Replace Batteries in Power Ride-Through Applications with Robust Supercaps and 3mm × 3mm Capacitor Charger

by Jim Drew

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 been dominated by batteries in the past, 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 fall.

In a power ride-through application, series-stacked capacitors must be charged and cell-voltage balanced. Supercaps are switched into the power path when needed and the power to the load is controlled by a DC/DC converter. The LTC3225 supercapacitor charger has a number of features that make it a good choice for power ride-through applications. It comes in a small, 10-lead 3mm × 3mm DFN package and features programmable charging current, automatic cell voltage balancing, low drain current on the supercapacitors and a patent pending, low noise, constant current charger.

Supercapacitor Characteristics

Supercapacitors come in a variety of sizes, for example a 10F/2.7V supercap is available in a 10mm × 30mm 2-terminal radial can with an ESR of 0.25Ω. A full cycle life of 500,000 cycles is quoted; batteries are specified for only a few hundred cycles. This makes the supercapacitor an ideal “set and forget” device, requiring little or no maintenance.

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25mΩ while a 350F/2.5V supercapacitor with an ESR of 1.6mΩ is available in a D-cell battery form factor. One advantage supercapacitors offer over batteries is their long life. A capacitor’s cycle life is quoted as greater than 500,000 cycles: 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 parameters of the supercapacitor that are critical to an application are cell voltage and initial leakage current. Initial leakage current is a misnomer in that the 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 over-charging of one of the series capacitors. Passive cell 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.

An alternative is to use a non-dispersive 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 voltage on the capacitors.

**Power Ride-Through Applications**

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 and the circuit distribution resistances.

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

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

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

The voltage required across the supercapacitor at the undervoltage lockout threshold of the DC/DC converter is:

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

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 $V_{C(UV)}$:

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

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 higher frequency. Manufacturers usually specify the ESR continued on page 12

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**Figure 1. A 5V power ride-through application**

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**DESIGN FEATURES**
either a petroleum based coke material or graphite. The voltage profiles for each are shown in Figure 4. The more widely used graphite material produces a flatter discharge voltage between 20% and 80% capacity, then drops quickly near the end, whereas the coke anode has a steeper voltage slope and a lower 2.5V cutoff voltage. The approximate remaining battery capacity is easier to determine with a coke material by simply measuring the battery voltage.

Parallel or Series Connected Cells
For increased capacity, Li-ion cells are often connected in parallel. There are no special requirements other than they should be the same chemistry, manufacturer and size. Series connected cells require more care because cell capacity matching and cell balancing circuitry is often required to assure that each cell reaches the same float voltage and the same level of charge. Connecting two cells (that have individual pack protection circuitry) in series is not recommended because a mismatch in capacity can result in one battery reaching the overvoltage limit, thus opening the battery connection. Multicell battery packs should be purchased assembled with the appropriate circuitry from a battery manufacturer.

Conclusion
The lifetime of a Li-ion battery is determined by many factors of which the most important are battery chemistry, depth of discharge, battery temperature and battery capacity termination level. The number of available charge/discharge cycles can be increased by selecting a charger that allows charging to less than 100% capacity, such as one that features a lower float voltage or one that terminates earlier in the charge cycle.

Figure 2 shows a 12V power ride-through application where the time requirements are in the seconds to minutes range. Capacitors 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 to charging and cell balancing series connected supercapacitors.