Managing high-current transient loads in battery-powered handhelds

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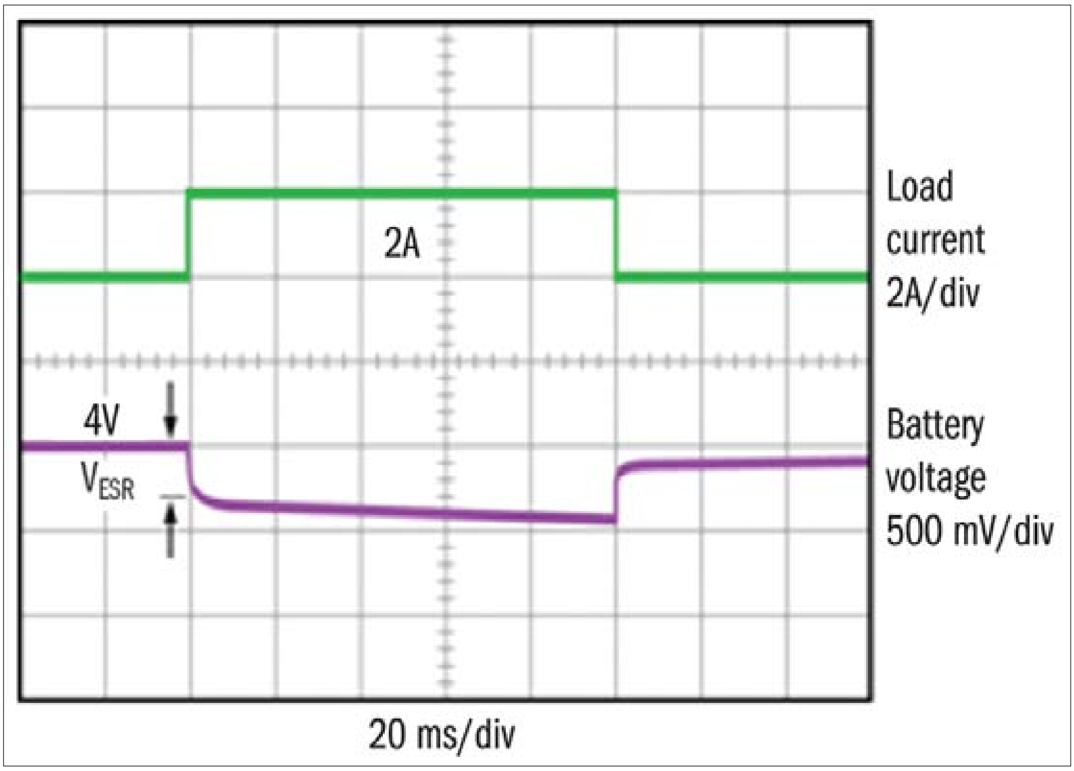

Figure 1: Shown is the effect of a 2A load transient on Li-ion battery voltage.

In the past, battery-powered handheld devices such as cell phones had fairly limited power requirements while they were in operation. Today, however, there is an increasing need to deliver high peak-current pulses, for example to support high-intensity flash in megapixel camera functions or large data transmissions.

In conventional cellphone designs, such high-current load transients have a significant impact on battery voltage and, therefore, system operation. The reason is that when a very high current is drawn directly from the battery, the terminal voltage drops momentarily, primarily because of the battery's series resistance. Now, the combination of very large-value capacitor components and advanced circuit designs makes it possible for these peak currents to be supplied without battery stress. This enables more feature-rich handheld devices to be developed, while at the same time extending battery life.

High transients

A high-current load transient applied to a Li-ion battery can have an acute impact on the system operation.

Consider a cellphone with an 800mA-hr Li-ion battery pack required to deliver a 2A current load for a duration of 100ms. As **Figure 1** shows, the battery-terminal voltage exhibits an instant drop (V_{ESR}), which is proportional to the battery equivalent series resistance (R_{ESR}) and the current (I), as defined by the equation $V_{ESR} = R_{ESR} \times I$.

