PHEV – Plug-In Hybrid Electric Vehicle Charger

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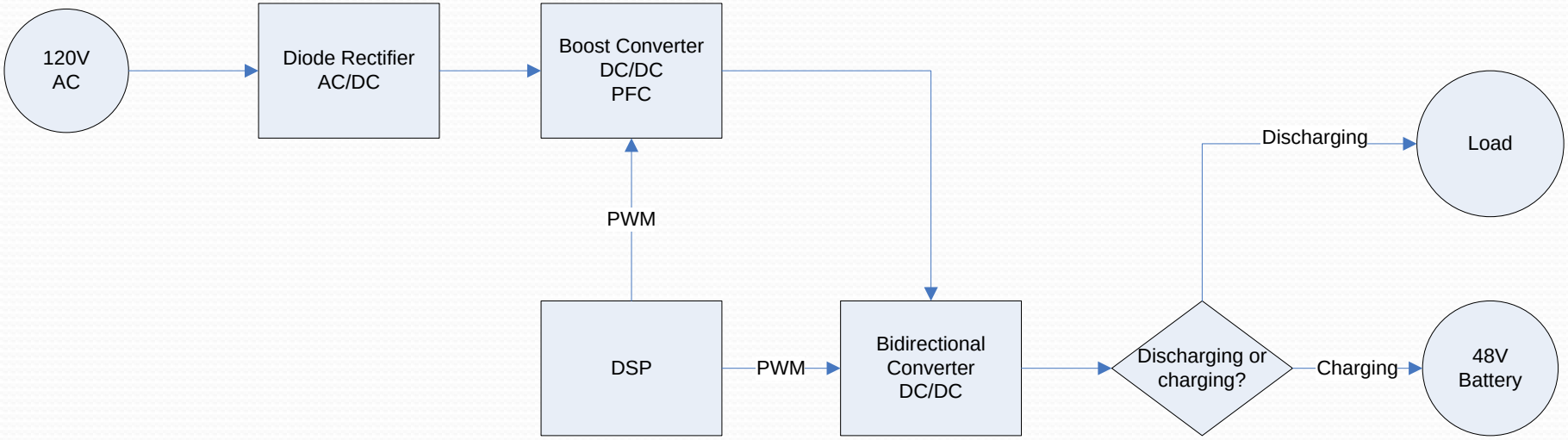
Outline

- Project Summary
- Background
- Detailed Description
  - Functional Description and Requirements
  - Equipment and Parts List
  - Preliminary Lab Work
- Schedule of Spring Tasks

Project Summary

- Convert 120 volt AC grid power to the required 48[V] DC value to charge an electric vehicle battery
- Discharge the battery into a variable load



Project Goals

- Create a model of PHEV that does not exceed 1000[W] of power
- No circuit element shall exceed 25[A] for safety purposes
- Develop a control algorithm using a DSP for the purpose of driving the MOSFET gates in the system

Background

- No previous work has been done at Bradley on this project
- PHEVs are a growing market

Detailed Description

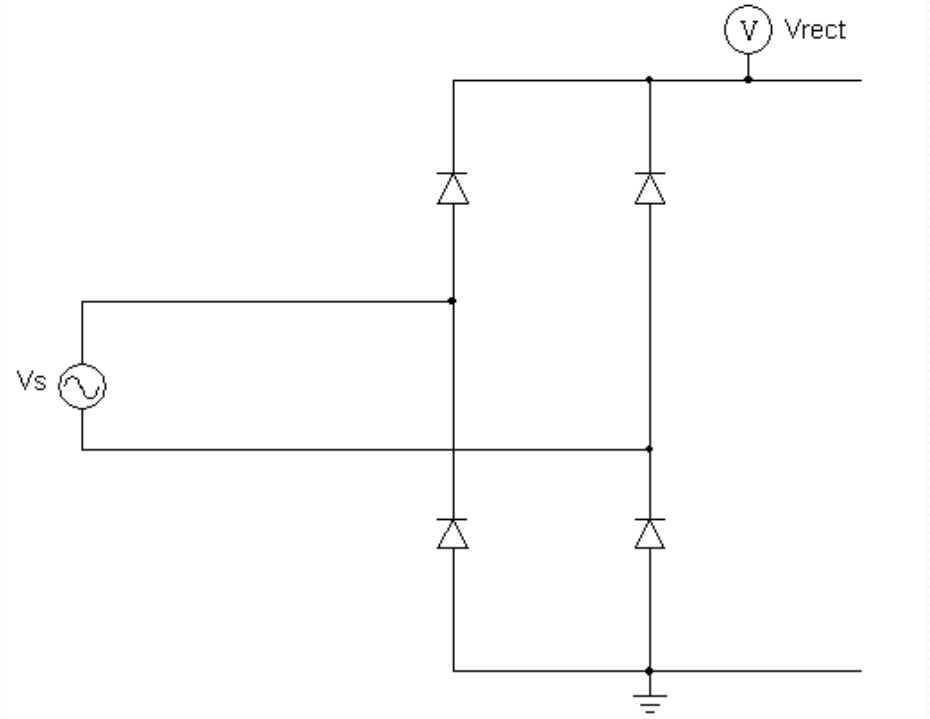
Functional Description & Requirements

- PFC
- Bi-Directional Converter
- Protection Circuitry
- Battery
- DSP

Function Description/Requirements

Diode Rectifier

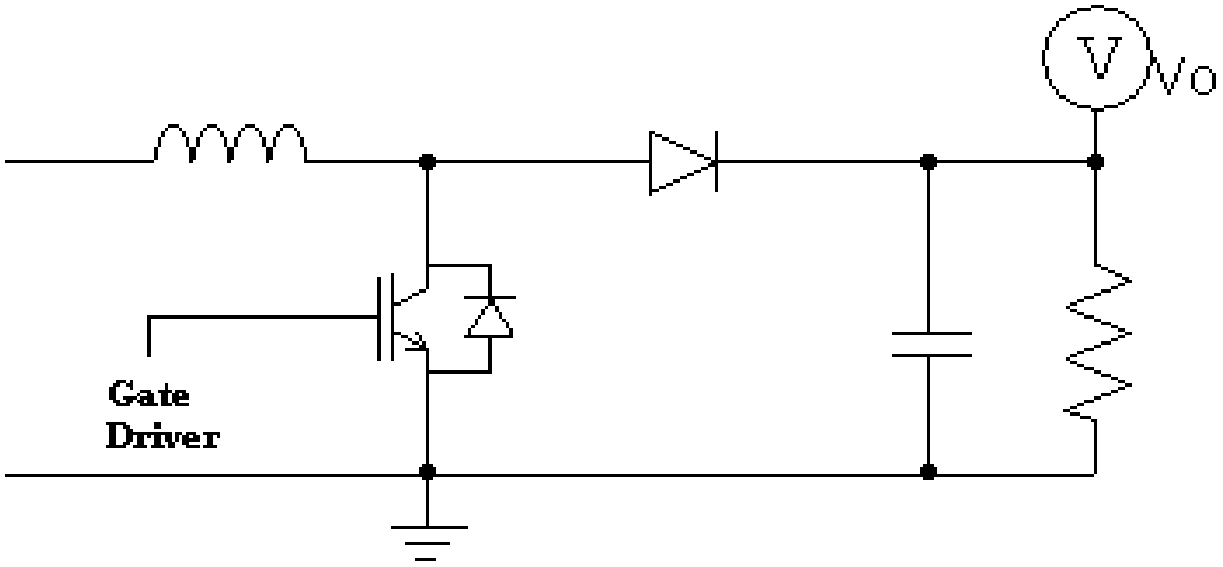
- Rectifies 120[V_{rms}] AC grid power
- Part of Power Factor Correction
- Current through Rectifier will not exceed 25[A]



