Using Supercapacitors to Solve LED Flash Power Issues for High Resolution Camera Phones

Design Problem:
Greater than 2M pixel camera phones require a high intensity flash in medium to low light conditions to ensure good pictures. However, the battery cannot deliver the high current pulse required for adequate LED light output for high-resolution images. The alternative solution is to use a xenon flash, but this requires 1) a storage capacitor that is very bulky for mobile phone form-factors and 2) high voltage, resulting in circuit and safety issues. Also, with LED flash, the same LED circuit can be used at lower current for video capture/torch function.

To get around this power limitation some camera phone suppliers have used long flash exposure times to compensate for the lack of light, resulting in blurry photos.

Design Solution:
To provide enough LED flash power to eliminate dark and blurry photos, camera phone designers can use a high capacitance (0.4F to 1F), low ESR (less than 100 milliohms), thin (1 to 3 mm) prismatic supercapacitor. CAP-XX Inc. (http://www.cap-xx.com) is the only supplier of supercapacitors that meet these requirements.

Fig 1. shows a block diagram of the CAP-XX solution while Fig 2 shows a circuit implementation. A small, low-cost, current-limited charge pump pre-charges the supercapacitor to ~5.5V. Once the supercapacitor is charged, the current switch is enabled to deliver a high current flash pulse, with the energy and power from the supercapacitor rather than battery and charge pump. During the flash pulse the charge pump can either be enabled or disabled. The charge pump is current limited in to
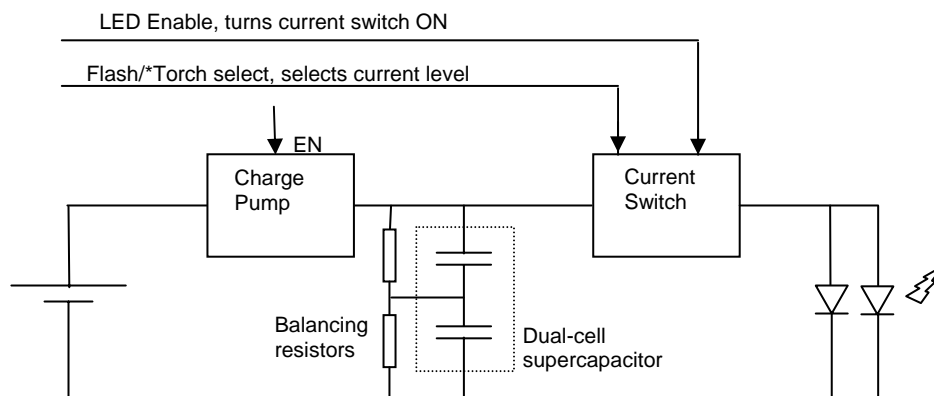
**Fig 1: High Power LED Supercapacitor Solution Block Diagram**

~300mA. In Torch mode, the charge pump is left enabled and the battery and charge pump can deliver a constant current less than the charge pump current limit.

For the reference design, CAP-XX chose the highest power LEDs, Lumileds LXCL-PWF1, which can handle a peak pulse current of 1A for < 200msecs. We drove 4 x PWF1 at 900mA each. The total LED current of 3.6A was limited by the Micrel MIC2545 current switch, was chosen for its current capacity and relatively small size. Supercapacitor C and ESR is selected as follows:

Total LED current (I_{LED}) = 3.6A for a 150msec flash pulse, denoted by PW_{FLASH}.

- From the Lumileds datasheet, at 0.9A nominal LED forward voltage = 3.75V, allow 4.2V

- From the Micrel datasheet, the R_{DSON} resistance < 50mΩ, so the voltage drop across the MIC2545 current switch < 180mV

- Therefore the minimum voltage at the supercapacitor at the end of the flash pulse must be $\geq$ 4.2V + 0.18V = 4.38V $\approx$ 4.4V

- Vout (charge pump voltage) is set to 5.3V, therefore the total voltage drop allowed at the supercapacitor, Vd = 5.3V − 4.4V = 0.9V

- Supercapacitor voltage drop, Vd = I_{LED} x (ESR + PW_{FLASH}/C)

- Or, re-arranging terms, C $\geq$ I_{LED} x PW_{FLASH} /(Vd − I_{LED}xESR)

- In the above example, C $\geq$ 2A x 0.15s/(0.9V − 2AxESR)

