EV Power Converter
“Functional Description & Block Diagram”

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Introduction:

This Electric Vehicle Power Converter project is an expansion of last year's project done by Matt Daly, Peter Burrmann, and Renee Kohl. The main focus of the last year was to design a buck and boost converter for a small scale system less than 100W. They did not have a chance to fully examine the charging and discharging circuits with the real battery. This year our project objective is to upscale to 400W and then attach the Li- ion 52 V battery. Consideration will be taken for the battery current and voltage characteristics along with its bidirectional control algorithm.

Goals:

- Being able to charge the battery throughout the wall power outlet, 120 V_{rms}, 60Hz.
- Having the DC signal able to charge a battery by making the signal approximately 52V.
- Using a DSP (Digital Signal Processor) to control the battery in charging or discharging the circuit by adjusting the PWM (Pulse Width Modulation) signal.
- Analyzing charging and discharging voltage current characteristics of 400W , 52 V Li-Ion battery using LabVIEW
- Developing a safe and efficient charging and discharging control algorithm of the battery

High Level Diagram:

In this project, the input source is 120V_{rms} 60 Hz sine wave from the utility. The input goes through a diode rectifier and Power Factor Correction (PFC) boost converter, which not only increases the input voltage but puts it in phase with the source voltage. The rectified and PFC input is also the DC link input for the bidirectional converter. The bidirectional converter will be responsible for the charging and discharging of the battery. The DSP will use PWM signals to control the PFC boost converter and the bidirectional converter.

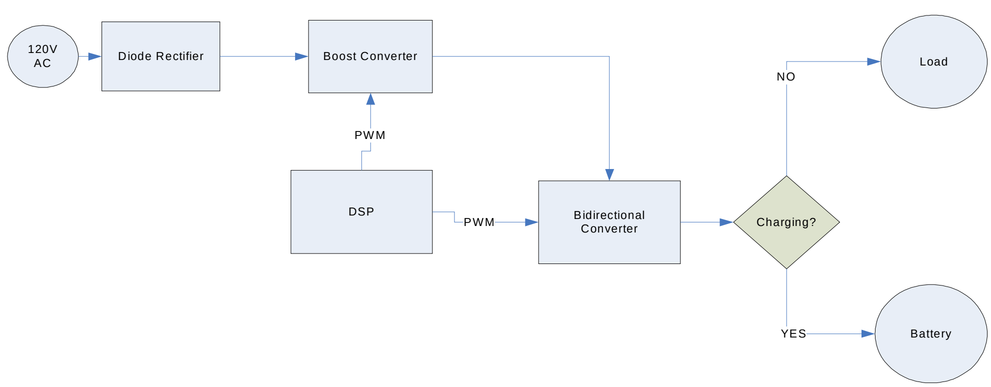

Figure 1: High System Block Diagram [2]

Subsystems:

1. Single Phase Diode Rectifier and PFC Boost Converter

Figure 2 shows the power circuit and control configuration for the PFC boost converter with a two-cascade control structure [1].

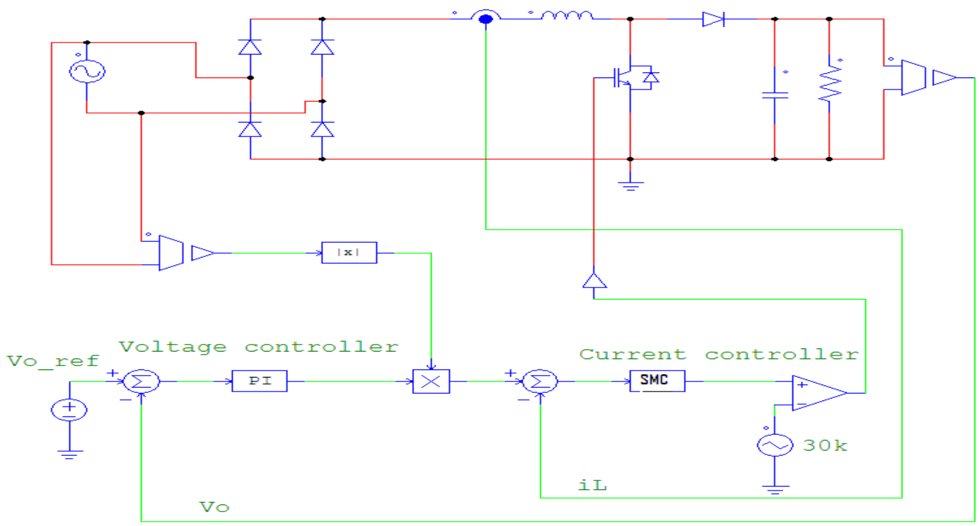

Figure 2: PFC boost converter with controllers

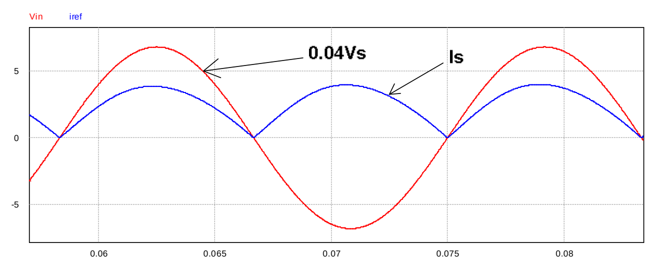

Figure 3: PFC V_s and I_s waveforms

To be 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 as shown Figure 3.

