Intelligent Electric Vehicle Driving System

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***Abstract* — The intelligent electrical vehicle driving system is a system that can be adapted for any electric vehicle. The purpose is a control system based on the battery capacity to alter the acceleration and velocity the vehicle can travel through three modes of operation. The user can select either the performance, normal or economy mode until the battery charge is low enough to automatically be set to economy mode. The design is based on a 12VDC auxiliary battery converted to both 5VDC and 3.3VDC for temperature, voltage and current sensors and to provide power to the microcontroller. The sensors and microcontroller work together to send readings to the user touch screen display.**

***Index Terms* — Power conversion, DC-DC power conversion, Microcontrollers, Power Amplifiers, Bridge Circuits, Pulse Width Modulation**

I. Introduction

Greenhouse gasses, such as carbon dioxide and methane, are constantly on the rise as society continues to live the "American dream". These gasses are responsible for climate changes throughout the world and depleting the ozone layer. Unfortunately the many people that feel a sense of confidence from their standards of living don't understand the repercussions to come. In this particular case the type of transportation vehicles that are used today have a great influence on the environment of tomorrow. Combustible or gas powered vehicles continually emit these pollutants and destroy the environment for future generations. Overall it is important to provide society with the same sense of confidence in their transportation vehicles without altering the environment.

This senior design project is to create an intelligent driving system for any fully electric vehicle. Any electric transportation device can be equipped with this system and provide society with an efficient, reliable and user-friendly vehicle that doesn't remove any of the standard features of a combustible car. Therefore people are able to maintain the sense of confidence in their vehicles without influencing the environment. This type of vehicle benefits the environment for societies to come, but is capable of benefiting the society of today. As gas prices are on the rise a fully electric vehicle with this system would eliminate more financial burdens. Furthermore the United States dependency on other nations for oil importation would decrease, making a more independent and sustainable nation overall.

An original combustible car is transformed to a fully electric vehicle by removing several main components, such as the engine, exhaust pipes, and gas tank. In place of these parts are 12 twelve volt lead-acid batteries and a fully electric DC motor. These two main components in conjunction with a microcontroller allow the vehicle to reach high speeds, similar to a combustible vehicle. In order to make the vehicle more self sustainable and beneficial to the environment, two 16VDC monocrystalline solar panels are added to charge the auxiliary 12 volt battery, that powers the microcontroller along with any D.O.T. required accessories, such as the headlights, tail lights, wipers, turning signals, etc.. Furthermore another microcontroller is connected to an LCD display that allows the user to choose from three modes of operation. The performance mode allows the driver to accelerate at the maximum rate to reach high speeds of operation. Whereas the normal mode provides a standard rate of acceleration and curtails the maximum speed to typical city driving limits. The economy mode is the most limited driving mode for power saving. This mode automatically engages after the battery pack capacity decreases to 15% and blocks user selection of the performance or normal modes. The economy setting decreases acceleration rate and maximum driving speeds to withhold as much charge as possible. After reaching the final destination the vehicle can be charged using a standard 120VAC grounded plug. The final product is prototyped using a PowerWheels F150 that is composed of a 12VDC battery, two 16VDC solar panels, a 7" LCD touchscreen display and additional power electronic components.

II. Goals and Objectives

The objective of this project is to provide PowerGrid Engineering a fully converted electric vehicle that meets the requirements and specifications stated by them. Primary goals for the outcome of the EV are high efficiency, reliable operation and a user-friendly interface.

In order to satisfy the goal of high efficiency additional sensors monitor the temperature, current and voltage output from several components within the vehicle such as the batteries, motor and microcontrollers. The total efficiency of the vehicle is improved through its intelligent control system. Furthermore the components for charging are selected to increase overall efficiency to maintain battery capacity.

By enabling additional monitoring and reporting the collected data, the user is able to feel confident on the reliability of their vehicle. Overall the vehicle is as reliable as the gas-powered vehicle. Similar to a gas meter, a battery capacity meter informs the user of how much power is left on the battery charge and therefore ensuring the capable distance to be traveled. To enhance the reliability of the vehicle solar panels are incorporated to charge the batteries during off time. This renewable source of energy from the sun convinces the user that charging is possible despite the location of stopping, as long as the sun is visible.

