



Storing Power with Super/Ultra Capacitors

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- **Problem/Solution in Portable Systems**
- **Super/Ultra Capacitors**
 - Benefits
 - Issues
- **Super/Ultra Capacitor Charging Options**
- **Example 1**
 - GSM GPRS Application/Test Results
- **Example 2**
 - Flash LED Application/Test Results

Problem: High Current Devices are Required in Portable Systems

- Limited sourcing current
- Standards limitation
- System/battery limitation

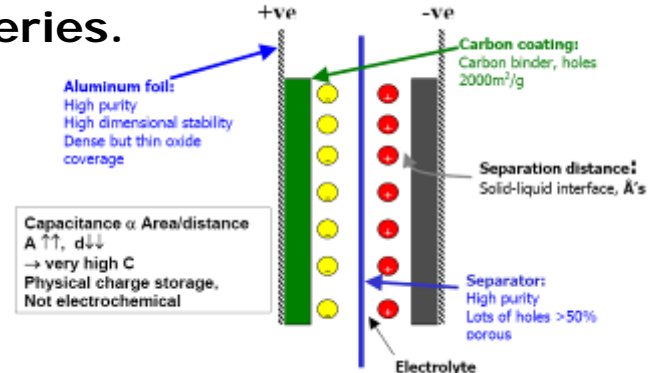
PC Card	
Voltage	Current Level (max)
3.3V	1000mA
5.0V	1000mA
Express Card	
Voltage	Current Level
3.3V	1300mA
USB Port	
Voltage	Current Level
5.0V	500mA

Solution: Super/Ultra Capacitors

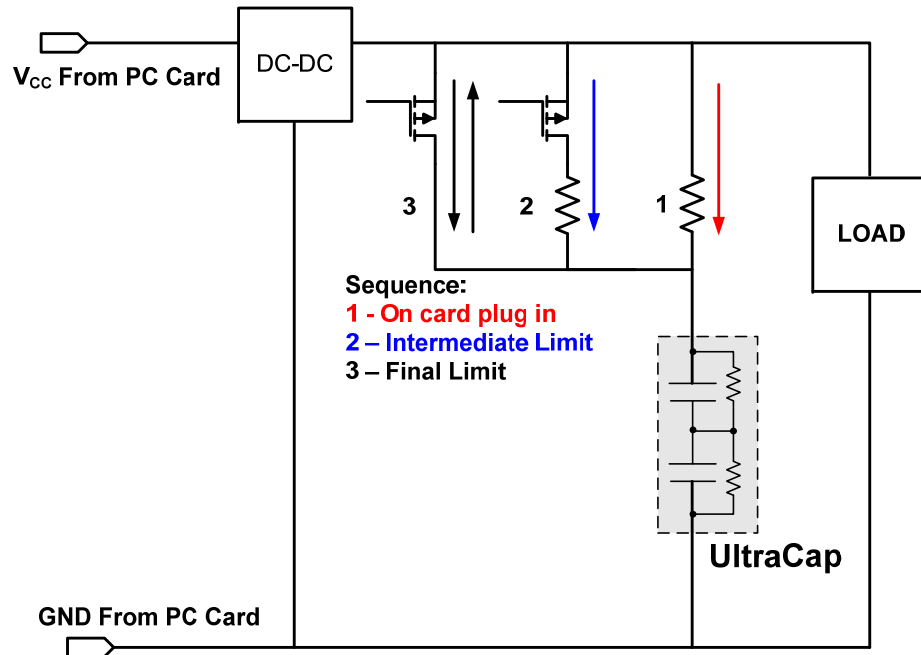
1. Can provide over 2A for a short duration from a laptop or other handheld device that has limited current sourcing capability
2. High power available for load leveling
3. Higher energy storage than Electrolytic