Function Description/Requirements

Boost Converter

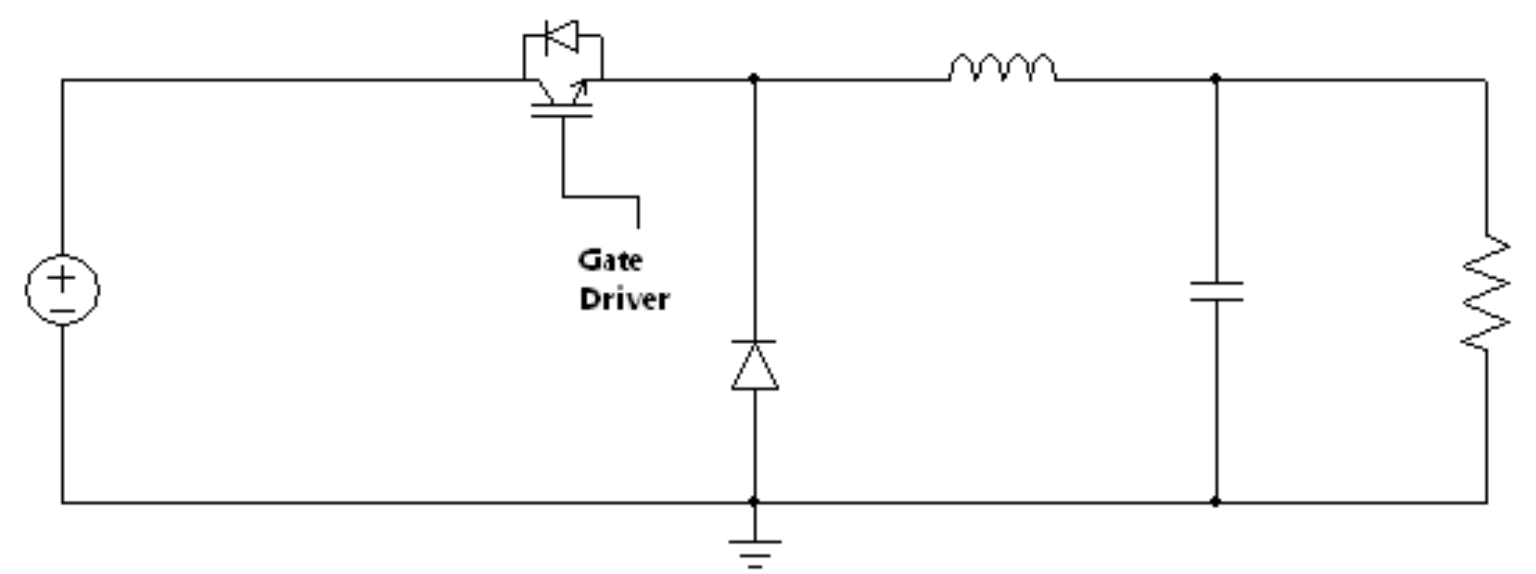
- Boosts input voltage based on MOSFET duty cycle
- Part of Power Factor Correction
- Half of Bi-directional Converter



Function Description/Requirements

Buck Converter

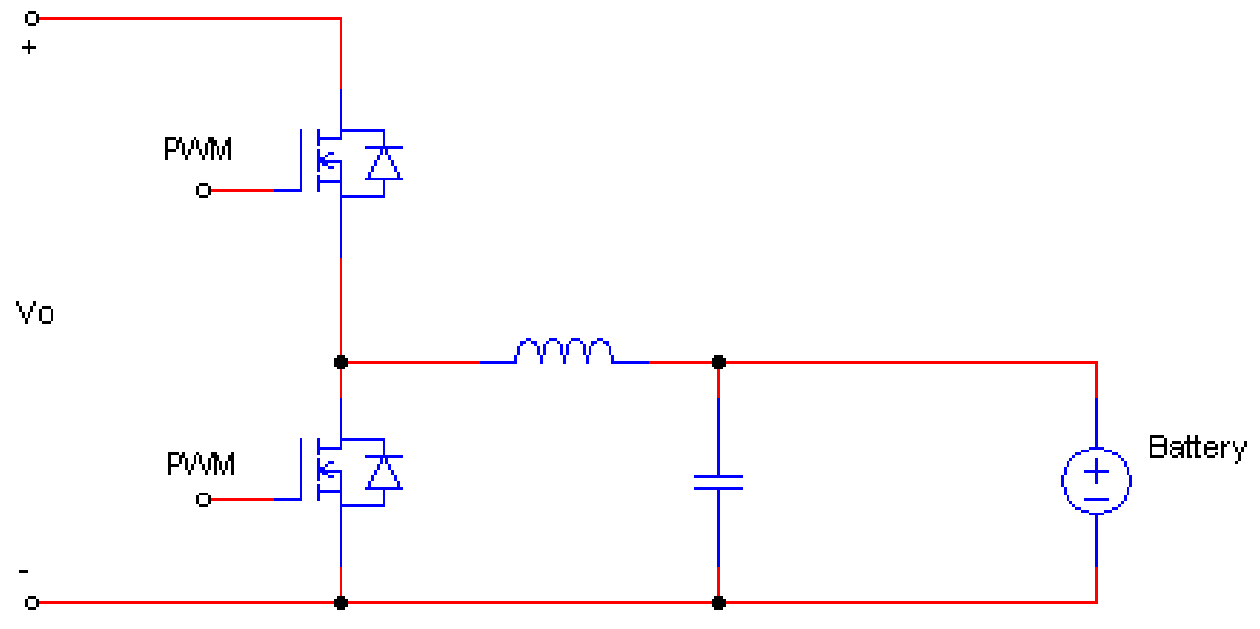
- Drops input voltage based on MOSFET Duty cycle
- Half of the Bi-directional Converter



Function Description/Requirements

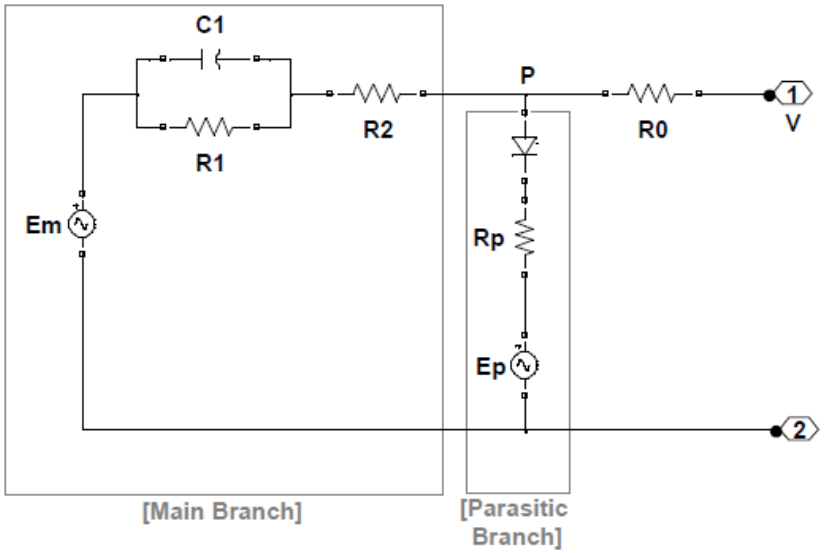
Bi-directional Converter

- To be used in place of the individual Buck and Boost converters
- Requires more detailed control system

