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APPEB1008 User's Manual
Camera Phone Flash Evaluation Board

WARNING: Limit max duration of FLASH to no longer than 200mS or damage to LEDs may result due to LED thermal properties. Allow 3 seconds between flashes.

APPEB1008 is a high current FLASH LED PCB that uses minimal circuitry to pre-charge a supercapacitor and then discharge LEDs at high current. The purpose of this PCB is to demonstrate the minimum LED driver circuit required to deliver very high power to Flash LEDs using a supercapacitor. Fig 1 shows a picture of this PCB.

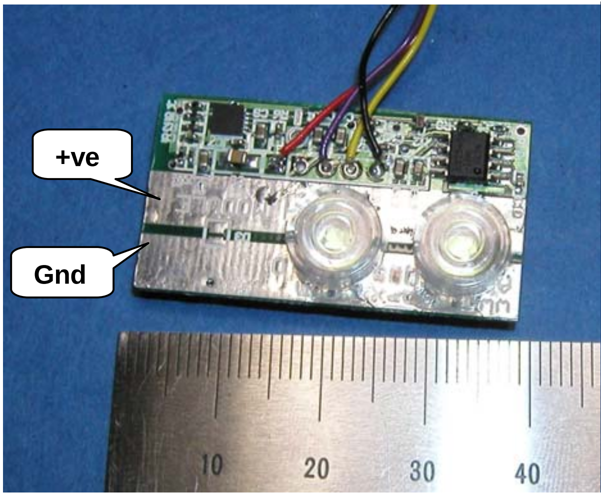

Fig 1a, Top side APPEB1008

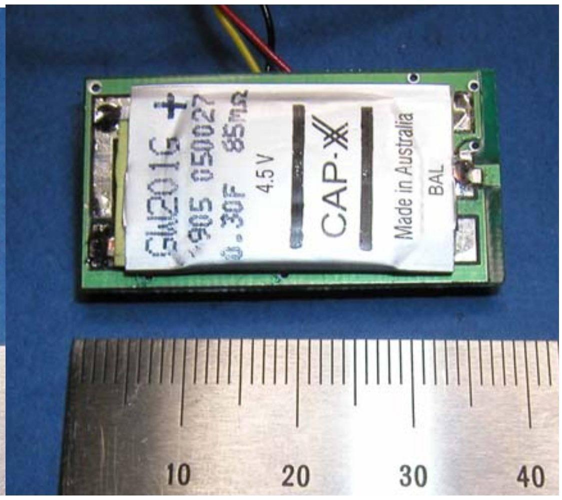

Fig 1b, Underside APPEB1008

Referring to CAP-XX Application Note 1004, this PCB can be configured either as solution B (circuit diagram Fig 5) or as solution C (circuit diagram Fig 6).

Configuring the evaluation PCB

The PCB is configured as Solution B or Solution C by making the appropriate connections on the underside when placing the supercapacitor. Fig 2a shows the configuration for Solution B and Fig 2b shows the configuration for Solution C.

