

Charging of Ultracapacitors

Charging of ultracapacitors is simple while at the same time may present some unique challenges. Unlike batteries, ultracapacitors may be charged and discharged at similar rates. This is very useful in energy recovery systems such as dynamic braking of transport systems. Here are a few characteristics of ultracapacitors that should be kept in mind when integrating/designing a charging system for the intended application.

An ultracapacitor with zero charge looks like a short circuit to the charging source. Most low cost power supplies fold back the output current in response to a perceived short circuit, making them unsuitable for charging of ultracapacitors.

Ultracapacitors have a low series inductance allowing easy stabilizing with switch mode chargers.

The RC time constant of passive charging networks is usually too long. Therefore, linear regulators are inefficient components for ultracapacitor charging. Covered in this application note are recommendations for constant current charging, constant power charging, and AC line charging.

Constant Current Charging

A DC-to-DC constant current regulator is the simplest form of active charging. Either a buck or boost regulator may be used depending on the application. A buck regulator is the preferred topology due to the continuous output charge current. The power losses or ultracapacitor heating is proportional to current squared times the duty cycle. Therefore, an ultracapacitor module with an I^2 rating of 40,000 may be charged at 200 amps using a buck converter with low ripple current, whereas, the same module could only be charged at 141 amps from a boost converter at a 50% duty cycle (282A squared times a 50% duty cycle \approx 40,000).

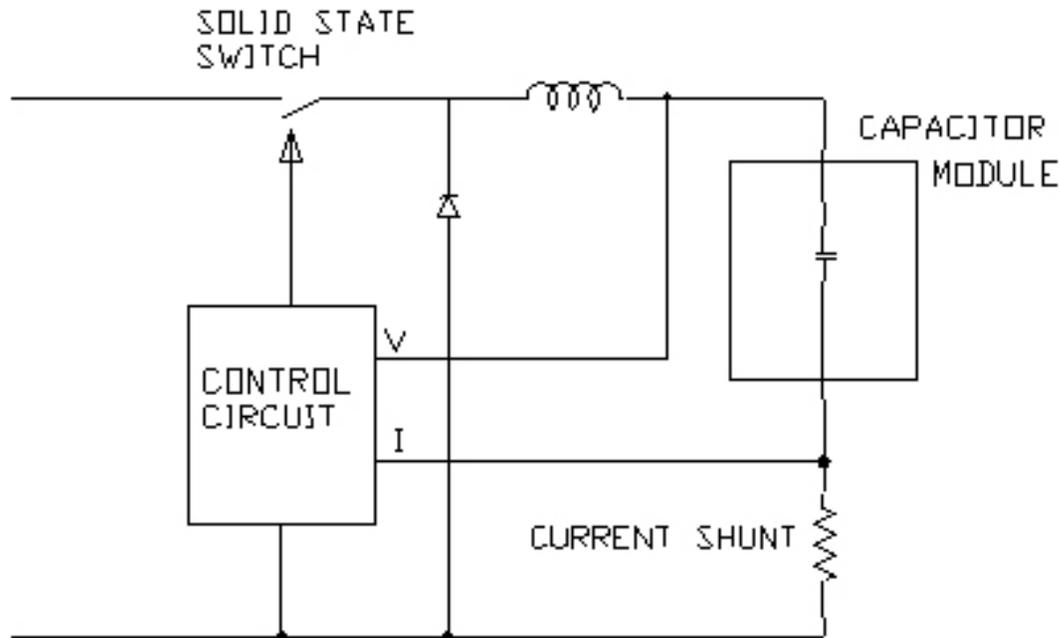


Figure 1: Constant Current Charging Schematic

A simple constant current charger may be built with standard power supply IC's. The current limit would be set to the required charge current and the voltage limit would be set to the maximum required voltage. An example circuit layout is provided in figure 1.

Constant Power Charging

When charge time is critical, constant power charging provides the fastest charge method. Constant power charging can transfer all the available power from the charge source into the energy storage capacitors.

