Electric Vehicle Power Converter

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Date: December 12, 2012

INTRODUCTION

A plug-in hybrid electric vehicle (PHEV) is a vehicle that utilizes a battery to power the vehicle's electric motor. This battery can be recharged when it is plugged-in to a power source, which is typically 60 Hz, 120 V_{rms}. PHEVs have much higher fuel efficiency and lower operating cost than average vehicles because vehicles employing the hybrid technology can significantly improve their fuel economy and produce less pollutants compared to conventional vehicles. These vehicles are environmentally friendly and do not produce as much pollution as their counterparts. Since these vehicles produce less harmful toxins in the air, this then reduces the need for annual emission inspections. These advantages help the PHEV become more and more popular in the growing market.

PROJECT SUMMARY

The primary goal of this project is to design a system that will function as an electric vehicle power converter. A Digital Signal Processor driven electronics system shall be designed such that the system can convert 60Hz, 120 V_{rms} AC grid power to the required 200 V, or higher DC link voltage to charge an electric vehicle battery. This system will consist of a single phase diode rectifier; boost converter, and bi-directional converter for discharging the battery into a variable load or charging of the battery itself. In order to implement the system, study regarding the battery characteristics and its modeling to be done for the proper charging and discharging of the battery with the consideration of the safety and efficiency of the system.

GOALS

- Research battery models that can help model the power converter
- Being able to charge the battery throughout the wall power outlet, 120 V_{rms} 60 Hz
- Having the 200V or higher, constant DC link voltage being able to charge a battery through the bidirectional converter
- Using DSP to control the battery in charging or discharging circuit by adjusting the PWM signal
- Analyzing charging and discharging voltage current characteristics 400W, 51.8V Li-Ion battery
- Developing a more safe and efficient charging and discharging control algorithm of the battery

For the electric vehicle power converter, the single phase, 60 Hz, 120V_{rms} sine wave is the input source from the utility. The input goes through a diode rectifier and then Power Factor Correction (PFC) boost converter, which not only increases the input voltage but also puts it in phase with source voltage. The rectified and PFC boost converter output is the DC link input for the bi-directional converter as seen in Figure 1. The bi-directional converter will be used for the charging and discharging of the battery. The DSP will generate PWM signals to control the PFC boost converter and the bi-directional converter. A high level system block diagram of the electric vehicle power converter can be seen in Figure 1.