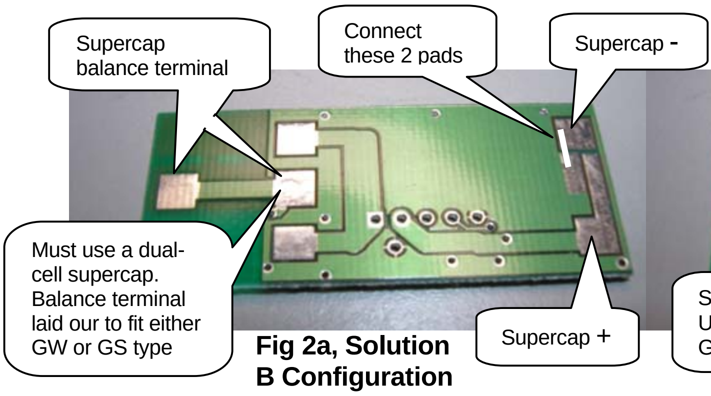

Fig 2a, Solution B Configuration

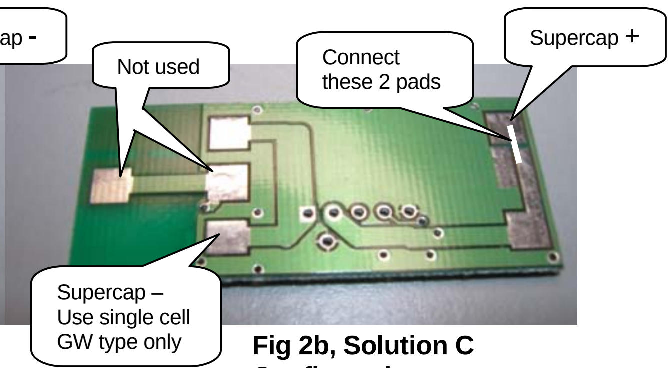

Fig 2b, Solution C Configuration

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Signal Connections

Red: Vbatt+
Must be in the range 3.0 to 5.0V

Black: Vbatt-

Purple: Flash/*Torch select.
Select Torch with signal low (in the range 0V to 0.5V) or floating,
Select Flash with signal Hi (in the range 2V to 5V), must be able to source ≥50μA
Connected to a 100KΩ pull down resistor on the PCB

Yellow: LED enable
Set this signal Hi (in the range 2V to 5V) to turn LEDs on
Set this signal Lo (in the range 0V to 0.5V) or floating to turn LEDs off
Connected to a 100KΩ pull down resistor on the PCB

Operation (Solution B configuration)

Fig 3 shows the solution B block diagram. The supercapacitor is in parallel with the output of the charge pump and the LEDs.

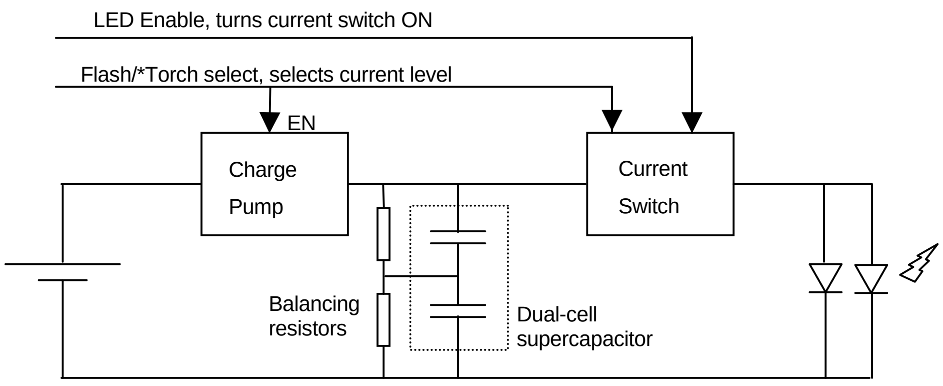

Fig 3, Solution B Configuration Block Diagram

Refer to Fig 5, the circuit diagram for the Solution B configuration of APPEB1008. C4 is the dual cell supercapacitor.

When power is first applied, the Flash/*Torch select must be low or floating so that U1 (SP6685 charge pump) is enabled. When the Flash/*Torch input is low or floating, M1 is OFF and U1 pin 5 (EN) is pulled high through R6. Depending on the size of the supercapacitor you will need to wait 10 – 15 secs before the supercapacitor is fully charged from 0V. Fig 7 shows the battery current and supercapacitor voltage when charging a GS206 (0.55F). Peak battery current is limited to ~750mA. This reduces quickly as the supercapacitor charges. There is a high inrush current when the supercapacitor is at 0V since until it is charged to a voltage ≥ Vin it looks like a short circuit on the output of the charge pump. R11 was added to the circuit to limit this inrush current.

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Note that the SP6685 is only used to charge the supercapacitor so it is always in its Torch mode (pin 4, Flsh connected to Gnd).

Once the supercapacitor has been charged, select Flash or Torch mode. When this signal is Hi (Flash mode), M2 is ON which sets the current setting resistor for U2 (MIC2545) = R9//R10 = 120Ω//1150Ω ≈ 110Ω. This sets the LED current ≈ 2A.

The LEDs are on while the Enable input (U2 pin1) is held Hi. This turns on U2. Due to the very large capacitance of the supercapacitor, the flash pulse discharges the supercapacitor only a relatively small amount, typically < 1V (see section On Supercapacitor Selection). This means the time to re-charge the supercapacitor between flash photos is short, typically ~2 secs. This is shorter than time the LEDs require between flashes to cool down. Fig 8 shows the supercapacitor voltage, battery current and LED current during and after a flash pulse. D6 was added to mprevent the supercapacitor discharging into the battery through U1 when U1 is disabled.