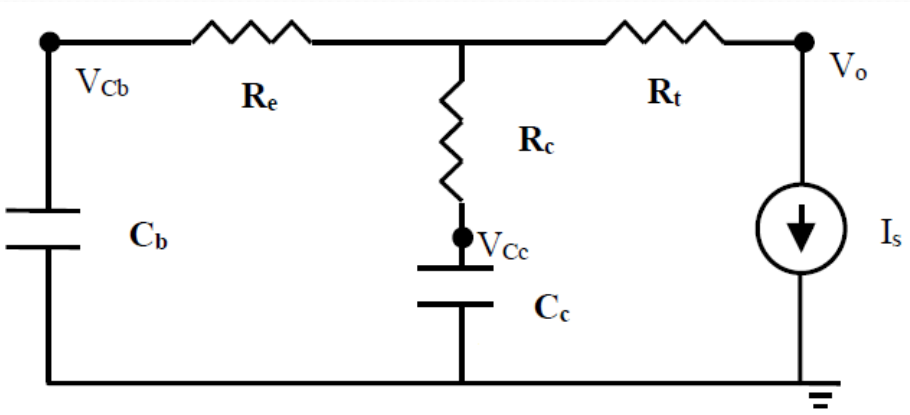


Function Description/Requirements

Battery



Lead Acid Battery Model

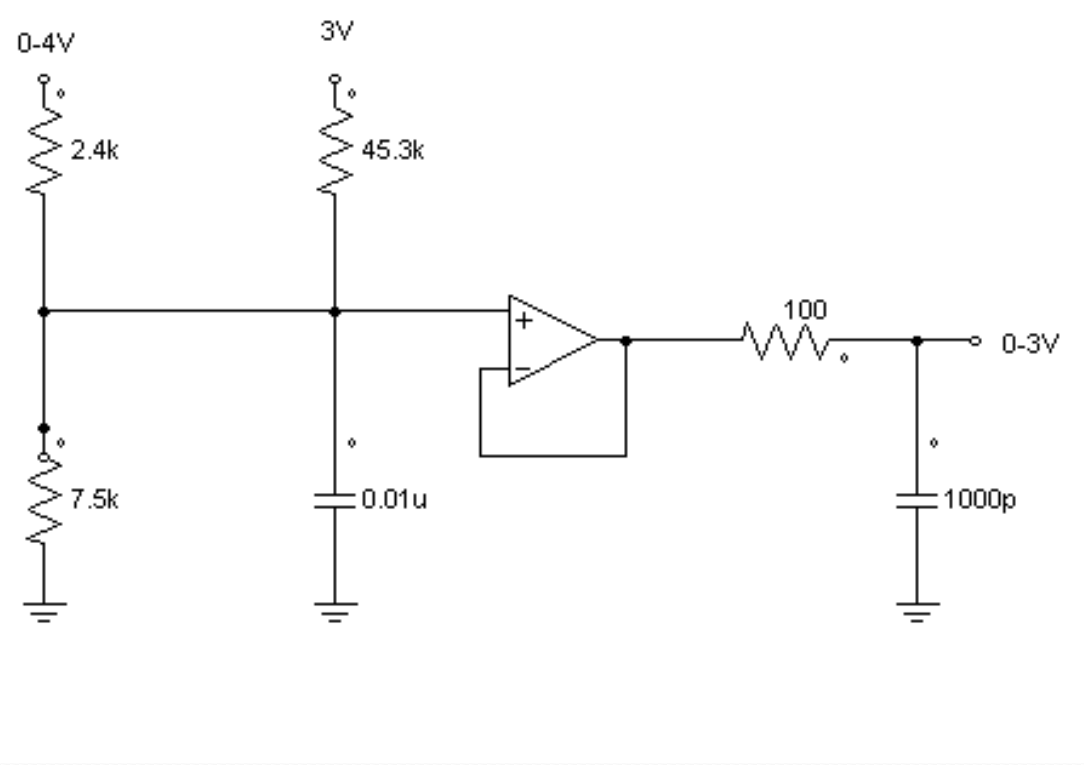


Lithium-Ion Battery Model

Interfacing & Protection Circuitry

- Current transducer will be used to measure the current
- Voltage dividers & op-amps to protect DSP board
- Gate Drivers are in place to protect the DSP from having to much current pulled from it

Interfacing & Protection Circuitry

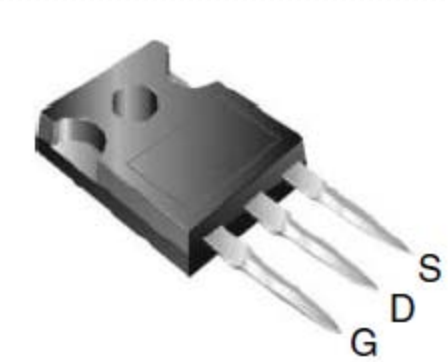


DSP

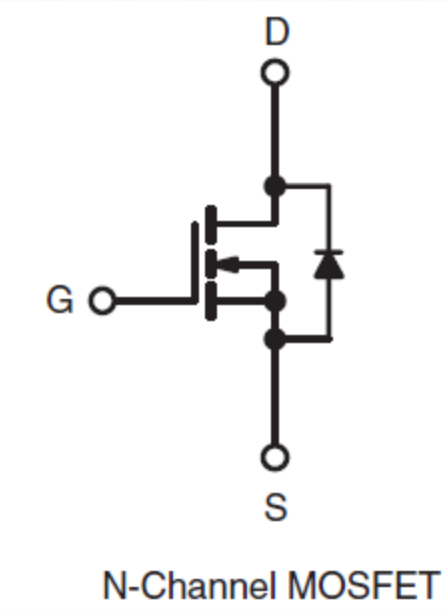
- Using TMS320F28I2 DSP board to control the PWM duty cycle
- Switching frequency between 10-15kHz
- Sensing frequency between 1-10kHz
- A/D inputs 0-3V
- PWM output 0-5V

MOSFET and Heat Sink

- IRFP460A N-Type Power MOSFET
- Drain-Source Voltage VDS = 500V
- Continuous Drain Current ID = 20A
- Handles Low Voltage High Freq
- 55ns minimum rise time
- Maximum Power Dissipation TC = 25 °C

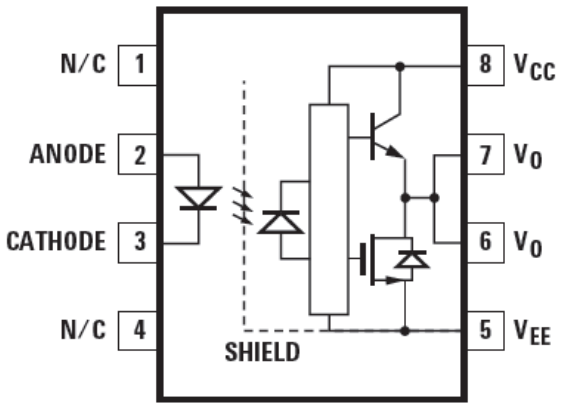


- SK 145 Heat Sink
- Thermal Resistance: 13.5K/W



MOSFET Gate Driver

- HCPL-3180-060E
- 2.5 A maximum peak output current
- Power Supply VCC-VEE $10V_{min}$ $20V_{max}$
- 250 kHz maximum switching speed
- PWM input

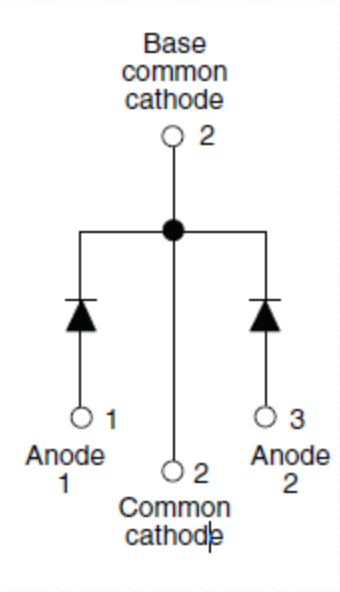


Diode Rectifier

- NTE5328 – Bridge Rectifier
- Maximum RMS Bridge Input Voltage = 700V
- Surge Overload Rating: 400A (Peak)
- Average Forward Current (TC = +75°C), IF (AV) = 25A

Diode

- VS-HFA50PA60CPBF
- VR = 600 V
- Maximum continuous forward current 25A per leg 50A per device



Current Transducer

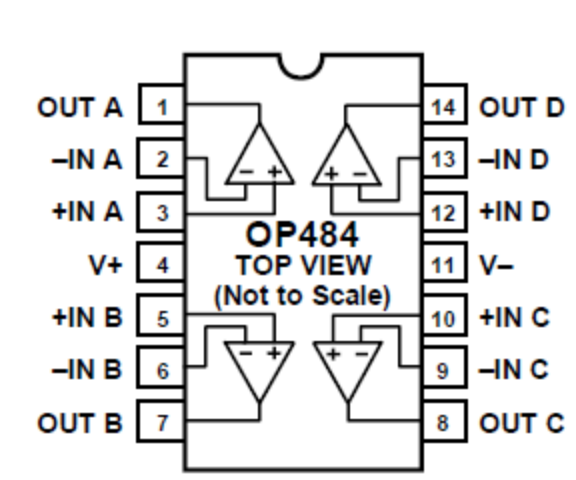
- Lo8P050D15 Current Transducer
- Power Supply VCC ±15V±5%
- Nominal Primary DC current

  If = 50AT (wrapping)
- Maximum Current If_{max} = ±150AT
- Output Voltage

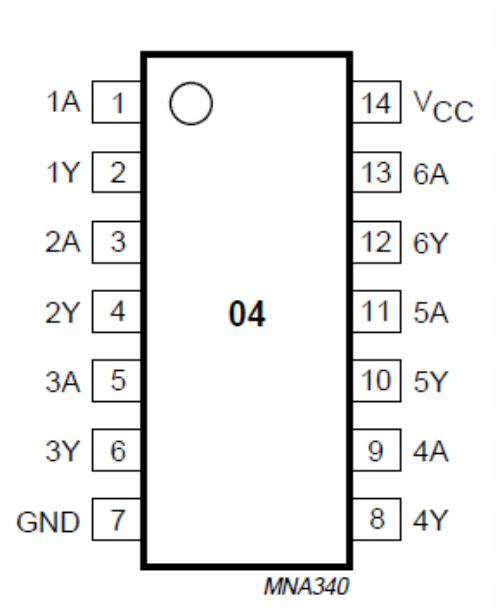
  VOUT = 4V±0.040V @ ±If
- Uses hall effect via cable winded through opening to sense current

Op-Amp

- OP484FPZ Op-Amp
- Supply Voltage Range
  VS = 3V - 36V
- Output Voltage High = $2.8V_{min}$
- Output Voltage Low = $125mV_{max}$
- Overvoltage protection



