LIGHTNING RIDERS

LOW LEVEL DESIGN

Rev	Description	By	Date	Approved
1.0.0	Initial Draft Release	Team	11/1/07	

	Approval Signature	Authority	Date
Prepared By	Lightning Riders Team	EE Seniors	12/4/07
Approved By		EE41430 Professor	

	University of Notre Dame 117 Fitzpatrick Hall Notre Dame, IN 46556	Specification Number	ND00-003	Rev 1.0.0	Sheet 1 Of 28

TABLE OF CONTENTS

1. INTRODUCTION

Electrical engineering seniors at the University of Notre Dame are privileged to undertake a year-long course in Senior Design. The students form 4-6 person teams and select a project based on their interests that involves a significant amount of in-depth engineering design. As our project, our team elected to design and build a series hybrid motorcycle. We have written a proposal document outlining the basic scope of our project, the project deliverables and various technologies that we may be able to leverage in our design. Our proposal was approved by the course professor with minor changes, which have been addressed. The next step was to provide a high level design proposal which documented the major subsystems and possible parts to be used within them. This document is the final stage of the design process and details the specific level design for our system with complete schematics and bill of materials.

2. PROBLEM STATEMENT & PROPOSED SOLUTION

As we become more aware of our potential to impact the environment, new vehicles must reflect the common desire to protect the planet by having a smaller environmental impact than their predecessors and generate less pollution and greenhouse gases. As fossil fuels are consumed and the laws of supply and demand drive fuel prices up, the next generation of vehicles must take advantage of alternative energy sources and use the limited fossil fuel sources in the most efficient way possible. Presently, hybrid vehicles are at the forefront of automotive research by commercial companies, though they have been somewhat neglected in academic environments. Few people fully appreciate the advantages and disadvantages of hybrid vehicles relative to their mature cousins, the conventional gasoline powered automobile.

Hybrid vehicle technology serves as a bridge between the old world of fossil fuel powered vehicles and a new era of electric vehicles. Current energy storage technology does not allow for the long range travel and rapid charging necessary to compete with conventional designs. However, the combination of fossil fuel and electric based technologies in a hybrid design serves as a compromise to take advantage of the best of both technological worlds. For our project, we will design and build a functional prototype of a series hybrid vehicle that combines the range of a fossil fuel vehicle with the efficiency and performance of an electric vehicle. Due to constraints imposed by funding, time and mechanical complexity, we have chosen to use a motorcycle as the base vehicle for our functional prototype.

3. SYSTEM DESCRIPTION & BLOCK DIAGRAM

3.1. Block Diagram
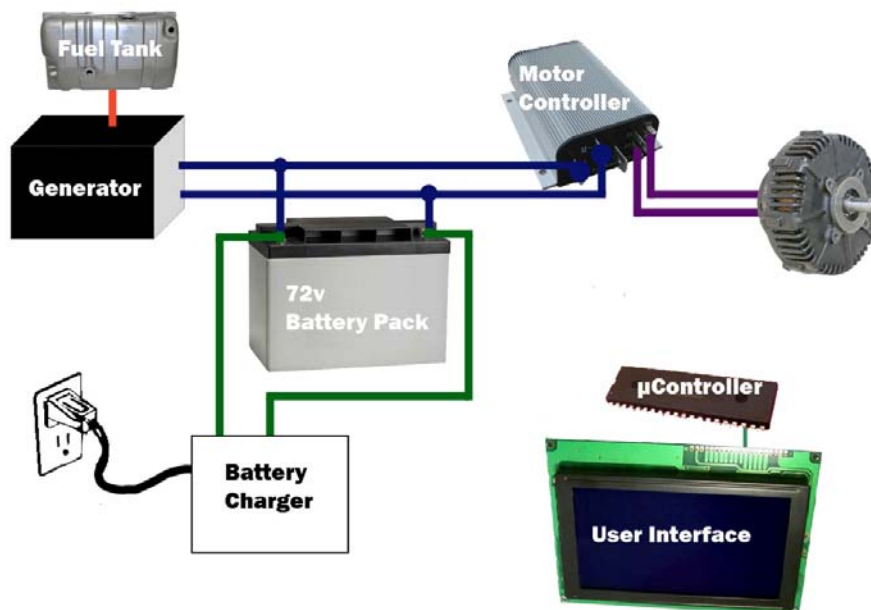
3.2. Generator

The Generator provides power to supplement and/or recharge the Battery Pack. Ideally, the Generator will have electric start functionality so that it can be started either by the embedded control system or through a push-button interface. In the end, we may not implement the electric start but at the very least, we will implement a kill switch for the generator sub-system.

3.3. Battery Charger

The Battery Charger monitors the State of Charge (SOC) of the battery pack, as well as the temperature of each battery and the voltage across each battery. It is responsible for controlling

the flow of input power to the batter pack from the generator. In addition, it communicates the SOC to the User Interface/Hybrid Controller.

3.4.   Battery Pack

The battery pack is the primary energy storage device on the motorcycle. To sustain the necessary voltages and currents into the motor controller we will use a 72V pack of 6 12V motorcycle batteries.

3.5.   User Interface/Hybrid Controller:

The Hybrid Controller oversees the entire vehicle system and communicates vital information to the user while allowing user feedback and parameter selection. It communicates with the Battery Charger to determine the projected range of the system. It displays system and component status information to the user through an LCD display while also having several buttons to accept user inputs. Mode and screen selector switches will also be implemented.

3.6.   Motor Controller:

The Motor Controller is a commercially available component that accepts a simple potentiometer throttle input and uses the energy supplied by the generator and battery pack to drive the traction motor. Most motor controllers have a serial interface that allows the user to program the device for particular performance characteristics.

3.7.   Traction Motor:

The traction motor is controlled by the Motor Controller and is directly coupled to the rear tire through the drive shaft and rear gear. It is a commercially available unit that will be purchased.

3.8.   Sub-System Interfaces

Due to the close physical proximity of the subsystems, all communications and interfaces between the systems will be wired; we will not use a wireless interface for communications. The motor controller, battery charger, and hybrid controller systems will contain embedded programs. Based on the technology available, these will programmed using a serial interface. Due to the nature of the systems, a more convenient system for reprogramming these devices (such as USB) is unnecessary.

4. SYSTEM REQUIREMENTS

4.1. Overall System

Our hybrid electric motorcycle will be designed to work as both a pure electric vehicle capable of traveling 10 miles and a hybrid electric/gas vehicle capable of 50 miles of travel. The vehicle will also be capable of sustaining a top speed of 50mph. The system will have a display that will provide the user with information concerning speed, remaining energy for travel, and rudimentary power flow of the system. The user will be able to manually start the gas generator and run the vehicle by key ignition. The lead-acid battery pack will be rechargeable via the gas generator, or by plugging the battery charging circuit into a regular household wall socket. The electric motor will be controlled by a motor controller, and our own proprietary hybrid controller will oversee the system, providing a user interface to the battery charger and energy monitor. For safety, the system will have an appropriately placed kill switch to shut off components in case of emergency. We will also have to design and physically assemble in addition to making any modifications to the frame to hold all the components in place.

4.2. Motorcycle

The bike will need to have enough space to contain all of the equipment associated with our hybrid drive system. Although the electric motor will be much smaller than the IC engine originally associated with the motorcycle, the extra components will require comparable space. The bike should also be relatively light to ease the load on the motor. In choosing a bike we will need a vehicle with sturdy wheels and tires as well as brakes, a sound frame and overall good condition.