The LCD touch screen display provides the user with an up to date means of displaying technical data about the car. This central location of information enables the user to pay adequate attention to the road while checking the statistics of battery capacity, RPM, speed, voltage, and current. Buttons allow the user to navigate to historical information, view more detailed statistics and further select their mode of operation. Many functions such as the "gas" pedal and braking remain consistent in the converted vehicle to maintain the same conventions many drivers are already accustomed to.

III. Requirements and Specifications

The main purpose for creating this vehicle is to supply the sponsor, PowerGrid Engineering, LLC, with a fully electric vehicle that is altered to meet any additional requirements set by them. The requirements consist of the vehicle being legal to drive; therefore the department of transportation standards must be met. Furthermore a renewable power source is included, specific monitoring and an intelligent driving system. These requirements are explained in detail below.

The Department of Transportation (DOT) requires that all vehicles have functioning turning signals, wipers, brake lights and headlights to ensure adequate safety of surrounding drivers. The benefit of converting a dealership standard combustible engine vehicle ensures the fact that many of the pre-existing components required to meet this standard are still readily available. Throughout the conversion process it is necessary to allow these external elements to remain accessible and powered for the drivers use.

Solar panels are to assist in charging the batteries as a renewable energy source. There is no specification to how many panels must be used or how much energy must be received from them. The only limitation is the surface area susceptible to the sun's rays and capable of generating power.

The user is able to view the real time RPM, speed, voltage, current and battery capacity. There is no requirement detailing the historical data to be shown to the driver, simply the real time data.

The driver is able to select different settings depending on their driving habits. The three modes consist of performance, normal and economy mode. The normal mode is for average driving conditions with slow acceleration and low speed levels. The performance mode allows fast acceleration and higher speed ranges and finally the economy mode limits both acceleration and speed to save the maximum battery power. The vehicle is capable of automatically switching to solar-economy mode when battery capacity decreases below 15%. During this period it blocks performance and normal modes from being enabled by the user. There is no requirement detailing the specific speed ranges or acceleration ratings for each mode of operation.

For the final prototype of the project the following specifications and requirements are fully adhered to. The vehicle operates electrically without a combustible engine. The vehicle also includes an emergency stop switch for additional safety. An auxiliary 12VDC battery provides power to smaller electronic devices and is measured for voltage, current and temperature readings. A 7" touchscreen display operates as if in a full size vehicle with all modes of operation enabled. The PowerWheels F150 includes two 16VDC crystalline solar panels to power the battery for the motor operation and for smaller electronics.

IV. Motor Design

Due to the fact that the overall project is to design a full size electric vehicle for PowerGrid Engineering the Warp 9 DC motor is selected. This motor is selected for its horsepower, weight and speed ratings compared to other DC motors such as the ADC FB1-400. Furthermore the Warp9 motor is less expensive with an improved design on the motor brushes where less maintenance is required. Since this vehicle is being represented as a power saving device, with three modes of operation, this motor is more suitable for this application. The lower current, torque and horsepower will improve the efficiency of the motor in these power saving modes.

Along with the motor, a motor controller is selected to modify the voltage supplied to the motor while it is operating in various modes. The Netgain WarP-Drive #201-WD-160/1000 Drive is an extremely high power motor controller designed and built by NETGAIN Controls, Inc. The controller is capable of operating up to

160 VDC at 1000 Amps in a basic design and is available in much higher power. The controller is capable of operating with CAN bus so that it can communicate and be controlled from other devices. The controller is extremely powerful in a small package. The controller is designed to operate with the WarP9 motor and can easily power the motor to its full efficiency. The controller also has built in over temperature protection that folds back the voltage drive in the event that an over temperature occurs. This controller is the drive selected for this EV project because it is optimized for the WarP9 motors. This selection ensures that the motor and controller are the most efficient as possible.