The 2A pulse causes the supply to drop initially from 4V to 3.7V and then, after 100ms, to be at a low of 3.6V. The battery voltage returns to its initial voltage when the load pulse stops. The battery internal resistance is calculated as $R_{ESR} = V_{ESR}/I$. In this particular example, that would mean RESR = 0.3V/2A = 0.15Ω.

If we assume that the cellphone will typically enter shutdown mode whenever the supply drops below a threshold level of 3.3V, we can see that for a battery at a low of 3.5V, this load event would cause a system shutdown (as if the battery were completely discharged).

The argument for supercapacitors

It is clear that as a battery discharges, the maximum acceptable load current must be reduced. Furthermore, the maximum current that can be drawn from a battery causes the terminal voltage to drop under load, reducing the current that can be drawn. This is an issue for Li-ion technologies, as their internal resistance is higher than that of other rechargeable battery types. Furthermore, an increase in the internal resistance commonly occurs over time on lithium-ion batteries.

One way to mitigate against such factors is to deploy supercapacitor technologies, which have hundreds of millifarads of energy storage at their disposal and exhibit very low ESR. as a result, they, rather than the battery, can supply the load during the peaks.

Supercapacitors are typically pre-charged with a low continuous current, and their nominal voltage can reach around 5V. The higher capacitor voltage powers the load for a longer time, since the charge (Q) is equal to the product of the voltage and the capacitance figure (C). However, because connecting a large capacitor directly to a battery can result in extremely high inrush current, additional circuitry is required to guarantee a limited controlled charge current and accurate final voltage.

Supercapacitors

The benefits of supercapacitors can be illustrated by considering the LED-based flash increasingly deployed in both digital cameras and camera phones. In these cases, currents of several amperes must be supplied for durations of up to 100ms.

The supercapacitor provides a reservoir to store the charge needed to power the LEDs, while driver circuitry regulates the constant current during the flash process. Additionally, because Li-ion battery voltage can range from 4.2V down to 3.3V when discharged, a boost converter will normally be required to step up the voltage and charge the capacitor to its nominal voltage.

Recently, to speed the implementation of such designs we have seen the advent of integrated driver ICs that combine both the LED driver capabilities and the supercapacitor charge functionality.