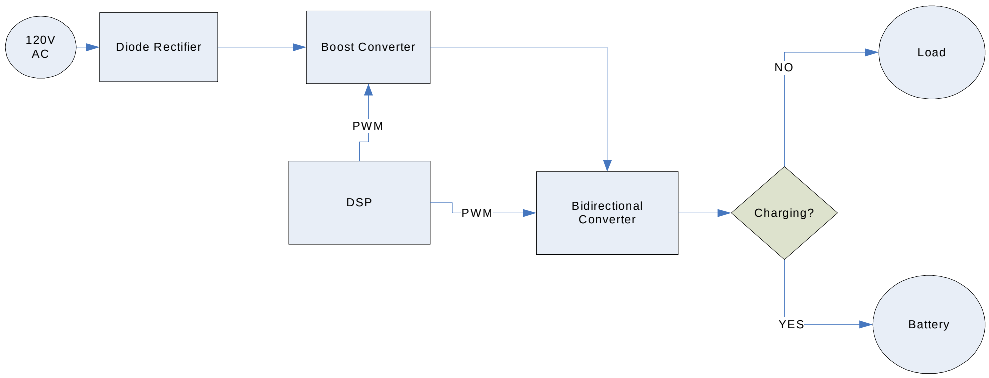


Figure 1: High Level System Block Diagram

SUBSYSTEMS

1. SINGLE PHASE DIODE RECTIFIER AND PFC BOOST CONVERTER

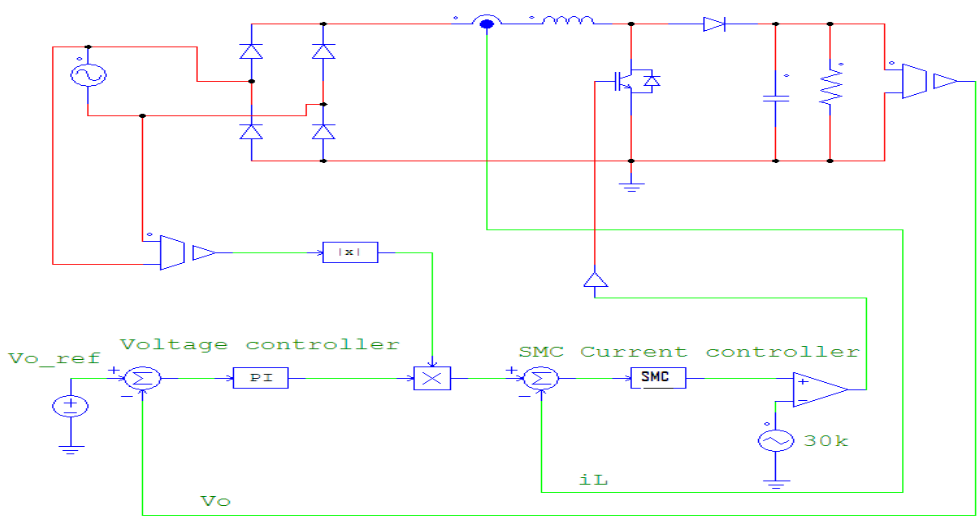
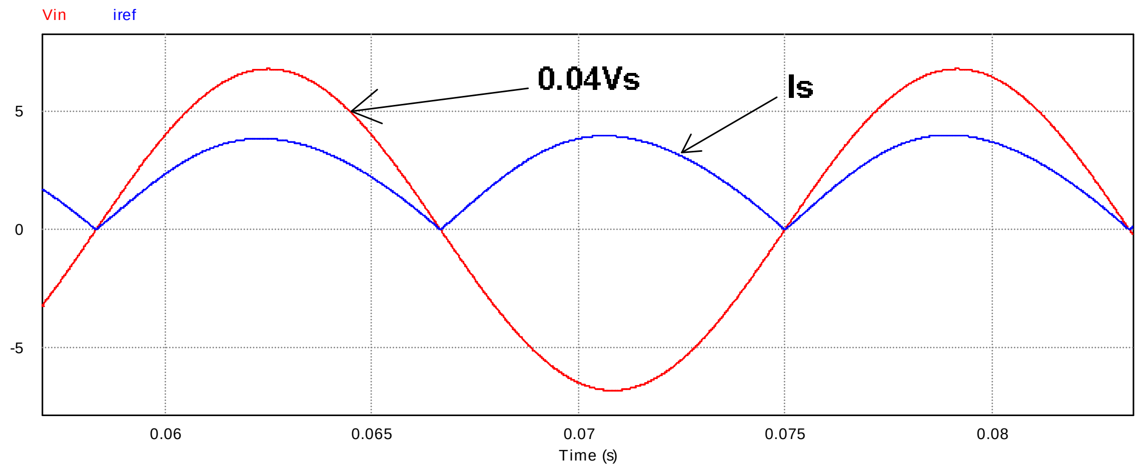


Figure 2: PFC Boost Converter with Controllers

In Figure 2, the configuration for the PFC boost converter can be seen with a two cascade control structure. The current through the diode rectifier shall not exceed 20A and shall dissipate the smallest amount of power possible to keep the system below 500W, our battery specification.



To be in unity power factor, the input sinusoidal current, I_s is to be in phase with the input voltage, V_s, throughout the PFC boost converter seen in Figure 3. The controller shall have a phase margin [1].

Figure 3: PFC V_s and I_s Waveforms

2. BI-DIRECTIONAL CONVERTER

By using a Buck and Boost converter, a bi-directional converter can be constructed as seen in Figure 4.