- **High-Capacity Capacitor**
 - Farads rather than micro-Farads
 - Values ranging from 30mF up to 2F
- **Recharge in seconds with >500k Cycles**
 - Stores energy in an electrostatic field not a chemical state
- **Small ESR, low impedance**
 - 30 – 185mΩ
- **Extends battery life by five times**
 - 'Averages out' high power demands
- **Manufactured in any size and shape**
 - Flat and small size
- **Allow smaller, lighter and cheaper batteries.**
- **Long life, 10 to 12 yrs**
- **Open-circuit (high ESR) failure mode**
 - Carbon, aluminum, organic electrolyte



- **Need to control inrush charge current**
 - Due to low ESR
- **Need to recharge when voltage drop/droop is below operational limit of system requirement**
- **Need to disconnect SC/UC from source**
 - Short circuit protection
 - Source OV protection
 - Current flow protection
- **Max voltage, Temperature Range, ESR**
 - 2.75/cell to 5.5V, 70 to 85°C, 30 to 185mΩ
 - Cell balancing resistors required for stacked SC
 - To Achieve Higher operating voltage



Pro

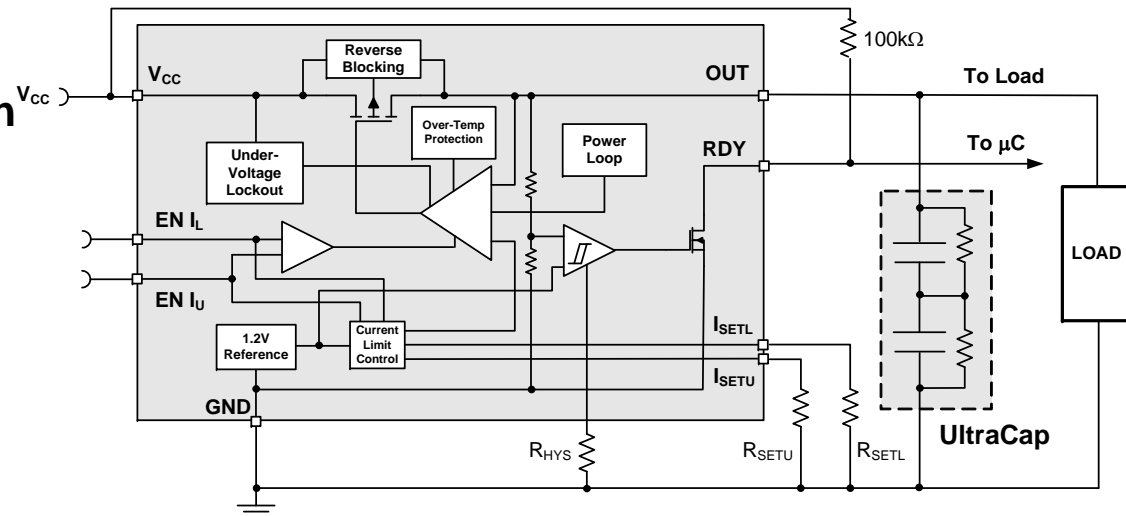
- Inexpensive

Con

- Switch in different R values
 - Requires Timed/Monitored
- Resistor values must be accurate
- Loss across resistor
- Long Charge Time if single R used

Option 2: Current Limiting Smart Switch with SC/UC charger

- **Independent Current Limits with Soft-Start - 75mA to 1200mA**
 - Power Loop (thermally activated current reduction)
 - Minimizes charge time while controlling power dissipation
- **Reverse Current Blocking**
 - Prevents discharge of the Ultra Cap back to the power supply
- **50-65mW Typical RDS(ON)**
 - Charges capacitor voltage close to the input supply
- **System READY Output**
 - Alerts the system that the cap is charged and ready
- **Programmable Hysteresis**
 - Adjustable recharge
- **Over-Temperature Protection**
- **Short Circuit Protection**
- **Under-voltage Protection**
- **Low Quiescent Current**



- **Example 1: PA Power for Cell Phone Data Cards**
- **HSPA and quad-band GSM/GPRS/EDGE**
 - USB - 1.8 to 3.1 MBPS
 - PC/EXPRESS CARD - 2 to 7.2 MBPS



PC Card



ExpressCard



USB

- **Example 2: High Current Flash LED for Ca**
 - Flash 1A, 2A and 4A
 - Movie/Torch Mode