Drawing a constant current from the source at a constant voltage is a simple implementation of constant power charging. This usually requires that a maximum switching current of 2.5 times the nominal be established to prevent overloading the switching circuitry when the ultracapacitor voltage is below 40% of maximum. An example schematic is provided in figure 2 (patent pending).

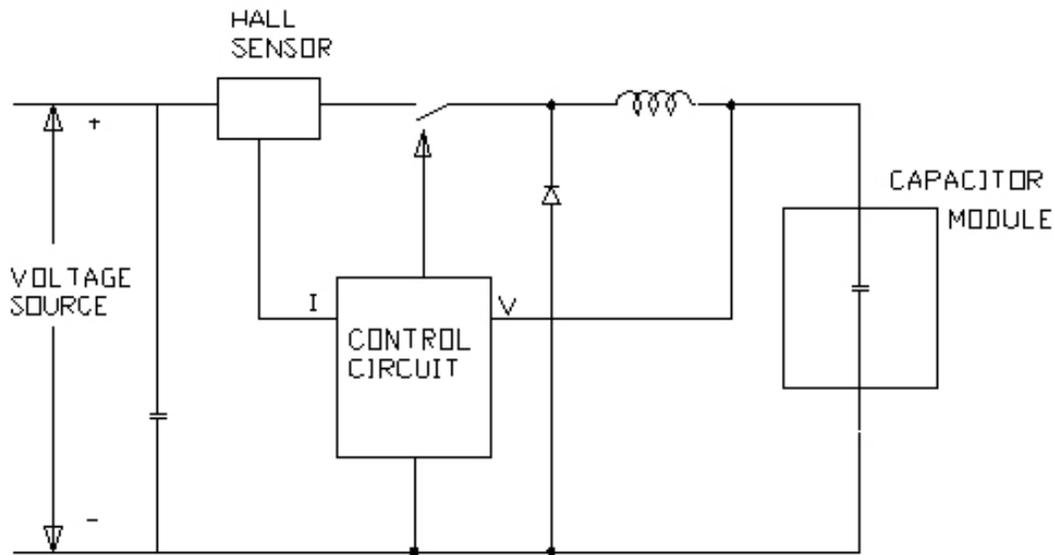


Figure 2: Constant Power Charging Schematic

To quantify the significance of constant power charging the following example is provided and illustrated in figure 3. A 100 farad, 50 V module is charged from a 50 V, 20 amp power supply. In the constant current waveform the module is charged at the maximum power supply current of 20 amps. In the constant power waveform the module is charged at a constant 1000 watts. The maximum charge current from the constant power charger was set at 50 amps.

The constant 20 amp charge current required 250 seconds to charge the module to 50 volts. The 1000 watt constant power charger required 145 seconds to charge the module to 50 volts. For the constant power waveform 50 amps charging current was utilized until the ultracapacitor module voltage reached 20 V with this limit is set by the switching circuitry.

Constant power charging is very useful in dynamic braking systems. This allows a constant power to be extracted from the vehicle's momentum and transferred to stored electrical energy.