For the final prototype of the PowerWheels vehicle this controller is not utilized but a custom controller is used. This controller alters the voltage provided to the dual motors located in the rear of the vehicle depending on the mode of operation. This sensor/motor controller will read the voltage and current levels of the battery to determine the battery capacity and the rate of charge left on the battery. Following this reading along with the temperature sensor reading that are taken throughout the vehicle the mode of operation will be determined or selected depending on the driver. For the task of interfacing with all of the sensors in the vehicle and controlling the motors operation, the Microchip PIC32 processor technology is used. The device model is the PIC32MX795F512L. It's a 100 pin LCC that is more than adequate to perform this task.

The main reason that the PIC32 is selected for the sensor/motor task is because the device closely matches the requirements for interfacing with all of the sensors. The other features are that the device is very user friendly and inexpensive. The average cost of the individual IC is less than $10 and the development cards for coding and debugging are less than $60.

Figure 1 is an overall diagram showing the interfaces with the sensor/motor controller including but not limited to the voltage pedal connection, and current and voltage measurements. All of the digital input/output is buffered using a driver that is connected to 5VDC. The 5VDC logic drives the gate of the MOSFET switches to make sure that the MOSFET switches are completely switched on. The analog circuitry uses the 12VDC battery voltage to do all of the amplification. This voltage is filtered so that the signals will have some noise rejection. The operational amplifiers have resistor networks on all of the legs so that during the debug stage they can be configured to any gain selection. The connector is a ribbon type cable connector to allow for a large amount of connection.

The power calculation is completed by the controller which multiplies the voltage times the current to get average and peak power. The voltage and current inputs pass through low pass filters in the controller to generate the average power reading. The calculated power data is sent to the microprocessor and displayed on the touch screen display in the form of power usage charts. The controller also compares the power being used to the estimated power in the batteries to determine the amount of drive time left.

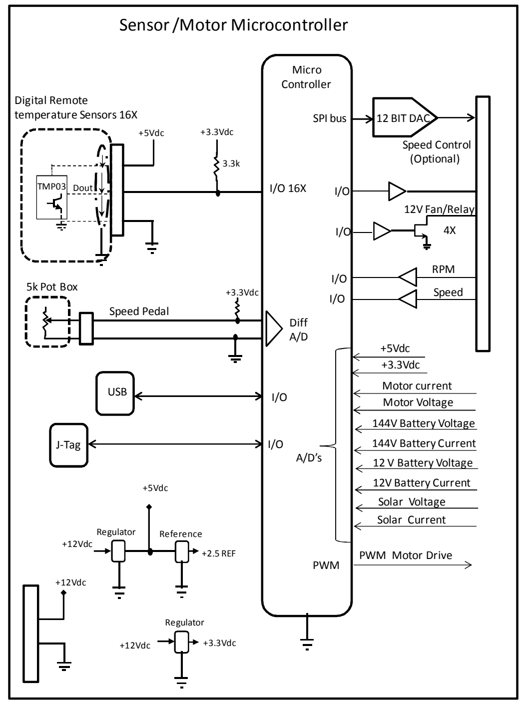

Fig. 1 Sensor/Motor Microcontroller

The 12 Bit DAC interfaces between the motor controller serial speed control output and the motor control electronics voltage pedal input. The microchip MCP4821-esn is a serial 12 Bit DAC and is designed to give a precision analog output. The DAC utilizes a SPI bus from the microcontroller and is used to drive the voltage pedal input of an existing motor controller. The DAC's supply voltage will be 5VDC. When the DAC voltage is at zero then the motor will be completely shut down. When the DAC is at full voltage then the motor drive will be at 144 VDC or 12VDC for the prototype. The 12 Bits of data gives the motor control 4095 steps in speed control. The circuitry also contains an override switch that automatically grounds the pins if the soft emergency shutdown button is pressed on the touch screen display.

The motor speed will be controlled by the PWM drive output. This proportional PWM switches three High Voltage and High Current IGBT devices. These devices are IXYS IXGK320N60B3 IGBT's. Each one of the IXGK320N60B3 devices are rated at 600VDC and average currents at 320 Amps with peaks currents up to

1200Amps. The voltage drop at 320 amps is only 1.2VDC so the power dissipation during the steady state motor drive is minimized. The combination of the three devices will give less voltage drop on the devices because each one will switch 1/3rd the power and as result power dissipation will reduce. These devices connect to the negative side of the motor and are the return path for the motor. The IGBT has protection diode going from the collector to the motor positive terminal to limit the amount of voltage that can be developed when the IGBT motor switches are in the off cycle of the PWM. There is also a large capacitor bank on the motor to help clamp these voltage spikes.

