University of Notre Dame

High Level Design

Team Baja

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1 Introduction

The Notre Dame Baja team is a Baja car design team staffed with Notre Dame students that designs and races their own Baja vehicle against other colleges around the country. These competitions consist of a variety of scoring areas, including dynamic events, such as hill climbs and maneuverability events, and static events, such as design evaluations and presentations. Historically the Notre Dame team has performed very well, finishing 32nd out of 118 teams in 2012 at their annual competition in Peoria, Illinois. The team is shooting for a top-10 finish this summer at the competition in Peoria, Illinois.

2 Problem Description

One aspect of the judging that the Baja team is looking to improve on is their electrical design. The Baja team hopes to add a user-friendly instrumentation system that will both help them score more points with the judges and also help them justify their design choices. Our senior design team plans to take on this challenge to help the Notre Dame Baja team reach its goal for the competition in June 2014.

Our team is responsible for installing the electrical system for the Baja car. Our final system will address the issues in checking and monitoring the engine and wheel speed, locating the Baja car in a race track, and storing the data to update the performance of the car. The system must also contain a way of tracking and recording lap times, and must provide all of the information to the driver in a legible manner. Because the car will be competing in a muddy racing environment and judged on a number of factors, there are also many other considerations we must overcome.

3 Proposed Solution

Our solution will be mounted in the Baja car and will consist of several different components. First of all, our solution will require a number of sensors to monitor the specific metrics the Baja team wants to track. These sensors will feed data into a central unit, probably mounted next to or in front of the driver. It is important that the central unit is near the driver because it will also house a monitor on which the driver can view vehicle performance and track lap data. After use, the central console can be detached from the vehicle and taken inside for data extraction. As track conditions are unknown but presumed muddy, the proposed solution must also be water and mud-proof, so as is can survive in the race environment.

4 System Description

4.1 Demonstration Features

The system we construct will record and store data for the following measurements:

- Engine speed
- Wheel speed (rpm and mph)
- GPS location
- Lap time

The system will have the following additional functionality:

- Data sent to the central unit will be stored on a memory card and accessible through a port on the unit.
- GPS data, once extracted, can be used to track lap routes to monitor how efficient the driver is.
- Data will be displayed in real time to the driver via a display on the central unit.
- Drivers can indicate when a lap is done by pressing a button on the central unit.

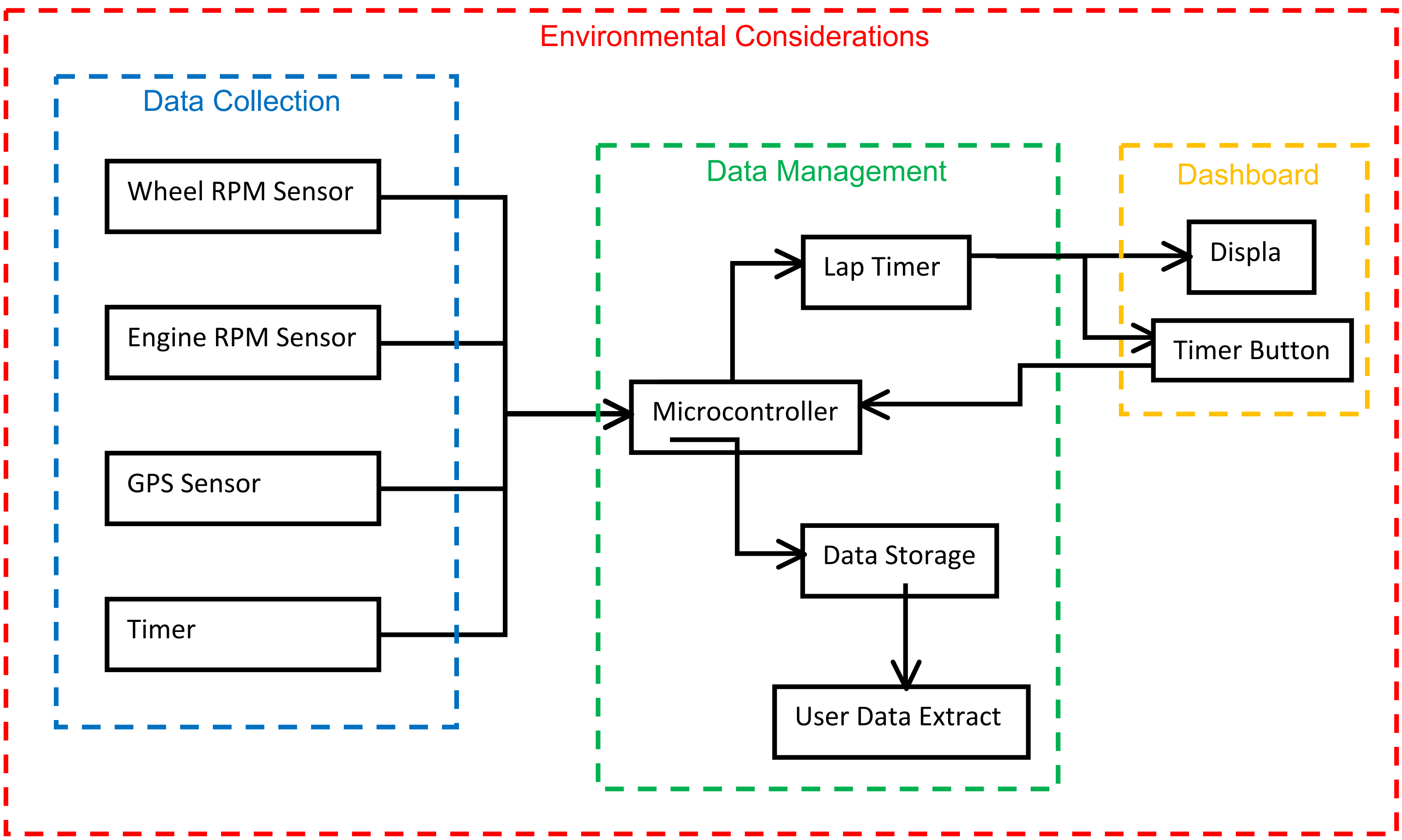
The following must also be taken into consideration:

- Sensors must be able to integrate within the Baja design.
- Central unit must be able to be mounted near the driver.
- Design must be lightweight.
- Design must be weatherproof and mud-proof for use in competitions.
- Design must be as small as possible to maximize room for the driver and other features on the Baja vehicle.
- Design must meet the budget requirement.

4.2 Available Technologies

To power our system we will have access to the Baja's 12V battery. For our display monitor we will look into LCD and seven segment displays. The central unit will be built around a standard microcontroller, which will intake data from the sensors and save it to an SD Card. The circuit board of the central unit will have input ports for all of the sensors as well as an interface for the SD Card. In addition it will need a power port to get power from the battery and any power electronics components needed to provide the appropriate supply voltage to the microcontroller. The board will also need a USB or mini/micro USB port to transfer data from the SD card to a computer for analysis. Existing technologies for sensors that we intend to pursue include mechanical magnetbased sensors, hall-effect sensors, IR sensors, and reed switches. Having checked with the Notre Dame Baja Design team, all options could be used without interfering in the mechanical design of the vehicle.

4.3 Block Diagram



5 High Level Decisions

5.1 Sensors and Data Measurement

The main challenge of this project will be to program the microcontroller in our central unit to receive data from the vehicle sensors and convert it into a meaningful form. When receiving the data it will be important to program the microcontroller with the appropriate frequencies to prevent the sensor data from containing inconsistencies and flukes.

To measure information for the project, such as wheel and engine speed, sensors will be placed on the vehicle's wheels and on the engine, in locations such that the vehicle's performance will not be altered in any way. For these measurements, Hall Effect sensors will be used, as they are the most commonly used sensors for measuring the speed of wheels, especially for engines. A Hall Effect sensor varies its output voltage in response to changes in magnetic fields. Using one of these sensors, in conjunction with placing magnets on the wheels and engine, will allow for measurement of the rotational speed, in revolutions per minute (rpm). In order to increase the resolution of the sensor, multiple magnets could be used, instead of just one, allowing for the sensor to measure smaller fractions of revolutions. If multiple magnets are to be used, it is important to insure that the changes in magnetic fields are still large enough to allow the sensor to switch between high and low states.

5.2 Lap Timer

Another key piece of functionality the system must possess is a subsystem for keeping timing and logging the racer's lap times. This subsystem will have three primary components: a running timer, a button allowing the driver to denote a completed lap, and a means of storing the completed lap times.