In the CAP-XX factory setup, the charge pump is disabled when Flash mode is selected. When the Flash/*Torch is Hi, M1 is turned ON which pulls U1 pin5 low, turning off U1. In the solution B configuration, this means that the battery is contributing zero current during LED Flash, so the battery can provide power to transmit a GSM pulse if necessary during LED flash. Alternatively, the user can remove M1. This allows the charge pump to continue operating during the LED Flash, so the battery is contributing ~300mA to the LED current. This enables a smaller supercapacitor to be used for a given flash pulse (see Supercapacitor selection). Note that if M1 is removed, then U1 is always enabled and the stipulation above that Flash/*Torch should be Lo or floating on power up is no longer required. With M1 removed Flash/*Torch can be in any state during power up.

Operation (Solution C configuration)

Fig 4 shows the solution C block diagram. The supercapacitor is in series with the positive terminal of the battery. In this configuration only a single cell supercapacitor is required. This is ~half the volume of the dual cell supercapacitor required for solution B and is also lower cost. However, the battery current = LED current, unlike solution B where battery current = supercap charge current only (and can = 0 during LED Flash). This configuration enables you to achieve much higher LED current for a given battery current than would be possible

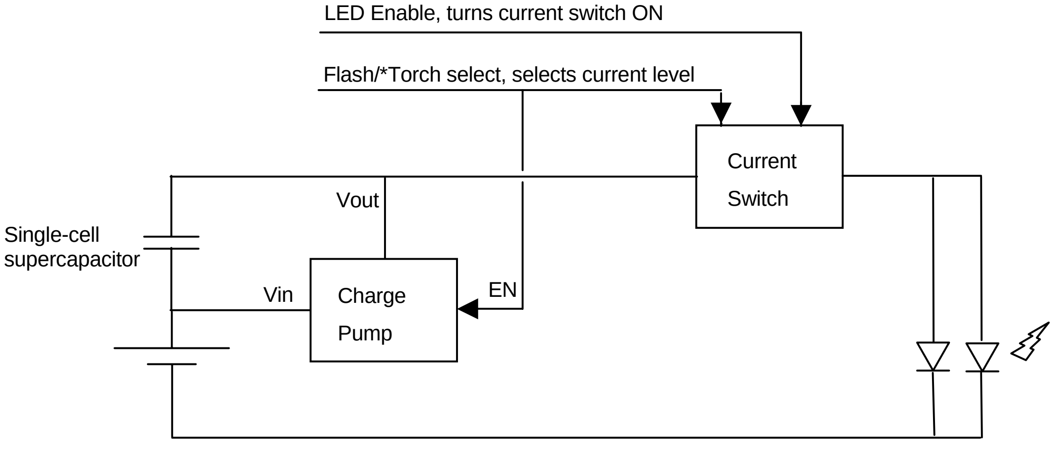

Fig 4, Solution C Configuration Block Diagram

using a “standard” topology of a current limited boost converter or charge pump to directly drive the flash LEDs. Consider a charge pump driving an LED at 70% efficiency with the LED current 800mA.

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Assume the LED forward voltage = 4.0V and the battery voltage = 3.3V. Then without the supercapacitor, battery current = 800mA x 4.0V/3.3V /70% = 1.4A which is too much for the battery to comfortably deliver and still power the rest of the phone. With Solution C, battery current is only 800mA.

Refer to Fig 6, the circuit diagram for the Solution C configuration of APPEB1008. C1 is the single cell supercapacitor.

In the same manner as for solution B, when power is first applied, the Flash/*Torch select must be low or floating so that U1 is enabled. Depending on the size of the supercapacitor you will need to wait 3 – 6 secs before the supercapacitor is fully charged from the battery voltage (0V across the supercapacitor) to the starting value of Vled (~5.1V or 1.2V across the supercapacitor). Fig 9 shows the battery current and supercapacitor voltage when charging a GW101 (0.6F). Peak battery current is limited to ~300mA during charging. This reduces quickly as the supercapacitor charges. The charge pump behaviour in Solution C is different to Solution B because Vout ≥ Vin always and the charge pump never sees the supercapacitor as a short circuit. Like Solution B, the charge pump, U1, is only used to charge the supercapacitor so it is always in its Torch mode (pin 4, Flsh connected to Gnd).

