Off-Vehicle Charger & Energy Monitoring System

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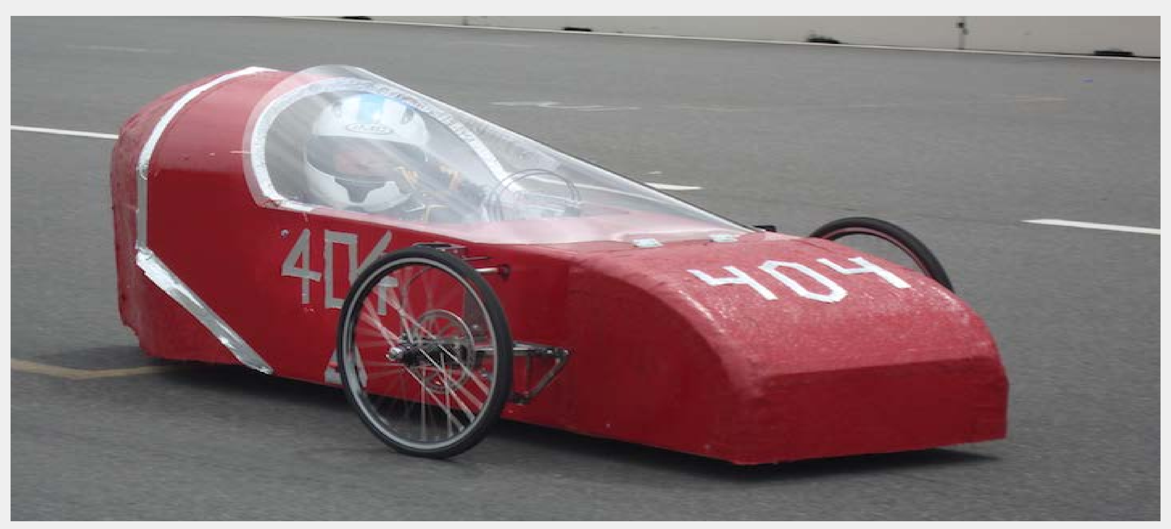
EV