Hex Inverter



- NXP - 74HC04N
- Inverts input
- VCC supply voltage = 5.0V

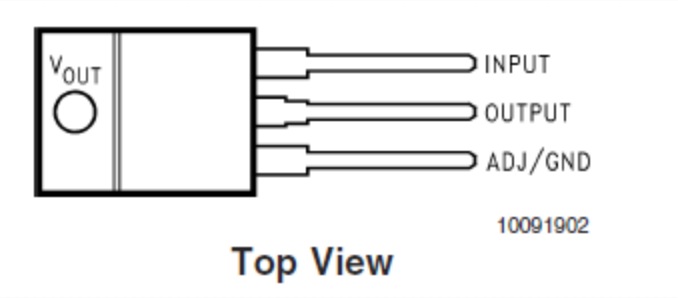
INPUT	OUTPUT
nA	**nY**
L	H
H	L

Power Supply

- TRACOPOWER - TMPM 10115
- 120VAC input
- 10W max output
- Vo = 15VDC
- Io = 667ma

Voltage Regulators

- LD1117V33C
- Vin = 15V
- Vo = 3.3V



- LM1117T-5.0/NOPB
- Vin = 15V
- Vo = 5V

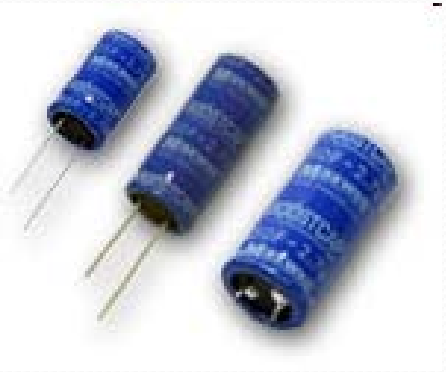
Capacitors and Inductors

- Aluminum Electrolytic Capacitor
- Capacitance = 1500UF
- Voltage = 400V

- Inductance =500UH,
- Current = 35A

Ultra Capacitors and Battery

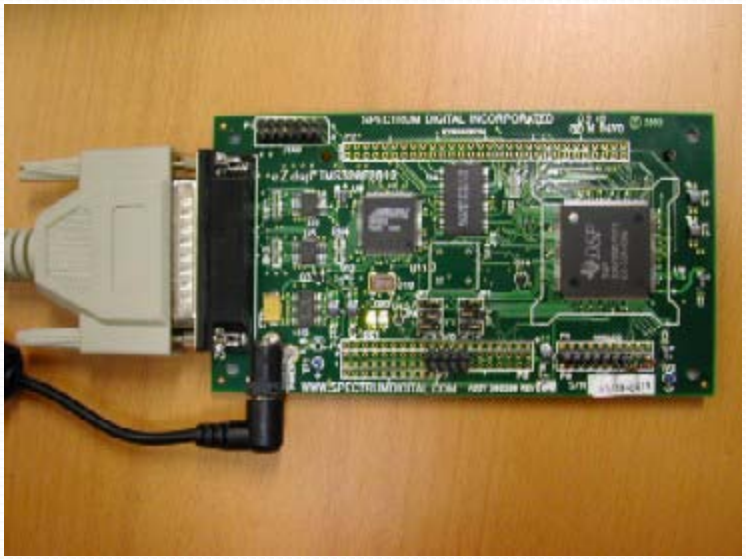
- Voltage and capacity 48V NIMH 13,000mAh
- Standard discharging rate (1C): 5-10Amp
- Standard Charging at 1.4 A current -10 Hrs



- Capacitance (C) = 150F
- Voltage (V) = 2.7V

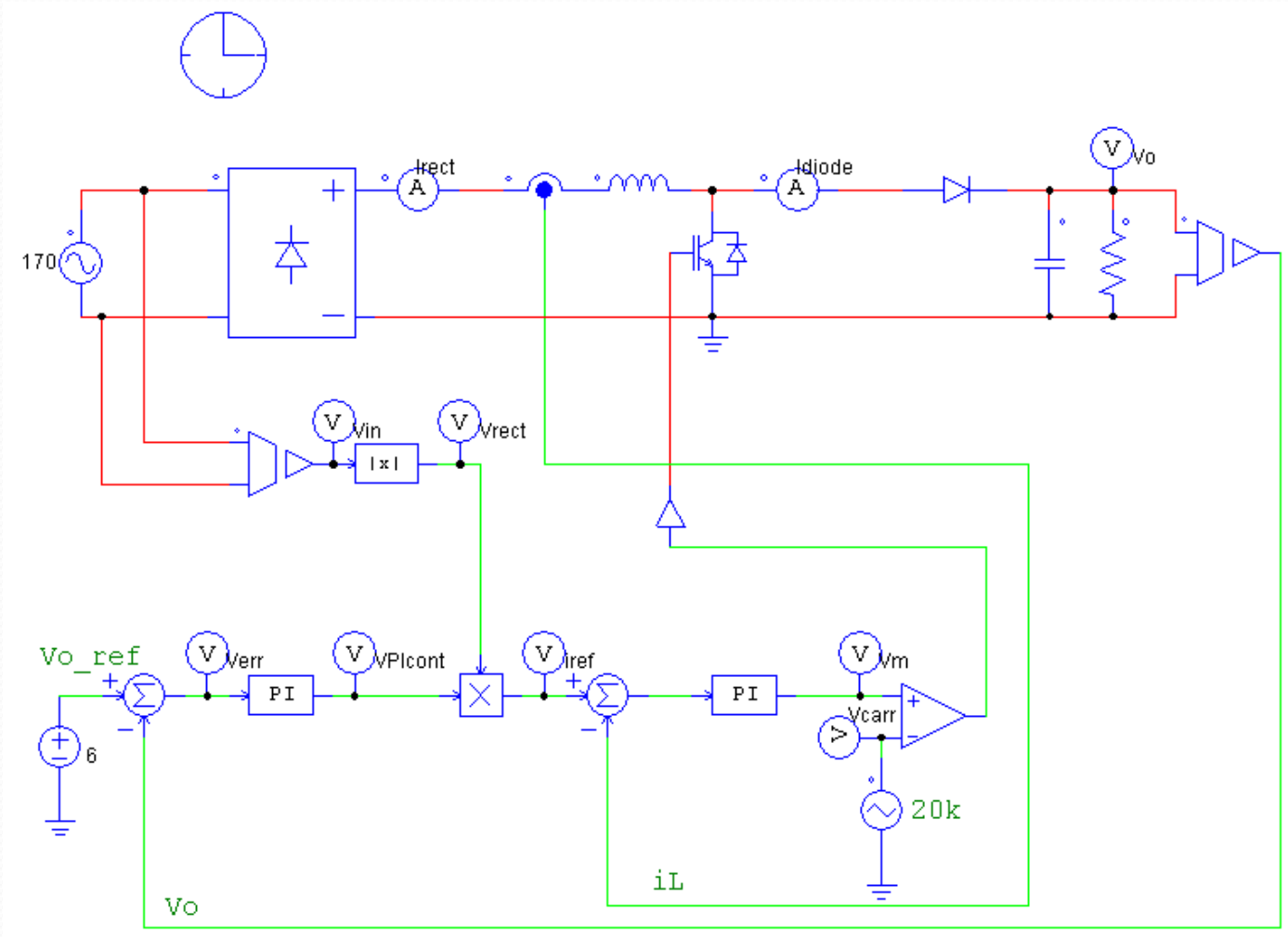
Digital Signal Processor

- TMS320F2812 DSP
- 32-Bit CPU
- 16 Channel ADC = 3V input
- 16 PWM Channels
- Programmable via Simulink and Code Composer