GPRS (General Packet Radio Service)

- First Column - Speed is a function of the **GPRS Multislot Class**.
- Second Column - downlink timeslots receiving data from the network
- Third Column - uplink timeslots to transmit data to the network

Multislot Class	Downlink Slots	Uplink Slots
2	2	1
4	3	1
6	3	2
8	4	1
10	4	2
12	4	4
32	5	3

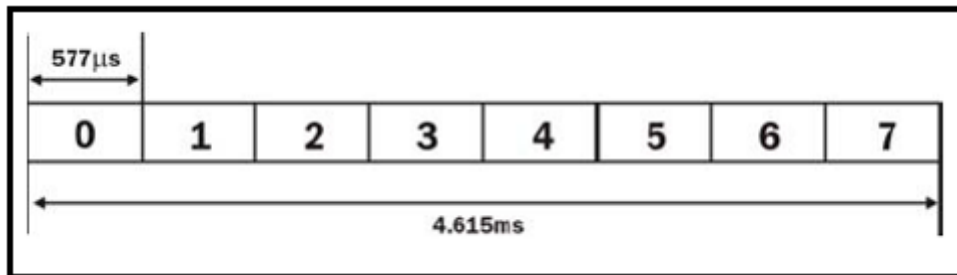
The most common GPRS multislot classes are:

- Class 8 - 33% faster data download than Classes 4 & 6
- Class 10 - better data uploading than Class 8
 - Cell phones and PC/Express Cards
- Class 12 - maximum upload performance
 - High-end PC Cards

GPRS Transmit = PA drive current

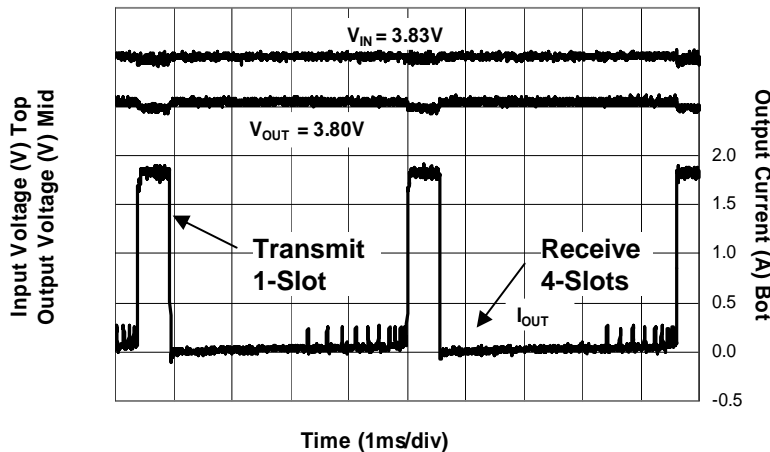
Class 8 (4R1T) = 4 receive slots and 1 transmit timeslot