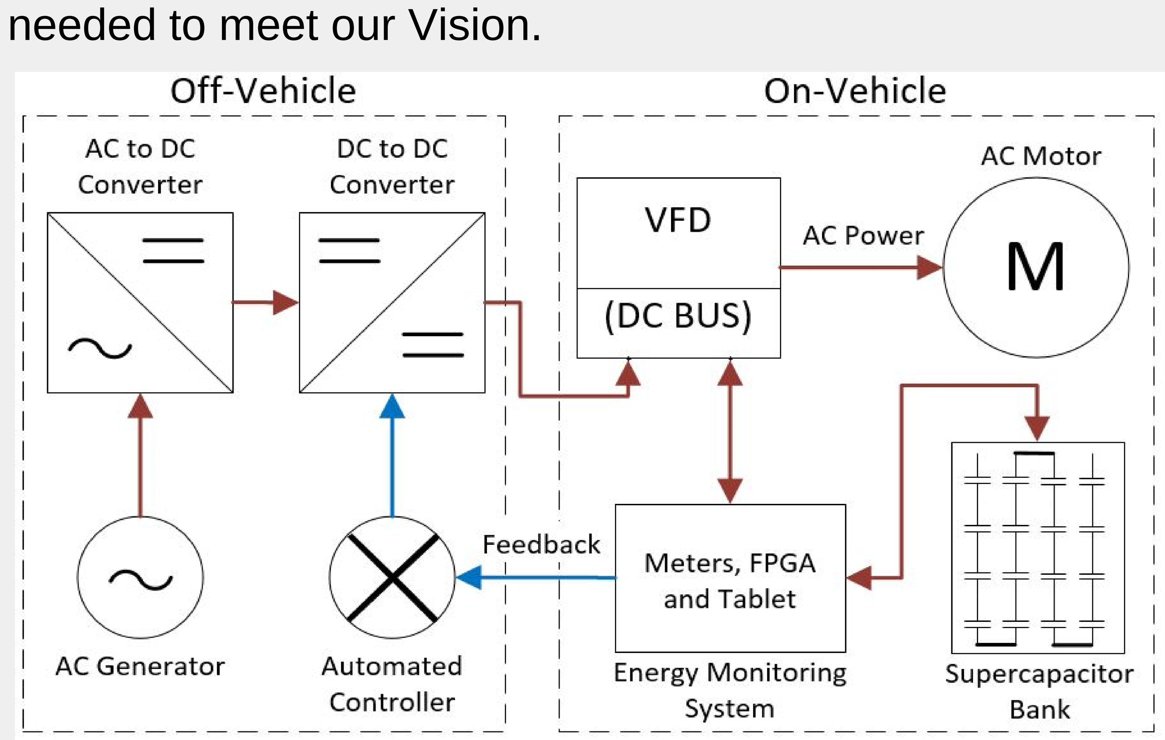
Abstract

The Washington State University Electric Vehicle Club is participating in the Electrathon America Competition in Summer 2017. The WSU EV club has opted to use supercapacitors instead of lead-acid batteries to prove it's alternate source capabilities for electric vehicles. Team Edison was tasked with designing and implementing an off-vehicle charging system as well as a portable energy monitoring system. The charger is composed of a rectifier circuit in series with buck-boost converter for charging the capacitor bank, while the monitoring system provides real-time data and GPS measurement updates for the driver.



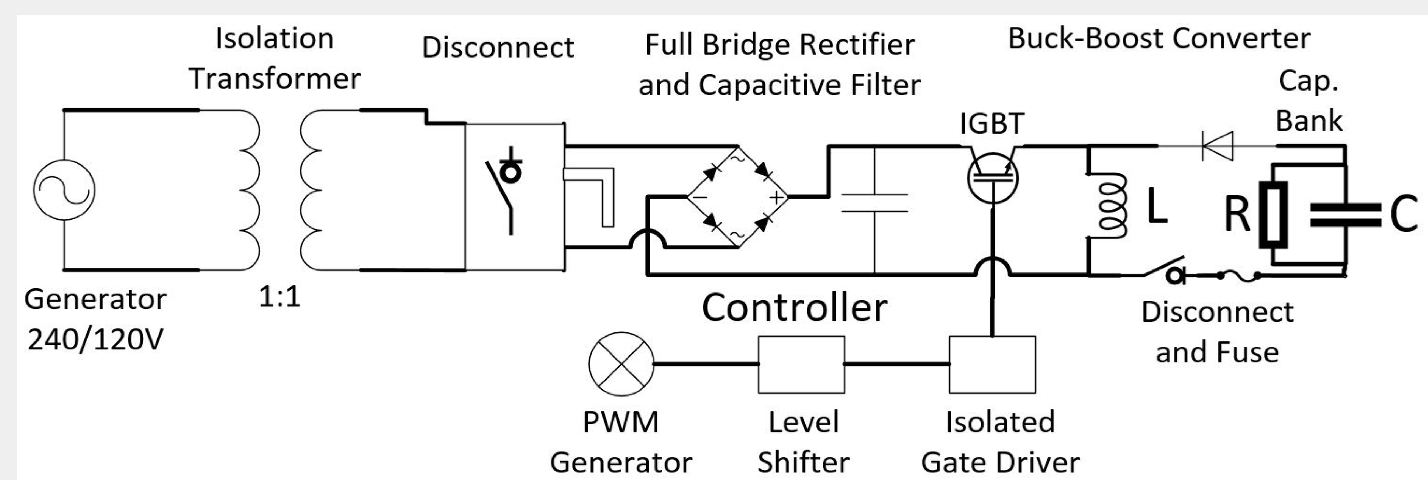
Vision

The strategy imposed to fulfill our clients needs was to develop two distinct systems that in junction would work together to accomplish an automated charge of the supercapacitor bank. Each system design is described in detail to the right. The Energy Monitoring System is designed to read voltage as well as current flowing into/out of the bank. These measurements will ultimately be used as part of the feedback loop for the automated controller of the Off-Vehicle Charger. The automated controller would be designed to hold the charger current constant as it charges and eventually disconnect the bank when the voltage reaches the desired 370V. To achieve this, the controller will use the feedback provided by the Energy Monitoring System to accurately update the duty cycle applied to the Off Vehicle Charger's IGBT. The Future Work section encompasses the next steps which would be needed to meet our Vision.