Once the supercapacitor has been charged, select Flash or Torch mode. When this signal is Hi (Flash mode), M2 is ON which sets the current setting resistor for U2 (MIC2545) = R9//R10 = 120Ω//1150Ω ≈ 110Ω. This sets the LED current ≈ 2A. Flash/*Torch Hi also turns ON M1 which disables the charge pump (pulls U1/pin5 Lo). This is done in solution C since the battery is already supplying the LED current through the supercapacitor. Leaving the charge pump enabled would cause the battery to provide > LED current with efficiency < 100%.

As in Solution B the flash pulse discharges the supercapacitor only a relatively small amount, so the time to re-charge the supercapacitor between flash photos is short, typically shorter than time the LEDs require between flashes to cool down (~2 secs). Fig 10 shows the supercapacitor voltage, battery current and LED current during and after a flash pulse.

Supercapacitor selection

The supercapacitor must have low enough ESR and sufficient C so that Vled at the end of the flash pulse is > forward voltage of the LEDs at the flash current. Supercapacitor selection will be illustrated by the following examples:

Solution B configuration example:

Drive 2 x Lumileds LXCL-PWF1 in parallel at 1A each (= 2A total current, denoted by I_{LED}) for a 150msec flash pulse, denoted by PW_{FLASH}.

- From the Lumileds datasheet, at 1A the forward voltage = 3.8V, allow 4.2V
- From the Micrel datasheet, the R_{DSON} resistance < 50mΩ, so the voltage drop across the MIC2545 current switch < 100mV
- Therefore the min voltage at the supercap at the end of the flash pulse = 4.2V + 0.1V = 4.3V

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- Vout (charge pump voltage) is set to 5.2V, therefore the total voltage drop allowed at the supercapacitor, Vd = 5.2V – 4.3V = 0.9V
- Supercapacitor voltage drop, $Vd = I_{LED} \times (ESR + PW_{FLASH}/C)$
- Or, re-arranging terms, $C \geq I_{LED} \times PW_{FLASH} /(Vd - I_{LED} \times ESR)$
- In the above example, C ≥ 2A x 0.15s/(0.9V – 2AxESR)
- Assume a supercap ESR = 100mΩ, then C ≥ 2A x 0.15s/(0.9V – 2Ax0.1Ω) = 0.43F. Select a supercapacitor with ≈ ½ the assumed ESR to allow for ageing over life. CAP-XX GS206 (0.55F, 50mΩ) meets the requirements.
- Note that for Solution B configuration you must use a dual cell supercapacitor (rated for 4.5V continuous operation) which is GS2xy or GW2xy in CAP-XX part numbering. 100mΩ is a good starting guess for ESR. There may then need to be some iteration between C & ESR to find a suitable supercapacitor.

Solution C configuration example:

Drive 1 x Lumileds LXCL-PWF1 at 0.8A for a 250msec flash pulse. Namenclature is as for Solution B.

- From the Lumileds datasheet, at 0.8A the forward voltage = 3.7V, allow 4.1V
- From the Micrel datasheet, the R_{DSON} resistance < 50mΩ, so the voltage drop across the MIC2545 current switch < 40mV
- Therefore the min voltage at the supercap at the end of the flash pulse = 4.1V + 0.04V = 4.14V
- Vout (charge pump voltage) is set to 5.2V, therefore the total voltage drop allowed at the supercapacitor, Vd = 5.2V – 4.14V = 1.06V
- Assume a supercap ESR = 50mΩ, therefore C ≥ 0.8A x 0.25s/(1.06V – 0.8Ax0.05Ω) = 0.196F. Choose GW109, C = 250mF, ESR = 35mΩ. Allow for ESR to double, so substitute 70mΩ & 250mF for ESR & C in the expression for Vd and check the voltage drop is < 1.06V:

  Vd = 0.8A x (70mΩ + 0.25s/0.25F) = 0.8 x 1.07 = 0.86 < 1.06V
- Therefore choose GW109 (250mF, 35V)

Note: CAP-XX product bulletins for supercap selection are available at http://www.cap-xx.com/products/products.htm

Mounting the LEDs

The PCB comes factory fitted with 2 x LXCL-PWF1, datasheet at http://www.luxeon.com/pdfs/DS49.pdf . The LEDs are soldered onto a bus on the PCB, +ve and -ve are shown on Fig 1a. To replace them with other LEDs if required, use a hot air gun to flow the solder and then replace them.