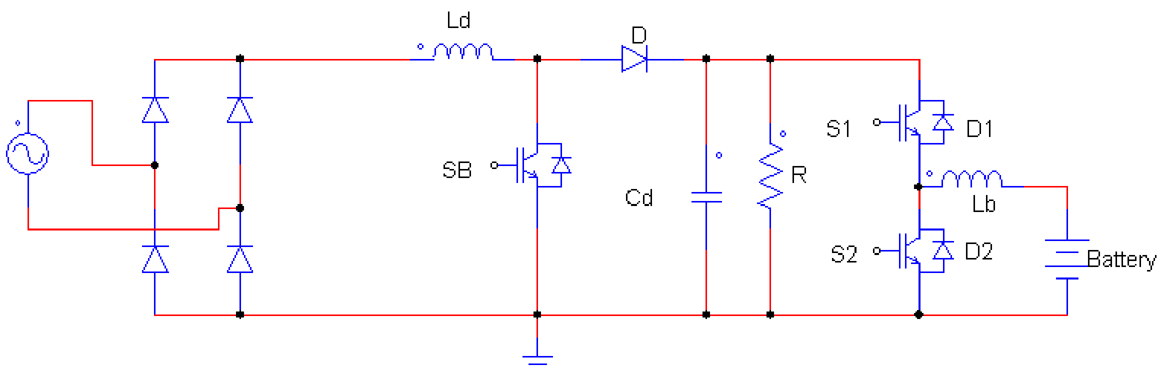


Figure 4: PFC Boost Converter and Boost Converter

The output V_o of the PFC boost converter in Figure 4 is connected to the DC bus across the capacitor C_d. From the DC bus, the 51.8V Li-ion battery can be charged through the buck converter. This project will just be focused on designing voltage and current controllers for the PFC boost converter, and bi-directional converter, buck (charging) and boost (discharging) modes. The elements in this system will be selected by considering less than 500W, battery system.

3. GATE DRIVER

The gate driver will receive an inverted square wave and boost it up to a level that will be able to power the IGBTs in the PFC converter and bidirectional converter. The Figure 5 represents the basic circuitry of the gate driver that will be used to design the gate driver for the electric vehicle power converter.

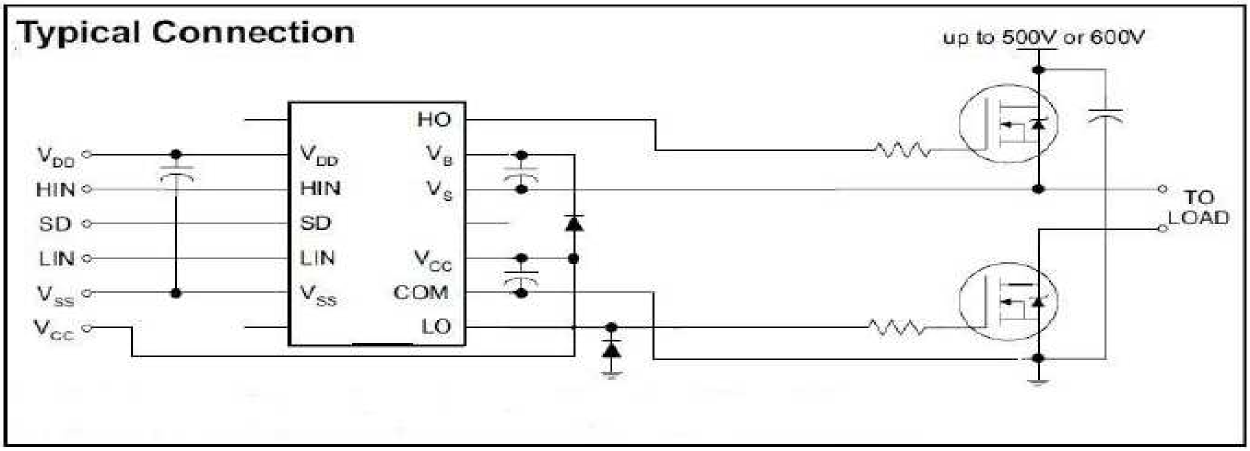


Figure 5: Exemplary Gate Driver Circuitry [8]

4. DSP CONTROL DIAGRAM

There are three PWM signals. One is for the PFC boost converter and two of them are for the bi-directional converter. Using the TMS320F2812 32bit fixed point DSP, these PWM signals can be generated. The sampling frequency of DSP could be between 20 to 50 kHz based upon the switching device performance. The switching frequency shall be within 20 to 50 kHz.

