

# DESIGN NOTES

## Complete Energy Utilization Improves Run Time of a Supercap Ride-Through Application by 40% – Design Note 485

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### Introduction

Many electronic systems require a local power source that allows them to ride through brief main power interruptions without shutting down. Some local power sources must be available to carry out a controlled shutdown if the main power input is abruptly removed.

A battery backup can supply power in the event of a mains shutdown, but batteries are not well suited to this particular application. Although batteries can store significant amounts of energy, they cannot deliver much power due to their significant source impedance. Also, batteries have finite lives of ~2 to 3 years, and the maintenance required for rechargeable batteries is substantial.

Supercapacitors are well suited to such ride-through applications. Their low source impedance allows them to supply significant power for a relatively short time, and they are considerably more reliable and durable than batteries.

### Complete Energy Utilization Maximizes Run Time of Supercap Ride-Through Application

Figure 1 shows a complete 3.3V/200mA ride-through application that maximizes the amount of power extracted from the supercap to support the load.

The main components of the ride-through application include:

- The LTC®4425 complete 2A supercapacitor charger. It clamps the individual cell voltages to ensure that the cells do not overvoltage during charging and balances the cells throughout charge and discharge.
- The LTC3606 micropower buck regulator produces the regulated 3.3V output.
- The LTC4416 dual ideal diode switches the supercap in and out depending on need.

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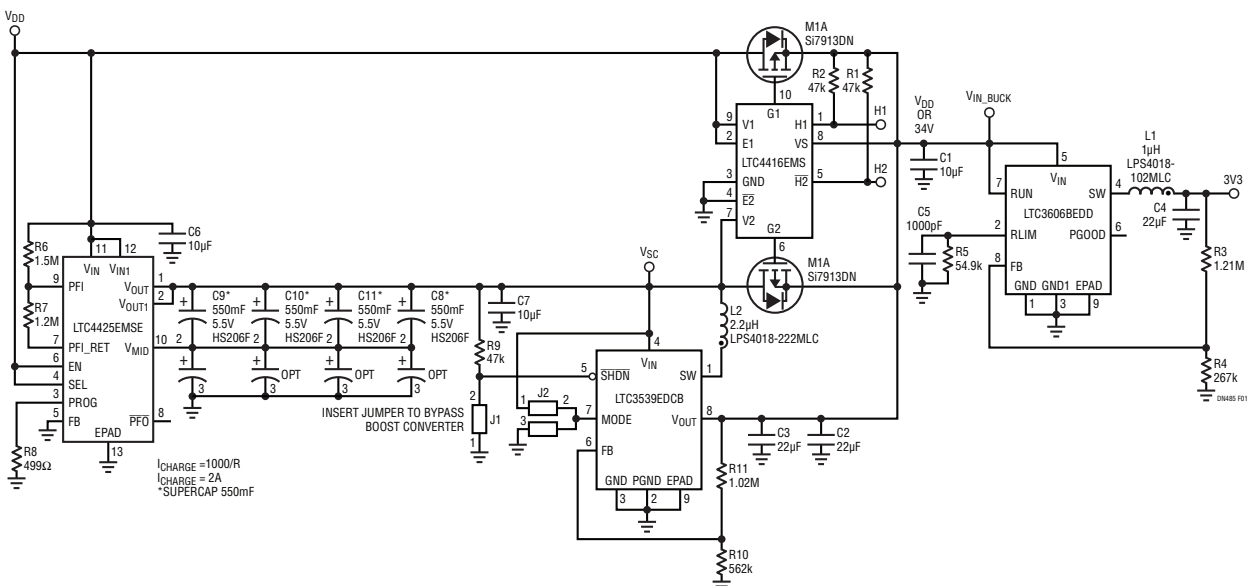


Figure 1. This Supercap-Based Power Ride-Through Circuit Maximizes Run Time Using an Energy Scavenging Scheme

- The LTC3539 micropower boost regulator with output disconnect recovers nearly all the energy in the supercap and it keeps the input to the LTC3606 above dropout as the supercap voltage drops. This boost regulator operates down to 0.5V.