Figure 2, for example, illus-

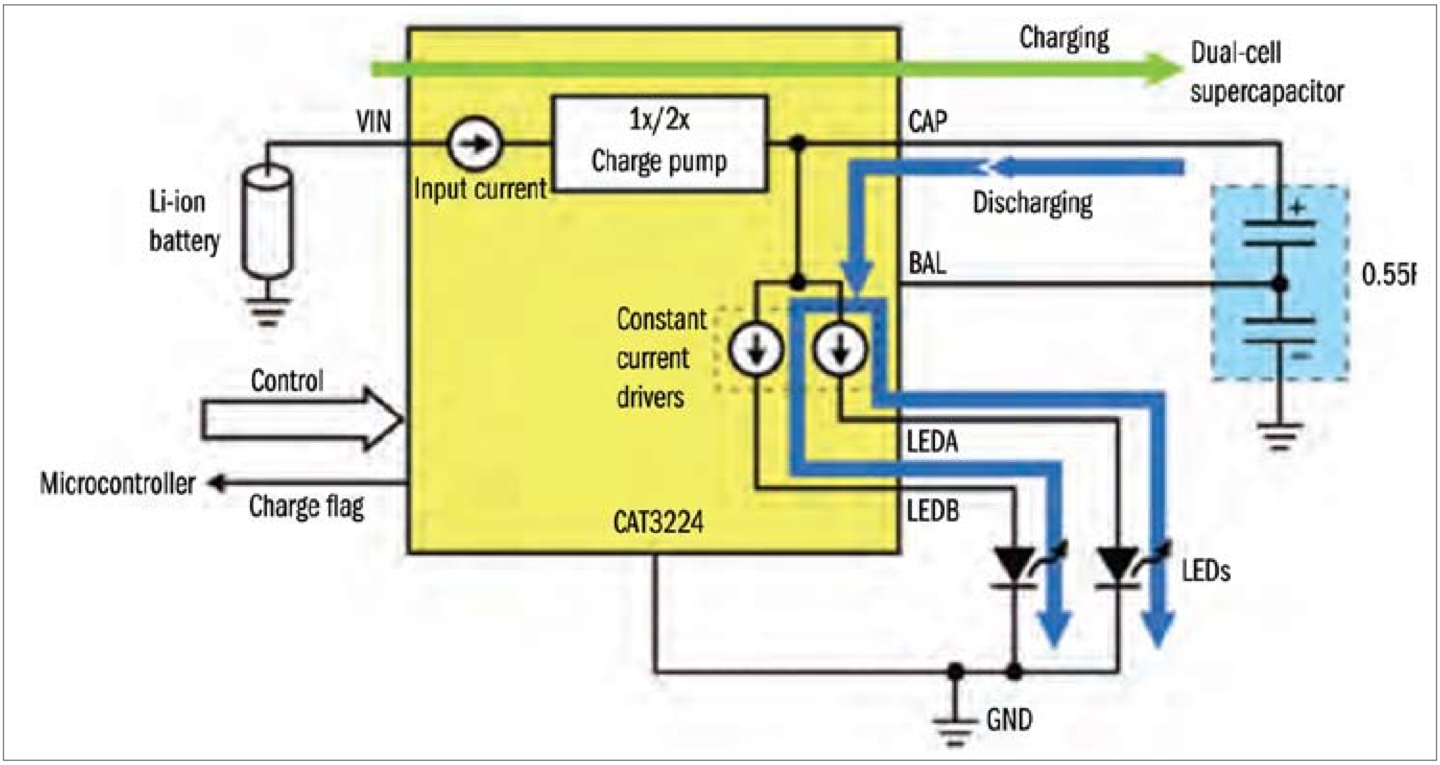

Figure 2: Shown is a supercapacitor charger and LED driver diagram.

trates an LED camera flash application that combines a supercapacitor with an integrated IC that brings together the functions of both supercapacitor charger and LED driver in a compact, 3mm x 3mm TQFN package.

If the supercapacitor is precharged up to 5.4V, it should have plenty of headroom for driving the LEDs with a typical forward voltage of 3.3V (allowing for part-to-part variation). The dual-mode charge pump in the IC starts in 1x linear mode and transitions to the 2x mode, as the capacitor voltage increases and approaches the battery voltage. The input current of the charger can never exceed a maximum current limit set by an external resistor, so as to protect the battery and supply rail from a sudden drop.

In 1x mode, the input current is effectively equal to the current charging the supercapacitor; while in 2x mode, the supercapacitor sees half the input current, as the voltage is doubled in the charge pump.

The maximum flash duration (T_{flash}), where the LED current is regulated, depends on the initial capacitor voltage (V_{cap}), capacitance value (C), LED forward voltage (V_F) and LED flash current setting. The total LED current equals to $IOUT = C \times \Delta V_{cap}/T_{flash}$, where ΔV_{cap} is the drop in the capacitor voltage due to the discharge.

Even in the worst-case scenario, where the charger is disabled, the capacitance can be calculated as follows:

where $I_{out}$is the capacitor's total output current, $R_{CAP\text{-}ESR}$ is the supercapacitor equivalent series resistance, and R_{LEDAB} is the LED A/B combined dropout resistance of the CAT3224 current sources. V_{cap}, the initial capacitor voltage, is set at around 5.2V typically. In this calculation, it is assumed that any interconnection parasitic resistance is negligible.

Conclusion

Combining supercapacitors with suitable charger and driver technologies provides a route to delivering the short duration high currents demanded in modern mobile products without compromising battery and system performance. As supercapacitor technology improves over time, with smaller packages being able to carry greater charge, large-scale adoption of these components within the handheld arena is certain. OEMs will be able to add more compelling functionality to their devices, despite the heavy loads involved, while still using more compact batteries with extended life time.

If the correct analog/power semiconductor devices to support these supercapacitors are employed (ensuring that their specifications are fully optimized), then the benefits to consumers will thus be three-fold; resulting in more handsets that are packed with exciting features, boasting smaller sleeker designs, and longer periods of operation between recharges.