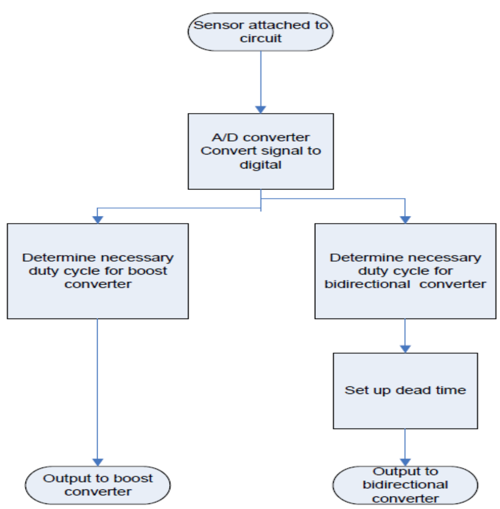


Figure 6: DSP program Flow Chart

5. BATTERY TESTING CIRCUIT

This subsystem will allow for the testing of the characteristics of the battery. By controlling the PWM signal of the switch, IGBT or MOSFET, the load through R_{test} resistor will be applied, the discharging characteristics of the battery will be analyzed. In addition, when the switch is open, leakage current can also be examined. The lower powered 7.4V Li-Ion battery or UC (Ultracapacitor) will be tested for the preliminary results. This will fulfill the small scale battery or energy storage test. The 52V Li-Ion, 500W battery will be tested eventually, which will fulfill our actually size battery. The battery testing circuit can be seen in Figure 7.

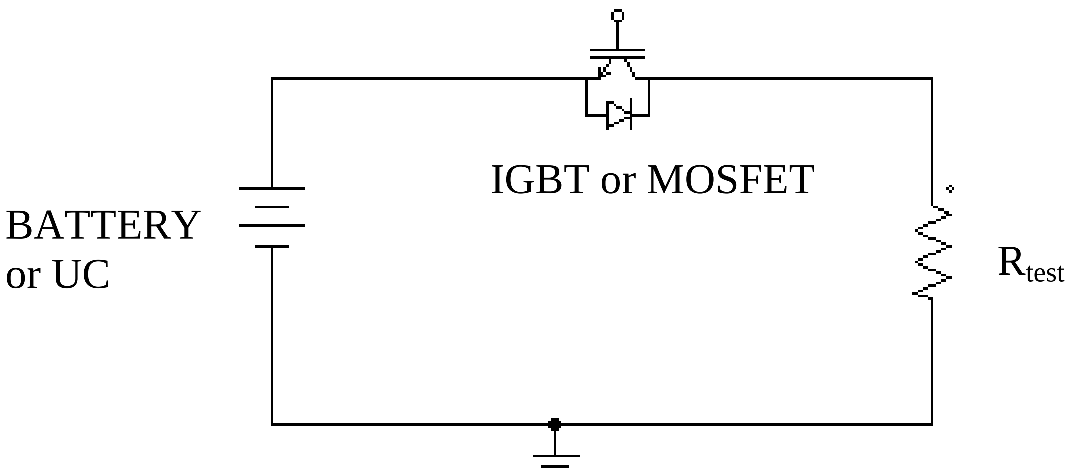


Figure 7: Battery Testing Circuit

6. BATTERY MODEL

The following battery model will be used to investigate the battery characteristic. The battery model represents the Saft-Battery model. The values for resistors and capacitors may have to be further measured for our battery. This battery model with the values was taken from the [9]

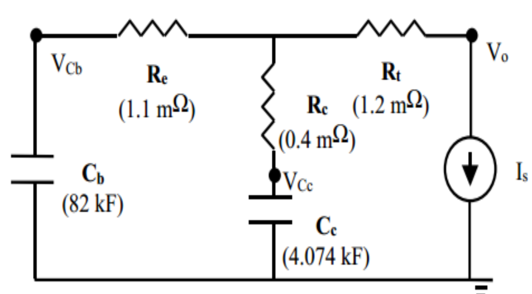


Figure 8: Diagram of the Saft-Battery Model [9]

7. BATTERY MODEL IN SIMULINK

Further applying the battery testing circuit, a battery model can be built in Simulink with the same values from [9]. Our simulation result in Figure 11 is almost correlated with the reference [9] simulation result, which shows that we may get a simulation result as long as the values of the RC parameters of our battery model are properly selected.

