

# Low Profile Supercapacitor Power Backup with Input Current Limiting

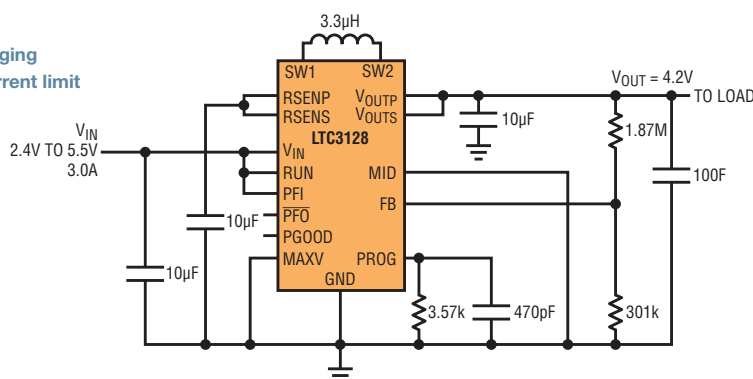
David Salerno

Supercapacitors are increasingly used as backup power sources, due in large part to their continually improving volumetric energy capacity and robust nature. Large output capacitors can strain the load capabilities of an input source, especially when that source is limited by protocol (USB or PCMCIA) or a high source resistance. Input source limitations can complicate designs. The LTC3128 simplifies power backup by adding a programmable accurate input current limit to a complete supercapacitor charger. Figure 1 shows that only a few components are needed to produce a supercapacitor charger with a 3.0A input current limit.

The LTC3128 is a buck-boost DC/DC supercapacitor charger with programmable accurate input current limit (up to 3A) and active balancing, offered in 4mm × 5mm × 0.75mm QFN or 24-lead TSSOP packages. The 1.2MHz switching frequency, along with low resistance, low gate charge integrated switches provide an efficient, compact and low profile solution for charging large output capacitors. The high accuracy ( $\pm 2\%$ ) of the programmable input current limit allows designers to limit the maximum current draw to just below the capability of the input source.

Capacitor voltage monitoring and protection, combined with the integrated active charge balancer, prevents mismatched capacitors from being overvoltaged and keeps capacitors with mismatched leakages in balance. This makes the LTC3128 ideal for backup or pulsed load applications. Supercapacitors, because of their long lifetime, large cycle capability (up to 10 years and 500,000 cycles) and relatively straightforward charging profiles, are ideal for backup solutions.

Figure 1. Complete supercapacitor charging circuit with input current limit



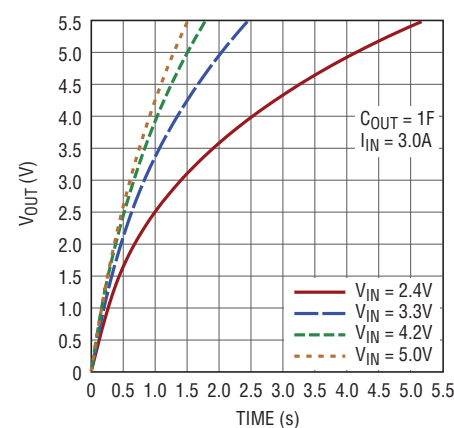
## SUPERCAPACITOR CHARGE TIME AND HOLDUP TIME

When designing a backup system, two of the most important criteria are charge time and holdup time. The charge time determines the minimum amount of time the system needs to be in operation before it can withstand a power failure, and holdup time determines how long a system can maintain operation from its backup source.

Charge time is determined by a combination of programmed input current limit, programmed output voltage, converter efficiency and output capacitance. Figure 2 shows the charge time for a 1F output capacitance at a programmed input current of 3.0A. This curve takes into account  $V_{IN}$ ,  $V_{OUT}$  and the converter efficiency. If the output capacitance is larger or smaller than 1F, the charge time scales proportionally to the output capacitance.

At the end of charging, the LTC3128 dials back the input current to top off the

Figure 2. LTC3128 charge time



The active charge balancer uses the inductor of the LTC3128 to efficiently move charge from one capacitor to another to balance them, maintaining the same voltage across each capacitor. Active charge balancing eliminates the high quiescent current and continuous power dissipation of passive balancing.

charge on the output capacitor stack. This is done to prevent chattering in and out of regulation due to the ESR of the output capacitors. Figure 3 shows an example of the charge current being dialed back as the capacitor approaches full charge. The current is typically dialed back at 95% of programmed output voltage, and this is the voltage that should be used for the charge time calculation.

