Electrical Engineering Within a Robotic System

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Synopsis

The NASA Robotics Mining Competition (RMC) is held every year at Kennedy Space Center, Florida. Fifty universities assemble robots to mine regolith, get to water ice, and deposit it into a bin. The University of Hawaii at Hilo entered as the Space Robotics Team and its first competition was in May 2016. Part of what we are scored on includes power usage and dust mitigation. Relating this to the overall performance is an important part of the electrical system. My contribution in the Space Robotics Team was the design and implementation of the electrical system within the robot. This specific project was focused on testing power usage, energy losses, and safety features of the electrical system. The new electrical system is designed to be easier to rebuild and transport for the 2017 competition. This paper outlines an assessment of the old wiring diagram, problematic features, and what improvements should me made for the 2017 new electrical design. Appendix 1 (old wiring diagram) and Appendix 2 (new wiring diagram) shows the different setups. Referring to Appendix 3 will give a more concise idea of the overall system setup related to the structure of the robot.

Overview of 2016 Electrical System

The 2016 electrical system (Appendix 1) was composed of two 12V batteries, and a main electrical box, controlling five different motors. The 12V batteries were wired together in series to make 24V output, both positive and negative lines were connected to kill switches on the outside of the robot. Each wire came in after the kill switch and on/off switch to the power logger. This would give us information on how much power the system was using.

The Voltages were then split into 24V and 5V for motor control and data using a voltage regulator (refer to glossary). The 24V used for motor control was distributed among four motor controllers, three Talon SRX and one Pololu. The Talon motor drivers (refer to glossary) controlled the left and right side of the robot to provide tank steering, and the wheel chair motor which is connected to our digger. We used the Talon motor drivers for these motors because they are able to deliver a high current if needed. The Pololu motor driver is controlling the brake of the wheel chair motor. The brake is magnetically engaged and does not need a high current so we save power by having a Pololu motor controller.

From the 5V regulator the data side is hooked up to a raspberry pi and then the arduino mega (refer to glossary). The raspberry pi (refer to glossary) works as a small computer, and the arduino worked as the brain or nerves that would connect to the motors. This setup created pulse width modulation that was controlled over wifi, and connect to our motor drivers. In other words we are able to control our motors over wifi from a different room than our robot. This relates to NASA's goals being able to communicate with a robot on the moon or mars while stationed on earth.

Power Usage, Energy Losses and Safety

Major Changes Within The System

Bundling

Bundling happens in DC (refer to glossary) when multiple wires are ran together with a high current and can not dissipate the heat. The old system had positive and negative wires separated running in the same main line and at times would overheat. The new system should have no more than four wires running in the same line so that all of the wires get air flow. With DC it does not matter if the wires are separated by positive and negative (such as AC giving Eddie Effect) as long as each has air exposure. By using a wire loom over the four or less sections of wire will create a boundary between the other wires and allow air flow, preventing bundling. Possessing the ability to keep the electronics cooler without adding additional features will keep the robot lighter and more simplified in space.

Electromagnetic Interference

When using both higher gauge and data wires, pulse width modulation may create an electromagnetic interference (EMI). Electromagnetic Interference is caused by a disturbance affecting the overall performance of the device. By having a clear boundary between the two provides a clear signal without any interference by the higher current carrying wires. A single point grounding and using shielded twisted pair cable can also be used to prevent EMI, or mitigate PWM noise. An extra line of polycarbonate could also be ran within the system to separate the main portion of data wires and higher current wires. There will be a delay in communications if the robot is sent to space, thus keeping the communication clear is ideal.

Adding a Relay

By adding in a relay before the on/off switches and after the power logger (Appendix 2) we are able to lessen the current load going through the switches. Having a high current going though the switches such as the old system, we were burning out switches from overheating. A relay is a coil controlled electrically or magnetically that you can hook up with your switches. In other words in order to turn on the main power line, the two smaller switches need to close. This connects the circuit within the inside of the relay, then the main power flows through the relay and not the switches. This will extend the life of our switches and create a safer system. If the switches overheat such as the ones in the old system, this risks not only the connection failing, but it may melt the connection together making it impossible to shut off the switch, adding a relay resolves these issues.

