2016

Supercapacitor Battery

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Abstract:

This project investigates the viability of supercapacitors as an energy storage device used to power a small robot. In order to demonstrate the charging and performance characteristics, the robot uses a supercapacitor array as its sole power source.

Background:

With the recent surge in renewable energy sources and electric vehicles, it becomes necessary to redirect focus on new means of storing power. Supercapacitors have a lower total energy density than rechargeable batteries but are able to provide short bursts of current at very high levels with low steady-steady values which have useful applications in cars, trains and elevators.

Supercapacitors have recently been made available to the consumer market. Their energy per unit volume is between 10 to 100 times that of ordinary capacitors which finally affords the opportunity for a device such as a robot to be powered only by a bank of capacitors.

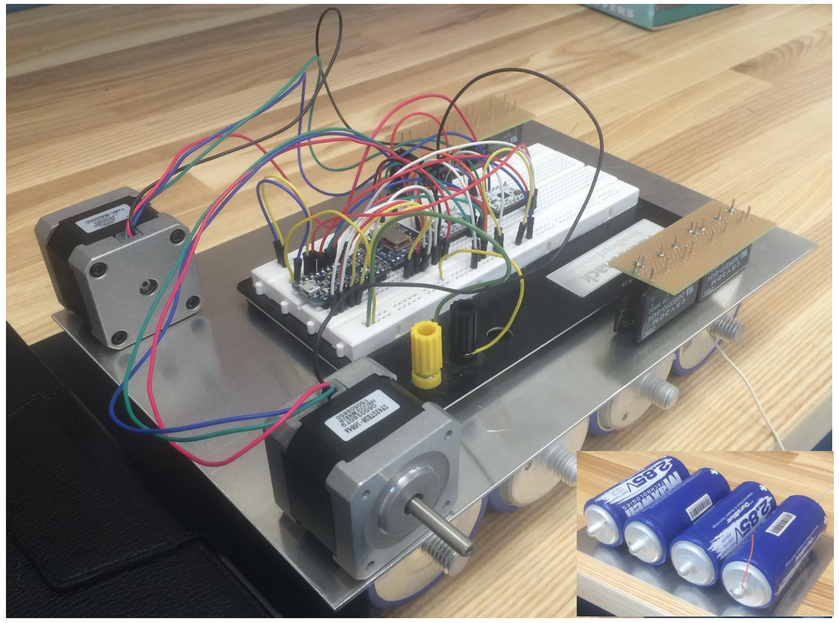
Design:

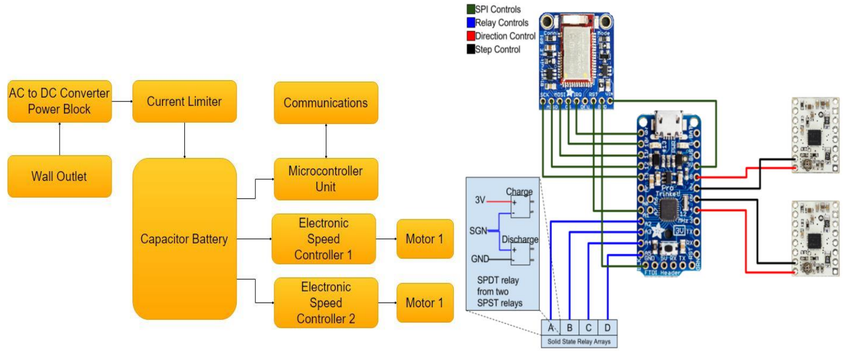
Our system is separated into two separate designs: one used for charging and the other for discharging. The charging design configures the relays in series allowing us to reduce the overall capacitance the charger sees. This allows us to reduce charging time for our circuit.

For safety, we designed a current limiter to both control the current to safe levels and to supply power to the rest of the circuit.

The discharge design sets our supercapacitors into a parallel-series combination. Decreasing the voltage while increasing the current allows the circuit to slow the discharge and extend the dissipation to fit the needs of any real device.

A microcontroller connected via bluetooth from a tablet is used to control our relays that switch between the two modes of operation and steer the robot.





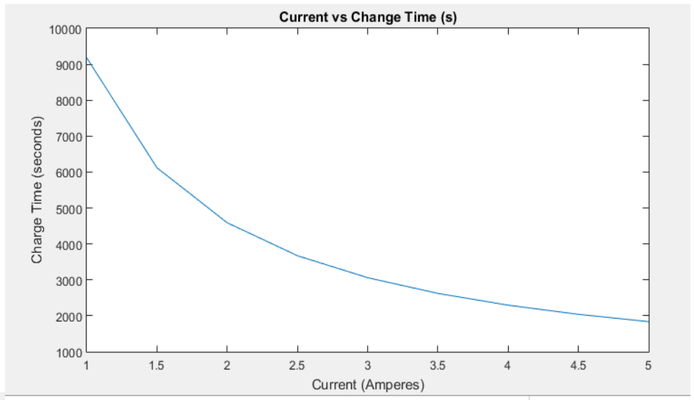
Power Block Diagram

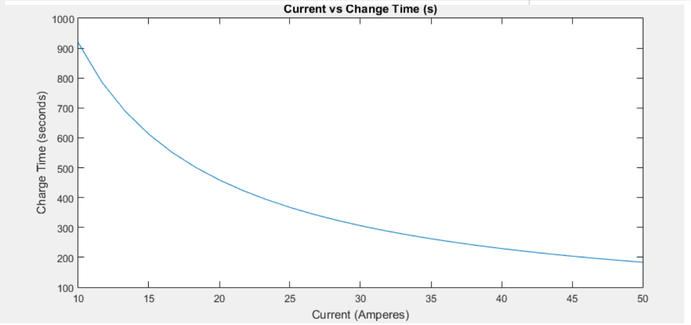
Control Block Diagram

Control System:

- The Arduino uses the SPI protocol to communicate with a slaved Adafruit Bluetooth chip.
- A custom protocol is used to communicate with the motor driver modules.
- The Arduino sends 3 bits to the motor stepper driver to control direction, speed and sleep abilities of the motor.
- The relay controls are used to control the switching of the relays that put the device into its charge and discharge modes.

Analysis:





Charge Time Calculation:

$$Q = VC = 2.85V \times 4 \times \frac{3.4 \times 10^3}{4} = 9690C = At_{sec}, \text{ since } I_{max} = \frac{Q_{max}}{t_{sec}}$$

The charge time can be calculated by dividing the capacitance by the current.

Discharge Time Calculation (based on motors):

$$\text{Energy } (J) = \frac{C \times (V_{start}^2 - V_{end}^2)}{2} = \text{Power} \times \text{Time}$$

$$\frac{1}{2} \times \frac{3.4 \times 10^3 \ C}{2} \times 2\,(5.7^2 - 3.5^2) = P \times t_{seconds}$$

$$\text{Average voltage} \times 2 \text{ motors} \times 1.3A \text{ per phase} = 4.6V \times 2 \times 1.3A = 11.96W$$

$$t_{seconds} = \frac{33{,}408 \ J}{11.96 \ W} = 2793.3s = 46 \text{ mins}$$

Conclusion:

According to our analysis, it is viable to substitute a supercapacitor bank in lieu of a battery.

Advantages include an extremely high cycle life, durability, ability to accept high current loads, low risk of overcharging and excellent charge/discharge performance at low temperatures.

As costs continue to decrease and performance improves, supercapacitors may change the way energy is stored in the future.