4.3. Mechanical Systems

The bike will need to be modified to hold the components of the hybrid system in place. These brackets must provide a solid mounting frame as well as keep the rider safe and the bike balanced. We will also need to attach the electric motor to the drive shaft of the rear wheel.

4.4. Hybrid Controller

The hybrid controller will be a microcontroller based device that will interface with other sub-systems to meet the requirements set forth in the proposal. The controller has the following requirements:

- Communicate with the Battery Charger sub-system to obtain the battery SOC
- Communicate with the Battery Charger sub-system to obtain voltage and temperature for each battery in the battery pack.
- Calculates projected range based on available fuel.
- Monitor the power flow in vehicle system (to/from generator, motor, and batteries)
- Calculates current efficiency since last reset
- Drive the User Interface display
- Accept inputs from the user through switches and buttons
- Monitor vehicle speed and display it to the user.
- Generate warning messages for user as necessary

4.5. User Interface

The user interface will both display information to the user and receive inputs from the user. It must have the following capabilities.

- ➢ Interface with the hybrid controller to receive vital information
- ➢ Display current fuel levels, both battery SOC and fossil fuel
- ➢ Display efficiency calculations and expected range
- ➢ Display real-time power flow information
- ➢ Display warnings to user as appropriate
- ➢ Enable user to interact with the system through simple button interface
- ➢ Enable user to select operating modes for the vehicle
- ➢ Enable user to change what is currently being displayed on the screen.
- ➢ Display overall system status information to the user

4.6. Hybrid Controller Software

The hybrid controller software is responsible for collecting and presenting vital information to the user while accepting user inputs. As such, the microcontroller will communicate with the battery charger microcontroller to exchange information, which will require a software component for communication. It will communicate with two separate LCD displays. And it will allow user inputs via buttons and switches. A draft version of the software flow is given in a later section.

4.7. Battery Pack & Charger

4.7.1. Batteries

After considering our performance requirements and available technologies, we have tentatively selected an electric traction motor and at least a class of motor controllers. In order to achieve the desired performance, the motor controller requires a 72 VDC input. We expect to meet the voltage requirement by connecting six 12V batteries in series.

To meet our range requirements, we simulated the bike's range in miles versus velocity in miles per hour for battery packs of varying energy capacity.
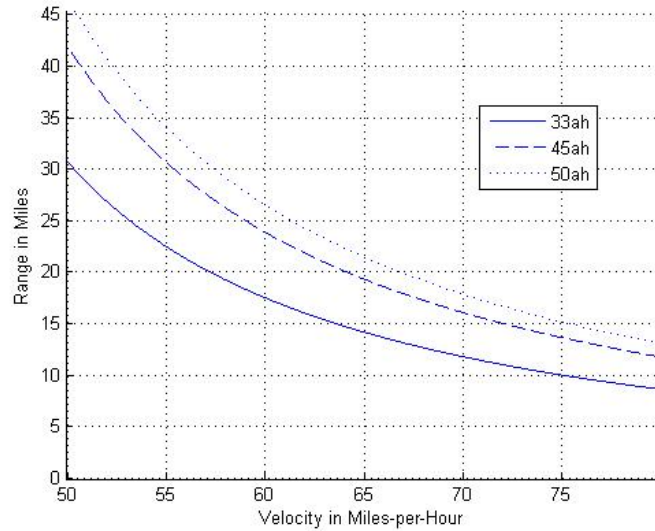
We also simulated the bike's range, assuming that the 2kW generator is constantly operating.
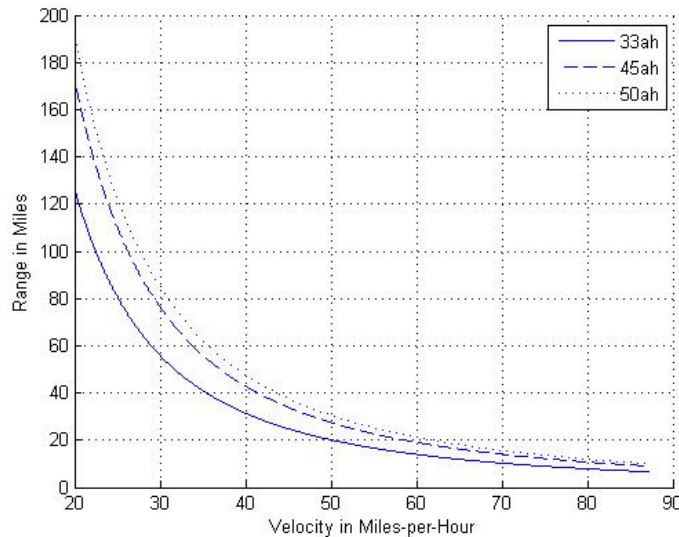
To get an idea of a possible generator strategy, we plotted the velocity and power requirements for various cross-sectional areas. The frontal area of the bike is the key parameter for calculating air drag, which is the dominant power sink as velocity increases. The frontal area of the bike is highly dependent on the model we choose for our system.
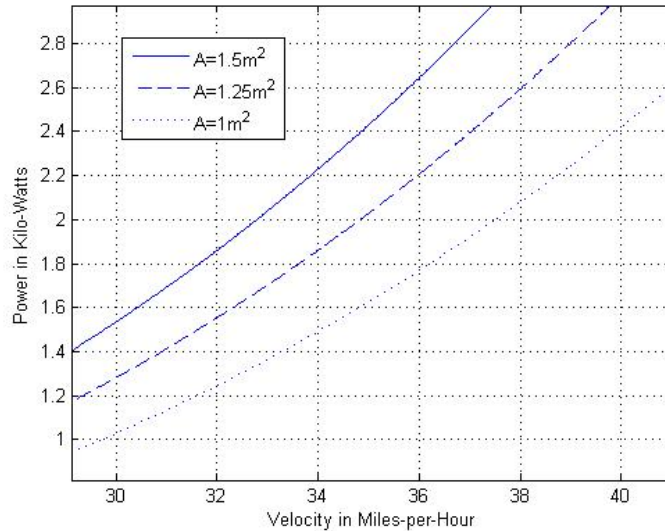
This graph suggests that the break-even point for the two power supply systems is 35MPH. For constant speeds below 35MPH all the power required for vehicle motion can be supplied by the generator. The further the constant velocity is below 35MPH the more power will be available to charge the batteries.

4.7.2. Battery Charger

The battery charger needs to take power from either a wall socket or the onboard generator, both of which are assumed to be AC voltage sources greater than 100V, and convert it to the appropriate charging voltage for the batteries. It must provide voltage above 72V in order for the batteries to charge; if we assume ~+2V per battery, the charger must supply 84V to the battery pack for charging.

The charger needs to monitor the battery pack and determine when the batteries have reached the point at which the cells have reached 2.3V each. At this point, the current applied to the battery must decrease to prevent excessive heating and damage to the battery. We anticipate that the battery charger control will reside in microcontroller driven circuitry. It will be capable of interacting with the hybrid controller microcontroller to provide update information on the battery system status.

4.7.3. Battery Charger Software

The Battery Charger Software is responsible for monitoring, protecting and charging the battery pack properly. To do so, the microcontroller must control the current inflow into the battery pack, as well as measuring that current into the pack, the voltages across the batteries, and their temperatures.

4.8.   Generator

The generator will provide power to charge the battery pack, or provide supplemental power to the traction motor. It must provide enough power to the system to have a measurable impact on the power flow, while also being small and compact. A 100 Watt generator, while small, is not really useful when the bike requires 1kW to travel at 28MPH.