2. Bidirectional Converter

By using a Buck and Boost converter, a bidirectional converter can be designed as seen in Figure 4

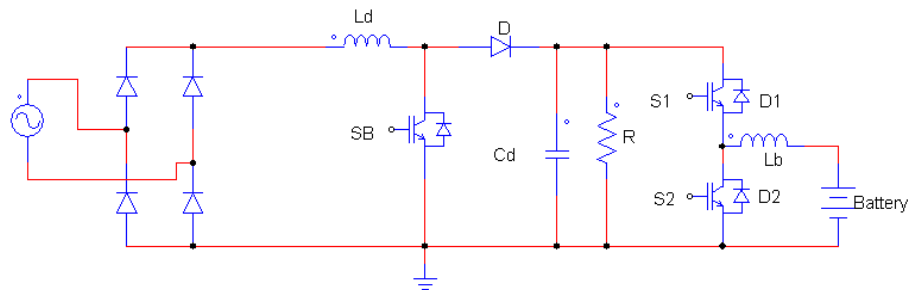

Figure 4: PFC boost converter and Bidirectional Converter

The output V_o of the PFC boost converter in Figure 3 is connected to the DC bus across the capacitor C_d. From the DC bus, 52V the 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 bidirectional converter, buck (charging) and boost (discharging) modes.

3. DSP Control Diagram

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

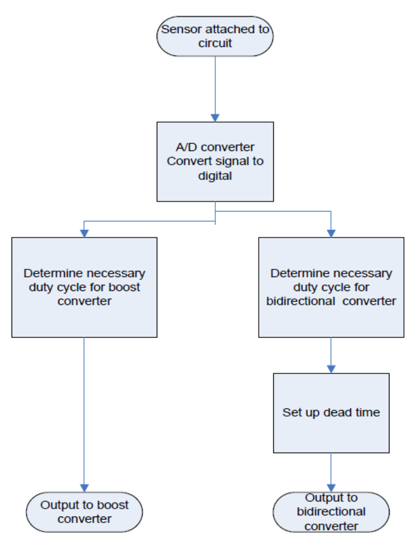

Figure 5: DSP program flowchart [2]

5. Battery Charger and Discharger Test Circuit

This subsystem will allow for the testing of the characteristics of the battery. By controlling pwm signal of the switch in Figure6, 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. A lower powered battery, 7.4V, Li-on 50W battery will be tested first with LabVIEW, and then we are going to move on 52V Li-on, 500W battery.

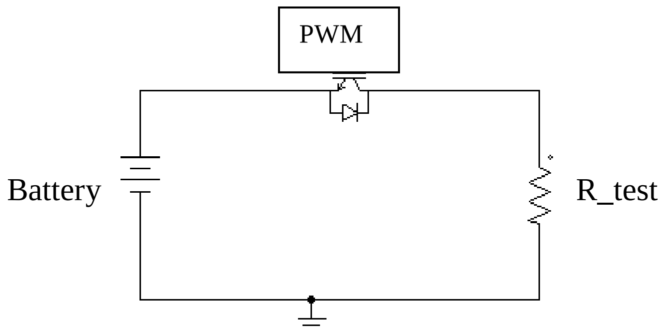

Figure 6: Battery Charging Circuit

6. Gate Driver

The gate driver will receive an inverted square wave and boosts it up to a level to be able to power the IGBT. The figure below is the gate driver circuit example.

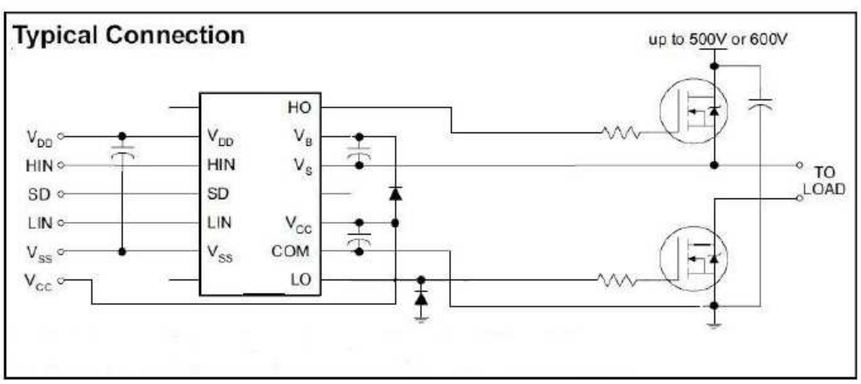

Figure 7: Gate driver example using IR2110 [8]

References:

[1] N. Mohan, First Course on Power Electronics. Minneapolis: MNPERE, 2009

[2] Daly, Matt, Renee Kohl, and Peter Burrmann. "Electric Vehicle Charger for Plug-In Hybrid Electric Vehicles." *PHEV: Plug in Hybrid Electric Vehicle Charger*. 26 Sept. 2011. Web. 24 Sept. 2012.

[3] B. Bagci, "Programming and use of TMS320F28I2 DSP to control and regulate power electronic converters," Master Thesis, Fachochschule Koln University of Applied Sciences, Cologne, Germany, 2003.

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[7] Y. Tian, "Analysis, simulation and DSP based implementation of asymmetric three-level single-phase inverter in solar power system," Master Thesis, Florida State University, Tallahassee, Florida, United States, 2007.

[8] Application Note AN-978, http://www.irf.com/technical-info/appnotes/an-978.pdf