The circuit of Figure 1 charges 100F to 4.2V with a programmed input current of 3.0A and a  $V_{IN}$  of 3.3V. Figure 2 shows that it takes 1.3 seconds to charge a 1.0F capacitor to 4.0V ( $4.0V \approx 0.95 \cdot 4.2V$ ) from 0V. Since the capacitor in this example is one hundred times larger, it will take roughly 130 seconds to charge a 100F capacitor to 4.0V from 0V.

To determine how long backup power can be provided to the system, the operational voltage range on the output needs to be determined. For this application, the operational output voltage is 4.2V down to 1.0V. The stored energy on the 100F capacitor can be determined as:

$$W = \frac{1}{2} C_{OUT} (V_{INITIAL})^2 - \frac{1}{2} C_{OUT} (V_{FINAL})^2$$

$$= \frac{1}{2} 100 \cdot 4.2^2 - \frac{1}{2} 100 \cdot 1.0^2 = 832J$$

where  $W$  is the work done in joules,  $C_{OUT}$  is the total output capacitance,  $V_{INITIAL}$  is the beginning voltage on  $C_{OUT}$ , and  $V_{FINAL}$  is the minimum voltage  $C_{OUT}$  can run down to.

If a secondary boost converter is connected to  $V_{OUT}$ , it acts as a constant power draw from the supercapacitor. Figure 4 shows an example of a secondary boost converter being powered by  $V_{OUT}$  of the LTC3128. The LTC3122 data sheet shows that for a 12V output with a 100mA load, the average converter efficiency across a 1V to 4.2V input is approximately 80%, resulting in a 1.5W constant power load on the holdup capacitor. The holdup time can be determined by:

$$t_{BACKUP} = \frac{W_{STORED}}{P_{LOAD}} = \frac{832J}{1.5W} = 554.66s$$

where  $t_{BACKUP}$  is the holdup time of the system,  $W_{STORED}$  is the available stored energy on the output

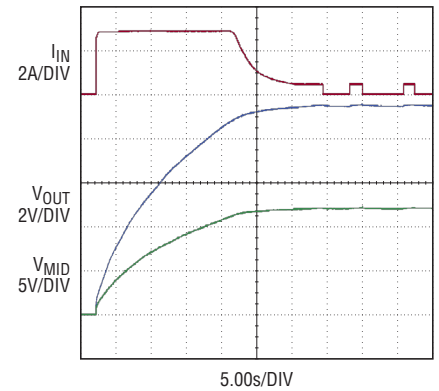


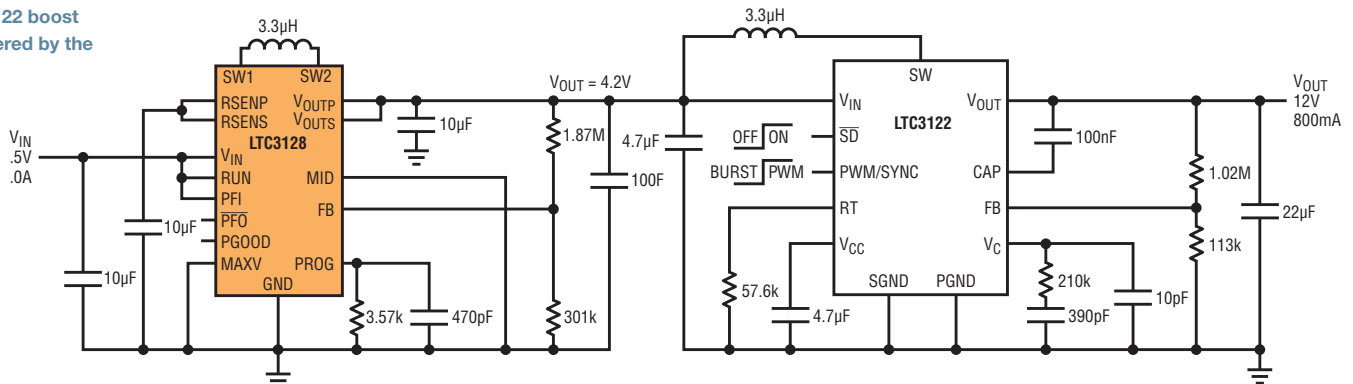
Figure 3. Input current charging profile

capacitor, and  $P_{LOAD}$  is the power draw from the secondary converter.

