**Electrical Systems Design (version 5)**

The electrical team decided to follow a strategy that focused on coming up with a design concept that would meet all required objectives, build the robot based on the design, run various performance evaluation runs, and redesign or restructure components in need of reconsideration.

For this year’s entry, the electrical team made significant adjustments to last year’s design, Moxom’s Master’s, improving the overall performance and reliability of the electrical systems. To achieve our goals on time, the members of the electrical team were assigned various and different tasks that had to be performed over a period of 10 weeks.

The team decided that to meet all goals and objectives for the completion, the robot design must meet several characteristics. The robot’s electrical structure must be modular to allow the team to replace components or reposition some components with ease. The robot’s electrical components must be robust and sturdy and capable of handling off-road terrain. The components must be reliable, user-friendly, and rarely experience serious or minor malfunctions.

**3.1 Objective and Electrical Design Concept**

From an electrical standpoint, the team decided that the robot must contain circuit protectors to prevent components from burning in case of an unexpected high current spike. A power supply should deliver power to the motors and electrical components of the robot individually. The robot must be able to determine the direction of travel, the speed of travel, and intelligently decide when to stop with minor problems or malfunctions. Using an array of several sensors, the robot should determine white lines that indicate the boundaries of the track, its current position and current operator mode, and allow the team to read the state of various critical components via some feedback. The robot must also be able to be safely shut off via wireless communication in case any unexpected problems arise.

The electrical team proceeded to incorporate the electrical components after the robot’s mechanical frame was constructed. To achieve the team’s overall objective, the electrical team split into several individual groups that would accomplish a specific task.

**3.2 Original Electrical Robot Design Build and Power Distribution**

Moxom’s Master’s derives its power from two 12-volt, 60AH Power-Sonic sealed lead acid batteries connected in parallel. One battery powers the on-board computer electronics and sensors while the other battery powers the motor. To achieve a high-level of modularity and adaptability, the computer and on-board electronics are mounted in 3U rack-mount server cases.

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| Figure 3.1: The power tether case helps illustrate how the power is distributed from the two 12V batteries to the electronics and motor. |

Mounted in one of the server cases, the team uses an Intel i7 860S for the processor that delivers a power budget of 65W TDP. The operating system and control software are installed on a 32 GB SSD which help reduce power consumption and eliminates the effect of moving parts.

Mounted in another of the server cases includes a 12V 30A battery charger, an AC-DC power supply, a main battery breaker, and a main cutoff switch as shown in Figure 3.1.

Mounted in another of the server cases, four Texas Instruments Black Jaguar motor controllers provide control to the motors of Moxom’s Master’s. The motors are controlled via a CAN bus over an integrated CAN to RS-232 bridge. Encoders attached to the wheels help provide a read of the rotational speed and direction that the wheels are turning and allow the robot to control and adjust the speed of the motors.

If a problem or malfunction is detected, the power to the motors can be safely interrupted via a handheld 100ms relay-controlled kill switch that transmits packets to an Arduino microcontroller mounted on the robot.

The robot also contains an array of several sensors and a computer monitor that is located along a vertical mast situated in the back of the robot. The sensors include a Garmin GPS 18LVC OEM connected via RS-232 interface, a SICK LMS 291 LIDAR, a 5-megapixel Elphel 353 camera, and the master relay-controlled kill switch.

**3.3 Performance Evaluations and System Redesign**

After the original design was finalized, the team performed several performance runs and tests to guarantee the performance of the robot design. Critical areas of concern such as turning ability, turning speed, power consumption, the average travel speed, responsiveness to the kill switch, the overall performance of electrical components, and the structural stability served as the basis for our tests.

Due to the lack of performance and reliability from the original robot design, the team re-organized and re-evaluated some areas that decreased the overall performance of the robot. After careful examination, the team concluded that the overall weight, the overall power consumption, significant motor controller unreliability, random kill switch malfunctions, and the inability to accurately detect its surroundings and its relative sense of direction had to redesigned to achieve optimal levels of performance to meet the team’s final objectives.

Overall Electrical Component Weight Displacement Restructure

Since weight played a major role towards the turning performance of the robot, the team decided to redesign the robot by removing one of the server cases that included the battery charger, a DC-DC 160 W converter, and the main power switch. The power switch was moved to one of the two other server cases while the battery charger unit and the DC-DC converter were allocated to an external and portable hard case. The team redesigned and reconstructed the external battery charger case in a manner that would facilitate access and ease of operation.

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| Figure 3.1: Shows the external battery charger case when removed from the robot unit (left) and when attached to the robot to provide battery charge (right). | |

Power Supply and Distribution Restructure

To increase performance, and help reduce the overall weight, the team reconsidered replacing the original power supply of the robot. Several options were considered and tested.

One option included removing one of the 12-volt batteries and having the robot run with only one 12-volt battery after both front-wheels were replaced with one caster wheel. After performing several pre-test, the team dismissed this idea as a viable redesign option since the robot drained the batteries at a faster rate than previously observed even with some electrical components unattached.

Another option included using only one 24-volt battery instead of two 12-volt battery. Since the team would have to completely redesign the power distribution to the computer, electrical components, and motors, as well as to make several changes to the circuit breakers and fuses, this option was not fully tested.

The last option that the team discussed was using an array of smaller independent lithium batteries that would power each electrical component individually. Due to practical concerns regarding power distribution, this option was not strongly regarded.

For next year’s new robotic design, the team will strongly consider using one 24 volt-battery so that the weight of the robot could be further reduced to improve performance. Furthermore, the team will be able to provide the same amount of power while creating more space for other electrical components.

