

LINEAR TECHNOLOGY

SEPTEMBER 2008

VOLUME XVIII NUMBER 3

IN THIS ISSUE...

COVER ARTICLE

Replace Batteries in Power Ride-Through Applications with Robust Supercaps and 3mm x 3mm Capacitor Charger1
Jim Drew

Linear in the News...2

DESIGN FEATURES

New Family of Integrated Power Controllers Combine Fast Battery Charging, PowerPath™ Control and Efficient DC/DC Converters in Less Than 20mm²4
Sam Nork

Charging and Discharging Methods That Extend Li-Ion Battery Life.....7
Fran Hoffart

Serial Interface for High Speed Data Converters Simplifies Layout over Traditional Parallel Devices13
Clarence Mayott

Synchronous Buck Controller in 3mm x 3mm QFN Fits Automotive and Industrial Applications with 4V-38V Input Capability.....16
Mark Mercer

Feature-Packed Charger Handles All Battery Chemistries and Produces 3A/50W for Fast Charging from a 4mm x 4mm QFN.....18
James A. McKenzie

Dual Hot Swap™ Controller in 3mm x 2mm DFN is Perfect for Backplane or Card Resident 1V-6V Applications21
CY Lai

0V to 18V Ideal Diode Controller Saves Watts and Space over Schottky.....24
Pinkesh Sachdev

Low Voltage, High Current Step-Down μModule™ Regulators Put a (Nearly) Complete Power Supply in a 15mm x 9mm x 2.8mm Package.....28
Judy Sun, Sam Young and Henry Zhang

DESIGN IDEAS

.....30-36
(complete list on page 30)

New Device Cameos37

Design Tools.....39

Sales Offices40



Replace Batteries in Power Ride-Through Applications with Robust Supercaps and 3mm x 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 x 3mm DFN package and features programmable

One advantage supercapacitors have 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.

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 x 30mm 2-terminal radial can with an ESR of

continued on page 3

LT, LTC, LTM, Burst Mode, OPTI-LOOP, Over-The-Top and PolyPhase are registered trademarks of Linear Technology Corporation. Adaptive Power, Bat-Track, BodeCAD, C-Load, DirectSense, Easy Drive, FilterCAD, Hot Swap, LinearView, μModule, Micropower SwitcherCAD, Multimode Dimming, No Latency ΔΣ, No Latency Delta-Sigma, No R_{SENSE}, Operational Filter, PanelProtect, PowerPath, PowerSOT, SmartStart, SoftSpan, Stage Shedding, SwitcherCAD, ThinSOT, TimerBlox, True Color PWM, UltraFast and VLDO are trademarks of Linear Technology Corporation. Other product names may be trademarks of the companies that manufacture the products.

LTC3225, continued from page 1

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-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 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