4.9.   Electric Motor & Motor Controller

In our proposal, one of the project deliverable goals was to have a motorcycle which can sustain a top speed of 50 mph. In order to do so, the electric motor must be able to achieve such a speed within the design constraints of the motor. Using a MATLAB simulation for horsepower vs. speed for motorcycles, we determined that the motor should be able to output about 9 HP to maintain a speed of 50 mph. This translates to roughly 7 kW of power. Given that our battery pack will provide 72 V to the system, this means the motor and motor controller should be able to handle 100 A of current at this speed. Therefore, the electric motor and motor controller must be able to take an input of 100 A at 72 V sustained in order to output 7 kW of power to the wheels.

5. LOW LEVEL DESIGN

5.1.   Controllers & User Interface

As described in our high level design documents, our vehicle system will be controlled by a pair of microcontroller based subsystems. As our project has evolved, the names for these subsystems has also changed; please note that the subsystem formerly known as the 'hybrid controller' is referred to as the 'system controller' in this document. The following sections contained highly detailed designs for the system and battery controllers along with their related hardware and software.

5.1.1.   System Overview Diagram

The following block diagram shows the general layout for the two microcontrollers and their associated hardware. The black arrows indicate data paths and provide an indicator for information flow in the system. The microcontroller pins required for implementing each part of the block diagram are indicated in the corresponding block. Detailed schematics for the system and battery controller subsystems are included in later sections.
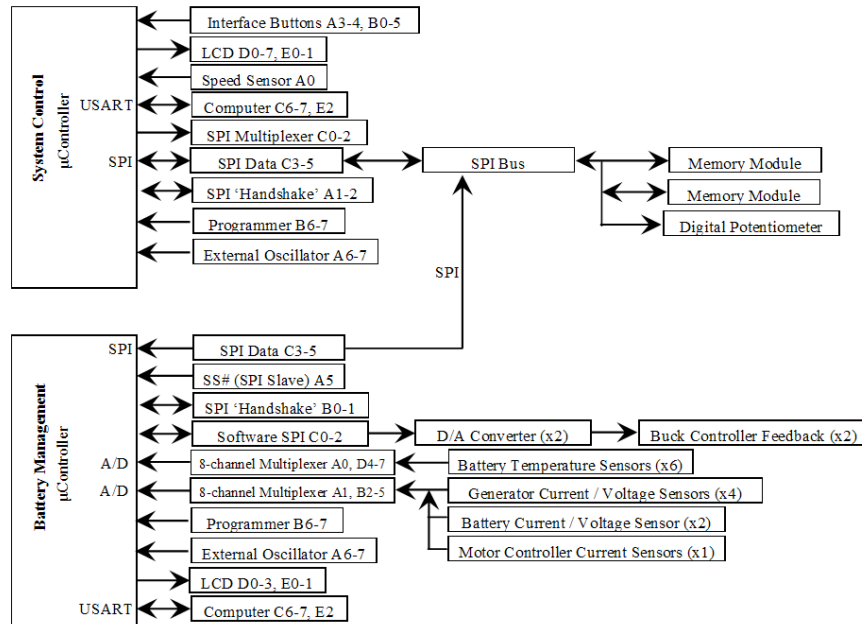
5.1.2. Interface Buttons / Switches

Our vehicle system will have a number of interface points for the end user. Some of these are standard motorcycle inputs while others are specifically designed for our hybrid system. A list of these interface buttons and switches is presented here:

- Keyed switch (off, accessory, and start)
- Two position rocker switch (electric only mode, hybrid mode)
- Three position switch for LCD (main screen, screen one, and screen two)
- Three momentary switches (multipurpose for user inputs and commands)
- Twist throttle (0-5K potentiometer input to motor controller)
- Standard motorcycle inputs (turn signals, high beam headlights, brakes)

5.1.3. Functionality by Key Position

As in a traditional car, in our design the presence and position of a key will be the primary access control to accessories and functionality of the vehicle. The key positions and available functionality for each position is broken down below.

5.1.3.1. No Key Present / Off
- No power to controllers, LCD, memory modules, etc.
- No controller reaction to button press
- No power to motor controller, potentiometer throttle disconnected.
- Generators deactivated
- If system is plugged in to an outlet for charging, then power on components to control battery charging system.

5.1.3.2. Accessory Position
- Power to controllers, LCD, memory modules, etc.
- Allow user to access data in memory modules and interface with buttons
  - View current data usage and remaining space
  - Upload data to computer
  - Clear memory
  - View system status and other 'normal' screens
- Allow wall charging
- Generators are deactivated and cannot be started

5.1.3.3. 'Start' Position
- Power to controllers, LCD, memory modules, etc.
- Provide power to motor controller
- Allow generators to be activated
- Prevent memory module access through computer or user interface
- Enable 'normal' screen usage

5.1.4. Sub-System Schematics

At our current point in the design process we have not determined the mounting points for the battery controller and system controllers on the motorcycle. Therefore, in order to maintain design flexibility, we chose to design the two controller sub-systems as though they were separate components with a wired communications link. This will allow us to mount the controllers in different locations on the motorcycle as necessary and also encourages a modular design that will facilitate testing; it will be easier to evaluate the performance of each individual sub-system rather than attempt to test the entire controller system simultaneously.

While the two controller sub-systems will be developed separately, the two controllers will share the same basic circuit board design with a similar set of basic features. Some features will be unnecessary for the final design but may prove useful for testing purposes. The basic components on each board are:

- 18LF4620 Microcontroller
- USART circuitry
- Programmer interface and reset circuitry
- Power supply connection & 5V LVDO regulator
- Set of pin headers linked to all microcontroller pins
- LCD connection header
- Emergency 9V battery power unit

5.1.4.1. System Controller Schematic

Using the free version of EAGLE board design software, we created a detailed schematic of the system controller. Our design uses a variety of parts from the board we were provided in our class kit along with modifications particular to our system. The following figure contains a partial view of the system schematic as it does not include the power section of the board. A complete version of the schematic is included in the Appendix.
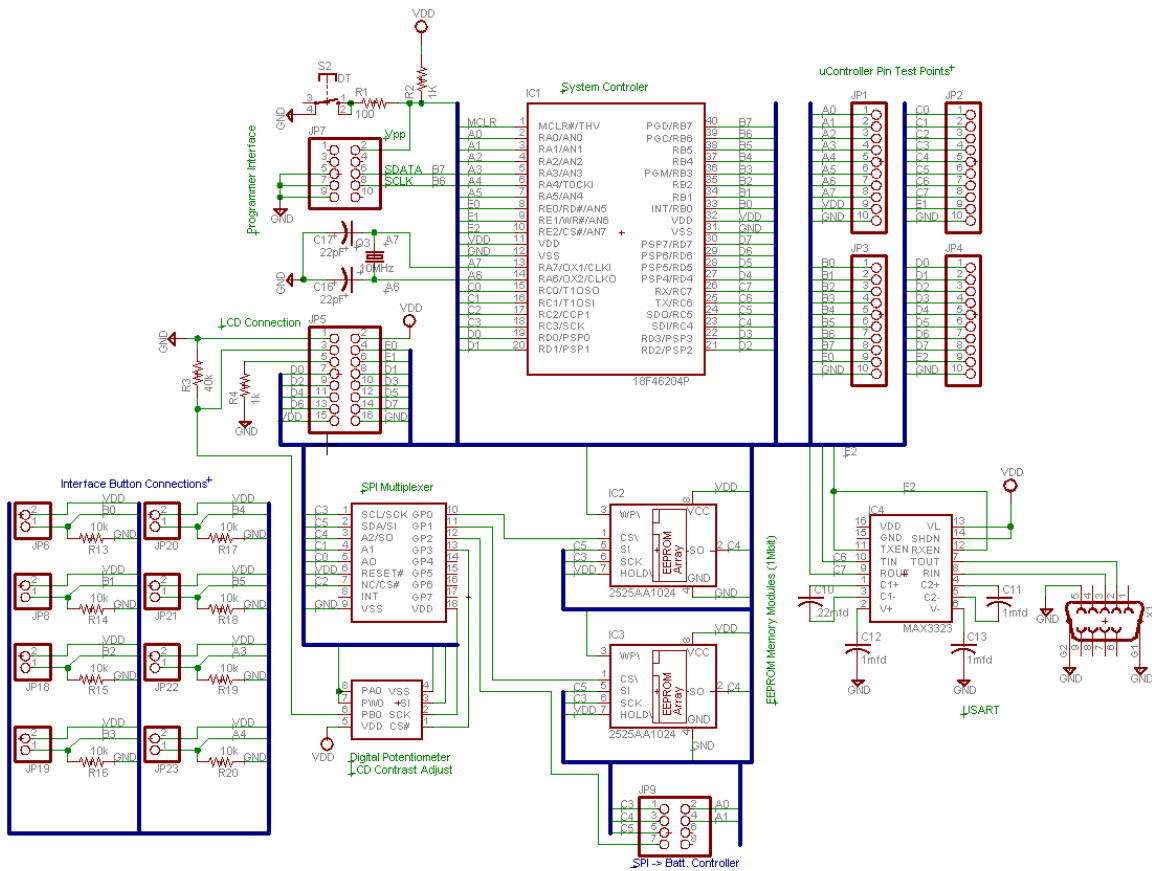
A variety of different components are used in the system controller sub-system. Labels are included on the board to provide an indication of each section's purpose.