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Setting the supercapacitor charge voltage
The charger o/p voltage = V_{FB} x (R2 + R5)/R5, where V_{FB} = 50mV ± 5mV. This has been factory set ~5.2V. The charge pump internally limits the output voltage to 5.5V. It is not recommended to increase the charge pump output voltage without first consulting CAP-XX. This voltage can be reduced by replacing one or both of R2, R5 to reduce the ratio (R2 + R5)/R5.

Setting the LED Torch current
Torch current ≈ 230/R10 (from the MIC2545 datasheet). This is factory set to 190mA (R10 = 1200Ω). Replace R10 to change the Torch current.

Setting the LED Flash current
LED current ≈ 230/(R10//R9) = 230xR10xR9/(R10+R9). This is factory set to 2.1A (R9 = 120Ω), R10//R9 = 109Ω. Replace R10 and R9 to select suitable values of Torch & Flash current.

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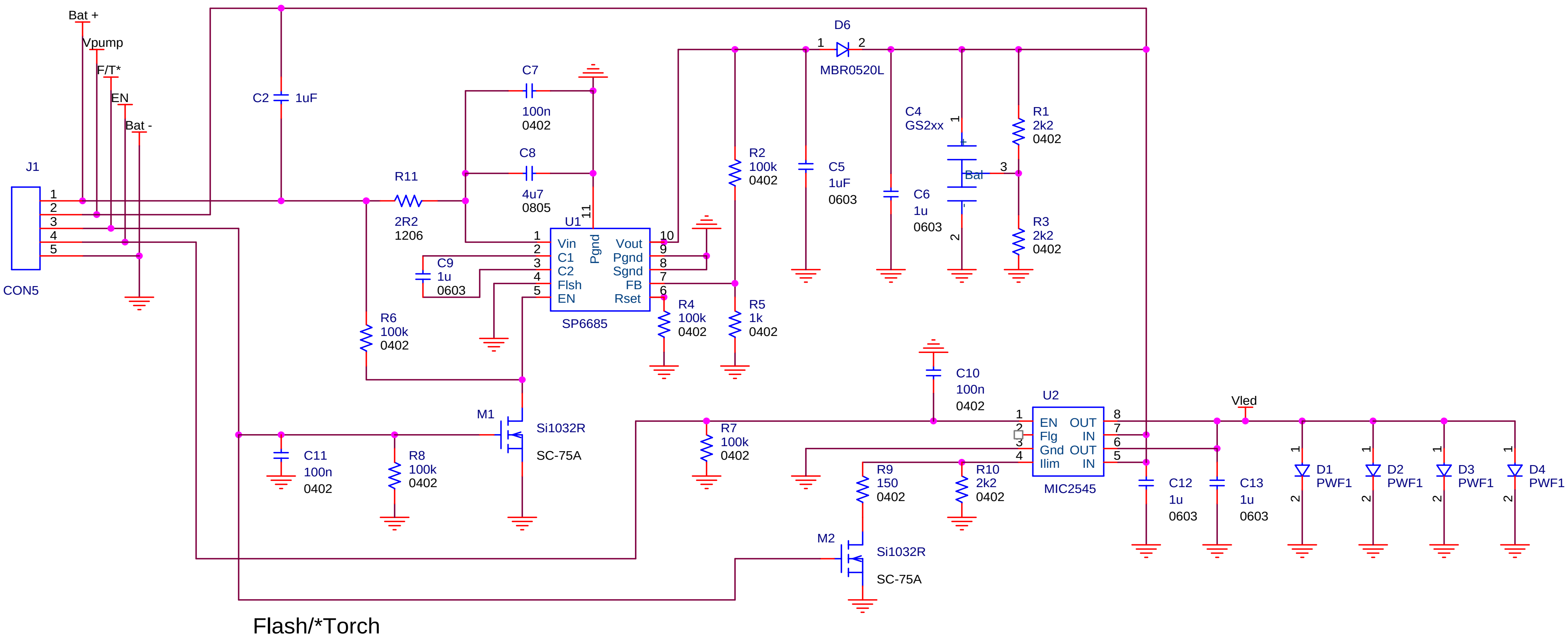