The speed control output connects to the purchased motor controller electronics voltage pedal input. The microcontroller looks at two inputs to determine the output serial data going to the DAC driving the controller. The first is the voltage pedal input voltage. This will be a proportional input to output voltage. Second is the mode of the intelligent driving system. This will limit the level of the output depending on whether the mode is set to economy, performance or normal mode. This will be sent by the touch screen display microcontroller and will take over the control of the output based on a desired speed value selected.

There are two USB interfaces that are used to the microcontroller. The first is used during the debug and integration phase of the project. This dedicated interface is implemented in the PWB so that data can be captured from the microcontroller and analyzed for refinement of the microcontroller during the entire project. The second USB is used to communicate with the touch screen display microcontroller. This is the path that all of the I/O data will pass between the microcontroller's.

The automobile speed will measured utilizing the existing speed sensor on the automobile. This sensor is usually located in the output of the manual transmission and is either a Hall Effect sensor output or a transformer coupled output. This output is connected to the Sensor / Motor Microcontroller circuitry and converted into either an analog or digital format that can be inputted into the microcontroller.

V. Battery Supply

The design of the battery supply is based off the 144VDC motor that is selected. With this required input several battery types are investigated for a total voltage of 144VDC. The design of the power system consists of the three major components: the primary battery bank, the secondary battery, and the solar charger. The primary battery bank is the total battery power needed to run the electric motor efficiently using lead-acid batteries. Lead-acid batteries were selected due to their ability to achieve the power needed to power the electric motor, but the major factor in choosing lead-acid over its competitor, Lithium-ion, is that it is inexpensive, the most widely used battery in early EV conversion, and it is the oldest battery of all the options and therefore more reliable. There are three different types of lead-acid batteries consisting of: flooded, absorbed glass mat (AGM), and gel. The battery chosen for this project is the AGM Universal Battery, Model:UB121100.

Another aspect of the battery supply is the battery box that contains all batteries and maintains their positions during driving. . The rear battery box consists of three pieces, sheet metal box, plywood length separator, and the plywood width separator. The box is 14.6 inches wide to fit another parallel row of four batteries. The sheet metal box has an overall dimensions of 54" x 14.6" x 10.10" with an overall thickness of 0.05". The length separator has dimensions of 53.9" x 10" x 0.5". The width separator has dimensions of 14.5" x 10" x 0.5". The front battery box is construction the same as the rear battery box except for is design for quantity of four batteries instead of eight like the rear. So, for the sheet box for the front battery box has overall 26.8" x 14.6" x 10.10' with an overall thickness of 0.05". The length separator has dimensions of 26.7" x 10" x 0.5". The width is exactly the same in both battery boxes.

In order to comply with the original goal to create a control system for Power Grid Engineering the PowerWheels vehicle contains a 12VDC battery which powers all of the smaller electronics. This 12VDC battery that is purchased with the vehicle is lead-acid and further complies with the battery selection for the full size vehicle. The battery is located in the front of the vehicle underneath the hood.

In addition to the 12VDC battery shown above the prototype vehicle includes two 16VDC monocrystalline solar panels, shown in figure 2 that supplies power to the battery. This is compatible to the original requirements of PowerGrid Engineering for additional charging capability using a solar panel. This feature allows the battery to be charged provided there is ample sunlight and the battery isn't being charge via grid connection.

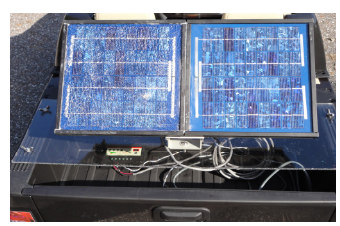

Fig. 2 Two 16VDC Monocrystalline Solar Panels

For the full size vehicle a separate monocrystalline panel is specified, particularly the PowerFilm Rollable solar charger R14. This flexible thin-film amorphous-silicon solar panel is chosen due to the variety of dimensions it can provide. Regardless of the final vehicle chosen by PowerGrid Engineering the rollable solar charger can supply power in any condition.