- Assume a supercapacitor ESR = 100mΩ, then C $\geq$ 2A x 0.15s/(0.9V − 2Ax0.1Ω) = 0.43F. Select a supercapacitor with $\approx$ ½ the assumed ESR to allow for ageing over life. CAP-XX GS206 (0.55F, 50mΩ) meets the requirements.
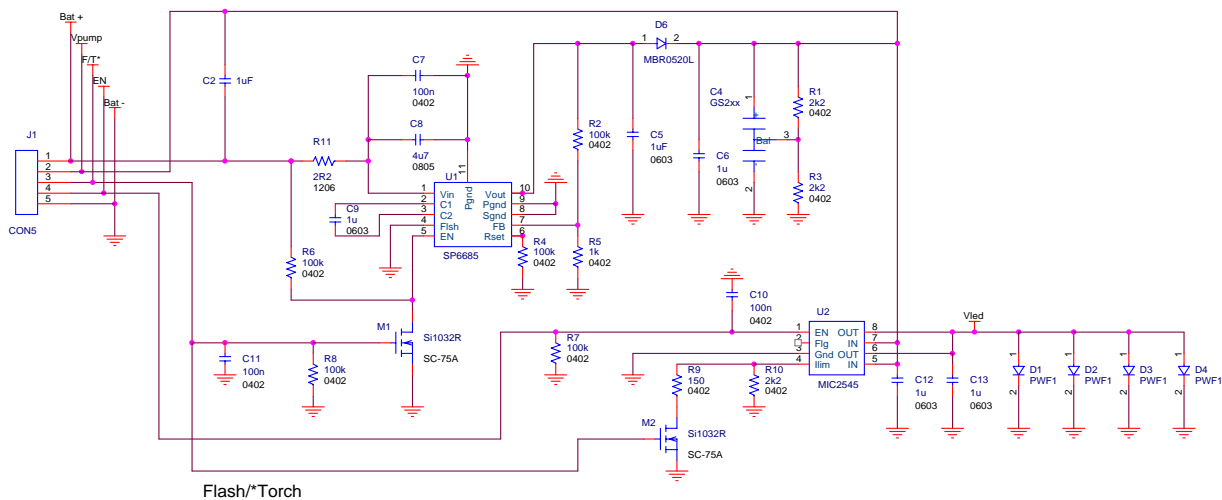
Fig 2: CAP-XX Supercapacitor Solution Circuit Implementation

Note that two supercapacitor cells are used in the circuit to achieve the necessary voltage rating of 5.5V maximum voltage. 100mΩ is a good starting guess for ESR. Designers may need to iterate between C & ESR to find a suitable supercapacitor. Set the charge pump output voltage to the lowest possible current while still having sufficient headroom for the solution.

Charge pump selection is not critical. We selected the SP6685 for its small size. Note that the soft start function of most charge pumps will not properly handle a supercapacitor at the output, but adding a current limit resistor at the input to the charge pump (R11 in Fig 2) is a simple solution if this is an issue.

Results:
CAP-XX was able to place two supercapacitor cells, the circuit of Fig 2 and four replacement LEDs in a leading brand camera phone and put it back together with no changes in external appearance. Fig 3 shows photos taken using the unmodified and CAP-XX-modified phone. The unmodified phone delivered 1W of flash power for 160ms while the modified phone delivered 15W of flash power for 160ms.

Fig 3: Photos in low light with normal phone (left) and phone modified with CAP-XX supercapacitor-based solution (right)

Fig 4 shows the battery current, LED current and supercapacitor voltage during a flash pulse and supercapacitor re-charge after the pulse. Note that battery current never exceeds 300mA even though the flash pulse is 4A. The supercapacitor provides the 3.7A difference.
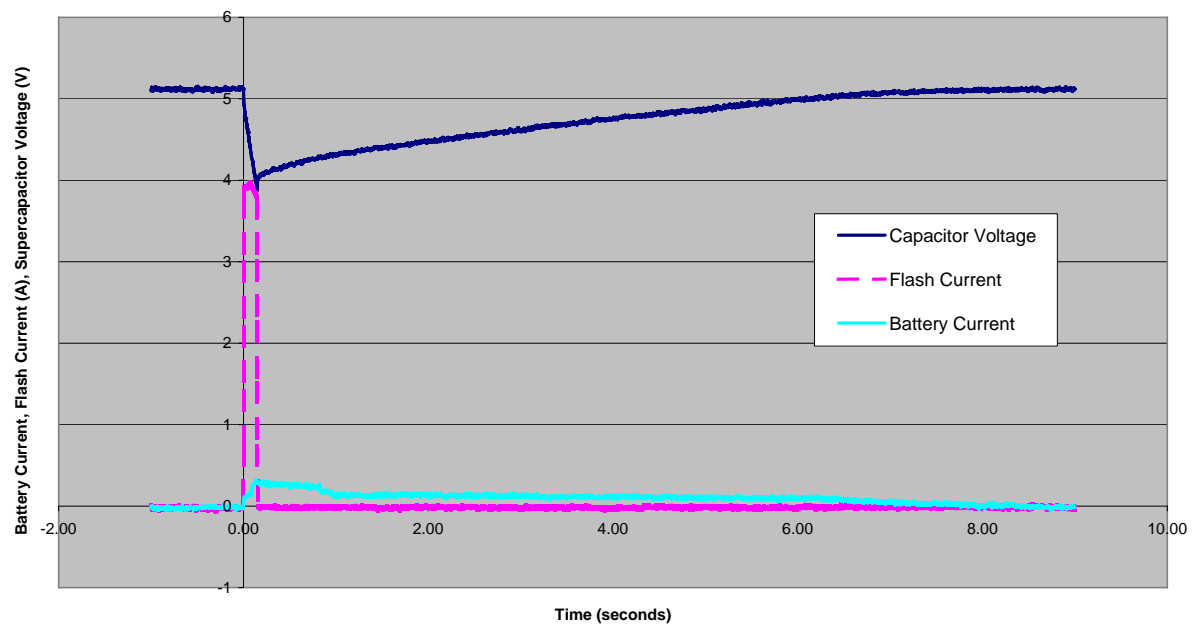
Fig 4: Battery current, LED current and Supercapacitor Voltage for the CAP-XX solution

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