Fig 5: APPEB1008 Configuration B, supercapacitor in parallel with the LEDs

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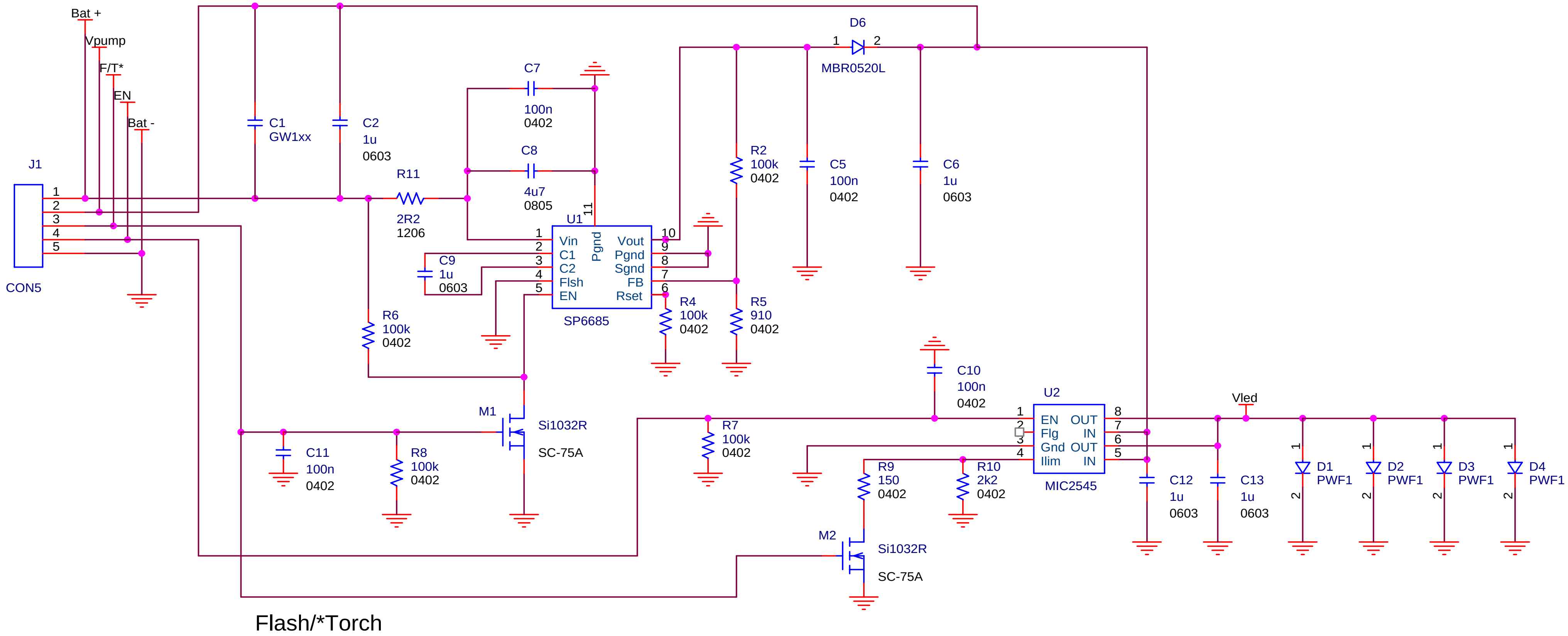

Fig 6: APPEB1008 Configuration C, supercapacitor in series with the battery

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Soln B Charging supercapacitor from 0V