VI. Temperature Sensor & Thermal Control Design

The design of the temperature monitoring and control is based upon the sensor selection. Whether the sensor is analog, digital or one-wire determines the overall configuration and additional parts that might be required. A variety of parts are compared such as LM335, TMP20, TMP03, TMP04, DS18S20, and DS18B20 in terms of their temperature range, input voltage, output type and the cost. After evaluating the properties of each device the TMP03 sensor is selected for use. Despite its high cost, it is an open collector device with a temperature range of 40°C to +100°C and an input voltage of 4.5 volts to 7 volts. Not only is the temperature range acceptable for monitoring the battery and motor temperature but the input voltage is also acceptable.

In order to reduce the chance of ground currents capacitors and proper filtering is added to each digital temperature sensor. The temperature sensor output is approximately a 35Hz square wave at 25 degrees Celsius that the motor controller can decode. Depending on the speed of the counter the TMP03 had an average accuracy of 1.5°C. The temperature data can then be analyzed and compared to temperature limits so that the microcontroller can take action such as turning on fans or go into emergency shutdown of subsystems. The temperature data is also shift loaded into the serial data being passed to the microcontroller that is controlling the touch screen display.

There will be several fan controls from the sensor/motor controller. These individual fan controls will be the outputs from the 74HCT7541device, mentioned in the buffered output section and drive the gate of small N channel power MOSFET transistors that will switch the negative side of the 12VDC fans to ground. The main fans that are on the Sensor/ Motor Controller electronics will run continuously unless mode control is requiring economy mode then the fan will be controlled based on the temperature of the output bridge and the microcontroller internal temperature. The second set of fans will be on the batteries for the motor drive. These fans will be controlled based on the ideal temperature of the batteries and will turned off completely if the mode control setting is selected to the economy settings. Figure 3 below shows the fan controller logic using the temperature sensors placed throughout the vehicle and the motor controller, user interface for displaying to the user.

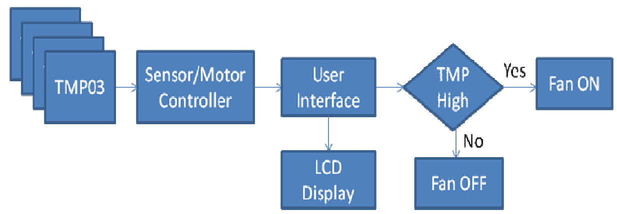

Fig. 3 Temperature Control Logic

VII. Voltage And Current Measurement

The voltages from Figure 4 that are being sensed have to be conditioned before they can be read by the microprocessor. Because the motor, battery, and solar voltages can be very high, the use of a precession high common mode input difference amplifier will be used. The AD629BRZ is ideal for this application.

The AB629BRZ can handle input common mode differences up to 300VDC. This will ensure that the expected voltage spikes >150V generated by the large drive motor will not damage the first amplifier or the microprocessor. The 12V, 5V and 3.3V will utilize a standard operational amplifier to sample the voltages. The LT1114 will be used for the purpose because it is a rail to rail output device that is designed to operate well with just a single supply. The rail to rail feature can easily measure voltages near ground level which can allow for large dynamic range voltage measurements.

The amplifiers will use a the battery supply voltage of 12VDC so the outputs of the amplifier amplifiers will have to be scaled by a resistor divider network because the microcontroller A/D inputs can only handle voltages in the range of 0 to 3.3VDC. A resistor ratio of ¼ in which a 10K ohm resistor will be in series with voltage going to the microcontroller input and a 2.49k will go to ground to achieve this ratio.

Voltage Source	Nominal Voltage	Voltage Range
Motor Drive Batteries	144	100 -170
Motor	144	0 -150
Solar Cells	12	0 - 15
Lead Acid Battery	12	10 -14.4
+5V	5	4.5 - 5.5
+3.3V	3.3	3 - 3.6

Fig. 4 Voltage Sensors

The microcontroller has a 16 channel 10 bit A/D that will be will utilize to sample the voltages. The microcontroller uses an analog MUX to sequence through the 16 channels and sample and holds each value. As the next data sample is passed to the sample and hold the previous value is converted to a digital value and loaded into the ADC buffers. The data is compared against predetermined values coded into the processor and if a threshold has been crossed then the microprocessor will flag that fault condition and take appropriate action. These digital values are also loaded onto the serial bus going to the touch screen display processor and can be accessed at any time by the user.