5.1.4.2. Battery Controller Schematic
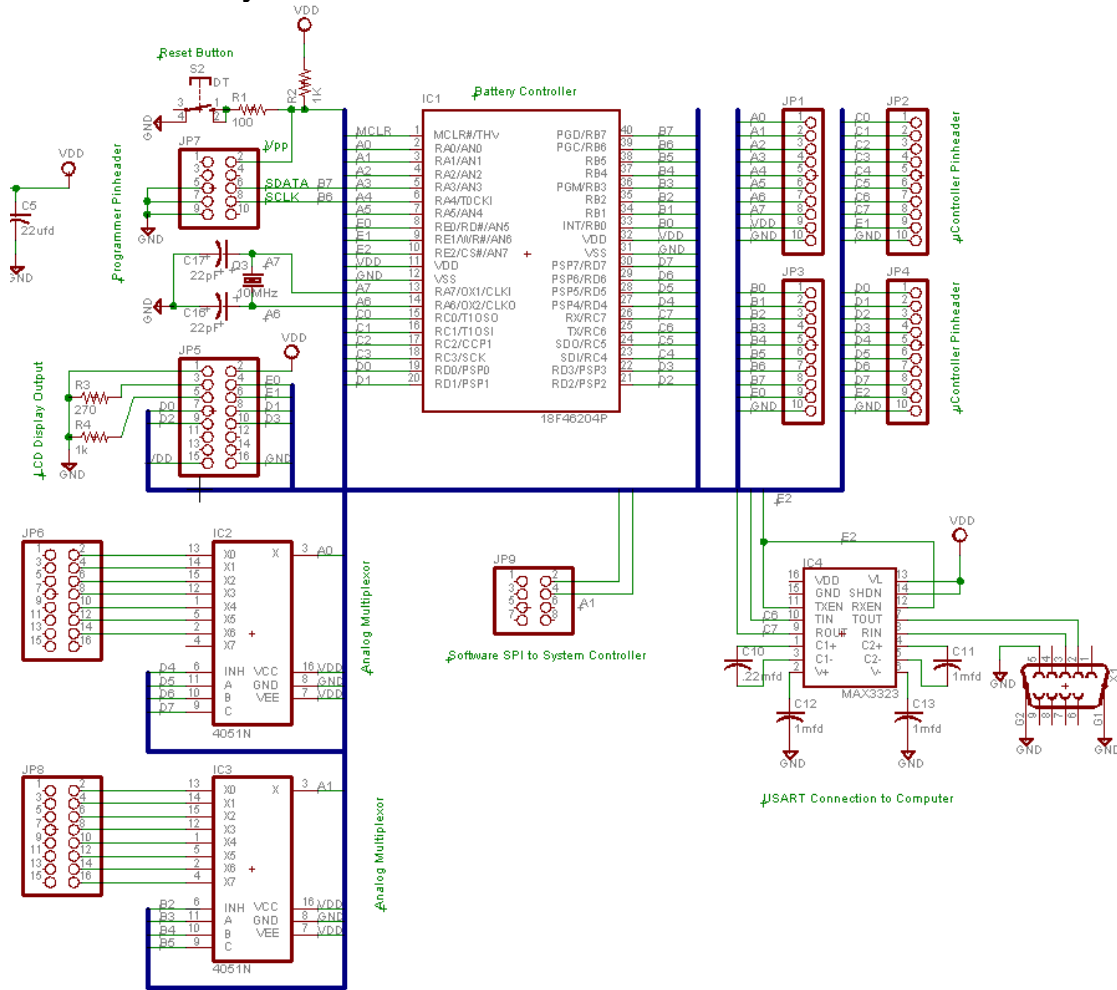
5.1.5. System Controller SPI Interface

We plan to make extensive use of the built in SPI interface for the system controller. The SPI interface gives us the ability to connect multiple peripheral devices to the same output ports on the microcontroller and use chip select signals to target the data to the correct device. In order to facilitate the process of selecting a device on the SPI bus we are using an SPI multiplexer to select the four connected peripheral devices. The four devices are: two 1 Mbit serial EEPROM chips for data storage, a digital potentiometer for adjusting the LCD contrast ratio, and a master to slave connection with the battery sub-system microcontroller.

5.1.6. System Controller USART Interface

We copied the same USART interface design from the EE41430 class board in order to reuse the same code developed during one of the class tasks. In addition to being an aid for debugging during development, the USART interface has an important place in our final design as we intend to retrieve data stored in the EEPROMs through the USART. The system controller will receive real-time data from the battery system microcontroller and will

appropriately store this information in the EEPROMs. The user will be able to access this data and send it to a computer when the key is in the 'accessory' position. MATLAB has the ability to communicate with the host computer's serial port, specifically to read data that comes in on the port. We will develop a MATLAB program, and corresponding code in the microcontroller, to access the stored data and read it into MATLAB.

5.1.7. Motorcycle Speed Sensor

The speed sensor that originally came with the bike is mechanically driven and it works regardless of what our controller does. However, we do want to record the speed for vehicle purposes. We have investigated a number of different sensor options and are confident that we can find one to suit our purposes. We will wait to determine the exact part to use until we have the electric traction motor mounted to determine how much space we will have.