## BALANCING SUPERCAPACITORS

Achieving higher output voltages with supercapacitors requires putting two or more cells in series with each other because the maximum voltage for each capacitor is typically specified between 2.3V and 2.7V, depending on the manufacturer and type of capacitor. The life of the capacitor is dependent on the voltage across the capacitor. To extend capacitor lifetime the voltage on the capacitor should be regulated below the rated

Figure 4. LTC3122 boost converter powered by the LTC3128



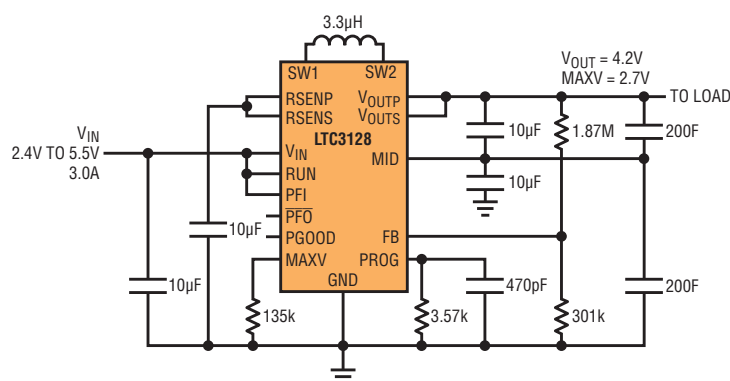


Figure 5. LTC3128 with charge balancer and maximum capacitor voltage protection

maximum voltage. Capacitor vendors typically specify how to derate the voltage on their supercapacitors to extend life.

The LTC3128 integrates a programmable maximum capacitor voltage comparator and an efficient active charge balancer. The maximum capacitor voltage comparators look at the voltage across each individual capacitor and ensure that the programmed voltage is not exceeded while charging. If the maximum programmed capacitor voltage is reached on either capacitor, the LTC3128 halts charging to balance the cells and then resumes charging.

The active charge balancer uses the inductor of the LTC3128 to efficiently move charge from one capacitor to another to balance them, so that the capacitors maintain the same voltage across them. This is important because during a holdup event, if the capacitors are far enough out of balance, the polarity of one of the cells could become

reversed, damaging the capacitor. The LTC3128 will only balance the cells if one of the cells has violated its programmed maximum capacitor voltage, or if the output voltage is in regulation and the capacitors are out of balance but the maximum voltage has not been violated.

Active charge balancing eliminates the high quiescent current and continuous power dissipation of passive balancing. Figure 5 shows the LTC3128 configured with 100F of total output capacitance, a programmed output voltage of 4.2V, and a maximum capacitor voltage of 2.7V, each.

## POWER RIDE-THROUGH APPLICATION

In a backup system, the ability to wait for the storage capacitors to charge before you begin operating is not always an option. A power ride-through application provides a means to power the secondary converter directly from the input supply while simultaneously charging the

supercapacitors. The LTC3128 allows the secondary converter to pull its current through a current sense resistor internal to the LTC3128. This allows the secondary converter to draw the required current from the supply, up to 4A, and the LTC3128 will charge the output capacitors with the programmed input current, less the current drawn from the secondary converter. As long as the secondary converter never draws more than the programmed input current, the LTC3128 limits the total current draw from the input supply to the programmed value, while charging the backup capacitors with the remaining available current.

To extend backup time, the LTC3128 draws less than 1µA from  $V_{OUT}$  when in shutdown, or less than 2µA when in input UVLO. Figure 6 shows a power ride-through application using the LTC3128 and LTC3122.

## CONCLUSION

The LTC3128 3A buck-boost DC/DC supercapacitor charger is a streamlined solution for efficiently charging and protecting supercapacitors in high reliability, long-life applications. It features a  $\pm 2\%$  accurate programmable input current limit, programmable maximum capacitor voltage comparators and active charge balancing. ■

Figure 6. Power ride-through application using the LTC3128 and the LTC3122 boost converter

