Electric Vehicle Charger for Plug-In Hybrid Electric Vehicles

FUNCTIONAL REQUIREMENTS AND PERFORMANCE SPECIFICATIONS

By:

Matt Daly
Peter Burrmann
Renee Kohl

Project Advisers:

Dr. Woonki Na
Dr. Brian Huggins

Date:

November 17, 2011

INTRODUCTION

A plug-in hybrid electric vehicle (PHEV) is a hybrid vehicle which utilizes a battery to power the vehicle's electric motor. This battery can be recharged when it is plugged-in to a power source (typically 120 [V_{rms}] from the grid). PHEV's have much higher fuel efficiency and lower operating cost than the typical vehicle. These vehicles help keep the environment clean by reducing the amount of toxins emitted from standard exhaust systems. This also removes the need for annual emission inspections. These advantages of a PHEV are some of the reasons why they are now increasing in popularity and have a growing market.

GOALS

The primary goal of this project is to design a system that will function as an electric vehicle charger. A Digital Signal Processor driven power electronics system shall be designed such that the system can convert 120 [V_{rms}] AC grid power to the required 48[V_{pp}] DC value 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 this system, a control algorithm must be developed using the TMS320F2812 DSP board. Values for all circuit elements need to be calculated and specific devices and circuit elements need to be selected and purchased to match specifications.

SYSTEM BLOCK DIAGRAM

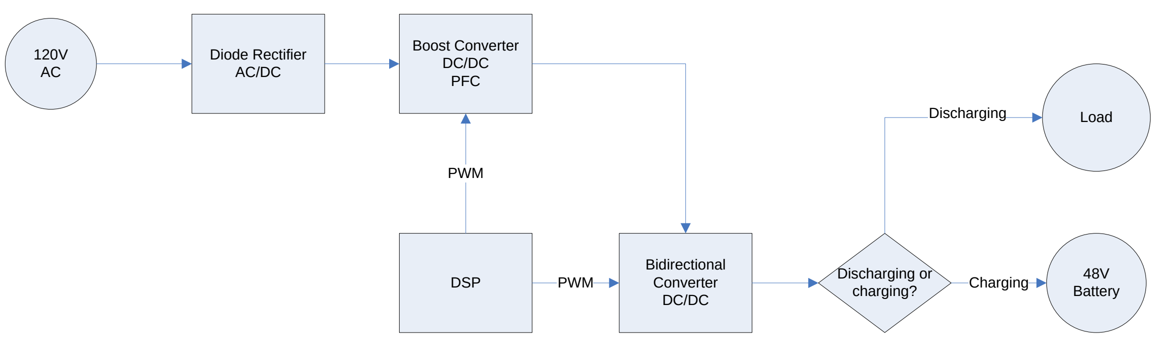

Figure 1. High Level System Block Diagram

The input to the system will be 120 [V_{rms}] from the grid and this shall be fully rectified. The rectified sine wave will then be passed through a boost converter driven by the DSP in order to correct the power factor as necessary. The output of the boost converter shall then be reduced to 48 [V] via a bi-directional converter for charging the battery. Once the battery is completely charged to 48 [V], the DSP will sense a voltage drop of zero from the battery to the battery input in order to prevent the battery from over-charging. The battery shall also be able to discharge to a variable load through the bi-directional converter by "boosting" 48 [V] to an appropriate amount for the load.

SUBSYSTEMS

Diode Rectifier:
The Diode Rectifier is used to convert 120 [V_{rms}] AC grid power to a rectified sine wave that will then be used by the PFC circuit. The current through the diode rectifier shall not exceed 20A and shall dissipate the smallest amount of power possible to keep the system power below 1k [W].