Variation in Wire Gauge

A change in the gauging of wire vs. the same gauge throughout the entire system will be an important note with the addition of fuses. The gauge of wire can be changed in the future as long as the fuse has the correct ratings to the new transition. Each gauge wire is rated differently in amps. A wire gauge transition can be made after a fuse or fuse block. By starting from the batteries into the 35 amp fuse with a 10 gauge wire (rated for 35 amps) we will not overdraw from the wire during higher torques. We can change from a 10 gauge to a 12 gauge wire after the relay and before the motor controllers (after the 20 amp fuse). We use the same concept with the transition to the logic with 15 amp fuses.

Polycarbonate Instead of Plexiglass

Our old system used Plexiglas as a frame to our electrical box. We were having some issues with cracking, reshaping, and sealing well for dust mitigation. We will be implementing a new polycarbonate base structure that will fix those problems by providing a solid straight structure to put a seal on. (Appendix 3) Even though this new structure is more sturdy it will also be heavier. I purchased the new Polycarbonate from Alumside products in Hilo to apply to the new electrical box. Transportation of the electrical box was also assessed and researched. Previously I had each motor wire separately inserted into the electrical box. After assessing this system I decided on a main terminal that would be wired to the box itself, instead each individual wire being ran through it. The terminal is a single connection, instead of 12 separate ones.

Power Usage, Energy Losses and Safety

Smaller Changes Within The System

Fuses

Fuses should be installed in the new electrical system as an extra form of over current protection. A fuse is a short piece of wire that will melt if the current gets too high disconnecting the system. We can refer to the wire gauging on where a fuse should be installed. By coordinating the wire gauge and fuses we will be making the system safer and protect against the devices current capabilities. The fuses that can be used in the system are 35 amp, 25 amp, and 15 amp, by keeping spares we are able to fix problematic errors that occur more efficiently. (Appendix 2)

Splicing

Splicing wires creates weak spots in the wiring. The covering of the splicing may be brittle or not be a good covering allowing weathering to come into the wire, possibly shorting out the system. Splicing wire increases corroding and overheating over time in the area that it was done. Our old system had an excess amount of splicing due to electrical devices being added in after the initial build of the electrical box. The new system should try to minimize splicing unless necessary. If a splice has to be made be sure to cut none of the stranded wires and consider heat shrink vs. electrical tape.

Heat Shrink VS. Electrical Tape

Heat shrink is stronger than electrical tape and provides a better seal over the wires, but does not dissipate heat very quickly in higher current wires. Heat shrink is also stiff after it shrinks possibly causing stress risers. Stress risers is when there is a area that stress is concentrated. A heat shrink is strongest when it is distributed over an area, and when it is not evenly distributed may cause cracking. Electrical tape, usually made of vinyl, dissipates heat more rapidly than heat shrink and provides protection from the wires. Electrical tape is elastic and stretches over the splice, but sometime may slip depending on the quality of tape and wire you are taping.