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| |  |  | | --- | --- | | **Battery Tests** |  | | Date Performed: 9/27/2011 |  | |  |  | | **Two 12 volt Batteries under Load** |  | | Max Average Current | 56 A | | Min Voltage under Load | 10.4 V | | Max Average Power | 560 W | |  |  | | **One 12 volt Battery under Load** |  | | Max Average Current | 41.8 A | | Min Voltage under Load | 10.2 V | | Max Average Power | 440 W | |  |  | | *Test Conditions:* |  | | Robot in Wii-mote interface; Killswitch operational; TI Black Jaguar motorcontrollers; 4-wheel drive; Three cases mounted |  | | C:\Users\solorzaa\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Outlook\28316QXF\Figure2ElectricalLayout.png |
| Figure 3.2: Tests for average power consumption (left). Improved power distribution (right). | |

Motor Controller Restructure

Another important factor reviewed and changed to improve the performance of the robot consisted of changing motor controller. Previously, the robot used 4 TI Black Jaguar Stellaris Motor Control Units (MDL-BDC24) to control the turning speed and direction of each of the four wheels previously mounted. After the replacement of the two front wheels with a single caster wheel, the electrical team decided to remove the TI motor controllers and replace them with the RoboteQ Motor Controller MDC 2250 that only controls two motors and proved to be more reliable than the previous design.

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| Figure 3.3: Motor controller tests showing the wheels change direction to change of current flow. |

The objective of this change was to add reliability, accuracy, and performance to our motor controllers. By replacing the previous motor controllers with the new model, the team managed to achieve improved communication between the motor controller and the computer via RS232 to USB communication.

Emergency Shut-Off Switch Restructure

After numerous tests, the team observed that the Arduino kill switch lost reliability due to signal interruption or unaccounted power fluctuations. As a result, the team replaced the entire emergency shut-off switch by replacing the Arduino boards with a long range wireless 2 channel relay box that responds well at distances of 150 feet plus at 433 MHz as long as the robot is in the line of sight.

The team connected the relay to the digital I/O pins available on the new motor controller so the motor controller correctly and safely cuts the power to the motor rather than setting the motor speed to zero. The handheld emergency switch device was also redesigned to make a more robust and reliable device than the previous design.

The objective of replacing the old kill switch mechanism was to augment the safety measures and the emergency capabilities of the robot in case of an unexpected problem. After continued testing of the new safety features, the robot constantly responded well and fast enough.

Improving the Vision and Object Detection Capabilities

After careful reconsideration, the team concluded to swap the 5-megapixel Elphel camera with a Logitech HD 1080p webcam that connects via USB. Since the camera will only detect traffic barrels and white lines, we decided to sacrifice unnecessary high resolution in order to consume less power. The objective of this redesign feature was to decrease power consumption while still allowing the robot to accurately detect its surroundings.

Lastly, the team also swapped the 24-volt SICK LIDAR sensor with a 12-volt Hokuyo UTM30LX LIDAR sensor. Aside from decreasing the power consumption, the new LIDAR also increased the robot’s scan angle to 270o with a 30 meter range. We decided that more scan angle rather than range was crucial since it would allow the robot to detect obstacles that are 90o left or right of the robot.

Sensors to Provide Travel Direction and Waypoint-to-Waypoint Travel

This year, the team managed to incorporate the IMU, or Inertial Measurement Unit, that allows the robot to read its current angle of travel, in degrees, due to the digital compass feature in the IMU. In addition, the team also installed the NAVCOM SF-2050 GPS that allows us to acquire the robot’s position within a 10-cm radius as long as the robot is in an open-field and the WAAS feature is enabled. The WAAS feature allows the GPS to improve accuracy, integrity, and availability by measuring small variations due to the geometry of earth, the ionospheric conditions, and electromagnetic disturbances. By analyzing the variations, the GPS allows us to acquire highly accurate data.

After individual testing for the IMU and the GPS, the team managed to read accurate data from the IMU for extended periods of time. However, continued testing showed that the GPS first needs time to acquire sufficient data and it sometimes loses connection after it is able to acquire data.

**3.4 Overall Electrical Performance Evaluations Following the Re-Design**

After the team made all the necessary electrical changes to improve the overall performance for the robot, we proceeded to test the new system with all the features running. We concluded that after various individual and separate tests for each for each of the components, the entire system should behave as expected with minor problems. After evaluating the specs of the components, we concluded that the GPS is our slowest sensor. The team took this fact into consideration when acquiring data from all of our sensors. Once the essential electrical components, the team then proceeded to build an intelligent, efficient, and reliable software program that would allow the robot to read data from the environment, process the data, and then perform the necessary actions and decisions.

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| |  |  | | --- | --- | | **Component Name** | **Power Consumed (W)** | | RoboteQ Motor Controller MDC 2250 | 3 (max) | | GPS NAVCOM SF-2050 | 8 | | IMU Microstrain 3DM-G | less than 1 | | Wireless Router Netgear N300 | 5 | | LIDAR Hokuyo UTM-30LX | less than 8 | | Logitech HD 1080p Webcam | less than 1 | | Shark Shk840 8 Inch Desktop TFT LCD Monitor | 10 | | Long Range Wireless 2 Channel Kit | less than 1 | | BaneBots Motor Drives | --- | | Intel i7 860S Processing Unit | --- | | Rocket GSRKT 12-24 Volt Non-Flashing LED Light | 3 | |
| Table 3.1: Lists the overall power requirements for the electrical components of the original robot design. |