The controller A/D inputs will be used to measure currents of the motor batteries, motor, 12VDC Bus and the solar cell. The currents of the motor and motor batteries will be extremely large pulsed peaks up to 1000 amps but average current will be 200 amps. There are two safe ways to measure current of the magnitudes that are generated during the motor switching. The first is a high current sensing transformer with a turns ration near 1:1000 or a high current Hall Effect transformer sensor. The current sensor chosen for this application is the F.W.Bell RSS-200-A Hall Effect sensor. The RSS-200-A is a current sensor that has a linearity over the +/-200A range and can also handle ranges up to +/- 500A with some minor non-linearity effects. The output sensitivity is 8mV/A centered around the 6VDC reference voltage.

The F.W.Bell RSS-100-A is chosen to handle the smaller currents generated by the solar panel and lead-acid batteries. The RSS-100-A is a current sensor that has linearity over +/-100A range and can also handle ranges up to +/- 250A with some minor non-linearity effects. The RSS-100-A outputs 16mV/A centered around the 6 VDC reference. Both of these types of sensors require a power supply voltage 12 to18 VDC and the reference voltage of 6VDC.

The outputs of the current sensors will be inputted into an operational amplifier that current sensor outputs input op-amp configured as a voltage follower. The output of the voltage follower will pass through a resistor divider ratio of ¼ in which a 10K ohm resistor will be in series with voltage going to the controller input and a 2.49k will go to ground to achieve this ratio. This will be inputted into the controller A/D input. Because the voltage is centered on a reference voltage at 1.5VDC the controller will have to be coded to recognize positive and negative currents. Because of the motors large current swings the resolution of the current data will be approximately 1 lsb/Amp. The microcontroller will have to take the PWM type current and average it over the 16kHz clock used to generate the motor drive. The 12VDC bus will be monitored to determine the state of usage of the lead-acid batteries and the charging system.

The following diagram, illustrates the connection between the current sensor and the battery terminals. This figure also shows the use of the operational amplifier to limit the amount of voltage and current into the controller circuit.

For both the current and voltage sensors a similar configuration is utilized in the prototype PowerWheels vehicle. Buffer circuitry is used for all of the temperature sensors, current and voltage sensors. The voltage sensors are no longer rated at such high peak values due to the currents will no longer peak, similar to the current sensors.

VIII. Power Converter Design

In order to provide a fully electric vehicle a means of charging is required. Aside from the solar panels that are incorporated into the design it is highly inefficient to charge a full size vehicle based only on solar power where charging would take days or months to provide a full charge. Instead several AC/DC power converters are analyzed and compared to determine which unit is powerful enough, temperature sufficient, and inexpensive for this transformation. The charger remains in the vehicle until the user arrives at a 120VAC source GFIC plug where it is rectified and amplified to 144VDC to the battery pack. The AC/DC charger chosen with the design consists of a 1500 Watt Elcon Battery Charger to provide power to the rear battery pack with various types of mounting in the vehicle. This is beneficial to the design due to the fact the vehicle may vary and space may be more or less limited depending on this.

Furthermore the auxiliary battery located in the front of the vehicle must also obtain a power supply. To ensure that the power electronics will never fail even if the motor charge dies a separate battery charger is used for this system. There are two options for this charger, a 400W ElCon isolated converter or a 300W HWZ series converter. After examining their physical and electrical characteristics the HWZ converter is selected due to its financial aspect as it is the best product with the most economic value.

As specified by the temperature sensors and controllers there is a requirement to provide smaller DC voltages. In order to maintain high efficiency and low heat due to high load currents, a switch mode regulator is used. The LM2596 simple switcher step down power converter is selected from National Semiconductor. This integrated circuit provides the functions of a buck converter with several output voltage options of 3.3V, 5V, 12V, and an adjustable version. Due to the fact that both 3.3V and 5V are needed two separate LM2596 circuits will be designed. The LM2596 guarantees ±4% tolerance of an output voltage under a specific load and input voltage. This component is also rated at 150 kHz switching frequency allowing smaller capacitor values than a lower switching frequency. The IC is a 5-lead TO-263 surface mount chip.