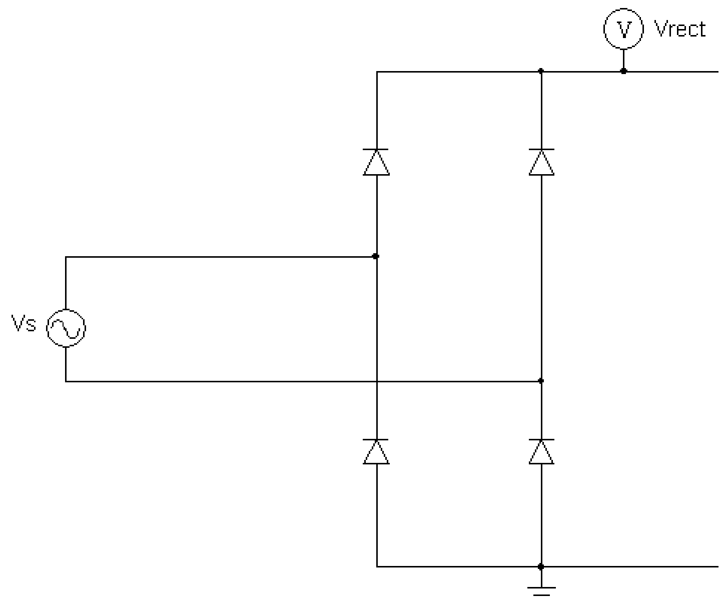

Figure 2. Diode Rectifier Circuit

Boost Converter:
The rectified sinusoid passes through a boost converter driven by the DSP. This is where power factor correction happens for providing the appropriate voltage at the Load and input to Bi-Directional Converter. The elements in this system will be selected to limit the amount of power dissipation to keep the system power below 1k [W].

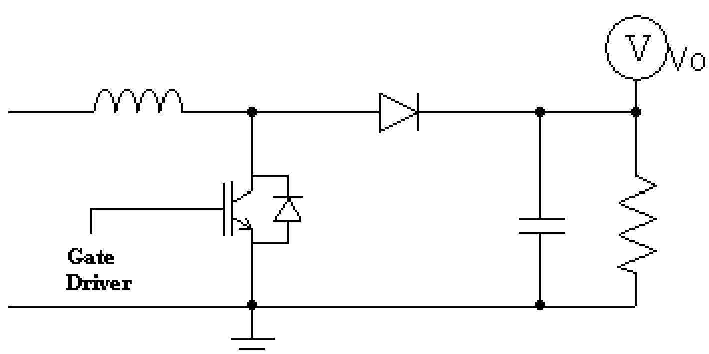

Figure 3. Boost Converter Circuit

Interfacing Circuitry:
The rectified sinusoid passes through a current sensor. The sensed current will be used by a PI controller implemented in the DSP. The current straight out of the rectifier shall be run through protective circuitry before going into the A/D converter of the DSP. The protective circuitry shall lower the current to a safe range for the DSP.

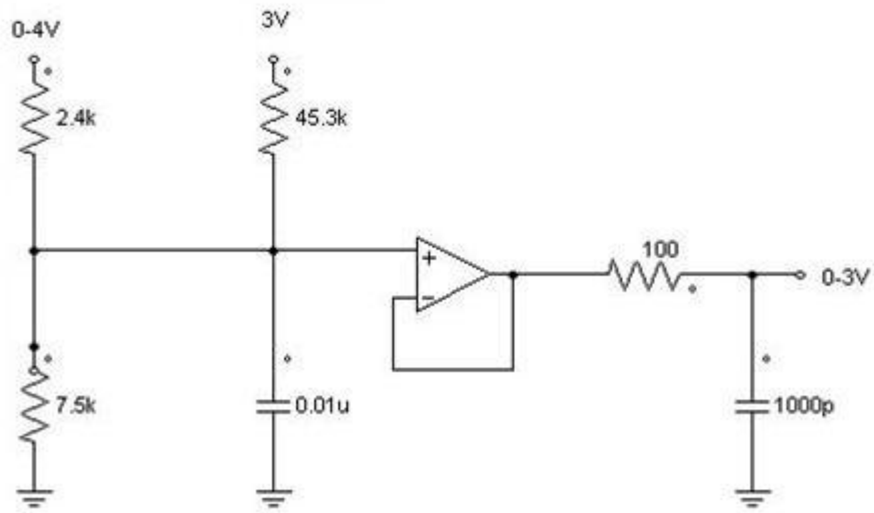

Figure 4. Interfacing Circuit

Bidirectional converter:
The bidirectional converter offers the option of lowering voltage one way and boosting it the other way. For our purposes, it shall convert the output voltage at the load to 48[V] for charging the battery and also convert the 48[V] battery back to the necessary load voltage. The necessary duty cycles for determining the mode of operation shall be determined by the DSP via the current and voltage sensors. The DSP will output the appropriate PWM to the switches.