5.1.8. System Controller Software

The system controller will serve in our motorcycle as the main interface between the rider and the data collected from the motorcycle components. The main functionality required of the system controller software is to monitor the battery controller for updated information pertaining to various component readings, store the collected data into the EEPROM memory modules, display the data collected in a user-friendly format on the LCD display for the rider, output the data over a USART connection to MATLAB on a computer for analysis, and take in requests from the rider to change current settings for the motorcycle or user interface. Below is a pseudo code outline as to how the program will function:

- ➢ Power on microcontroller
- ➢ Display default welcome screen to LCD, indicating POST (power on self test) mode
- ➢ Start infinite loop checking key state
  - ❖ Accessory position
    - o Disable power to main system parts (motor controller, generators, etc.)
    - o Display user option menu
    - o Perform one of the following based on user decision:
      - ▪ Display last data sampled to LCD
      - ▪ Output data from EEPROM to USART (computer)
      - ▪ Clear data banks
    - o If none above selected, monitor battery controller for flag to display current data
  - ❖ Start position
    - o Determine user-defined driving mode (electric only, hybrid)
      - ▪ Electric only – Disable power output from generators to motor controller
      - ▪ Hybrid – Activate generator power output connection
    - o Set flag to tell battery controller that system controller is ready for new data
    - o When new data received, display data to screen and store in EEPROM
- ➢ End infinite loop checking key state

- ➢ Interrupt for LCD contrast change
  - ❖ If decrease button pressed, lower digital potentiometer setting one level
  - ❖ If increase button pressed, raise digital potentiometer setting one level
  - ❖ Return to main program

- ➢ Interrupt for screen rotation
  - ❖ Display data requested for screen in current rotation state

❖Return to main program

➢Interrupt for system error
  ❖Display general warning screen to LCD with warning message as to error
  ❖Halt all major system functions

5.1.9. Battery Controller Software

The battery controller software should be discussed in the section of this design document that describes the battery controller. However, for the ease of the reader we have included the software description with the system controller software design as the two elements must work closely together. The battery controller is a microcontroller based subsystem and thus contains a significant amount of software. The main goals of the controller are to monitor the temperature and voltage of each battery in the battery pack, utilize the generator or wall-power provided current to appropriately charge the batteries, and send battery information to the system controller. A pseudo code layout of the software is given below as an initial idea of how the software will be implemented:

➢Power on the controller
➢Receive operational mode information from the system controller
➢Obtain initial system conditions
  ❖All battery temperatures and voltages
  ❖Check generator status
  ❖Check wall power status
  ❖Evaluate SOC
➢Set flag for system controller to receive data (this also serves as an indicator to the system controller that the initialization is complete.

➢Start infinite loop
  ❖Check for A/D conversion to be complete
  ❖Initiate next A/D conversion in sequence
  ❖If complete set of conversions is complete
    ▪ Evaluate battery subsystem status
    ▪ Take appropriate action
    ▪ Set flag to send information to system controller
➢End infinite loop

➢Interrupt when system controller is ready to exchange information
  ❖Send information to system controller
  ❖Receive information from system controller
  ❖Update subsystem status variables

5.1.10. Controller Software Testing Plans

As stated in the sub-system schematics section above, the most realistic way we see of approaching the testing of our battery and system controllers is to realize the controllers on separate boards. By doing so, we can prototype, test and debug the operation of functions specific to each controller rather than being overwhelmed by the entire system at once. To accomplish this plan, our proposed stages for testing are as follows:

5.1.10.1. Stage 1: Prototyping Stage

System Controller: In this stage we would prototype the controller circuit on its own breadboard in a bench top arrangement. After acquiring all the necessary components, we would interconnect the parts using the schematics shown above. In terms of powering the circuit, we will assume an ideal power source from the batteries of the motorcycle by using a power supply in the lab to source the 12 V to the voltage regulator.

The software in this stage would implement the basic communication avenues required (USART to the computer into MATLAB and SPI interface to the EEPROM memory and digital potentiometer) as well as displaying to the LCD. SPI communication to the battery controller will not be implemented until the next stage. To test the SPI interface with the EEPROM memory and digital potentiometer, we will create a basic program which will cycle through the possible values for the potentiometer using the interface buttons, store the potentiometer values in the EEPROM memory and then retrieve the value from memory to be displayed on the LCD and transferred over USART to the computer. Using this program will incorporate almost all the desired functions of the system controller and can be further tailored to incorporate the rest of the functionality. Also, being in a breadboard environment, we can easily measure the resistance on the digital potentiometer as well as use the logic analyzer to debug any communication errors.

Battery Controller: In this stage, the battery controller will also be implemented using a breadboard on a bench top, as well as powered through a fixed power supply of 12 V into the voltage regulator. The main functionality which will need to be tested on the battery controller is the A/D conversion of outputs from the various sensors (voltage, current, temperature) on the motorcycle. The variety of voltage levels these sensors can produce are easily realizable using a variable voltage power supply in the lab. We can upload essentially write the same program for the controller as needed for actual implementation, except with the SPI communication removed for this stage. The varied voltage values can be read from the A/D multiplexer, processed by the microcontroller and output to the LCD rather than SPI.

5.1.10.2. Stage 2: SPI Communication

Once the majority of the functionality of each controller works fine separately, then we can move to implementing the SPI communication link. For the battery controller, we will modify the implemented program to output the readings to the SPI instead of the LCD display. For the system controller, we will adjust the variables in the program from fixed potentiometer values to the variable data received from the battery controller and keep the rest of the program essentially the same. One new feature which will need to be implemented is the SPI 'handshaking' between the controllers. The handshaking will tell the each controller when the other is ready to send data. The key area where problems may arise for this testing stage is making sure the system controller finishes whatever SPI communication it is currently doing before handling the battery controller data.

5.1.10.3. Stage 3: Final System Integration

With the SPI communication link established, the final stage for testing will be to connect the system-battery controller unit up to the actual sensors to be used in the motorcycle and adjust the program to interpret the sensor values correctly. This step is contingent on the rest of the sub-systems (battery charger, motor controller, power conversion systems, etc.) are implemented and functioning properly.

5.2. Battery Charger

The battery charger sub-system contains a number of different components, both circuits, controllers and software. Each component is described separately.

5.2.1. Sub-System Block Diagram

The following diagram gives a general overview of the components in the battery charger sub-system. It is followed by schematics for the individual components.
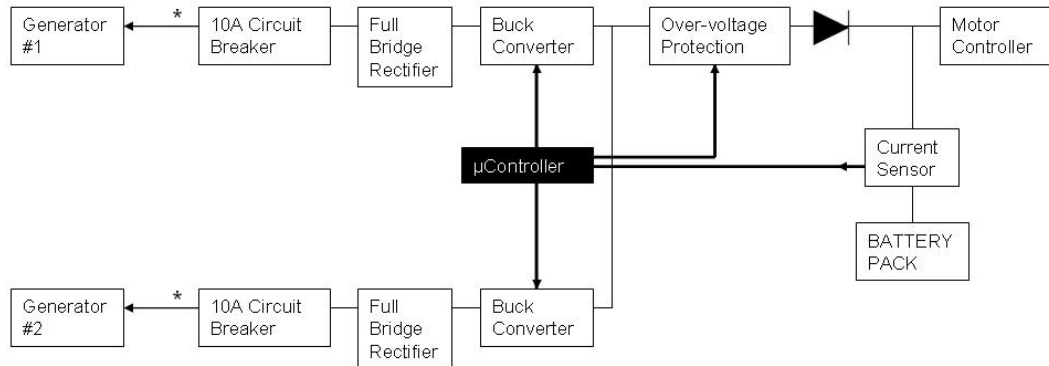
* For safety reasons, we do not intend to hard wire the generators. Instead, we intend to leave them as they are and physically plug standard household plugs into the generators. For safety reasons, we decided that the best way to protect the user, and also utilize the power supplies we had already built is to physically unplug the generators and plug them into a Y adapter (pictured at right). This would allow the two power supplies to use a total of 20A, a reasonable value for a household breaker.