Figure 5 shows the schematic for the 12VDC to 5VDC buck converter. This converter is designed based upon a 12VDC input voltage, a 5VDC output voltage and finally a 1Amp output current.

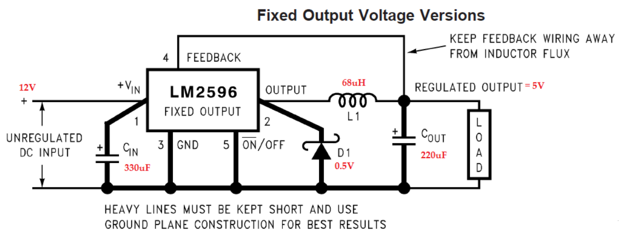

Fig. 5 12VDC/5VDC Buck Converter Schematic

Figure 6 shows the schematic for the 12VDC to 3.3VDC buck converter.

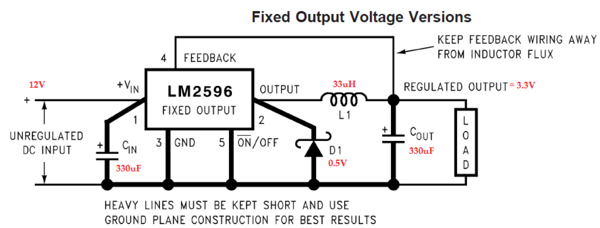

Fig. 6 12VDC/3.3VDC Buck Converter Schematic

This converter is designed based upon a 12VDC input voltage, a 3.3VDC output voltage and an output current of 2Amps. This converter is designed similar to the 5VDC converter with a larger output capacitor and a smaller output inductor.

For the final prototype of the vehicle, the PowerWheels F150, both the 12VDC/5VDC and the 12VDC/3.3VDC circuits are built, tested and used to power the temperature, voltage and current sensors placed throughout the vehicle. These circuits are tested using a flat copper plate, placing the components as detailed in the schematic and finally adding load bank resistors to the output pin. By doing the out output voltage was tested, read and verified regardless of the load current the desired 5VDC and 3.3VDC resulted. Due to the fact the small scale vehicle no longer required a 144VDC battery pack the two large scale power converters are removed from the prototype design. Instead of using the over rated selections the 120VAC/12VDC battery converter is used that is provided with the vehicle. This battery converter allows the battery to charge via the grid, or outlet power. Furthermore since this battery is used for the the power electronics and the two rear wheel drive motors in the F150 a second auxiliary battery charger is also no longer needed.

A final block diagram of the power conversion throughout the prototype PowerWheels vehicle is seen in Figure 7. The 120VAC power transforms in the Fisher-Price Battery charger to provide power to the 12VDC PowerWheels battery. This 12VDC is then transformed to 5VDC and 3.3VDC via the LM2596 simple switcher.

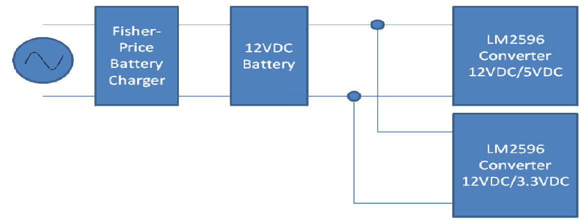

Fig. 7 Power Conversion Block Diagram

IX. User Display Design

The project specifications call for a touch screen display that will provide real time data to the user. There are to be three "modes": Normal, Economy, and Performance. These modes are presets that modify different attributes of the system. For example, Economy mode may restrict the rate of acceleration in order to conserve energy, whereas Performance mode will not so you can "floor it". In addition to system controls, the display will have different "Views". The different modes and views are described below.

The "Normal Mode" is also known as the default mode where the rate of acceleration will be balanced to an average rate for the given type of vehicle. The peripheral systems will be used in a balanced way (e.g. A/C turns on and off to maintain the desired temperature).