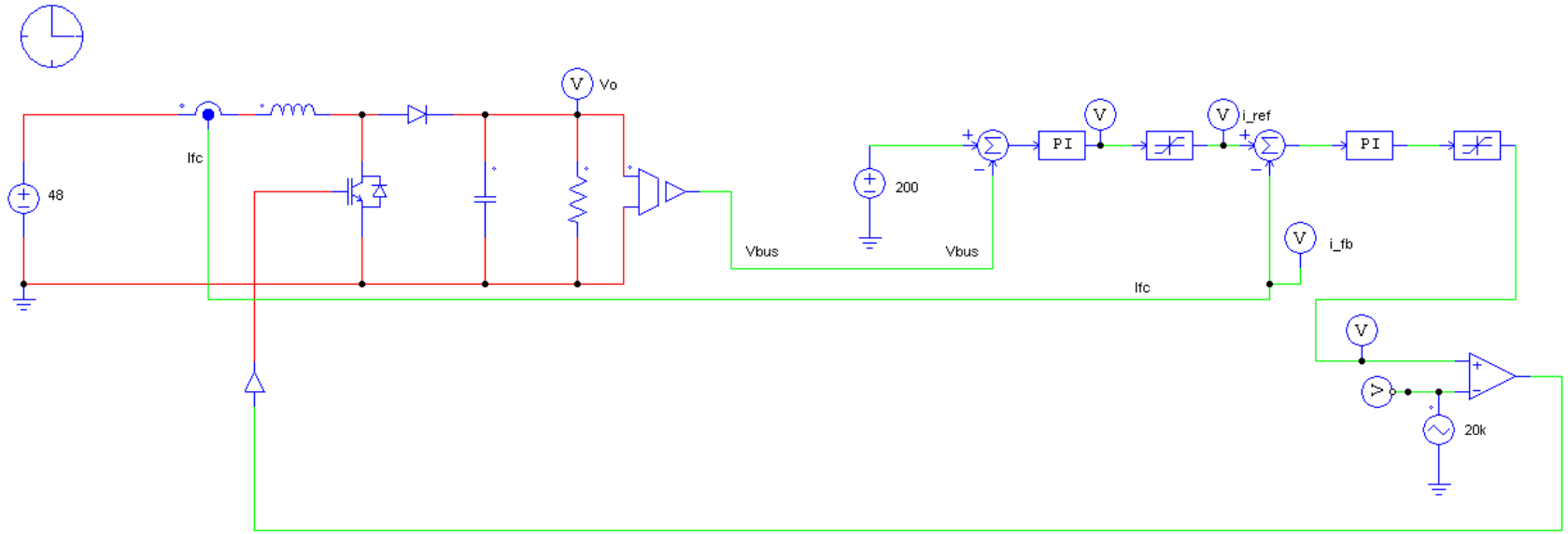
Schematics

Power Factor Correction



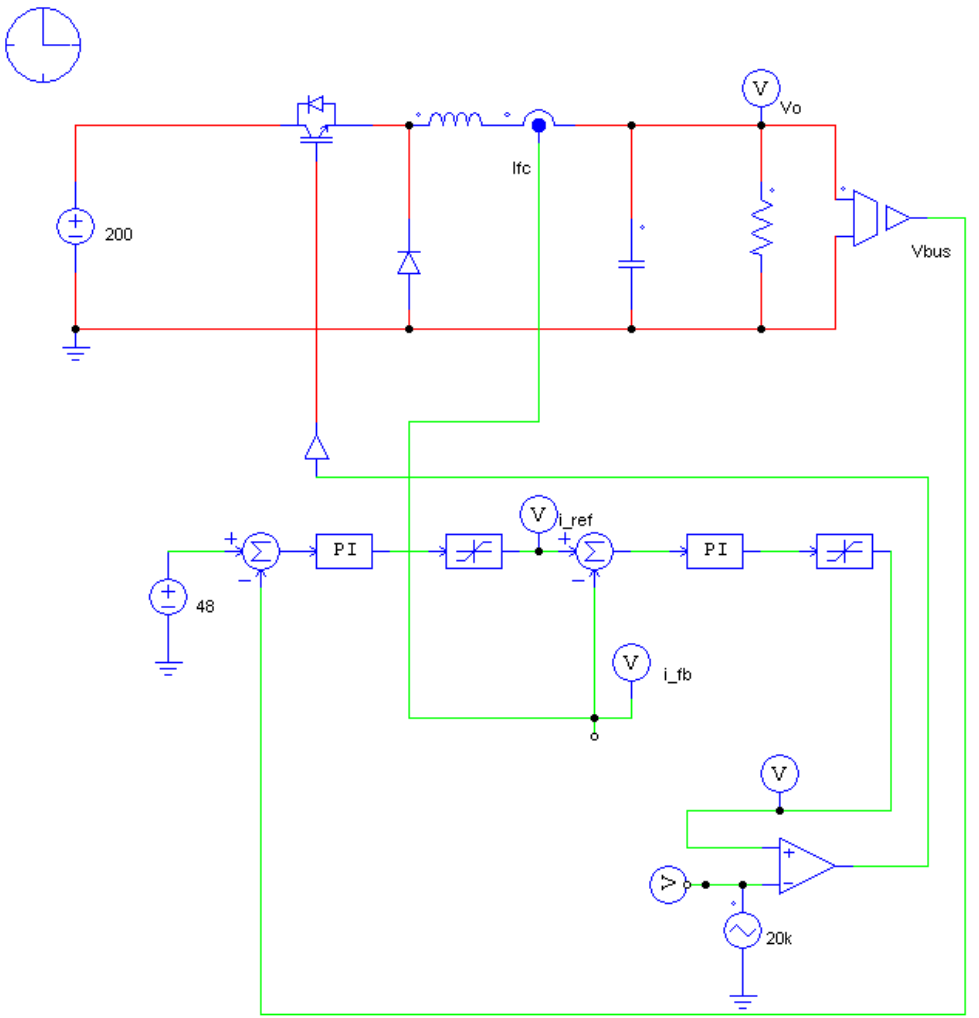
Schematics

Boost Converter



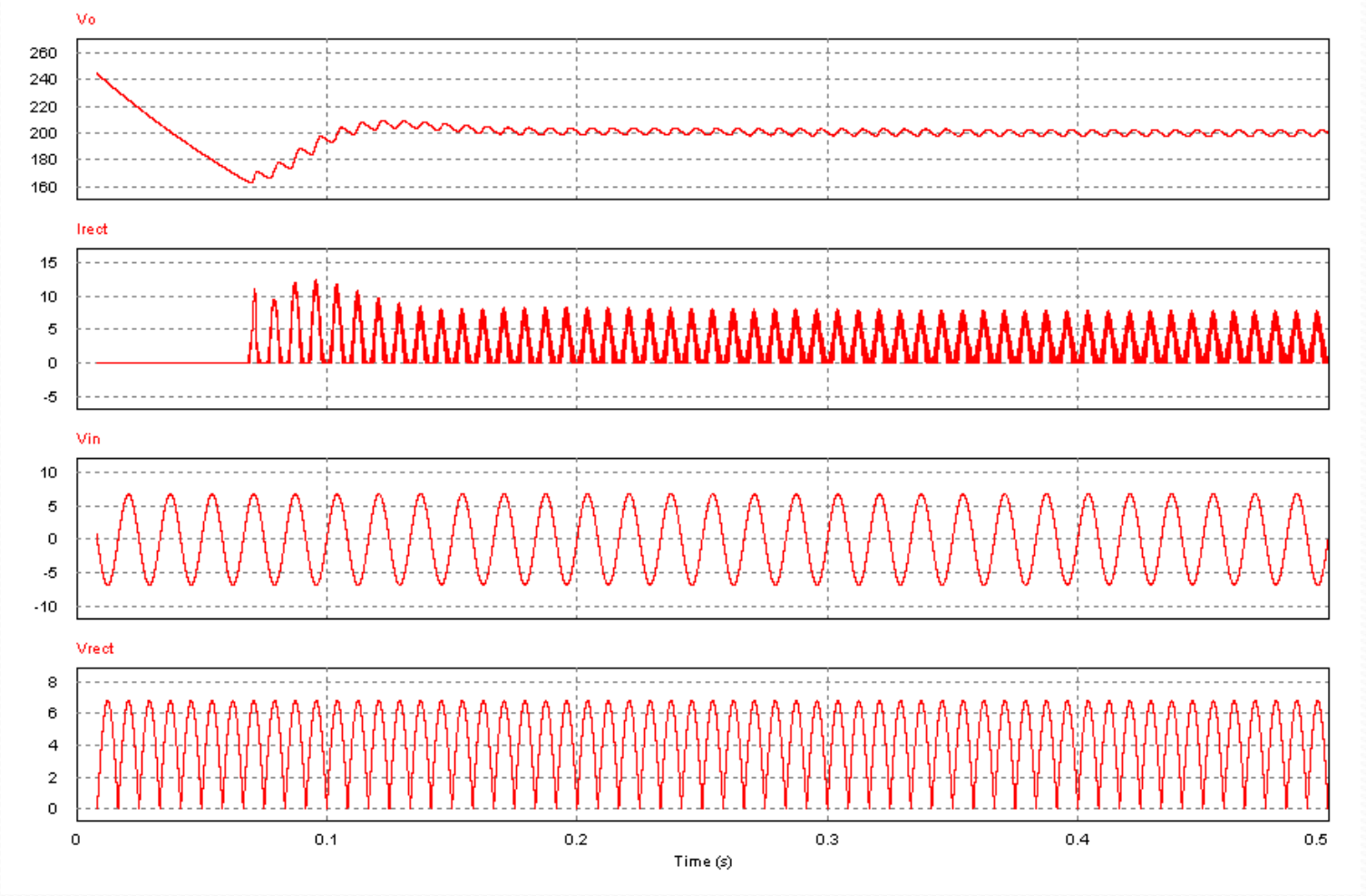
Schematics

Buck Converter



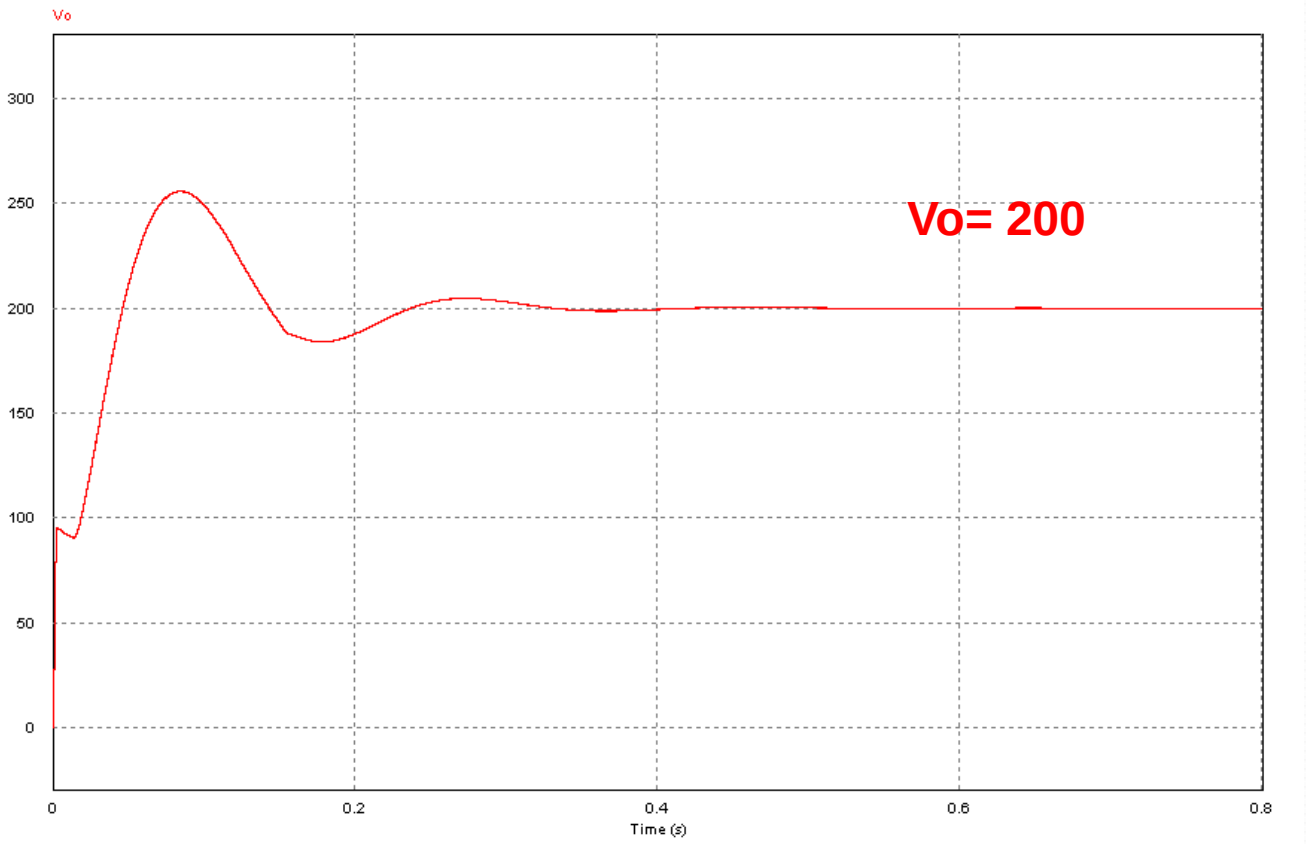
Simulation