Class 10 (3R2T) = 3 receive slots and 2 transmit timeslots

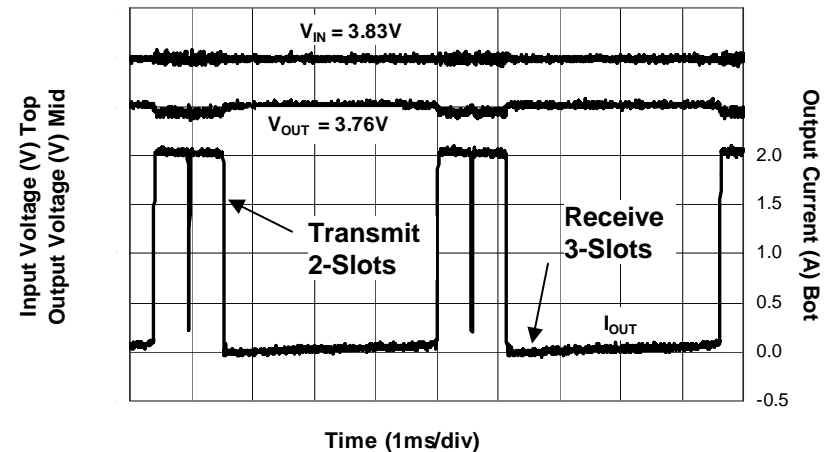


GSM FRAME = 8 TIMESLOTS

CLASS 8
GPRS Transmit 1-Slot Ch975, 33dBm

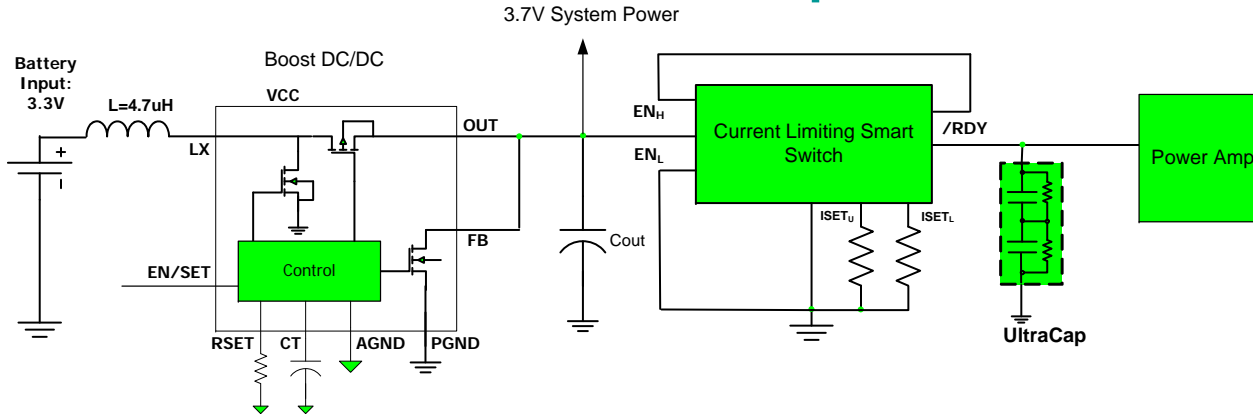


CLASS 10
GPRS Transmit 2-Slot Ch975, 33dBm



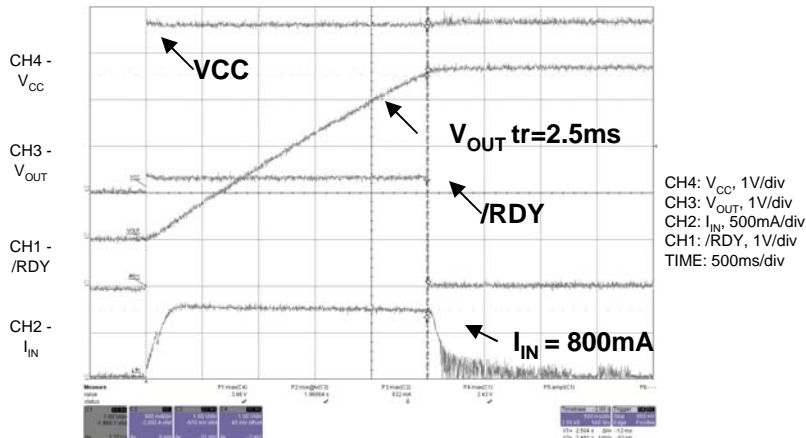


Boost Converter plus Smart Switch

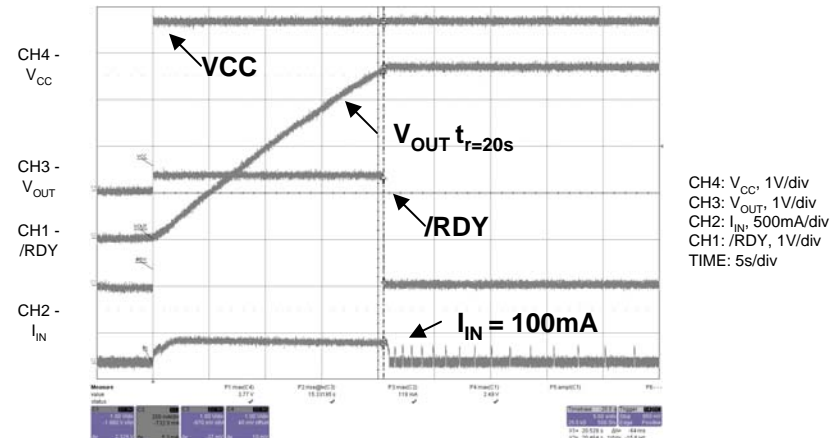


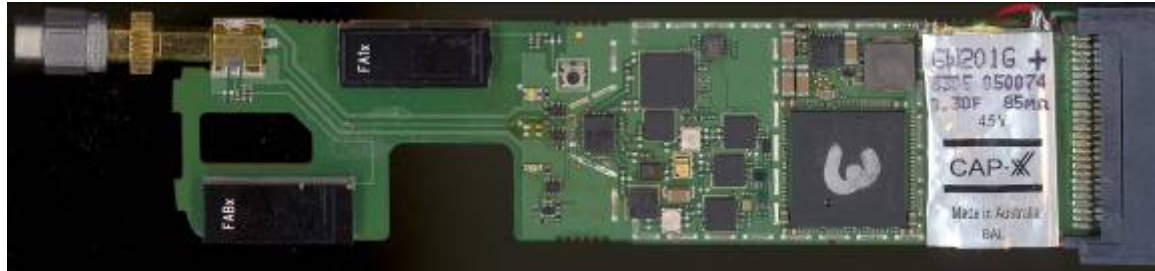