Please note the above description for the expected wall charging configuration. This type of connection will not only increase safety but also reuses our designs for the normal generator powered configuration. It will prevent the user from using the generators in conjunction with wall-based charging, which would be a safety hazard.

The output diode is necessary to protect the FETs from being reverse biased.

5.2.2. Buck Converter Circuit

The generators produce 120VRMS, or a peak of 170V. We intend to rectify the full voltage via a full bridge diode conformation. Using a capacitor (C_{bridge}) we will convert that full large voltage rectified signal to a relatively high voltage DC. That large DC voltage will then be fed into a buck converter. A buck converter pulses the input voltage as a square wave signal with a duty cycle which can be calculated as D=Vout/Vin. This pulsed square wave passes through an LC filter to yield a lower steady DC voltage. Due to the rather large voltage that this buck converter is operating at the signal to the gate of the FET must be electrically isolated. Opto-isolators were considered but do not have a fast enough turn on time to work with the buck chip's internal frequency of 200kHz. Therefore, an isolation transformer will be used to send the appropriate V_{gs} to the FET. The feedback network will be configured so that it can shift the output voltage of the buck from 72V to 90V dependant. This will be realized by using 3 resistors and a FET to effectively create a parallel resistance with the 26kΩ.
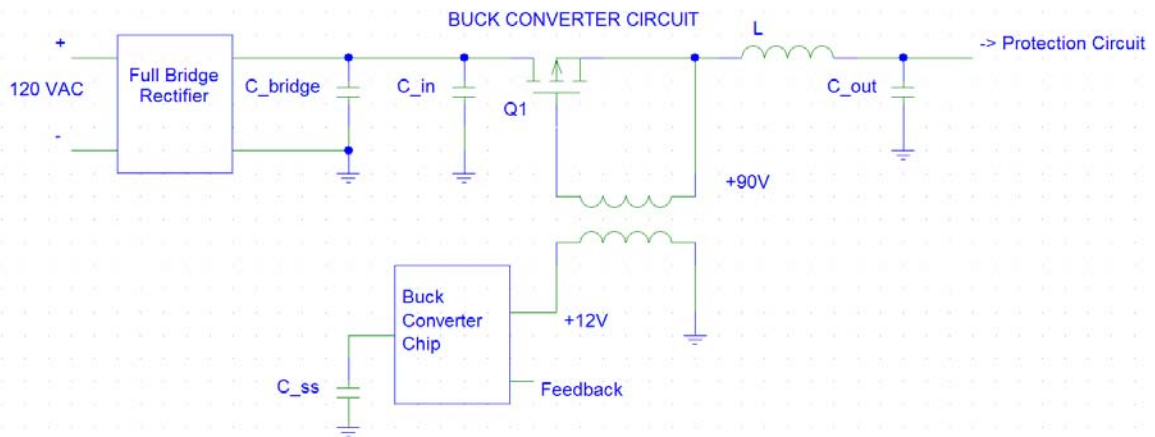
5.2.3. Feedback Circuit

The buck converter chip we have selected tries to maintain the feedback voltage at a set point. By adjusting the effective resistance in the feedback circuit we can force the controller to shift the output voltage to a new level. The circuit shown below gives an idea of our final design. The 1.25mA current source was used to simulate the input current to the feedback loop as specified in the buck controller datasheet. The voltage source tied to MOSFET will be controlled by an SPI interface digital to analog converter connected to the battery sub-system microcontroller. Using PSPICE for the schematic allowed us to generate the system response for a DC voltage sweep from 0-10V from the voltage source to simulate the D/A output. The generated graph is shown below:
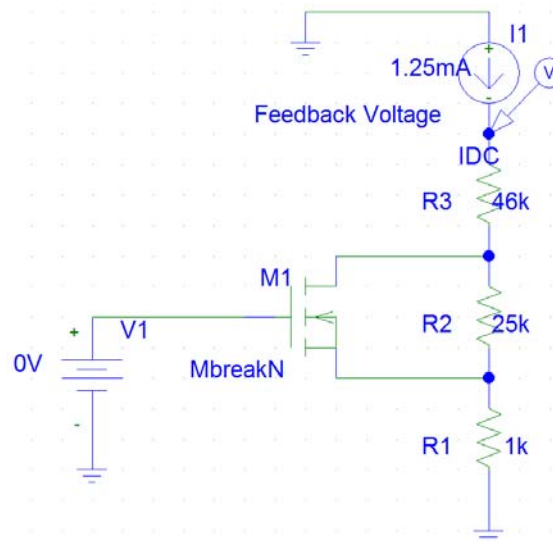
Voltage response at IDC point as the input voltage varies.

(A) feedback_network (active)
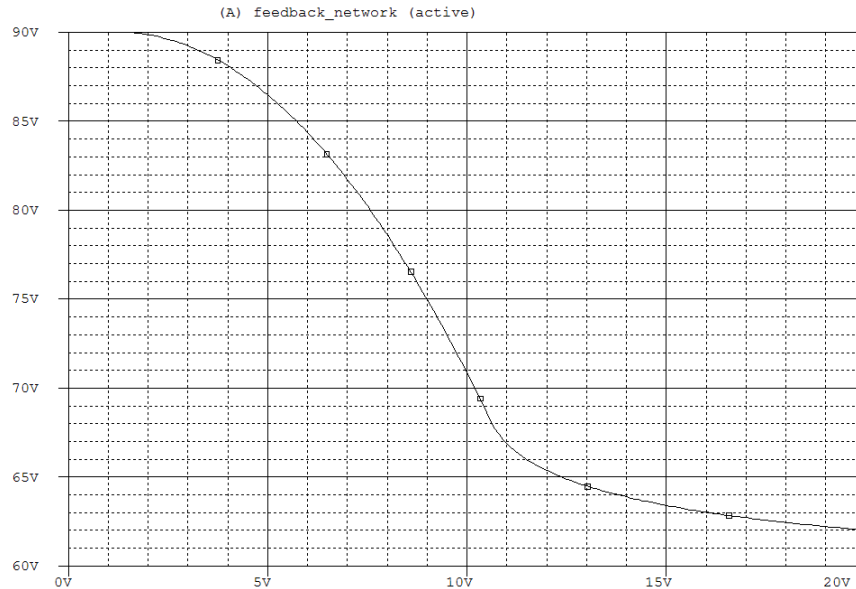
5.2.4. Battery Protection Circuit

The motor controller has a maximum voltage rating. The buck converter should not be able to exceed that voltage based on its feedback network, but for safety's sake we decide to introduce another safety circuit which would disengage the buck from the batteries and the motor controller if the bus voltage exceeded 90V. The idea is quite simple, use the AC voltage to create an isolated power supply which will float on top of the bus so that it can provide the necessary V_{gs} to turn the FET on. The "decision" to turn the FET off will be made by a comparator which feeds into the optoisolator which turns on to provide the voltage to the gate. If the voltage presented by a voltage divider to the comparator exceeds the reference voltage, the comparator turns off the optoisolator and the resistor on the FET drags the gate to zero.
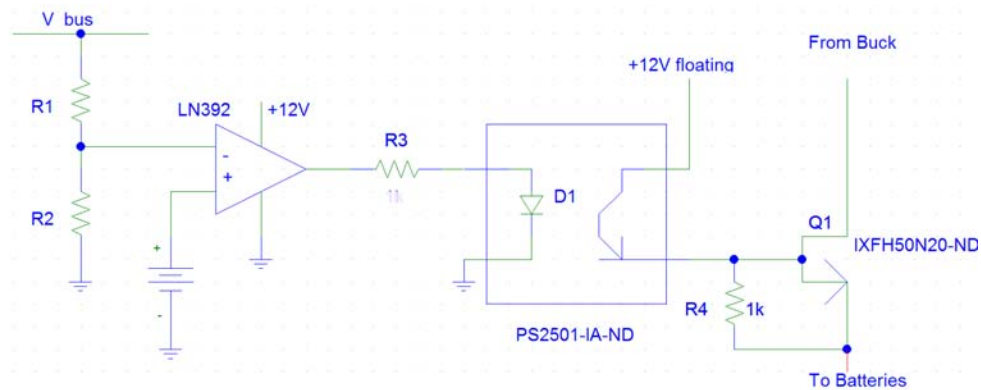
5.2.5. Buck Converter Power Supply

