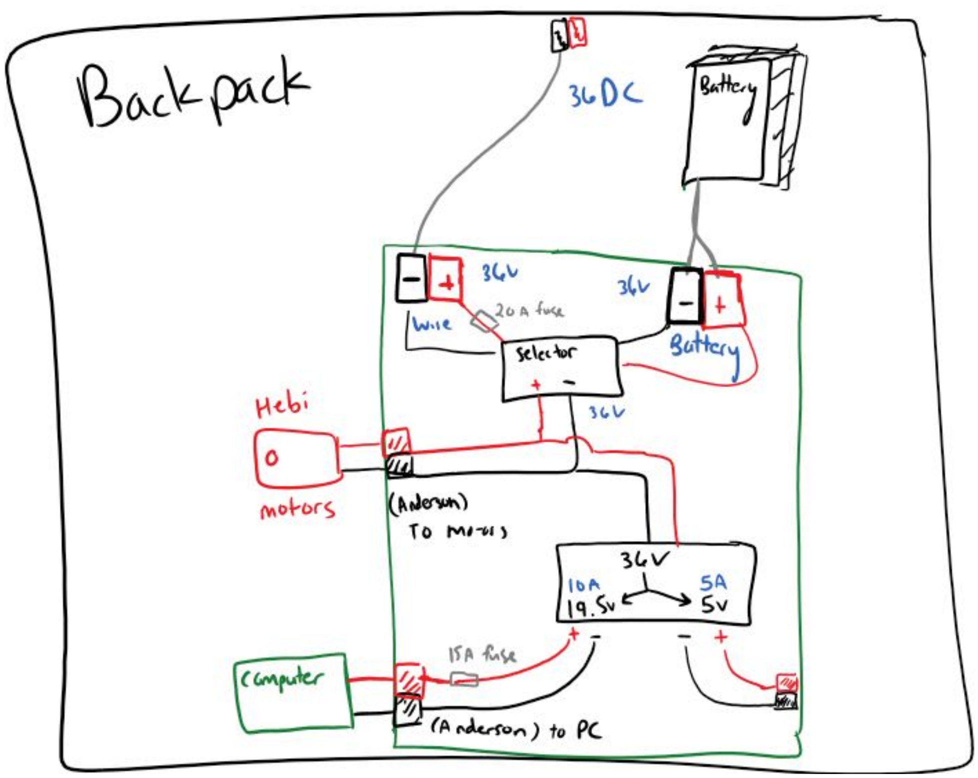
Figure 1 - LiGo Parallel Connection (3)

2. Design Requirements

2.1. Design Overview

In the figure below we conceptualized our design requirements and sketched out the major PCB components for the project's power distribution:

Figure 2 - PCB Conceptual Design



2.1.1. Power Source Selection

The power distribution PCB will be able to accept power from either an external AC-DC converter plugged into a wall outlet or our on-board battery pack, either supplying 36VDC to the PCB. The power supplies will be switched between with priority to the AC-DC converter wall outlet power using a LTC4412HV board to control a P-channel MOSFET that will "disconnect" the battery supply power in the presence of power from the AC-DC converter.

2.1.2. Circuit Protection

The PCB Will include fuses for overload protection at the input of the AC-DC converter and the output of each regulator, the LiGO batteries have built in overload protection for both current and voltage. The input AC-DC converter power will be fused at 20A to match the limitations of the LiGO battery supply limiter. The 36V->19.5V regulator will be limited to 15A, a limit of 50% over the peak current expected for the Zotec PC. The 36V->5V regulator will be limited to 5A, a limit roughly 50% over the expected nominal current for the router and any other logic components. Overvoltage protection will be provided by TVSs rated for 10%-30% over the nominal voltage coming out of each regulator. The AC-DC converter and the LiGO batteries each have built in overvoltage protection.

2.1.3. Power Indication

The PCB will include LEDs indicating if the regulator is outputting power as well as LEDs indicating which power source the system is currently drawing power from (batteries or AC-DC converter).

2.1.4. Number of Connectors and Types

We will be using the Anderson Powerpole 15/30/45 series connectors. These connectors are rated for a maximum output of 45A; however, the rating differs based on the cable/pcb contacts inserted into the connector. We plan on using 25A contacts on the PCB which will provide a 3x factor of safety for future expansion of the board. The number of connectors we need is 20. This corresponds to 10 pairs of I/O coming into the PCB as shown in *Figure 2*.

2.2. Motor Subsystem

2.2.1. Load Details

Table 5 - Motor Subsystem

Load Source	Required Voltage (V)	Continuous Current (A)	Peak Current (A)	QTY	Peak Power Required (W)	Connector Type
HEBI X5-9	24-48 | (36)	0.5	1.6	3	173	Molex Mini-Fit Jr.

