LINEAR TECHNOLOGY
DESIGN NOTES

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 (V_{UV}) of the DC/DC converter.

To estimate the minimum capacitance of the supercapacitor stack, the effective circuit resistance (R_T) needs to be determined. R_T 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 R_T at V_{UV}, $R_{T(MAX)}$ may be determined:

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

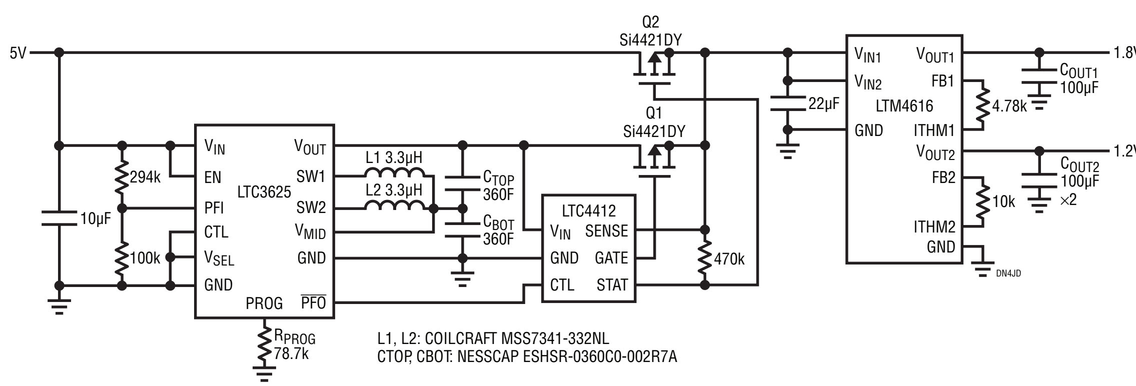

Figure 1. Supercapacitor Energy Storage System for Data Backup

The voltage required across the supercapacitor stack ($V_{C(UV)}$) at V_{UV}:

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

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 ($V_{C(UV)}$):

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

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 143k. 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:

$$R_{PROG} = 143k \bullet \frac{10F}{C_{ACTUAL}} \bullet \frac{5.3V - V_{C(UV)}}{V_{OUT} - V_{C(UV)}} \bullet \frac{t_{RECHARGE}}{t_{ESTIMATE}}$$

$V_{C(UV)}$ 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} = 10mΩ, ESR = 20mΩ and $R_{DS(ON)}$ = 10mΩ.

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

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$V_{C(UV)}$ is estimated at 3V. C_{MIN} is 128F. Two 360F capacitors provide an end-of-life capacitance of 126F and ESR of 6.4mΩ. The crossover switch consists of the LTC4412 and two P-channel MOSFETs. The $R_{DS(ON)}$, with a gate voltage of 2.5V, is 10.75mΩ (max). An R_T of 26.15mΩ is well within $R_{T(MAX)}$. The value for R_{PROG} is estimated at 79.3k. The nearest standard 1% resistor is 78.7k. The data sheet suggests a 3.3µH value for both the buck and boost inductors.

The LTC3625 contains a power-fail comparator, which is used to monitor the input power to enable the LTC4412. A voltage divider connected to the PFI pin sets the power fail trigger point (V_{PF}) to 4.75V.

Figure 2 shows the actual backup time of the system with a 20W load. The desired backup time is 45 seconds, whereas this system yields 76.6 seconds. The difference is due to a lower R_T than estimated and an actual V_{UV} of 2.44V. Figure 3 shows the actual recharge time of 685 seconds compared to the 600 seconds used in the calculation, a difference due to the lower actual V_{UV}.

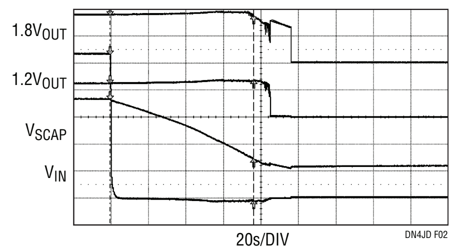

Figure 2. Supercapacitor Backup Time Supporting a 20W Load

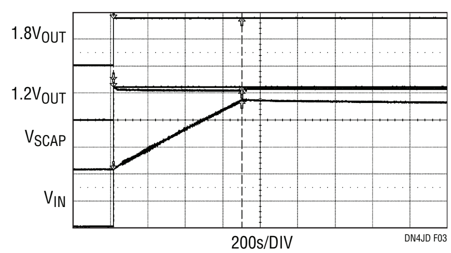

Figure 3. Recharge Time After Backup

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.

For applications help,
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