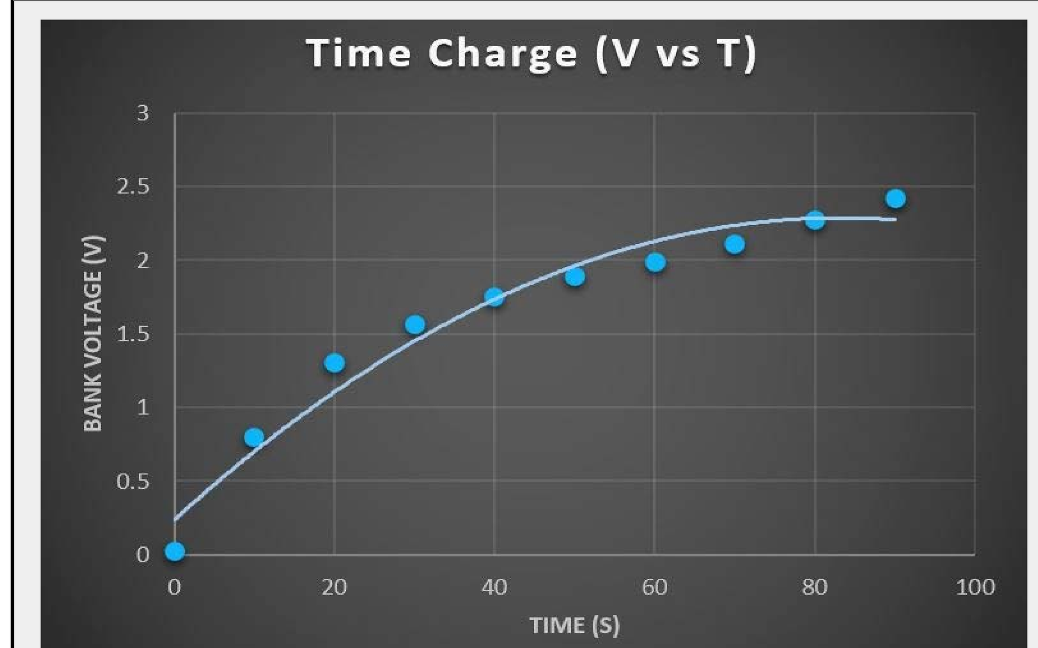
Off-Vehicle Supercapacitor Charger

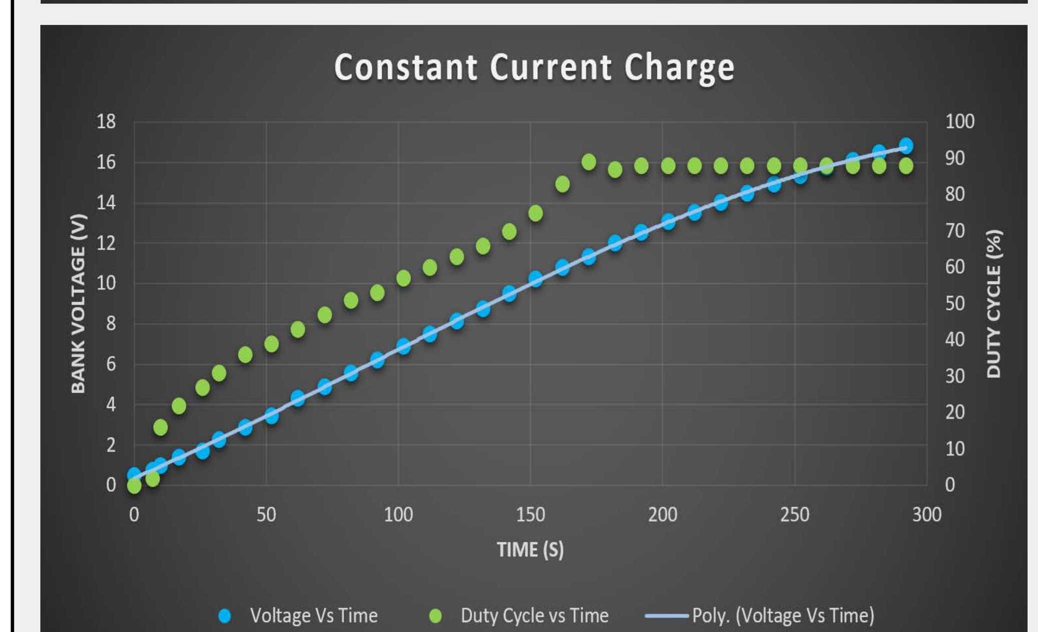
Charger Design



AC to DC Circuit	• Power Source: 120/240V AC Generator • Isolation: 240/240V Isolation Transformer • Disconnect Switch: Isolate Power source from DC Circuit • Rectifier: Full Bridge Rectifier with Smoothing Capacitor
DC to DC Converter	• Buck-Boost Converter ○ Insulated Gate Bipolar Transistor (IGBT) ○ 600V Blocking Diode ○ 0.08mH Air Core Inductor • Supercapacitor Bank ○ 154 Series Capacitors ○ 4.48 Farad Total Capacitance
Controller	• PCB designed in Eagle • Infineon 600V Half Bridge Gate Drive IC Isolates Cerebot microcontroller from IGBT • Duty Cycle controlled via potentiometer with a mounted dial. • Controlled is floated to allow proper gating of IGBT

Prototype Results





- Time Charge Graph (voltage of bank, time)
  - Constant duty cycle (10%) and DC voltage (10V)
  - Charge trendline representative of I = CdV/dt, with charge slowing as dV (VDC - Vcaps) decreases
  - Proves bucking (decreasing) functionality, Vout < Vin
  - Notable overcharge, compared to expected voltage
- Constant Current Charge Graph (voltage, duty cycle, time)
  - Constant DC voltage (10V) and current held constant
  - Proves boosting (increasing) functionality, Vout > Vin
  - Characteristic curve matches theoretical output
  - Proves current can be constant by changing the duty cycle at a steady rate. Matches I = C*(dV/dt) exactly.
  - Test models how the automated controller would charge the bank. Feedback controlled duty cycle.