The buck converter chip and circuit requires regulated 12V and 5V. We intend to provide this in a similar fashion to the power for the battery and system controller boards by using the DC voltage available from the batteries and regulating it on the board. A simple schematic for this power scheme is given as follows:
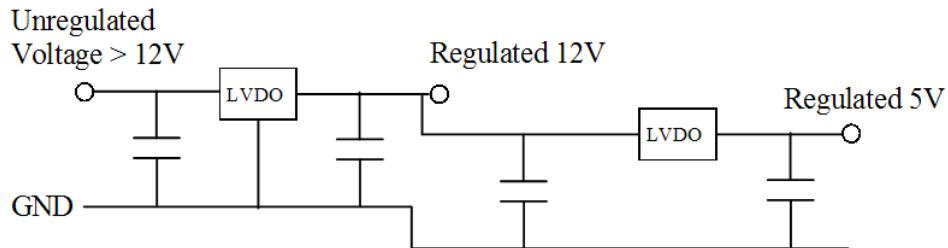
5.2.6. Battery Charging Algorithm

The main goal of the system is to adjust the voltage expressed across the batteries and thus control the current flow into the batteries. The two buck converter circuits give us the ability to adjust the voltage from the generators. The final charging algorithm will be at least partially determined in an experimental fashion after we have components in-hand to test.

5.2.7. Testing Methodology

The method that we will use for testing our circuitry will begin with a low power run of the circuits. We will test the circuits to verify that they perform their desired tasks without any major discrepancies. These tests will be run in isolation from other parts of the circuitry.

The circuits will then be tested with wall outlet power so as not to damage our generators. We will test the rectification circuit with output capacitor to verify a steady DC voltage. We will then test the Buck Converter feedback system to make sure that it works as planned. It will be necessary to verify that the circuit provides the correct output signal to match the desired increase or decrease in voltage output of the system. With a verified rectification circuit and feedback system we will combine the two with the Buck Converter circuit to test our ability to control the DC output to variable levels. Finally, we will test the protection circuit isolated from the rest of the system and then implement it with the final system to test the entire circuitry. The protection circuit testing must show that the FET can completely isolate the battery charging system from the battery system and that it will have low power losses when in the on position. After we have verified that this system works we will run it with the Generators connected to it and then evaluate the system as a whole and make any final changes to the circuit to make it run to our desired specifications.

In testing the battery charging ability of the system we will run it with only one battery connected to it. Once we verify a working charging system for one battery we will add a second battery to the system. With this second battery we will discover the affects of having batteries in series being charged by our system. Finally we will place all the batteries into the battery pack and run the entire system with all batteries to create our entire battery charging system with battery pack.

6. REFERENCES

How to construct a lead-acid battery charger:

http://www.powerstream.com/SLA.htm

Building a battery pack

http://www.evadc.org/build_batteries.html

Calculating resistivity

http://www.allmeasures.com/formulae/static/formulae/electrical_resistivity/12.htm

Wire guide and current capacities

http://www.powerstream.com/Wire_Size.htm

Existing Electric Motorcycle

http://www.evdaytona.com/

EV Parts

http://www.beepscom.com/

Really amazing battery technology that we can't afford

http://ev-battery.com/

SOC Strategies

http://www.mpoweruk.com/soc.htm

How to use a thermocouple

http://www.circuitcellar.com/library/details/1299/c1299cd2.asp

Thermocouple resource

http://zone.ni.com/devzone/cda/tut/p/id/4237

McCullock solid state inverter Generator

http://www.electricgeneratorsdirect.com/catalog/product_info.php?products_id=653

Electronic Circuits Manual by Markus (book purchased from Amazon)

Perm-Motor 132 Motor Specifications
http://www.perm-motor.de/pm_e_htm/products/pmg/daten_pmg_132.htm

Alltrax Controller Specifications
http://www.alltraxinc.com/Products_AXE.html

Briggs and Stratton Etek Motor Specifications
http://www.thunderstruck-ev.com/etek.htm

Kelly Controls DC Motor Speed Controller Specifications
http://dc-permanent-magnet-motor-speed-control.motcontroller.com/

7. PRELIMINARY BILL OF MATERIALS

7.1. System Controller BOM

Part	Value	Device	Package	Description
C1	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C3	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C4	10ufd	CPOL-USE2-5	E2-5	POLARIZED CAPACITOR, American symbol
C5	22ufd	CPOL-USE2-5	E2-5	POLARIZED CAPACITOR, American symbol
C6	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C7	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C8	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C10	.22mfd	C-US050-025X075	C050-025X075	CAPACITOR, American symbol
C11	1mfd	C-US050-025X075	C050-025X075	CAPACITOR, American symbol
C12	1mfd	C-US050-025X075	C050-025X075	CAPACITOR, American symbol
C13	1mfd	C-US050-025X075	C050-025X075	CAPACITOR, American symbol
C14	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C15	0.47ufd	CPOL-USE2-5	E2-5	POLARIZED CAPACITOR, American symbol
C16	22pF	C-US075-032X103	C075-032X103	CAPACITOR, American symbol
C17	22pF	C-US075-032X103	C075-032X103	CAPACITOR, American symbol
D1	1N5400	1N5400	DO201-15	DIODE
D2	1N5400	1N5400	DO201-15	DIODE
IC1	18F46204P	18F46204P	DIL40	MICROCONTROLLER
IC2	2525AA1024	2525AA1024	DIL8	Serial EEPROM
IC3	2525AA1024	2525AA1024	DIL8	Serial EEPROM
IC4	MAX3323	MAX3323	DIL16	RS-232 level converter (3.3 - 5.0 VDD)
IC6	LM2937-5.0	LM2937-5.0	TO220(V)	
JP1		PINHD-1X10	1X10N	PIN HEADER
JP2		PINHD-1X10	1X10N	PIN HEADER
JP3		PINHD-1X10	1X10N	PIN HEADER
JP4		PINHD-1X10	1X10N	PIN HEADER
JP5		PINHD-2X8	2X08	PIN HEADER
JP6		PINHD-1X2S	1X02N	PIN HEADER
JP7		PINHD-2X5	2X05	PIN HEADER
JP8		PINHD-1X2S	1X02N	PIN HEADER
JP9		PINHD-2X4	2X04	PIN HEADER
JP18		PINHD-1X2S	1X02N	PIN HEADER
JP19		PINHD-1X2S	1X02N	PIN HEADER
JP20		PINHD-1X2S	1X02N	PIN HEADER
JP21		PINHD-1X2S	1X02N	PIN HEADER