- PFC Plots



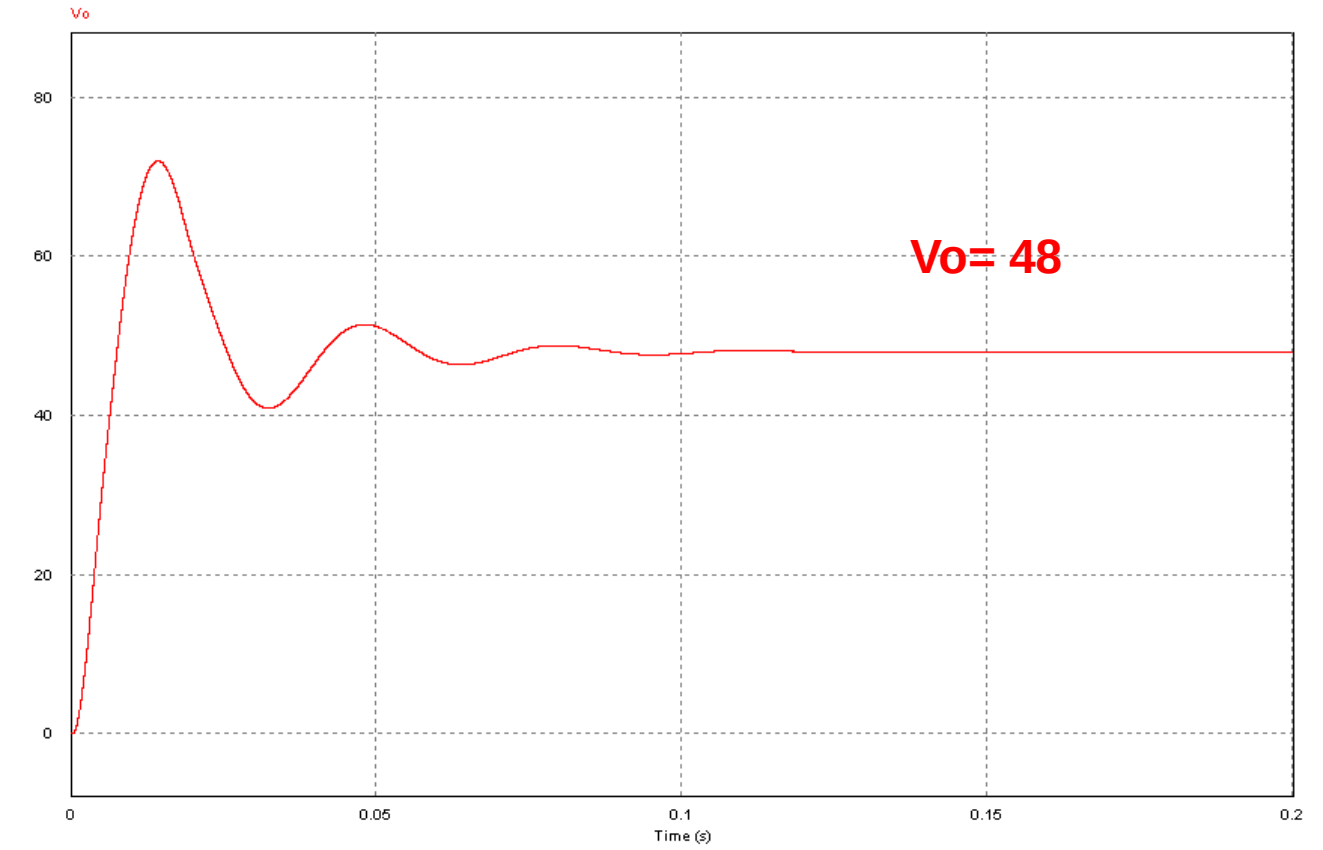
Simulation

- Boost Converter Results



Simulation

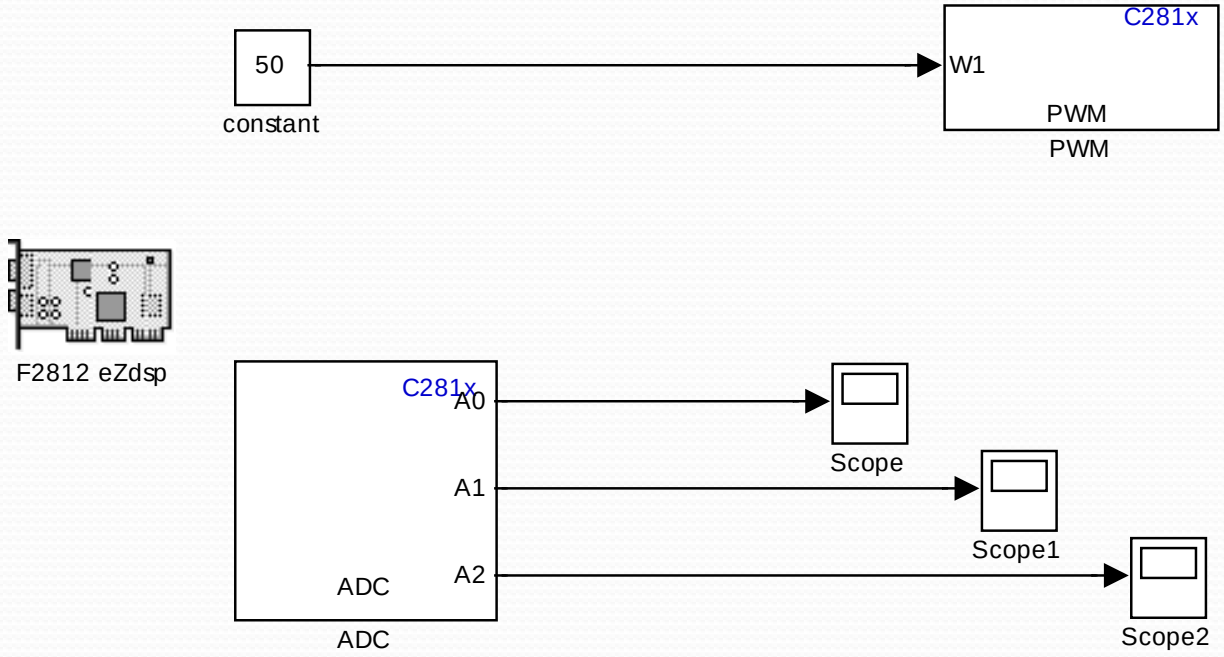
- Buck Converter Results



DSP Simulations

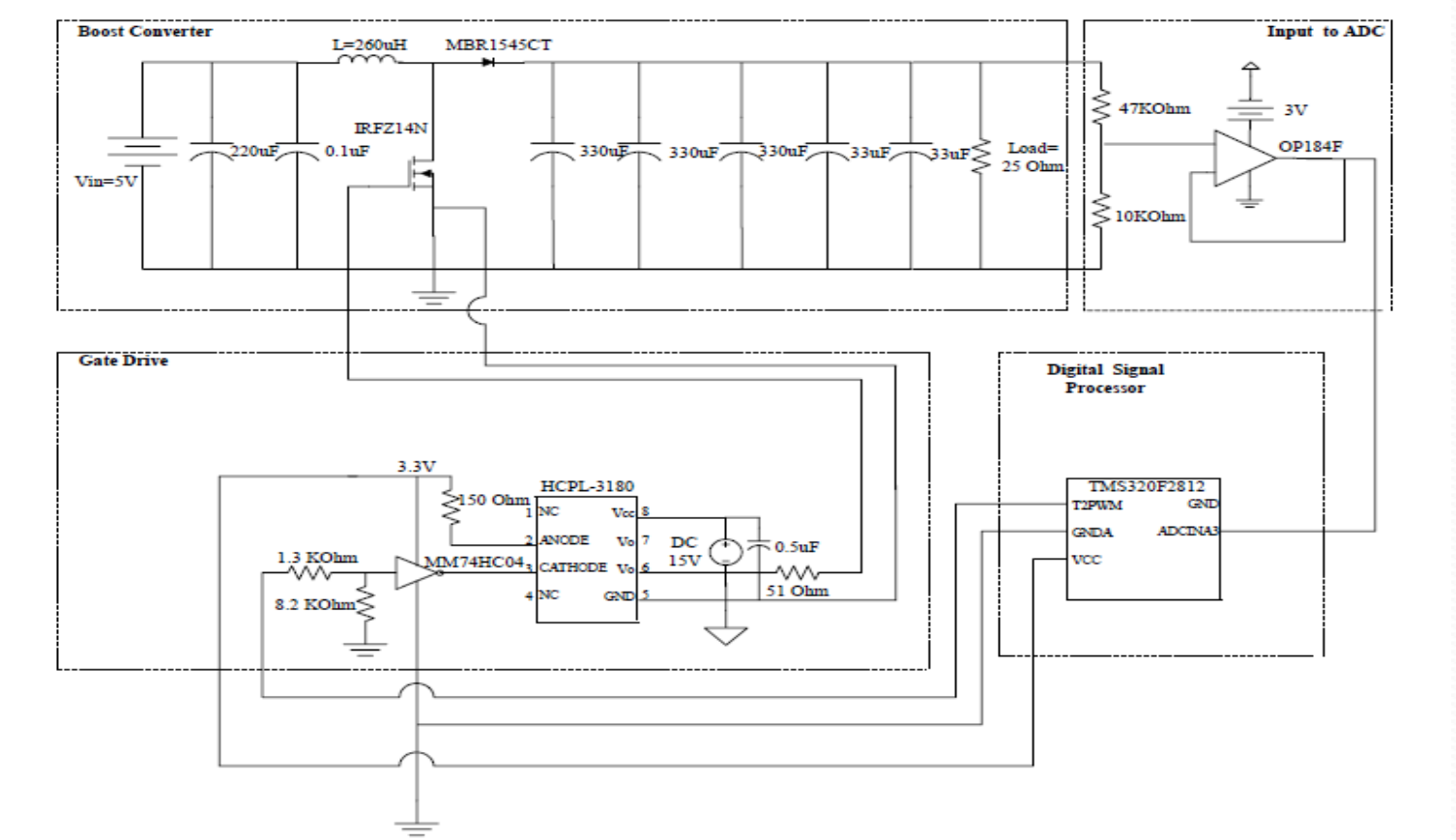
- PWM generator
  - Adjustable duty cycle and frequency