Power Usage and Safety Features

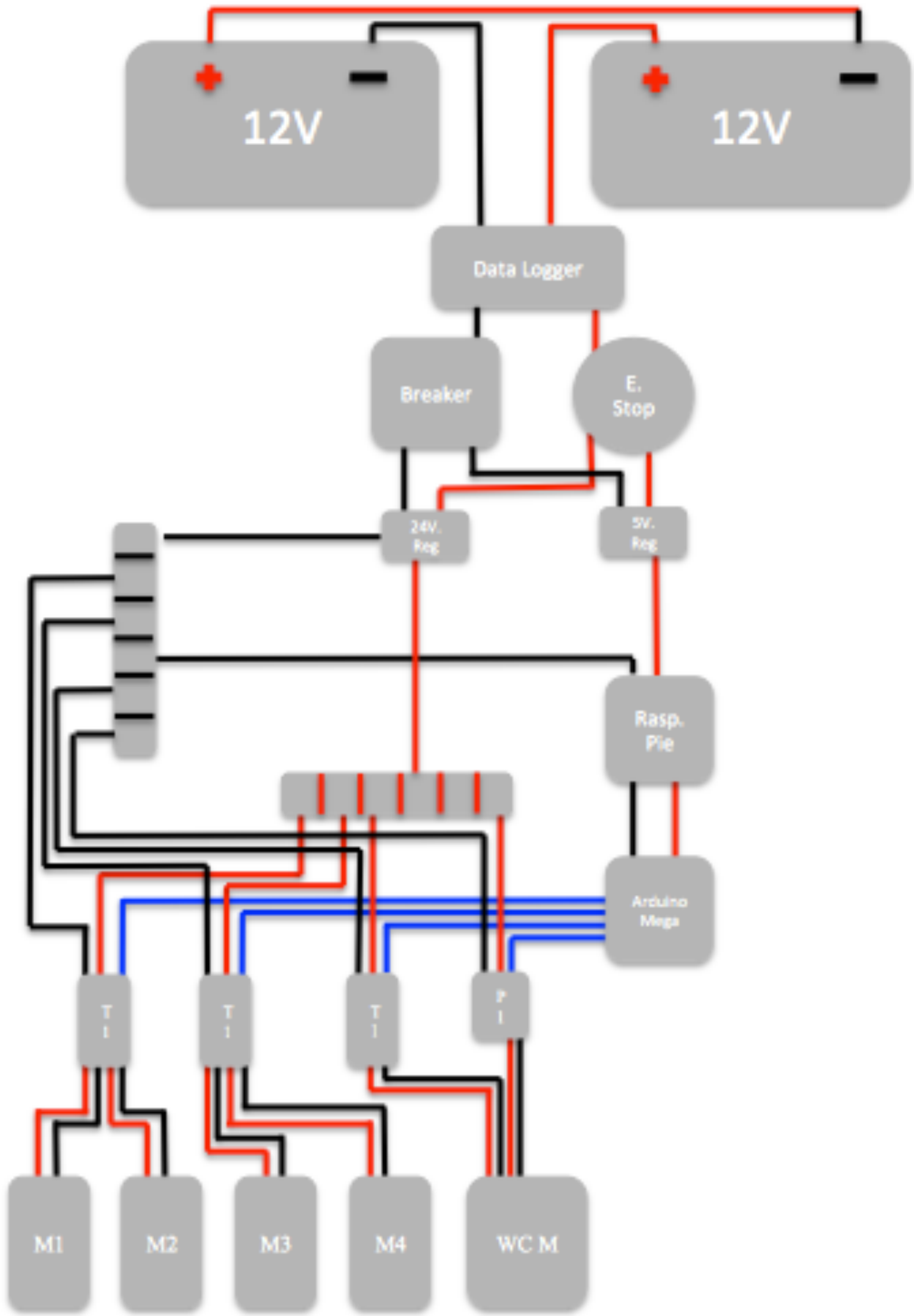
Lithium Iron Phosphate Batteries

Our electrical systems efficiency concerning power consumption is important. With new technology developing in batteries we are able to make our system lighter and have more energy available. Furthering my knowledge on LiFePO4 batteries I have been able to make educated decisions on how to properly use our batteries with our system. LiFePO4 batteries are a type of lithium ion battery. The crystal structure of the LiFePO4 battery does not break down after continuous charging and discharging. Comparing the crystal structure of the LiFePO4 battery to the lead acid battery I was able to find this is one reason why the Lithium iron battery typically lasts longer. Charging of the LiFePO4 battery takes two steps. Looking at figure 1 first constant current for the first 60 percent that it is charged (1hr), second when the cell reaches its upper limit of voltage per cell, turning its charging to constant voltage for the last 40 percent (2hrs). What makes these batteries ideal for our system is they are fast to charge. They use most of the batteries power percentage wise unlike lead batteries.