2.2.2. Motor Connector Type

We will use Anderson connectors throughout the PCB to keep its consistency, and create a cable that adapts from Anderson to Molex Mini-Fit Jr.

2.3. Computer Subsystem

2.3.1. Load Details

Table 6 - Computer Subsystem

Load Source	Required Voltage (V)	Continuous Current (A)	Peak Current (A)	QTY	Peak Power Required (W)	Connector Type
Zotac EN51050	19.5	9.25	-	1	180	DC Barrel (5.5 mm x 2.1)
GL.iNet N300 Router	5	1	-	1	5	Micro USB Type A

2.3.2. Computer Connector Type

We will use Anderson connectors throughout the PCB to keep its consistency, and create a cable that adapts from Anderson to DC Barrel. We will create a similar cable for the 5V Micro USB output.

3. Appendix

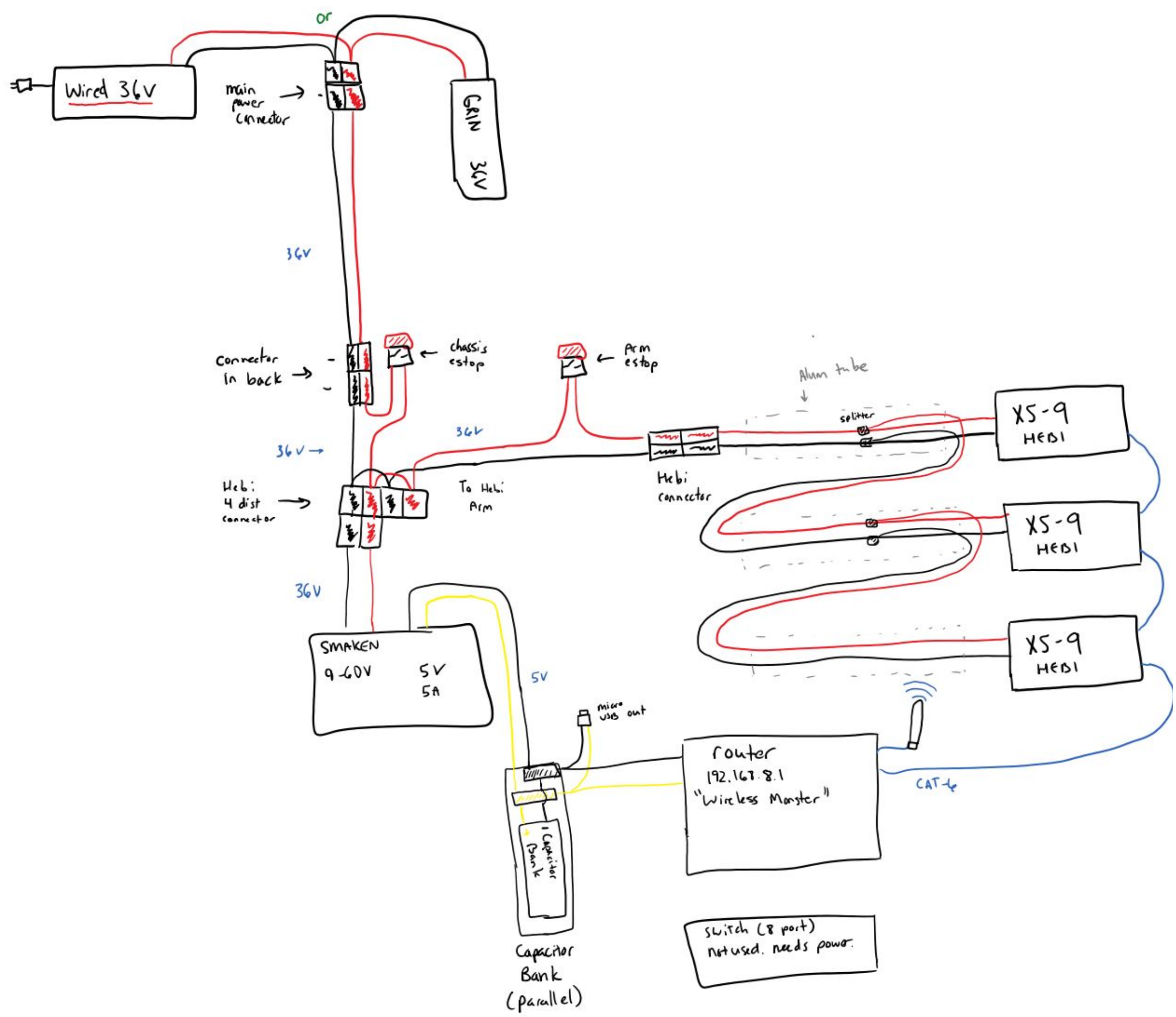


Figure 3 - Current Electrical System Schematic