Supercapacitor-Based Power Backup Prevents Data Loss in RAID Systems – Design Note 487
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Introduction
Redundant arrays of independent disks, or RAID, systems, by nature are designed to preserve data in the face of adverse circumstances. One example is power failure, thereby threatening data that is temporarily stored in volatile memory. To protect this data, many systems incorporate a battery-based power backup that supplies short-term power—enough watt-seconds for the RAID controller to write volatile data to nonvolatile memory. However, advances in flash memory performance such as DRAM density, lower power consumption and faster write time, in addition to technology improvements in supercapacitors such as lower ESR and higher capacitance per unit volume, have made it possible to replace the batteries in these systems with longer lasting, higher performance and “greener” supercapacitors. Figure 1 shows a supercapacitor-based power backup system using the LTC®3625 supercapacitor charger, an automatic power crossover switch using the LTC4412 PowerPath™ controller and an LTM®4616 dual output μModule® DC/DC converter.

The LTC3625 is a high efficiency supercapacitor charger ideal for small profile backup in RAID applications. It comes in a 3mm × 4mm × 0.75mm 12-lead DFN package and requires few external components. It features a programmable average charge current up to 1A, automatic cell voltage balancing of two series-connected supercapacitors and a low current state that draws less than 1μA from the supercapacitors.

Backup Power Applications
An effective power backup system incorporates a supercapacitor stack that has the capacity to support a complete data transfer. A DC/DC converter takes the output of the supercapacitor stack and provides a constant voltage to the data recovery electronics. Data transfer must be completed before the voltage across the supercapacitor stack drops to the minimum input operating voltage (VUV) of the DC/DC converter.

To estimate the minimum capacitance of the supercapacitor stack, the effective circuit resistance (RT) needs to be determined. RT is the sum of the ESR of the supercapacitors, distribution losses (R DIST) and the R DS(ON) of the automatic crossover’s MOSFETs:

\[ R_T = ESR + R_{DIST} + R_{DS(ON)} \]

Allowing 10% of the input power to be lost in RT at VUV, R T(MAX) may be determined:

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

Figure 1. Supercapacitor Energy Storage System for Data Backup
The voltage required across the supercapacitor stack (\(V_{C(UV)}\)) at \(V_{UV}\):

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

The minimum capacitance (\(C_{MIN}\)) requirement can now be calculated based on the required backup time (\(t_{BU}\)) to transfer data into the flash memory, the initial stack voltage (\(V_{C(O)}\)) and (\(V_{C(UV)}\)):

\[ C_{MIN} = \frac{2 \cdot P_{IN} \cdot t_{BU}}{V_{C(O)}^2 - V_{C(UV)}^2} \]

\(C_{MIN}\) is half the capacitance of one supercapacitor. The ESR used in the expression for calculating \(R_T\) is twice the end-of-life ESR. End of life is defined as when the capacitance drops to 70% of its initial value or the ESR doubles.

The Charge Profile into Matched SuperCaps graph in the LTC3625 data sheet shows the charge profile for two configurations of the LTC3625 charging a stack of two 10F supercapacitors to 5.3V with \(R_{PROG}\) set to 143kΩ. This graph, combined with the following equation, is used to determine the value of \(R_{PROG}\) that would produce the desired charge time for the actual supercapacitors in the target application:

\[ R_{PROG} = 143k \cdot \frac{10F}{C_{ACTUAL}} \cdot \frac{10F}{V_{OUT} - V_{C(UV)}} \cdot \frac{t_{RECHARGE}}{t_{ESTIMATE}} \]

\(V_{C(UV)}\) is the minimum voltage of the supercapacitors at which the DC/DC converter can produce the required output. \(V_{OUT}\) is the output voltage of the LTC3625 in the target application (set by \(V_{SEL}\) pin). \(t_{ESTIMATE}\) is the time required to charge from \(V_{C(UV)}\) to the 5.3V, as extrapolated from the charge profile curves. \(t_{RECHARGE}\) is the desired recharge time in the target application.

**Design Example**

For example, say it takes 45 seconds to store the data in flash memory where the input power to the DC/DC converter is 20W, and the \(V_{UV}\) of the DC/DC converter is 2.7V. A \(t_{RECHARGE}\) of ten minutes is desired. The full charge voltage of the stack is set to 4.8V—a good compromise between extending the life of the supercapacitor and utilizing as much of the storage capacity as possible. The components of \(R_T\) are estimated: \(R_{DIST} = 10m\Omega\), ESR = 20m\Ω and \(R_{DS(ON)} = 10m\Omega\).

The resulting estimated values of \(R_{T(MAX)} = 36m\Omega\) and \(R_T = 40m\Omega\) are close enough for this stage of the design.

**Conclusion**

Supercapacitors are replacing batteries to satisfy green initiative mandates for data centers. The LTC3625 is an efficient 1A supercapacitor charger with automatic cell balancing that can be combined with the LTC4412 low loss PowerPath controller to produce a backup power system that protects data in storage applications.