- Important features
- Charge ramp of the UC
 - R_{DSon} source IR drop
 - Duration of the current pulse

Startup waveform no load 800mA current limit



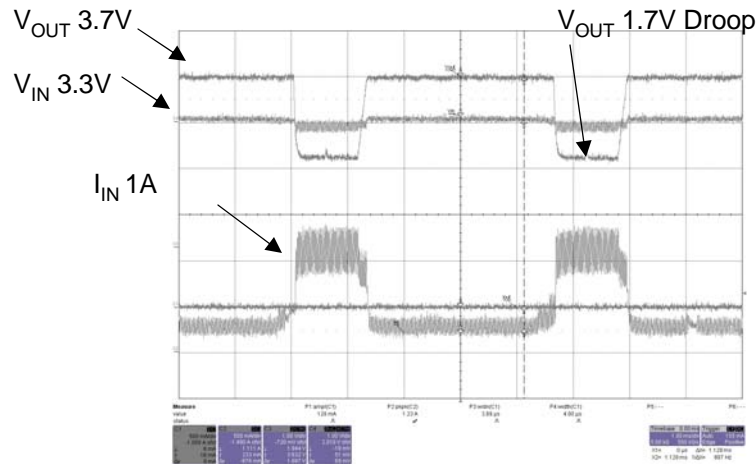
Startup waveform no load 96mA current limit



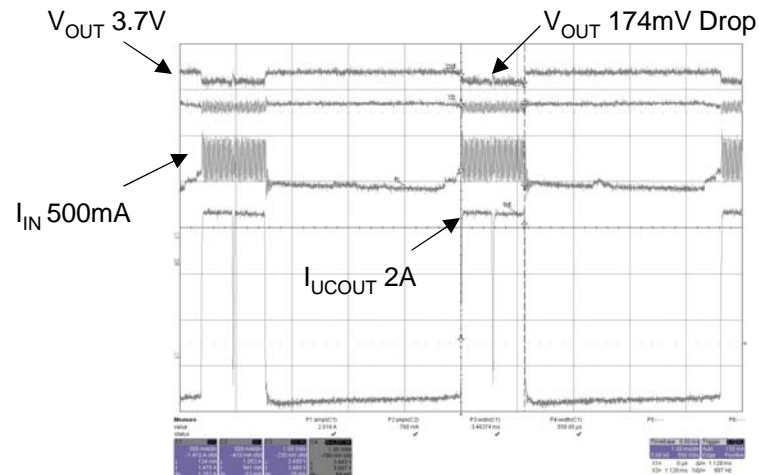


3.3V Express card, $V_{out}=3.7V$, Ultra Cap=Cap-XX GW201G, 0.3F, 85mΩ
 $V_{drop}=I \cdot ESR + I \cdot (tmS/CmF)$