- A/D conversions
  - Value*3/$(FFFF)_h$ to calculate input value

DSP Simulations

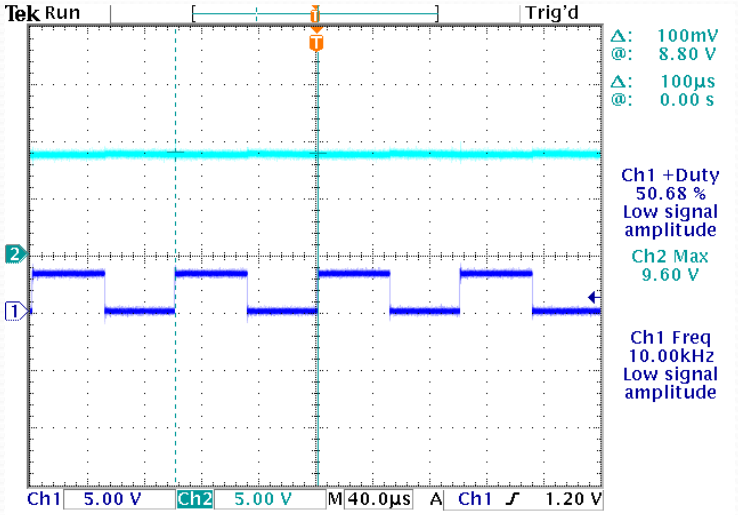


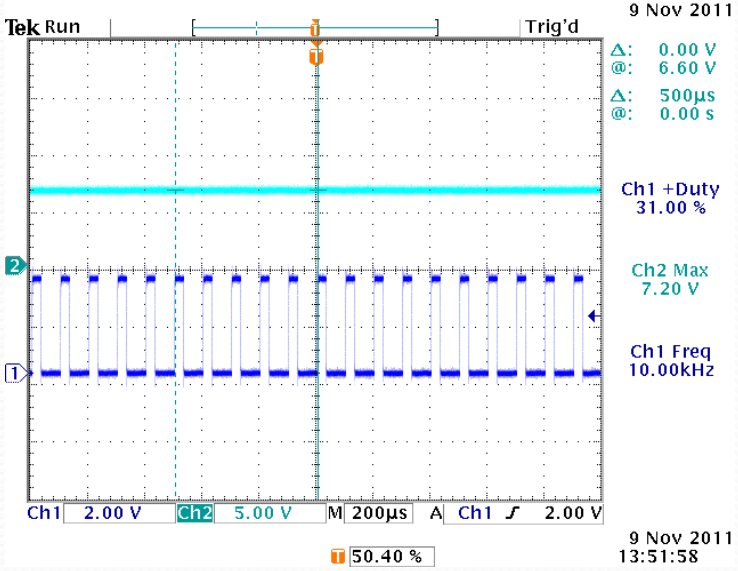
Small Scale Model

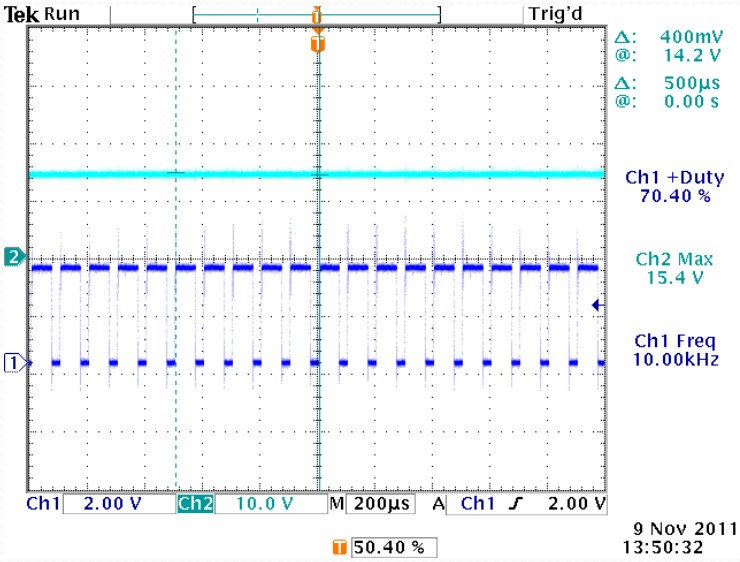
- Boost converter w/ protection circuitry