The running timer will be based off of the microcontroller's internal clock, which, when the frequency is decided and known, will simply need to me divided by the appropriate number in order to keep track of seconds. In order to accurately log the initial lap time, this timer will need to be initialized by pushing the lap time button on the dashboard. The inclusion of the lap time button means that the microcontroller will need to have the ability to receive data input from the button. Pressing the button will also need to store the previous lap's time, and begin timing the new lap. The new lap time must also be displayed on the dashboard with the button press, replacing the previous lap's running time.

5.3 Data Storage

An SD card was selected as the desired data storage medium, for several reasons. The first, and most significant, is that an SD card can be easily removed and inserted into a computer, insuring that the extraction of data from the system will be a simply process. Secondly, an SD card is small and lightweight, making it ideal for a system which must occupy minimal space, while also weighing as little as possible.

5.4 Real Time Display

Once the data is collected the microcontroller must then output it in real time with a visual display. The visual display will need to either have multiple different displays to provide all of the relevant data or be programmed to switch between metrics at a given rate. If the display only shows one metric at a time, the display should be programmed so that the driver can interact with the central unit to switch between performance metrics.

The display must show the driver his current speed and engine rpm, as any car dashboard would be expected to do. In addition to that information, the display should be able to show a running timer for the driver's current lap, allowing the drive to gauge how quickly or slowly his current lap has progressed.

5.5 Environmental Considerations

Furthermore the design must be engineered with the environment in mind, understanding that these vehicles will be in a wet, hot, muddy environment, and all features and functionality must be able to withstand these conditions. Throughout the system development process, each function will be tested on a prototype car before the overall system is installed in to the Baja car. Similarly, the design must also be small enough to fit inside the Baja car easily, and lightweight enough to avoid hindering the car's performance.

Designing environmental protection will be difficult, as the protection must be able to be removed or opened so that the SD card can be accessed for data extraction. This step is vital to the overall performance of the system. If it cannot stand up to the environmental conditions during the course of the race, it will be rendered useless, leaving the driver without vital performance information.

6 Remaining Decisions

6.1 GPS Data Collection

One potential design element which was not addressed above was the inclusion of a GPS chip, for the measurement and storage of the car's GPS data during the course of the race. While this would be useful information to collect, it is far down the priority list of features which should be included. When meeting with Notre Dame's Baja team, they were of the opinion that GPS data was not a necessity. With this in mind, we have elected to only include it should time permit for us to do so. If we are pressed for time, inclusion of the GPS chip would be dropped in the interest of completing higher priority system elements.

6.2 Display Screen

It also has yet to be decided what type of display screen would be used for the dashboard. The two realistic options are an LED display or a LCD display. While an LCD display would be more easily visible and display the information in a more aesthetically pleasing manner, it would be significantly more difficult to program and interface with. An LED display would be capable of displaying the relevant information as well, and would be easier to implement into the design.

Similar to the handling of the GPS subsystem, we will decide which screen will be used based on our time constraints. Time permitting, we will implement the LCD into the design, allowing for a more user friendly display. Should we be pressed for time, we would opt to use an LED display, choosing easier implementation without any functionality reduction over the aesthetics of the LCD display.

6.3 How to Weatherproof

While it is one of the most important elements of the design, much is still left undecided as to how the system will be weatherproofed against mud and water especially. Once greater details about the size and shape of the systems are known, the weatherproof enclosure can be designed to a larger extent.

7 Component Costs

Element	**Price Range**
Microcontroller	$1.00 - $5.00
Hall effect sensor	$1.00 - $10.00 each
GPS chip	$50.00 - $60.00
SD card	$10.00 - $150.00
LED display	$20.00 - $30.00
LCD display	$20.00 - $50.00
Weatherproofing materials	$10.00 - $50.00

8 Conclusions

This project has the opportunity to greatly improve the Notre Dame Baja's efforts in their summer competition. By installing the electrical system and allowing for data analysis, the team will be able to monitor the performance and optimize their vehicle before the competition. With more data available, the team will be able to provide much stronger arguments for their design decisions when questioned by the judges this coming summer. In addition to aiding the team overall, the display function of the system will help the Baja driver improve performance by allowing him or her to monitor and track lap times as well as lap routes. Finally, the weatherproof and mud-proof packaging of electrical system will be crucial to avoid any malfunction of the system during the competition.