Automated Off-Vehicle Rapid Charging System
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Abstract
In this project, team Bach was assigned with designing and implementing a rapid charging system for a vehicle model. We use a buck-boost converter to charge the voltage across a bank of super-capacitors. When the capacitors are full of energy, they will supply power to the cart and make it run. The system will charge from a minimum zero-voltage to a maximum voltage as quickly as possible from the source. As the capacitors voltage decreases, a microcontroller will determine whether they are needed to be charged or not. If the voltage of the capacitors drops near a critical value, the buck-boost circuit will be connected to them and start charging. The final product will travel autonomously around a track, stop for recharging, and continue the race.

Off-Vehicle Capacitor Charger

Charger Design
DC-DC Converter
- Buck-Boost converter
  - MOSFET
  - 20V Schottky Diode
  - 1mH Air Core Inductor
  - 2F Capacitor
  - Balancing resistors
- Capacitor Bank
  - 16 capacitors (5V, 2F each)
  - 4 capacitors in series stacked in parallel.

Signal Controller
- Fixed duty cycle from uC32 Microcontroller to trigger the MOSFET
- If the analog input reads below 15V, the system will stop charging (zero duty cycle).
- If the analog input reads below 8.5V, the system will boost the capacitors' voltage (70% duty cycle)

Feedback Controller
- To monitor the capacitors' voltage, the ADC was used to convert the voltage from the capacitor to analog pin in uC32.
- With the analog input, the microcontroller can decide if the PWM signal should be triggered.
- The microcontroller also can detect the car's last lap to command it to stop and wait for charging at the charging station.

PCB Design
Off-Vehicle PCB Design
The PCB contains the charging system and the feedback control. The uC32 microcontroller will make a decision to provide a PWM signal based on capacitor voltage read by the analog input.
- Buck-Boost converter
- Voltage Isolator: keep the capacitor voltage isolated from the analog voltage in the uC32 to prevent having short circuit inside uC32
- Grounding Isolation: An optical isolator (Op-Isol) used to separate uC32 ground from the buck-boost converter ground to prevent the common ground problem

On-Vehicle PCB Design
This PCB is a components holder added on the uC32. The analog input of uC32 will read the capacitor voltage to determine whether the cart can make a lap.
- Capacitor Bank: Store energy
- Balancing Resistors: Balance voltage across capacitor bank
- Voltage Isolator
- LEDs: Indicate the capacitors' voltage status
- Servos: Control the DC motors
- IR Proximity Sensors: Detect the brightness for line-following

Prototype Results
- Voltage versus time Graph
  - The voltage stays within limits of 15V and 20A current.

Future Work
- For the full-scale model, the component selection will be part of the work.
  - Choose the components with good ratings so that they can handle the required current (20A) and voltage (370V).
- The components for the full-scale model should be synchronized with each other to create a complete system.
- Isolation will be another part of the full-scale model.
  - The grounding of each individual part of the circuit should be isolated to prevent short circuits.
- The signal from a microcontroller should also be isolated to make sure that the capacitors' voltage will not affect the analog input.

Glossary
- ADC: Analog to digital converter
- Buck-Boost converter: DC to DC converter
- PCB: Print Circuit Board
- Arduino: Programming language
- PWM: Pulse-Width Modulation

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Team Bach