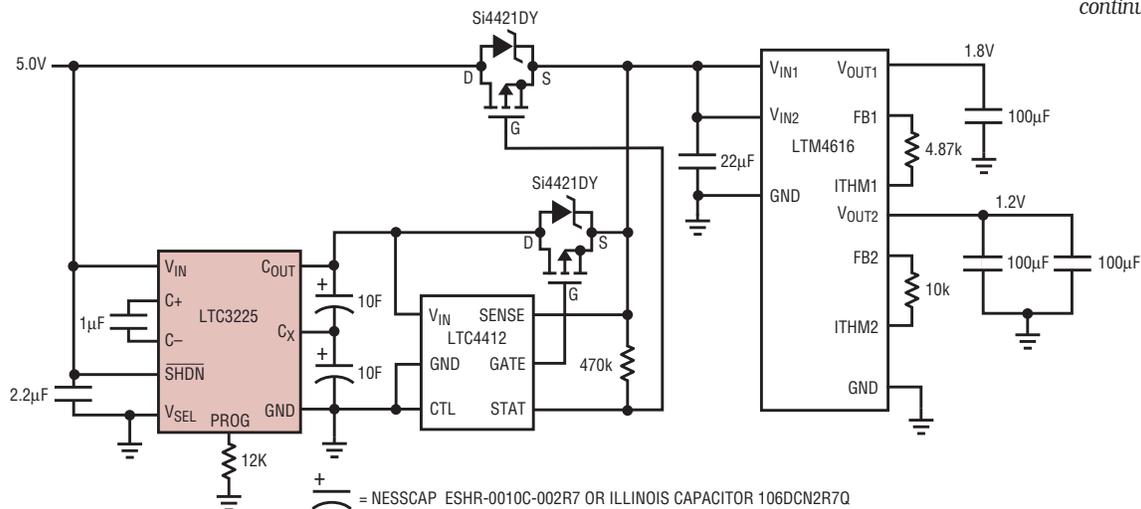


Figure 1. A 5V power ride-through application

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. 

Authors can be contacted
at (408) 432-1900

LTC3225, continued from page 3

at 1kHz, while some manufactures 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 as 0.3Hz.

Applications

Figure 1 shows two series connected 10F, 2.7V supercapacitors charged to 4.8V that can hold up 20W. The

LTC3225 is used to charge the supercapacitors at 150mA and maintain cell balancing, while the LTC4412 provides an automatic switchover function. The LTM4616 dual output switch mode μ Module DC/DC converter generates the 1.8V and 1.2V outputs.

Figure 2 shows a 12V power system that uses six 10F, 2.7V supercapacitors in series charged by three LTC3225's set to 4.8V and a charging current of 150mA. The three LTC3225's are powered by three floating 5V outputs generated by the LT1737 flyback controller. The output of the stack of six supercapacitors is set up in a diode OR arrangement via the LTC4355 dual ideal diode controller. The LTM4601A

μ Module DC/DC regulator produces 1.8V at 11A from the OR'd outputs. The LTC4355's MON1 in this application is set for 10.8V.

Conclusion

Supercapacitors are meeting the needs of power ride-through applications 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. 

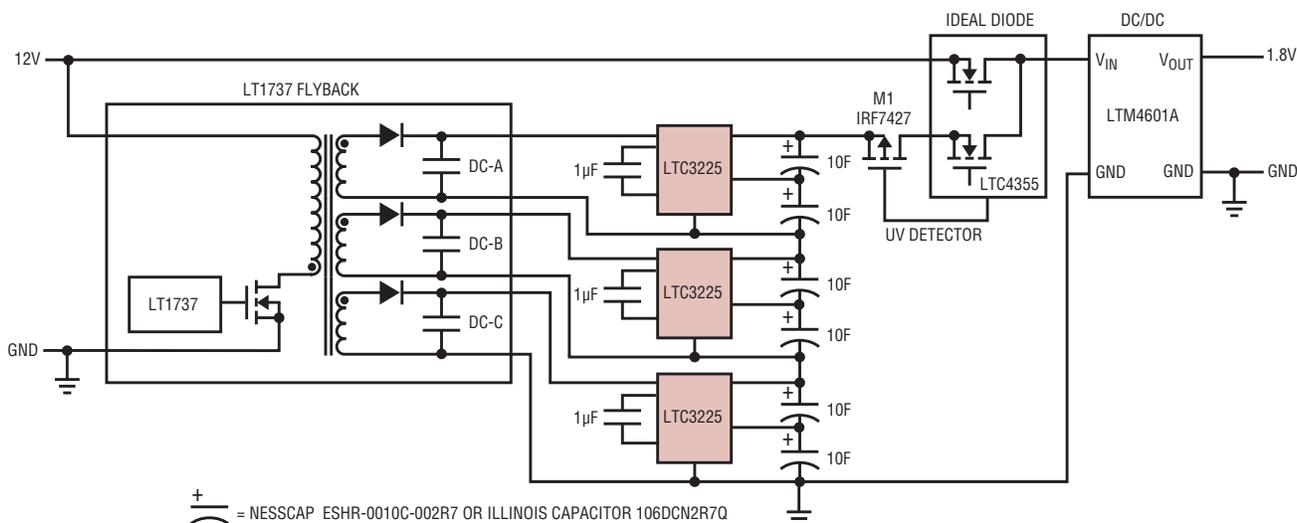


Figure 2. A 12V power ride-through application