### 40% Improvement in Run Time

Figure 2 shows the waveforms if the LTC3539 boost circuit is disabled. Run time from input power off to output regulator voltage dropping to 3V is 4.68 seconds. Figure 3 shows the waveforms if the LTC3539 boost circuit is operational. Run time from input power off to the output regulator dropping to 3V is 7.92 seconds. Note in Figure 3 that the output is a steady 3.3V voltage with a sharp cutoff.

### How it Works

When the LTC3539 boost regulator is disabled, as soon as input power falls, the LTC4416 ideal diodes switch the input energy supply for the LTC3606 buck regulator to the supercap. In Figure 2, the voltage across the supercap ( $V_{SC}$ ) is seen to linearly decrease due to the constant power load of 200mA at 3.3V on the buck regulator output (3V3).

In Figure 3, when the LTC3539 boost regulator is enabled, the voltage across the supercap ( $V_{SC}$ ) is seen to linearly decrease due to the constant power load of 200mA at 3.3V on the buck regulator. When the voltage at  $V_{SC}$  reaches 3.4V, the regulation point of the boost regulator, the boost regulator begins switching. This shuts off the ideal diode and disconnects the buck regulator from the supercapacitor. The energy input to the buck regulator is now the boost regulator's output of 3.4V.

Because the input of the buck regulator remains at 3.4V, its output remains in regulation. When the boost regulator reaches its input UVLO and shuts off, its output immediately collapses, and the buck regulator shuts off.

### Maximizing Usage of the Energy in the Supercap

Because each power conversion lowers the overall efficiency, the boost circuit should be held off as long as possible. Therefore, set the boost regulator output voltage as close to the buck regulator input dropout voltage as possible, in this case, 3.4V.

If the supercapacitor is initially charged to 5V, then the energy in the supercapacitor is 6.875J:

$$\frac{1}{2}CV^2 = \frac{1}{2}0.55F \cdot 5^2 = 6.875J$$

$$0.67W (3.33 \cdot 0.2A)$$

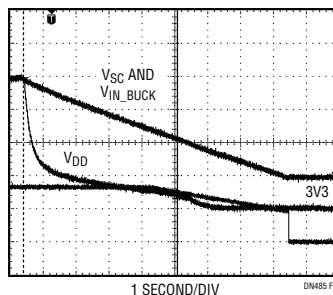


Figure 2. Power Ride-Through Application Results without Boost Circuit

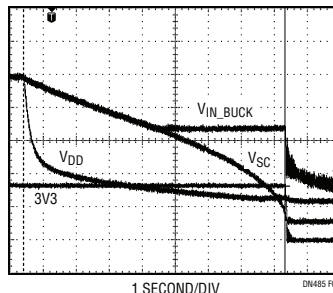


Figure 3. Power Ride-Through Application Results with Boost Circuit Enabled. The Boost Circuit Yields a 40% Improvement in Run Time

The output power is  $3.33V \cdot 0.2A = 0.67W$ , so the percentage of energy extracted from the full supercap when the boost regulator is disabled is 45.1%:

$$\frac{\epsilon_{LOAD}}{\epsilon_{CAP}} = \frac{0.67 \cdot 4.68s}{6.875} = 45.1\%$$

The percentage of the energy extracted from the supercap's available storage when the boost regulator is enabled is 77%:

$$\frac{\epsilon_{LOAD}}{\epsilon_{CAP}} = \frac{0.67 \cdot 7.92s}{6.875} = 77\%$$

This represents a 40% improvement in ride-through run time—significant when seconds count.

### Conclusion

The run time of any given supercapacitor-based power ride-through system can be extended by 40% if energy is utilized from the discharging supercap. This is particularly relevant if the supercapacitor charge voltage is reduced to ensure high temperature reliability.

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