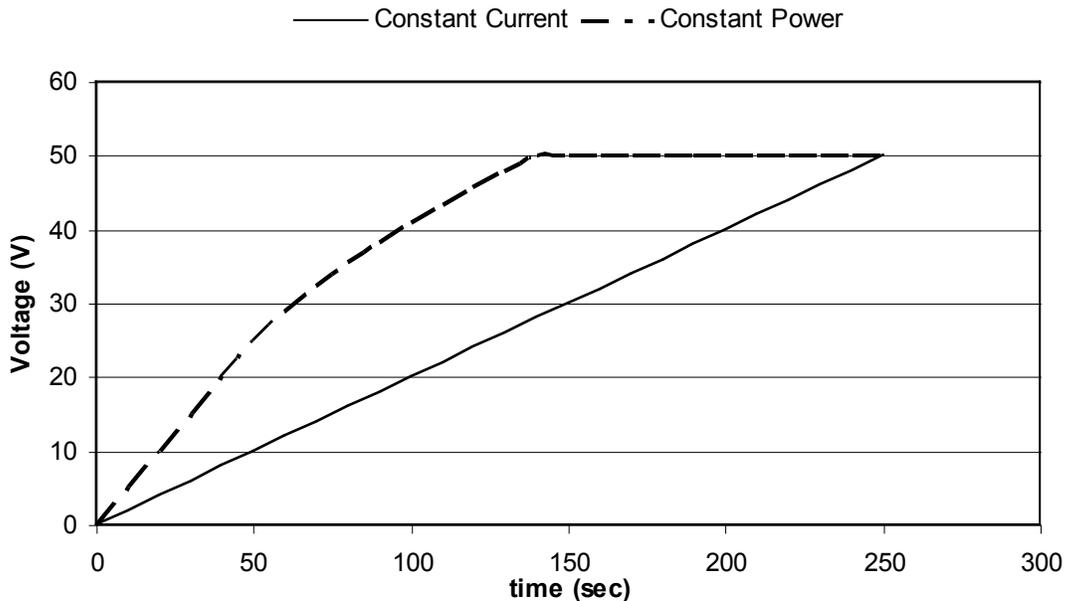


Figure 3: Constant Current vs. Constant Power Charging Time

Isolated AC Line Charging (U.S Patent 6,912,136 – Thrap)

It is often difficult to cover the wide dynamic range requirements for charging ultracapacitors from a varying AC power line. The circuit illustrated in figure 4 uses the L/V characteristics of the switching transformer to set the switching frequency permitting the circuit to provide full output current at zero volts with no risk of saturating the magnetics.

The switch Q1 turns on, charging the primary of T1 to a preset current limit. The switch Q1 then turns off permitting the energy stored in T1 to discharge through D1 into the ultracapacitor module, C1. When the secondary current has discharged to a preset lower limit then Q1 will turn on again repeating the cycle. The time required to charge T1 is inversely proportional to the instantaneous line voltage while the time required to discharge T1 is inversely proportional to the ultracapacitor voltage at C1. The combination of low line voltage and low ultracapacitor voltage will produce the lowest switching frequency. The highest switching frequency occurs at the peak of the AC power line at maximum voltage and full charge voltage on the ultracapacitor. Depending on the application the switching frequency can cover a range of 20:1. When C1 reaches its maximum voltage then the voltage sensor will drive the control circuit into discontinuous operation.

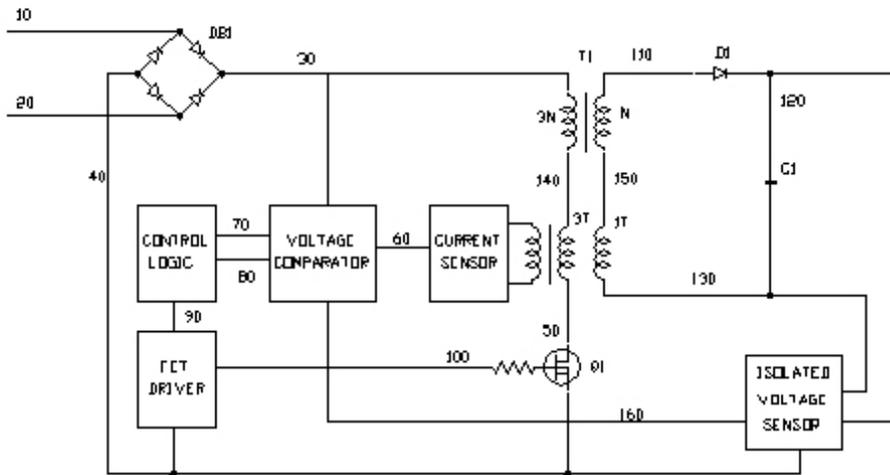


Figure 4: AC Charging Schematic