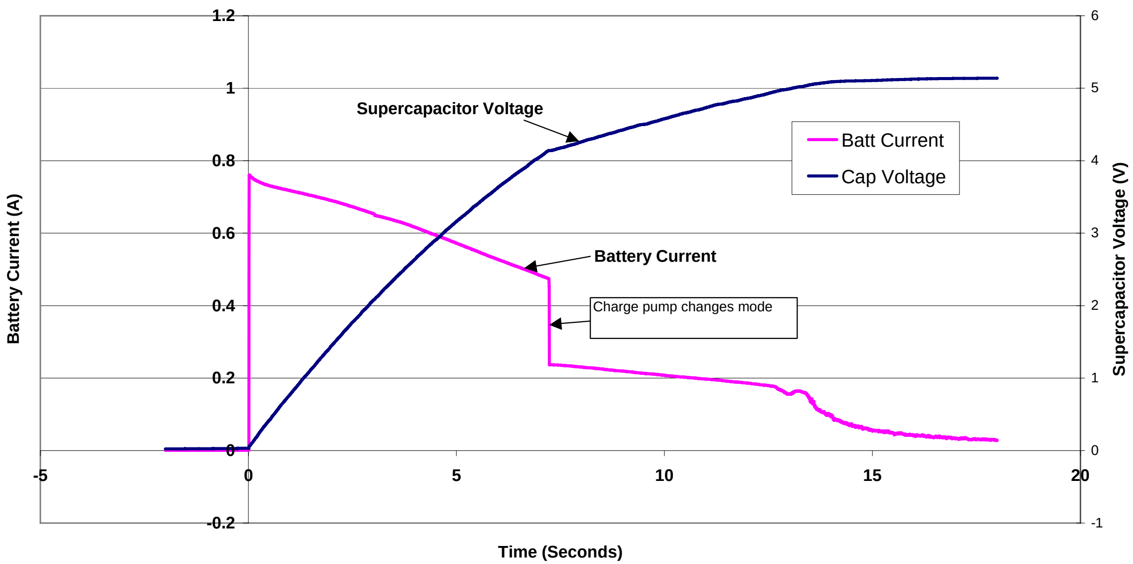
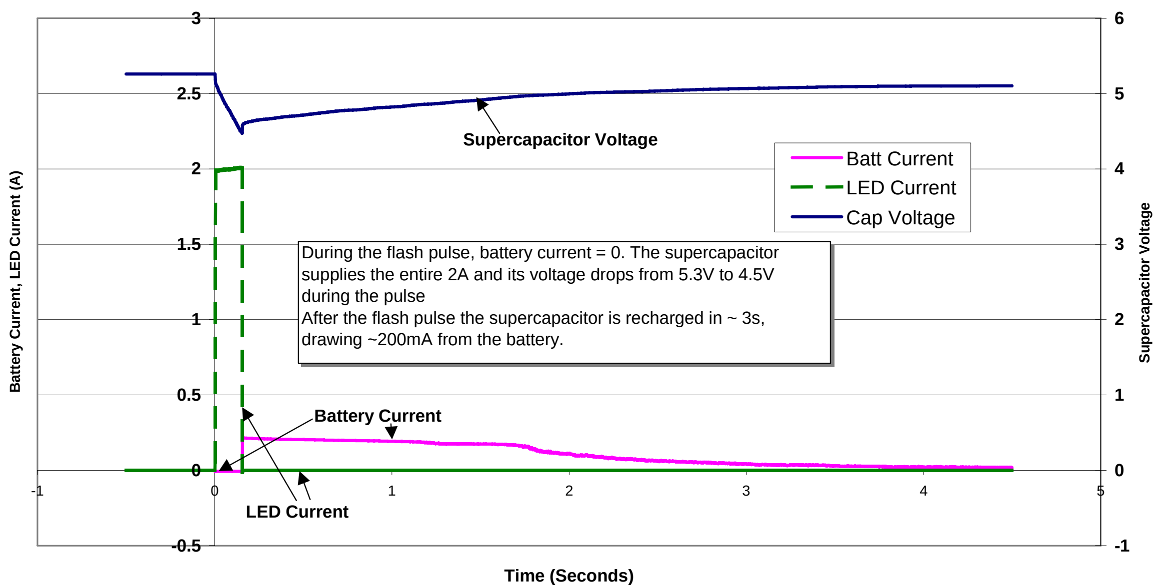