Small Scale Model



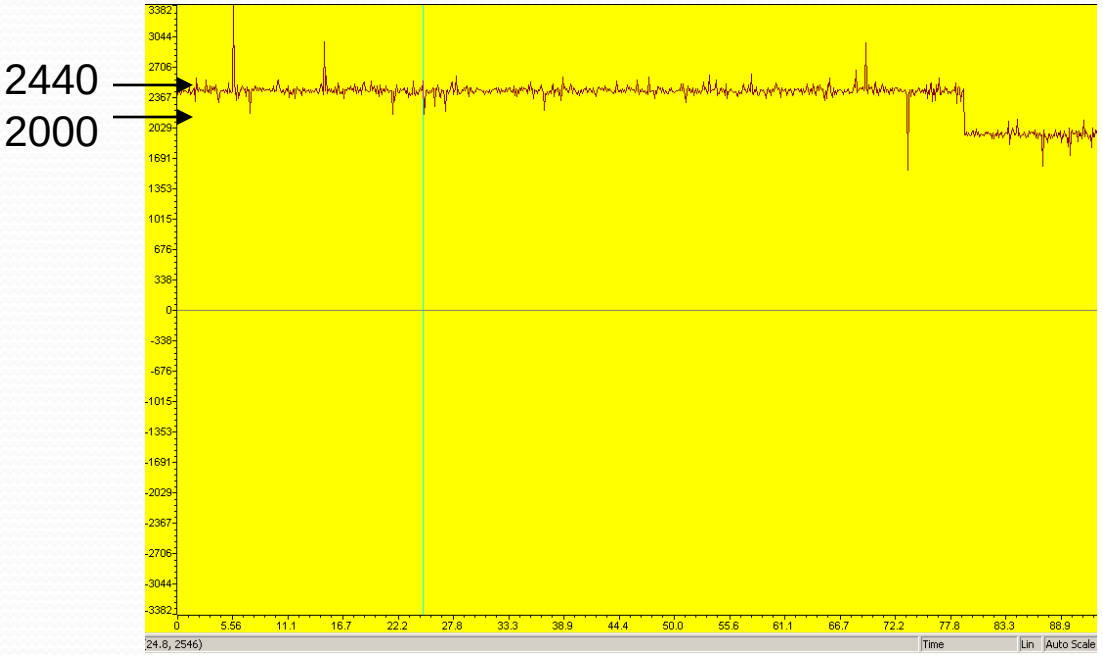




5V Input

Duty Cycle:	Output:
30%	7.2V
50%	9.6V
70%	15.4V

DSP Simulations



Duty Cycle of 50%

$2440*16*3/(FFFF)_h$= 1.76V

Voltage Divider Factor = 10.99V

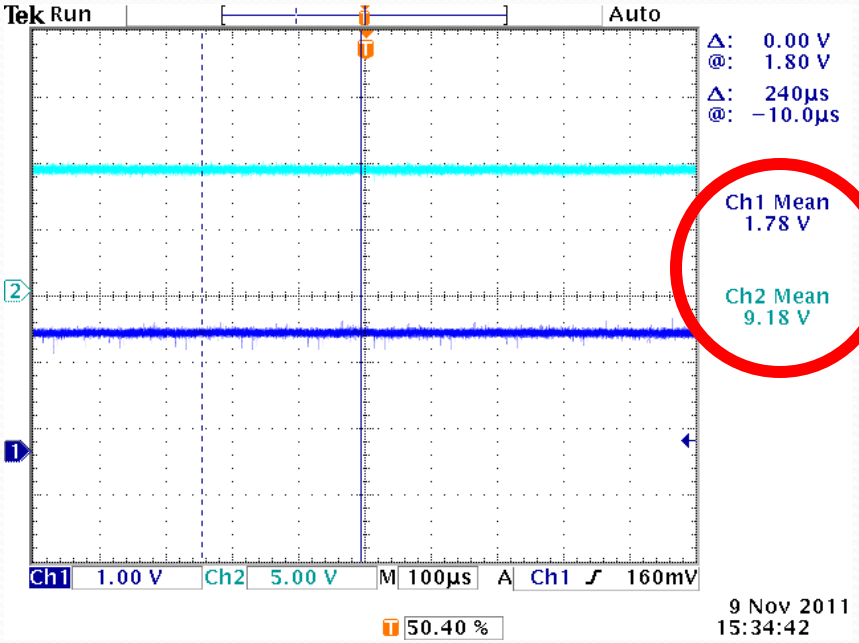
Duty Cycle of 30%

2000*16*3/(FFFF)h= 1.46V

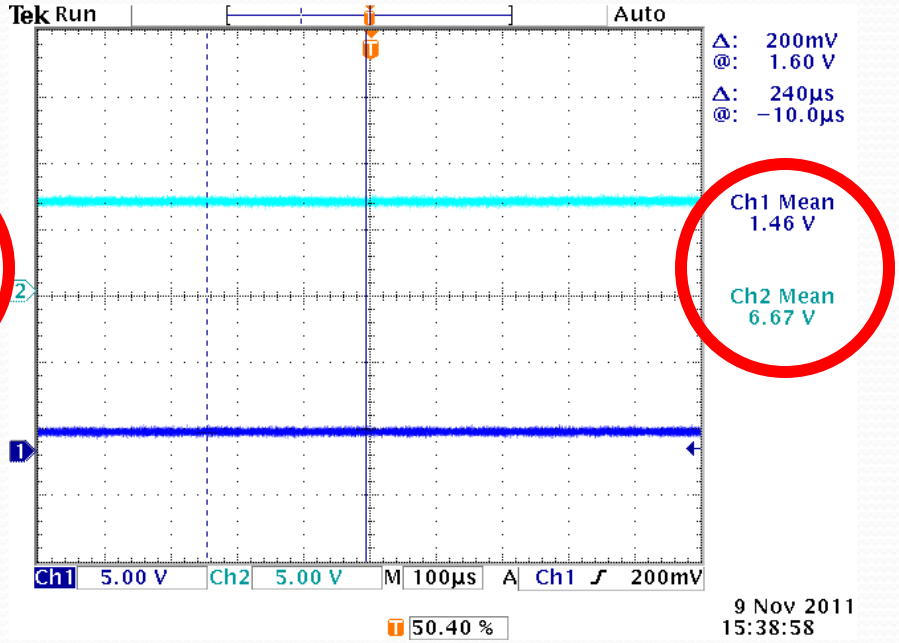
Voltage Divider Factor = 9.0V

DSP Simulations

50% Duty Cycle



30% Duty Cycle



What's Next

- Implement closed loop feedback control for small scale model
- Build model with ordered parts
- Continue refining simulations to optimize charging times and reduce overshoot from PI control system

Schedule of Tasks

	Schedule of Events/Tasks Spring 2012
Week	Event/Task
1	Test Power Factor Correction Ciructry, Continue developing DSP code
2	Refine Power Factor Correction Ciructry, Continue developing DSP code
3	Test Buck and Boost Converter Circuity, Continue developing DSP code
4	Test Buck and Boost Converter Circuity, Continue developing DSP code
5	Implement Bi-Directional converter with Ultra-Capacitors, Continue developing DSP code
6	Refine Bi-Directional converter with Ultra-Capacitors, Continue developing DSP code
7	Refine Bi-Directional converter with Ultra-Capacitors, Continue developing DSP code
8	Test Entire System and refine DSP Code
9	Swap Ultra Capacitors with 48V battery and test systemmaking changes as needed
10	Refine System/Debug DSP
11	Refine System/Debug DSP
12	Prepare for Presentation
13	Prepare for Presentation
14	Prepare for Presentation

Questions?