Wireless GSM Card w/o Ultra Cap



Wireless GSM Card with Ultra Cap



The initial IR voltage drop caused by the Ultra Cap ESR plus the Cap voltage drop
 $V_{DROP} = 2A \times 85m\Omega + (2 \times (1.154mS/300mF)) = 174mV$

- **Ultra Caps Can Operate High Current Devices Such as rf PAs during Transmit**
 - Load Leveling, Energy Storage
- **UCs are getting smaller**
 - Improved Specs
 - Temp Range (85°C) and Max Voltage Limits (5.5V)
- **Battery Life and System Operation Improved**
- **Meets Standards and Run Time Requirements**
- **A Current Limiting Smart Switch Alleviates the Issues with Super/Ultra Caps**
 - Inrush Control
 - Short circuit protection
 - Source OV protection
 - Current flow protection

Why is Camera Flash Needed?

- Camera/Smart phone camera resolution continues to improve
- Image sensors need more light for high MPix photos
- 1st Generation Camera Phone Flash offers limited light intensity
- 2nd Generation Camera phone Flash still not suitable for >3MPix cameras
- Video capture requires Movie/Torch Mode

- **WLED Flash**

- Charge-pump based, limited to up to 800mA
- Inductive based Step-up Converter
 - Limited to 1-1.5A
 - High Input Battery Current

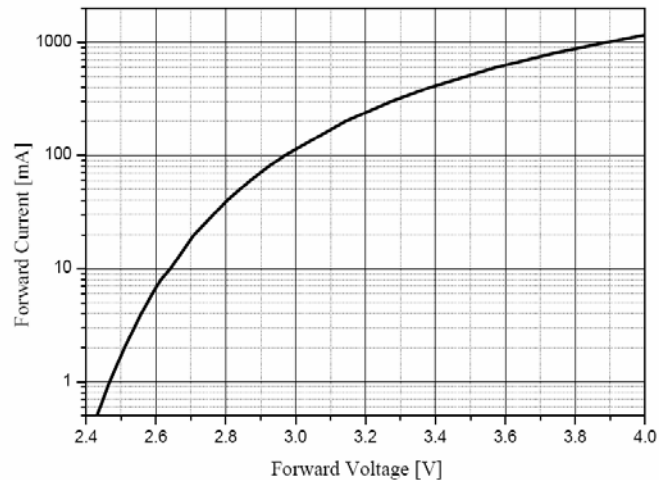
- **Xenon Flash**

- Requires high voltage, 300V with ignition at several kVs
- Bulky
 - Reflector
 - Capacitor
- Cannot do torch mode
- Fragile

- **High intensity LEDs require large currents**

- High-Intensity LEDs requiring $>1A$
- LED V_F is Proportional to I_D

Forward Current vs. Forward Voltage



- Step-up converter required to provide compliance voltage from Lithium Ion Battery
 - $3.0V - 4.2V \leq V_F$