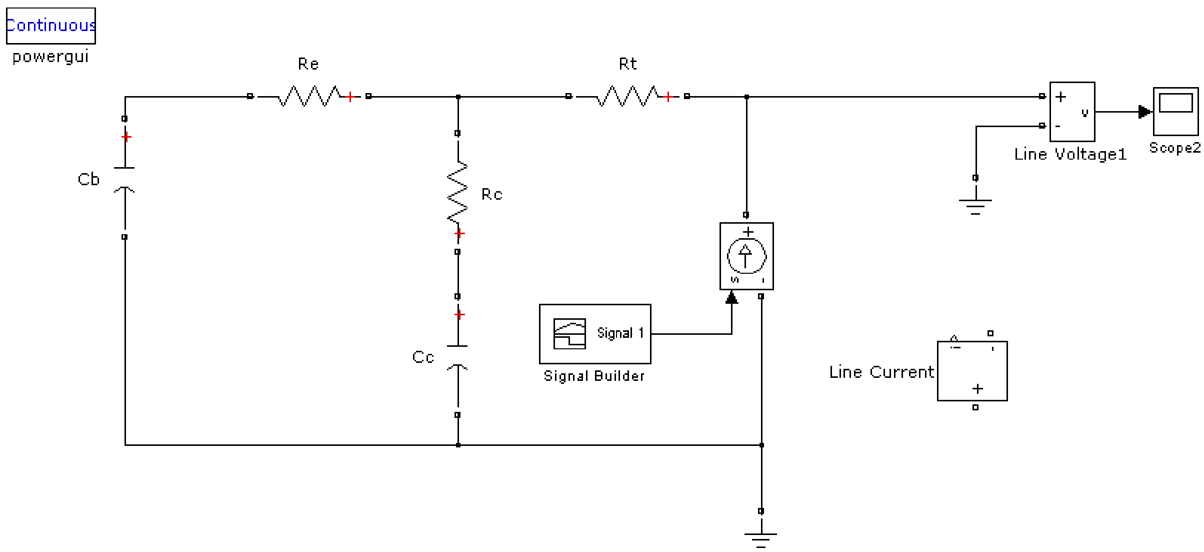


Figure 9: Battery Testing Circuit in Simulink

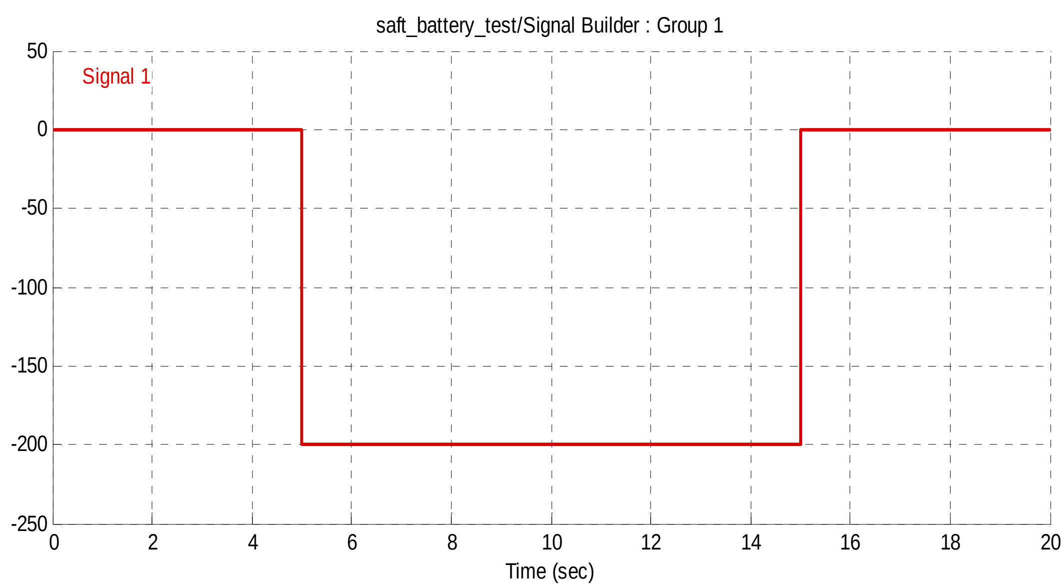


Figure 10: The Load Current Profile of the Battery Model in SIMULINK

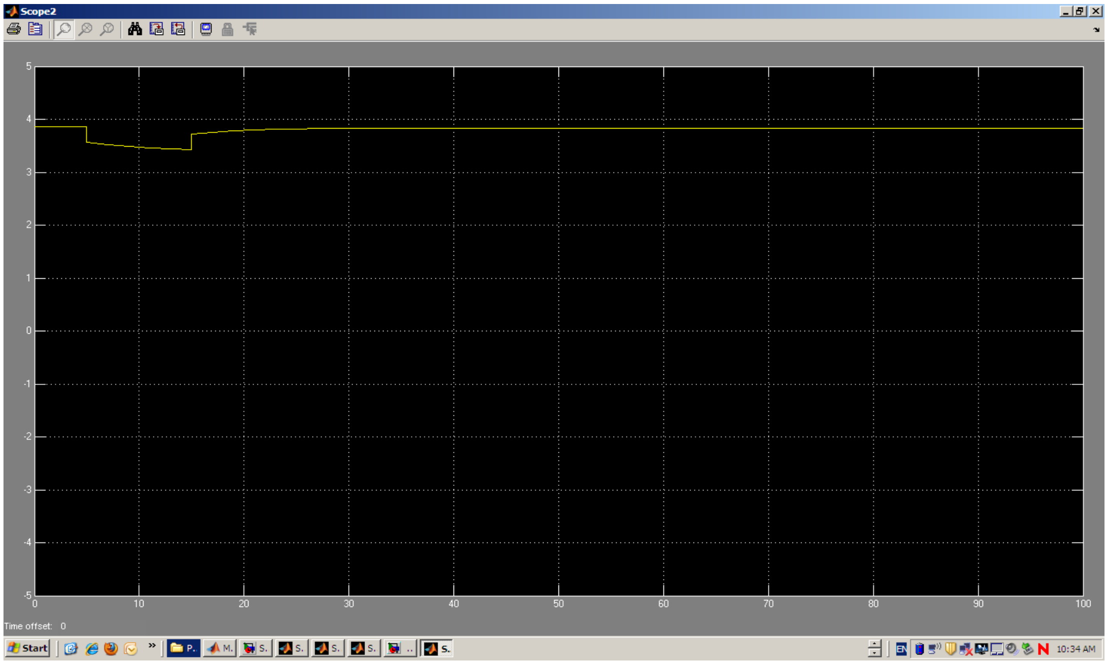


Figure 11: The Output Voltage of the Battery in Simulink

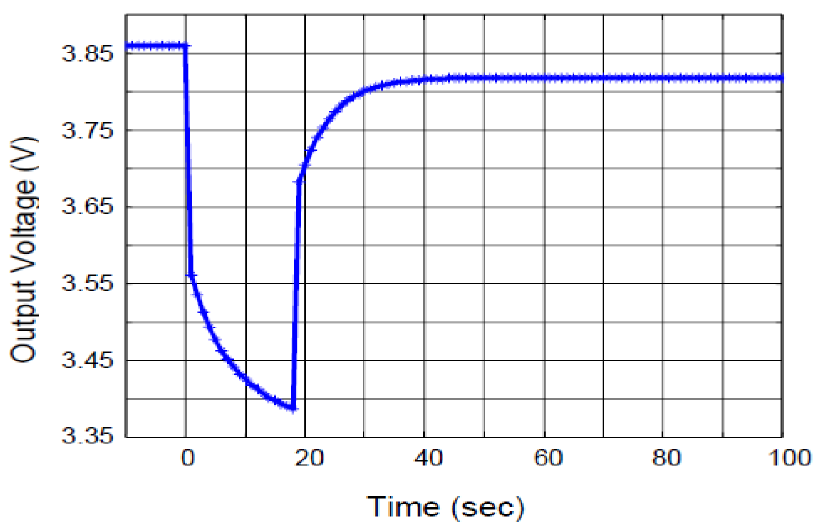


Figure 12: The output voltage of the Saft Battery from [9]

SCHEDULE AND CONCLUSION

Week 1: Any Extra Battery Research	**Week 7:** DSP Design
Week 2: Small Scale Battery Testing	**Week 8:** DSP Design
Week 3: Small Scale Battery Testing	**Week 9:** DSP Design
Week 4: PCB Design	**Week 10:** Large Scale Battery Testing

Week 5: PCB Design	**Week 11:** Large Scale Battery Testing
Week 6: PCB Design	**Week 12:** Final Implementation

TABLE 1: Spring Work Schedule

In TABLE1 1, the spring work schedule can be seen for the project. The project will be done based on the schedule. There may be times where the project individuals may have to work separately. Such a case would be during the PCB design and DSP design. The PCB and the DSP may have to be done concurrently, since the design for both may have to be constantly changed in order to debug the system properly. This schedule is designed so that if the project group were to fall behind for any reason there would still be enough time to implement the project successfully. As previously mentioned, our project is to implement the PFC converter and bidirectional converter with the battery. The PFC converter control and bidirectional converter control can be designed with PSIM for simulation and DSP for implementation. Also the battery charging and discharging test will be performed using the bidirectional converter.

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