JP22		PINHD-1X2S	1X02N	PIN HEADER
JP23		PINHD-1X2S	1X02N	PIN HEADER
PWR2	DC-IN	DC-IN	DC-POWERJACK	
Q3	10MHz	CRYTALHC49U-V	HC49U-V	CRYSTAL
R1	100	R-US_0207/7	0207/7	RESISTOR, American symbol
R2	1K	R-US_0207/7	0207/7	RESISTOR, American symbol
R3	40k	R-US_0207/10	0207/10	RESISTOR, American symbol
R4	1k	R-US_0207/10	0207/10	RESISTOR, American symbol
R13	10k	R-US_0207/10	0207/10	RESISTOR, American symbol
R14	10k	R-US_0207/10	0207/10	RESISTOR, American symbol
R15	10k	R-US_0207/10	0207/10	RESISTOR, American symbol
R16	10k	R-US_0207/10	0207/10	RESISTOR, American symbol
R17	10k	R-US_0207/10	0207/10	RESISTOR, American symbol
R18	10k	R-US_0207/10	0207/10	RESISTOR, American symbol
R19	10k	R-US_0207/10	0207/10	RESISTOR, American symbol
R20	10k	R-US_0207/10	0207/10	RESISTOR, American symbol
S2	DT	DT	PBSWITCH	ITT SWITCH
U$1	PVOLTBAT	PVOLTBAT	9VBATHOLDER	
U$2	MCP23S08	MCP23S08	DIL18	
U$4	MCP41XXX	MCP41XXX	DIL8	Microchip MCP41XXX, Single Digital
X1		F09HP	F09HP	SUB-D

7.2. Battery Controller BOM

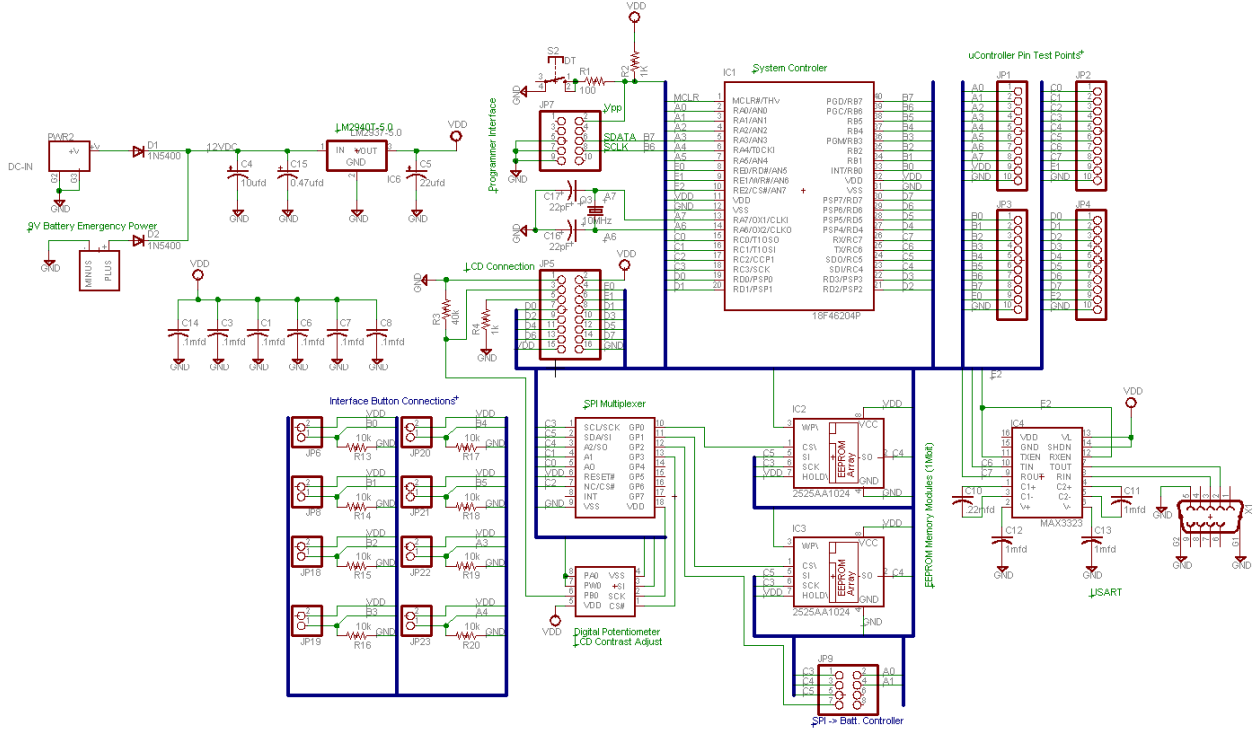| Part	Value	Device	Package	Description
C1	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C3	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C4	10ufd	CPOL-USE2-5	E2-5	POLARIZED CAPACITOR, American symbol
C5	22ufd	CPOL-USE2-5	E2-5	POLARIZED CAPACITOR, American symbol
C6	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C7	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C8	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C10	.22mfd	C-US050-025X075	C050-025X075	CAPACITOR, American symbol
C11	1mfd	C-US050-025X075	C050-025X075	CAPACITOR, American symbol
C12	1mfd	C-US050-025X075	C050-025X075	CAPACITOR, American symbol
C13	1mfd	C-US050-025X075	C050-025X075	CAPACITOR, American symbol
C14	.1mfd	C-US025-025X050	C025-025X050	CAPACITOR, American symbol
C15	0.47ufd	CPOL-USE2-5	E2-5	POLARIZED CAPACITOR, American symbol
C16	22pF	C-US075-032X103	C075-032X103	CAPACITOR, American symbol
C17	22pF	C-US075-032X103	C075-032X103	CAPACITOR, American symbol

D1	1N5400	1N5400	DO201-15	DIODE
D2	1N5400	1N5400	DO201-15	DIODE
IC1	18F46204P	18F46204P	DIL40	MICROCONTROLLER
IC2	4051N	4051N	DIL16	8-channel ANALOG MULTIPLEXER
IC3	4051N	4051N	DIL16	8-channel ANALOG MULTIPLEXER
IC4	MAX3323	MAX3323	DIL16	RS-232 level converter (3.3 - 5.0 VDD)
IC6	LM2937-5.0	LM2937-5.0	TO220(V)	
JP1		PINHD-1X10	1X10N	PIN HEADER
JP2		PINHD-1X10	1X10N	PIN HEADER
JP3		PINHD-1X10	1X10N	PIN HEADER
JP4		PINHD-1X10	1X10N	PIN HEADER
JP5		PINHD-2X8	2X08	PIN HEADER
JP6		PINHD-2X8	2X08	PIN HEADER
JP7		PINHD-2X5	2X05	PIN HEADER
JP8		PINHD-2X8	2X08	PIN HEADER
JP9		PINHD-2X4	2X04	PIN HEADER
PWR2	DC-IN	DC-IN	DC-POWERJACK	
Q3	10MHz	CRYTALHC49U-V	HC49U-V	CRYSTAL
R1	100	R-US_0207/7	0207/7	RESISTOR, American symbol
R2	1K	R-US_0207/7	0207/7	RESISTOR, American symbol
R3	270	R-US_0207/10	0207/10	RESISTOR, American symbol
R4	1k	R-US_0207/10	0207/10	RESISTOR, American symbol
S2	DT	DT	PBSWITCH	ITT SWITCH
U$1	PVOLTBAT	PVOLTBAT	9VBATHOLDER	
X1		F09HP	F09HP	SUB-D

University of Notre Dame
117 Fitzpatrick Hall
Notre Dame, IN 46556

Specification
Number **ND00-003**

Rev
1.0.0

Page 26
Of 28

8. APPENDIX