The "Economy Mode" is where the system will enter when the charge level of the battery system reaches a set threshold (e.g. 20%charge left) or manually by the user. In this mode the rate of acceleration will be reduced and the peripheral systems will be shut down or reduced (e.g. A/C fan turned off or set to lowest setting).

Finally the "Performance Mode" is selected manually and all restrictions on the rate of acceleration will be lifted. The peripheral systems can be used as the user pleases (e.g. A/C always on).

The user will also have several views consisting of either the basic, advanced or historical view. The normal, economy and performance view are in the basic view with separate background colors to indicate the current mode of operation. The normal mode is blue, economy is green and finally performance is red. The advanced user view will contain additional information such as power draw and battery status of charge and temperature. Finally the historical view will show efficiency, and energy used, along with last charged status and indication buttons of engine check, previous mode, etc.

This is the desired configuration for the full size vehicle to be provided to PowerGrid Engineering. For the current prototype vehicle the specifications were curtailed and limited to the basic view with additional options for later enabling the historical and advanced user views.

Figure 8 shows the basic view used for the prototype vehicle.

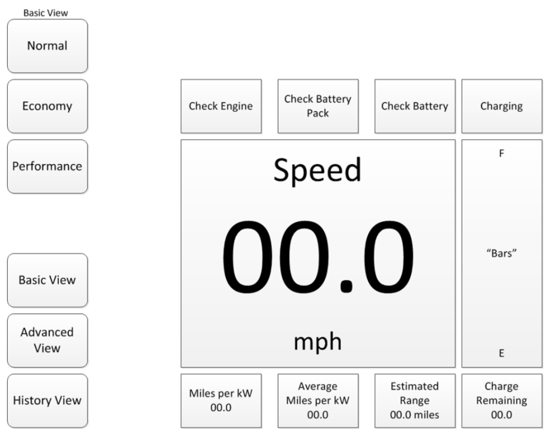

Fig.8 Basic View

X. Conclusion

Overall the PowerWheels F150 prototype vehicle performs as the full size electric vehicle would. Through minor sensor alterations and ratings to change the overall concept and functionality is achieved. PowerGrid Engineering has the ability to substitute this intelligent driving system into their vehicle and have a fully functioning electric vehicle with three modes of operation consisting of the performance, economy and normal mode. Throughout the process of creating the PowerWheels vehicle the most difficult aspect was creating the PCB. No team member had prior experience working with printed circuit board software prior to this project and therefore the difficulty was learning the software within ample time to create, manufacture and populate the board. Another difficult aspect was establishing the communication between the sensor/motor microcontroller and the LCD display board. After successfully establishing this communication the ability to control the voltage to the two rear wheel motors was incorporated. Due to time constraints of the project the original requirements provided by Power Grid Engineering were altered.

Acknowledgement

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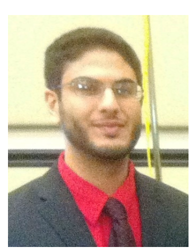
Biography

Celina Martin will graduate from the University of Central Florida with a Bachelors degree in Electrical Engineering in May of 2011. She currently works as an Electrical Engineering intern in the Wind Power group at Siemens Energy Sector. Come June of 2011 Celina will begin working as an Electrical Engineer in Siemens Engineering Development Program with plans to one day work in renewable energy.

James (Jim) Kies will graduate from the University of Central Florida with a Bachelor of Science degree in Electrical Engineering in May of 2011. Jim has worked at Lockheed Martin Missiles and Fire control as an electrical power systems design engineer since 1994. He plans to continue working for Lockheed Martin and will start a part time consulting business with plans to create a new business in the area of alternative energy.

Mike Jones will graduate in May of 2011 with a Bachelors degree in Electrical Engineering. Mike has worked with V&N Advanced Automation Systems, based out of Rockledge, Florida, as an Electrical Engineering Intern since June of 2010. Mike hopes to continue working with this company following the completion of his degree.



Yazen Ghannam will graduate from the University of Central Florida with a Bachelors degree in Computer Engineering in May of 2011. Yazen plans to start his own business and consulting for other companies in the areas of embedded systems.