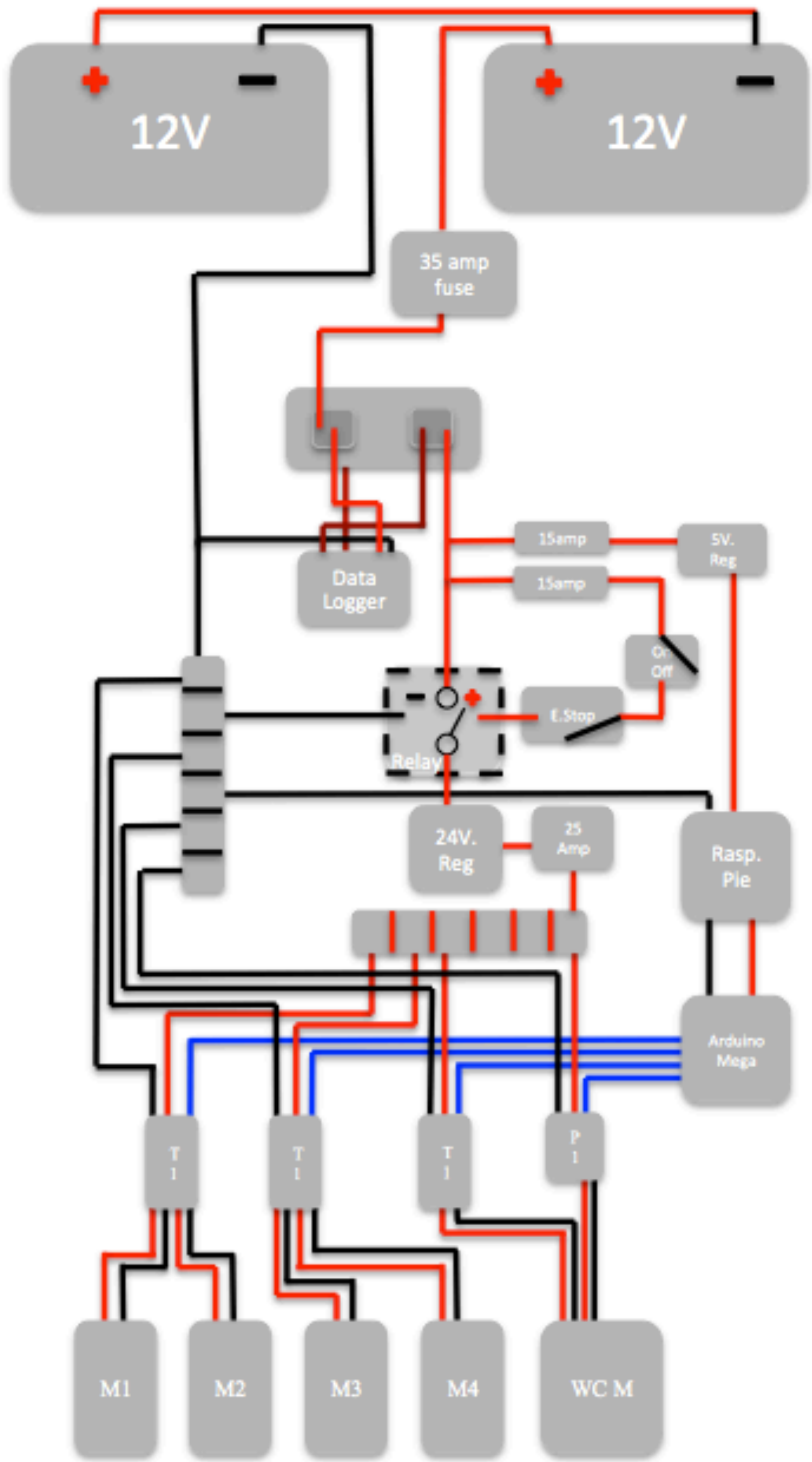
Conclusion

Changing some of these key components in the electrical system will mitigate power usage, energy losses, and advance safety features of the electrical system. The new electrical system is designed to be easier to rebuild and transport for the 2017 competition. By using the polycarbonate we can improve our dust mitigation and the overall structure of the electrical box. Safety being one of the largest factors we are adding a relay, and fuses. By eliminating bundling and splicing within the system we will be securing the electronics and providing safety measures for the public.