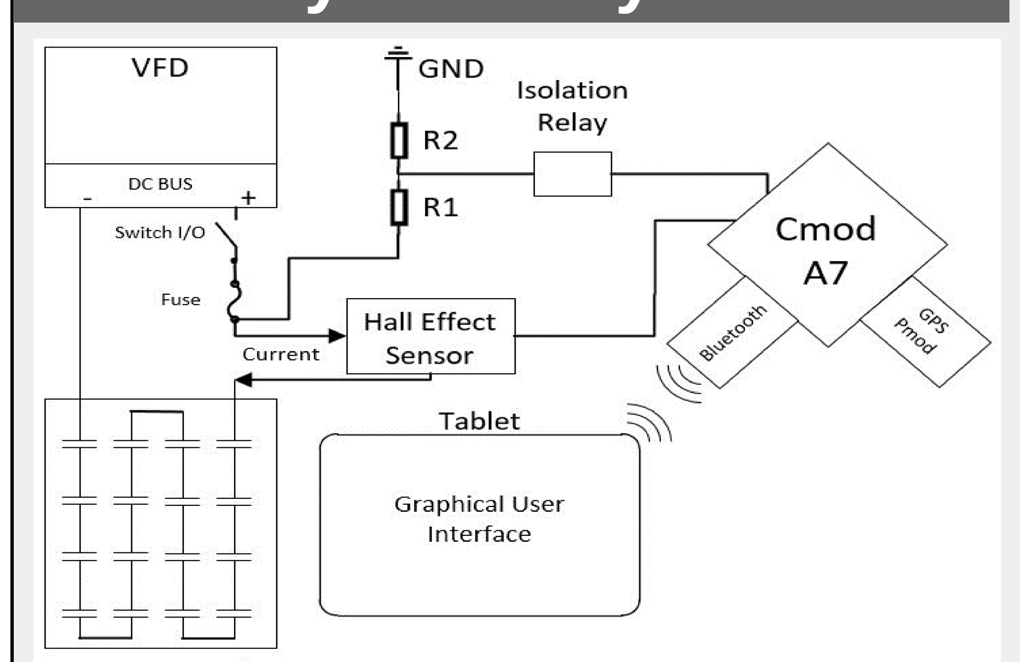
Future Work

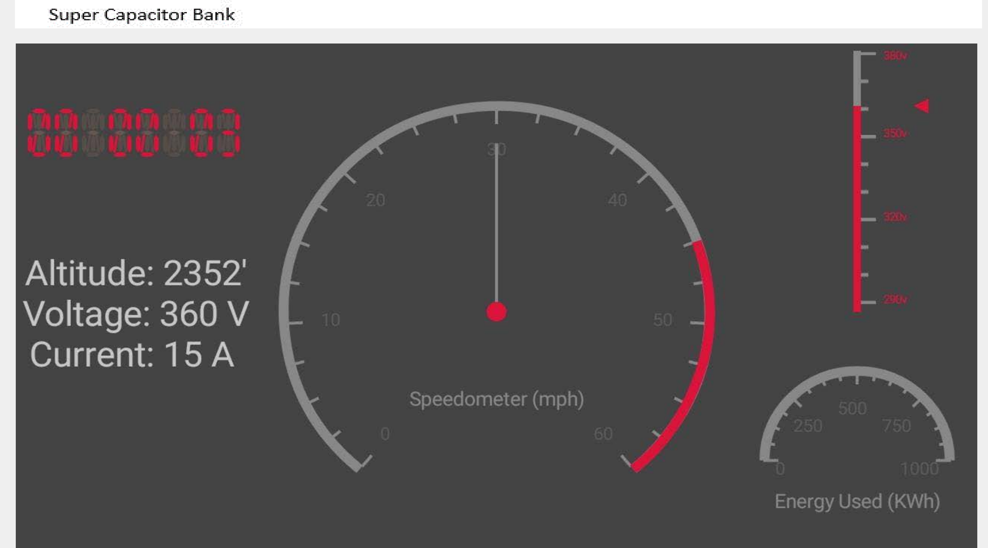
Charging System:

- Upgrade component ratings to handle power spikes
- Automated Controller
  - Sweeping duty cycle
  - Incorporate monitoring system feedback loop
- Transportable charger housing

Energy Monitoring System

System Layout





Measurement Devices	• Hall Effect Sensor for current measurement • Voltage divider with isolation circuit for voltage step down • Cmod A7 FPGA board for data acquisition and processing • Created a custom breakout board for the Cmod A7 to expand IO • Acquire vehicle's altitude and speed using Digilent's Pmod GPS • Bluetooth communication using Digilent's Pmod BT2 • Analog voltages from divider read using Digilent's Pmod AD2
Graphical User Interface	• Monitor/GUI hosted on Android tablet • Driver Profile Configuration • Real-time vehicle's speed display • Display current reading between VFD and Capacitor Bank • Capacitor bank voltage monitoring • Display vehicle's real time Potential Energy
Software Implementation	• Voltage divider PCB designed in Eagle • Develop FPGA using Vivado and Vivado SDK • Digilent's Cmod A7 running Microblaze, a soft core processor • Incorporates Bluetooth communication between devices • Entire program stored in flash memory

Future Work

Monitoring System:

- Improve speed and altitude measurement accuracy
  - Attach high-gain antenna to Pmod GPS to obtain greater accuracy
- Save user information and runtime data on tablet for later usage analysis
- Encapsulate project in a protective enclosure
- Calculate mechanical, potential and electrical energy of the system

Global Impacts

- Minimal greenhouse impact caused by generator, used only during charging
- Supercapacitors are small, have a high power density and are recyclable. Ideal for use on electrical vehicles.
- With more research, supercapacitors could be suitable for use in electric vehicles, alongside batteries. One has high energy density, other has high power density.

Glossary

- ADC/AD: Analog-to-Digital Converter
- Buck-Boost Converter: DC-Variable DC Converter
- C#: Programming language
- FPGA: Field-Programmable Gate Array
- Full-Bridge Rectifier: AC-DC Converter
- PCB: Printed Circuit Board
- VFD: Variable-Frequency-Drive

Acknowledgements

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Team Edison