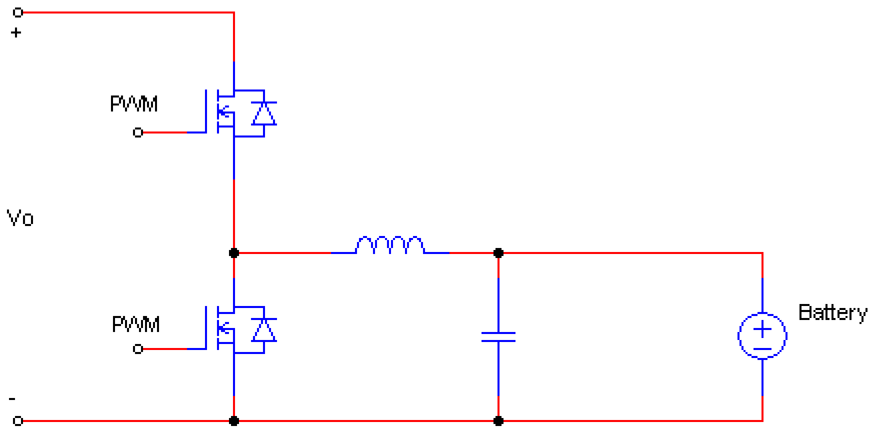

Figure 5. Bidirectional Converter Circuit

Microprocessor Control

The DSP will control and monitor the system for charging and discharging of the battery while performing the power factor correction and protecting the system from the high voltage and current. The switching frequency shall be within 10-15 kHz and the sensing frequency shall be between 1-10 kHz.

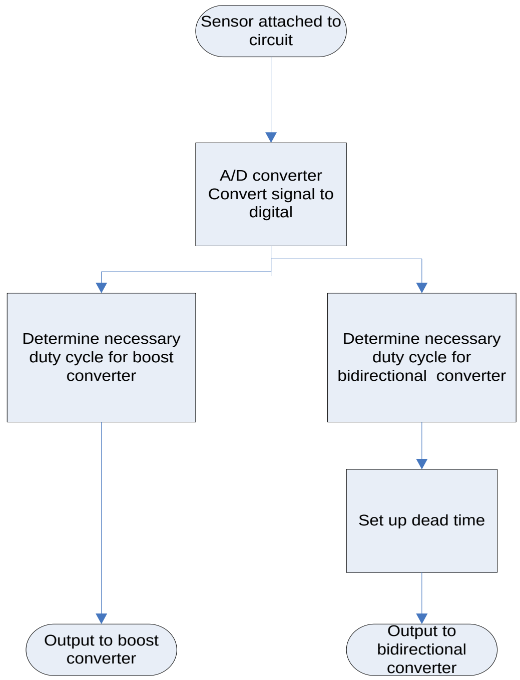

Figure 6. Microprocessor Flow Chart

References

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.

G. Mathieu, "Design of an on-board charger for plug-in hybrid electrical vehicle (PHEV)," Master Thesis, Chalmers University of Technology, Göteborg, Sweden, 2009.

L. Zhou, "Evaluation and DSP based implementation of PWM approaches for single-phased DC-AC converters," Master Thesis, Florida State University, Tallahassee, Florida, United States 2005.

M. Hedlund, "Design and construction of a bidirectional DCDC converter for an EV application," Master Thesis, Uppsala University, Uppsala, Sweden, 2010.

N. Mohan, *First Course on Power Electronics*. Minneapolis: MNPERE, 2009.

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.