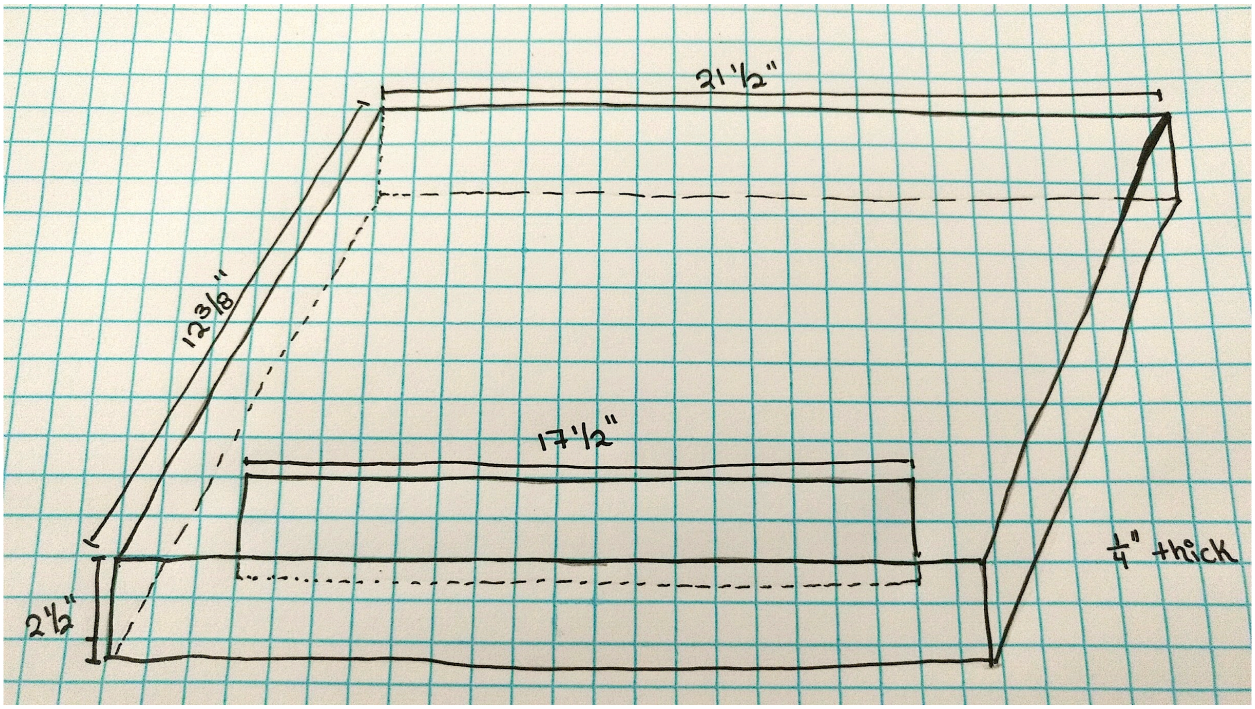
Appendix 1
Old Electrical Diagram



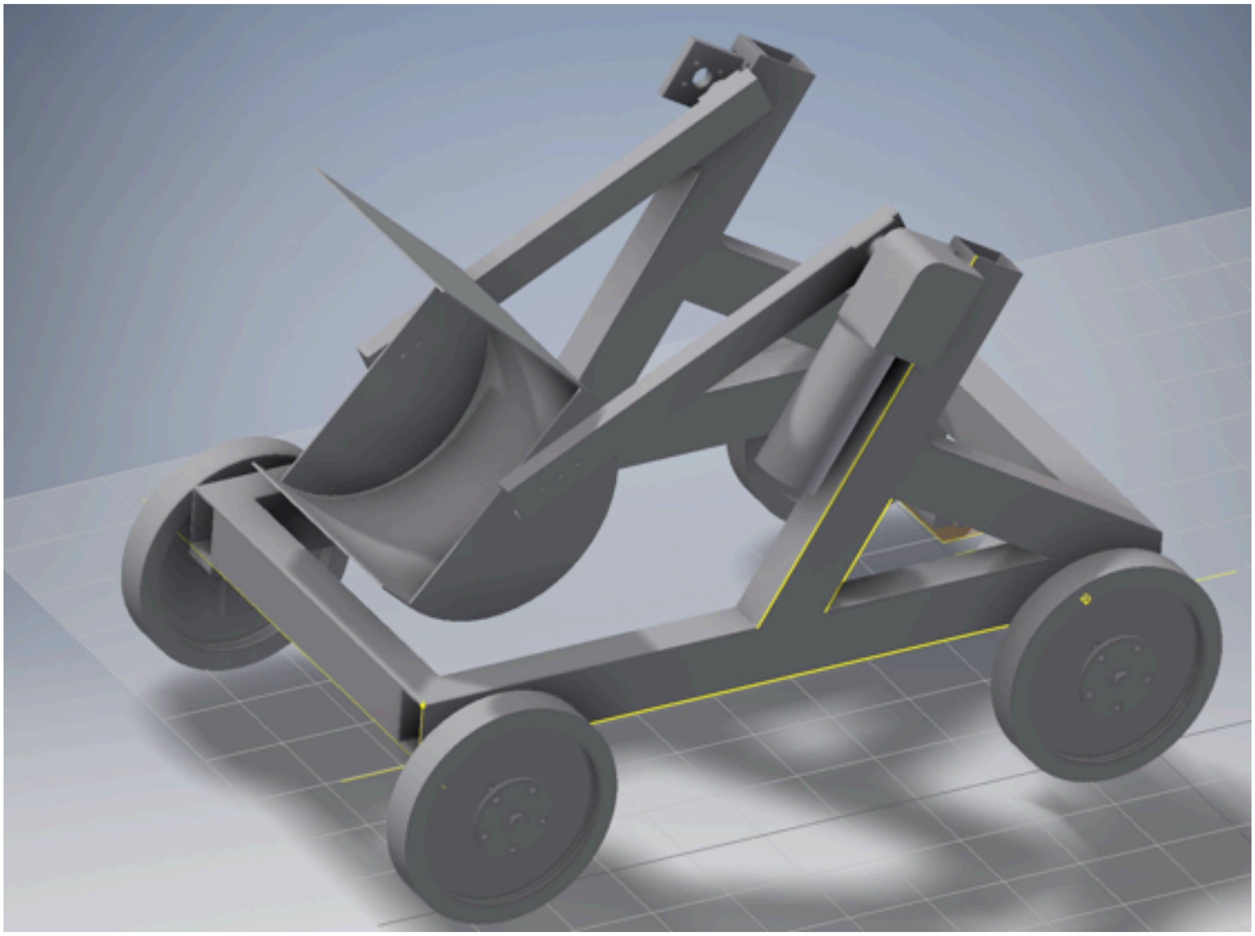
Appendix 2
New Electrical Diagram



Appendix 3
New Polycarbonate Structure



Appendix 4
Overall Structure of the Robot



Glossary

Motor Driver (Talon, Pololu)

The motor driver is a device used between the power source and the motors. They are a connection that supplies power to the motors, and tells the motors what to do from the data line provided in them. They are able to control the motors speed, direction, and protecting against overloading.

AC VS. DC

DC power supply is one which comes from the words direct current. DC power comes from a single source such as batteries and flows in a constant direction. AC power supply is one which comes from the words alternating current. AC is when the power can change directions, and is usually seen in houses. We note this because you will see different problems arise with each power supply.

Arduino

An arduino is an open-source board and the software used to program your devices. They consist of a physical programmable circuit board and a piece of software or Integrated Development Environment that will run on your computer, used to upload and write computer code to the physical board.

Raspberry Pi

The raspberry pi is a series of computers made into a small portable computer. It is slower than a normal Linux, but consumes a lot less power.

Voltage Regulator

A voltage regulator is an electromechanical device used to control a precise output voltage. It will be a consistent voltage no matter what the input voltage is.

List of Materials Needed for New Electrical System With New Design

- Fuses (35amp, 25amp, 15amp)
- 10 and 12 Gauge Stranded Wire (Black and Red)
- DC Relay
- Two Terminal Blocks
- Power Logger
- Kill Switch
- On/Off Switch
- Potentiometer
- Voltage Regulators
- New Drive Motors
- Silicon
- Battery Covers
- Two Electrical Boxes for Switches
- Pololu Motor Controller
- Main Terminal Connection for Polycarbonate Box

Work Cited

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