DESIGN NOTES

Supercapacitors Can Replace a Backup Battery for Power Ride-Through Applications – Design Note 450

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Introduction

Supercapacitors (or ultracapacitors) are finding their way into an increasing number of applications for short-term energy storage and applications that require intermittent high energy pulses. One such application is a power ride-through circuit, in which a backup energy source cuts in and powers the load if the main power supply fails for a short time. This type of application has typically been dominated by batteries, but electric double layer capacitors (EDLCs) are fast making inroads as their price-per-farad, size and effective series resistance per capacitance (ESR/C) continue to decrease.
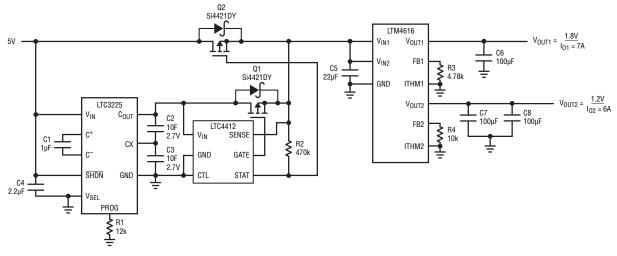
Figure 1 shows a 5V power ride-through application where two series-connected 10F, 2.7V supercapacitors charged to 4.8V can support 20W for over a second. The LTC3225, a new charge-pump-based supercapacitor charger, is used to charge the supercapacitors at 150mA and maintain cell balancing while the LTC4412 provides automatic switchover between the supercapacitor and the main supply. The LTM4616 dual output DC/DC μModule™ regulator creates the 1.8V and 1.2V outputs. With a 20W load, the output voltages remain in regulation for 1.42 seconds after the main power is removed.

Supercapacitor Characteristics

A 10F, 2.7V supercapacitor is available in a 10mm × 30mm 2-terminal radial can with an ESR of 25mΩ. One advantage supercapacitors offer over batteries is their long lifetime. A capacitor's cycle life is quoted as greater than 500,000 cycles, whereas batteries are specified for only a few hundred cycles. This makes the supercapacitor an ideal "set and forget" device, requiring little or no maintenance.

Two critical parameters of a supercapacitor in any application are cell voltage and initial leakage current. Initial leakage current is really dielectric absorption current, which disappears after some time. The manufacturers of supercapacitors rate their leakage current after 100 hours of applied voltage while the initial leakage current in those first 100 hours may be as much as 50 times the specified leakage current.

The voltage across the capacitor has a significant effect on its operating life. When used in series, the supercapacitors must have balanced cell voltages to prevent overcharging of one of the series capacitors. Passive cell

Figure 1. 5V Ride-Through Application Circuit Delivers 20W for 1.42 seconds

balancing, where a resistor is placed across the capacitor, is a popular and simple technique. The disadvantage of this technique is that the capacitor discharges through the balancing resistor when the charging circuit is disabled. The rule of thumb for this scheme is to set the balancing resistor to 50 times the worst case leakage current, estimated at 2µA/Farad. Given these parameters, a 10F, 2.5V supercapacitor would require a 2.5k balancing resistor. This resistor would drain 1mA of current from the supercapacitor when the charging circuit is disabled.

A better alternative is to use a non-dissipative active cell balancing circuit, such as the LTC3225, to maintain cell voltage. The LTC3225 presents less than 4µA of load to the supercapacitor when in shutdown mode and less than 1µA when input power is removed. The LTC3225 features a programmable charging current of up to 150mA, charging two series supercapacitors to either 4.8V or 5.3V while balancing the individual capacitor voltages.

To provide a constant voltage to the load, a DC/DC converter is required between the load and the supercapacitor. As the voltage across the supercapacitor decreases, the current drawn by the DC/DC converter increases to maintain constant power to the load. The DC/DC converter drops out of regulation when its input voltage reaches the minimum operating voltage (V_{UV}).

To estimate the requirements for the supercapacitor, the effective circuit resistance (R_T) needs to be determined. R_T is the sum of the capacitors' ESRs plus the circuit distribution resistances, as follows:

$$R_T = ESR + R_{DIST}$$

Assuming 10% of the input power is lost in the effective circuit resistance when the DC/DC converter is at the minimum operating voltage, the worst case R_T is:

$$R_{T(MAX)} = \frac{0.1 \bullet V_{UV}^2}{P_{IN}}$$

The voltage required across the supercapacitor at the minimum operating voltage of the DC/DC converter is:

$$V_{C(UV)} = \frac{V_{UV}^2 + P_{IN} \bullet R_T}{V_{UV}}$$

The required effective capacitance can then be calculated based on the required ride-through time (T_{RT}), and the initial voltage on the capacitor ($V_{C(0)}$) and $V_{C(UV)}$ shown by:

$$C_{EFF} = \frac{2 \bullet P_{IN} \bullet T_{RT}}{V_{C(0)}^2 - V_{C(UV)}^2}$$

The effective capacitance of a series-connected bank of capacitors is the effective capacitance of a single capacitor divided by the number of capacitors while the total ESR is the sum of all the series ESRs.

The ESR of a supercapacitor decreases with increasing frequency. Manufacturers usually specify the ESR at 1kHz, while some manufacturers publish both the value at DC and at 1kHz. The capacitance of supercapacitors also decreases as frequency increases and is usually specified at DC. The capacitance at 1kHz is about 10% of the value at DC. When using a supercapacitor in a ride-through application where the power is being sourced for seconds to minutes, use the effective capacitance and ESR measurements at a low frequency, such at 0.3Hz. Figure 2 shows the ESR effect manifested as a 180mV drop in voltage when input power is removed.
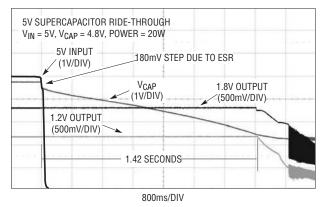

Figure 2. 5V Ride-Through Application Timing

Conclusion

Supercapacitors can meet the needs of power ride-through applications where the time requirements are in the seconds to minutes range. Supercapacitors offer long life, low maintenance, light weight and environmentally friendly solutions when compared to batteries. To this end, the LTC3225 provides a compact, low noise solution for charging and cell balancing series-connected supercapacitors, without degrading performance.

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