Fig 7

Fig 8

Soln B Flash pulse and supercap re-charge



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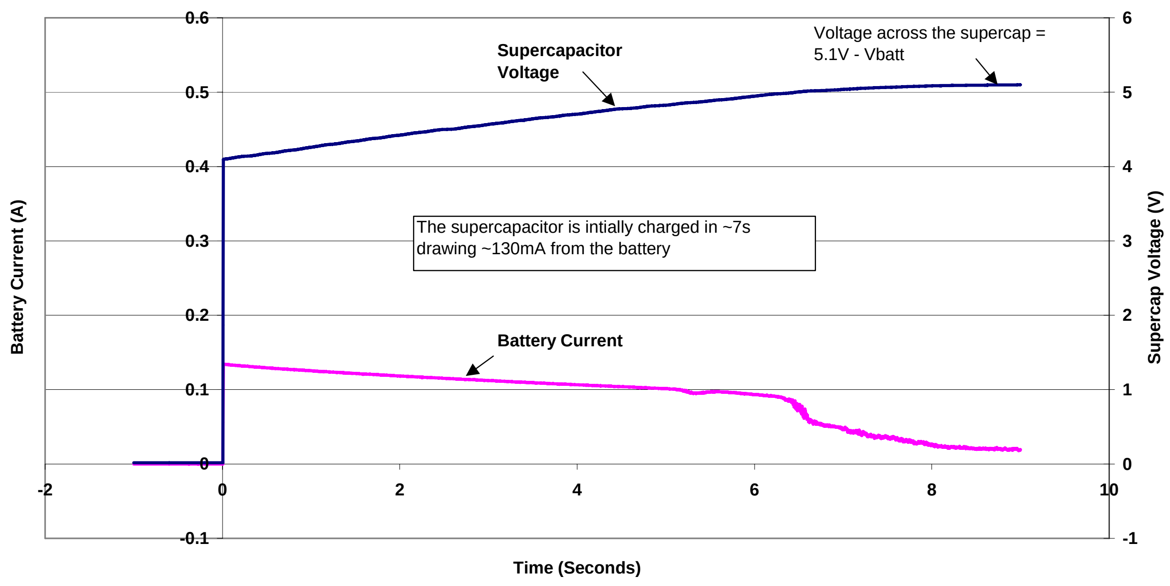
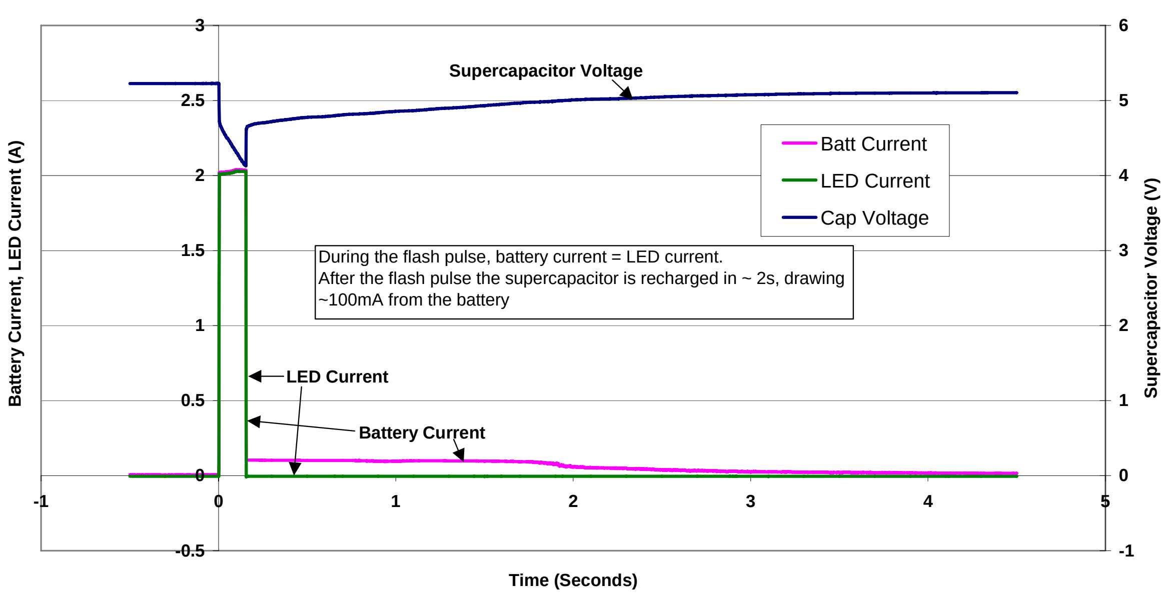


Fig 9

Fig 10



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