- **Typical Example:**

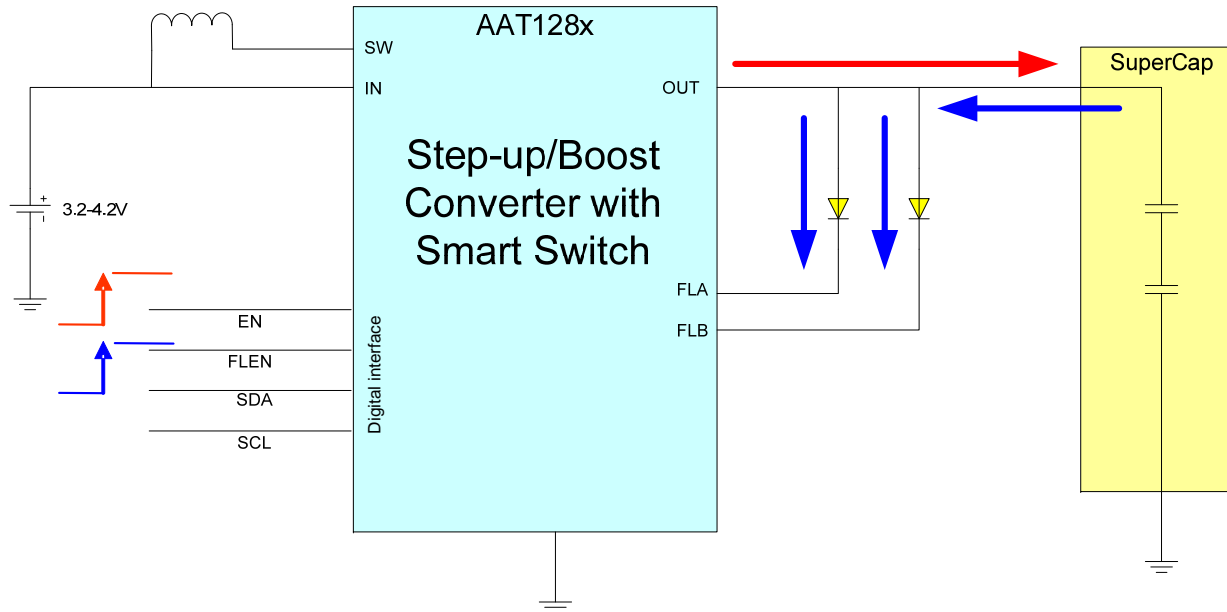
- If $V_{BATT} = 3.3V$ and $I_F = 1.5A$ @ $V_F = 4.4V$ then:

$$I_{BATT} = \frac{V_F \times I_F}{Eff \times V_{BATT}}$$
$$I_{BATT} = \frac{4.4 \times 1.5}{0.85 \times 3.3}$$
$$= 2.35 A$$

- **This current can cause a number of issues:**

- Peak current causes a battery voltage drop, causing the phone to reset
- Current exceeds the maximum allowed battery current and battery disconnects for safety
- Battery is damaged

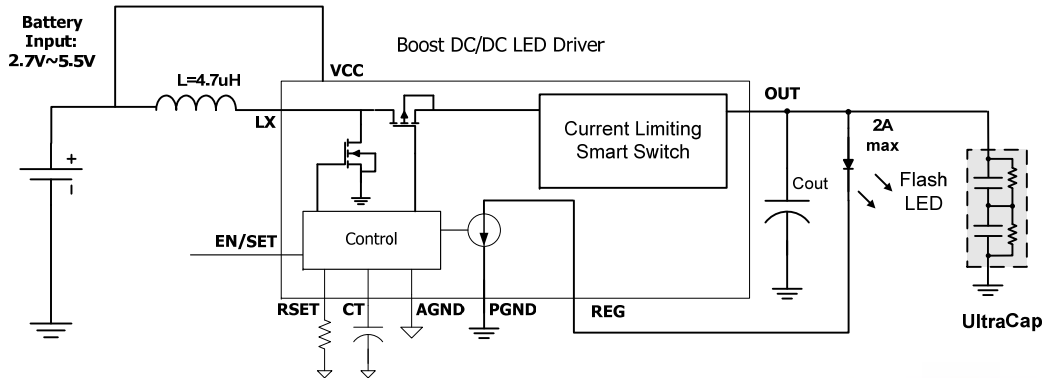
- **Combines:**
 - High-frequency boost converter with fixed input current limiting smart switch
 - High-capacity supercapacitor
 - Dual output regulated current sinks
 - I²C control
- **Supplies high intensity light required for mobile phones using cameras with resolutions of >5 Mega Pixel**
- **Limits peak current consumed by the battery**



1. Step-up convertor charges the UC to 5.5V in seconds (Red).
2. The step-up convertor automatically changes to light load mode.
3. During the flash (FLEN), the boost engine is shut down,
4. The two LEDs connected to current channel (FLA or FLB) share the output current supplied by the UC equally (Blue).

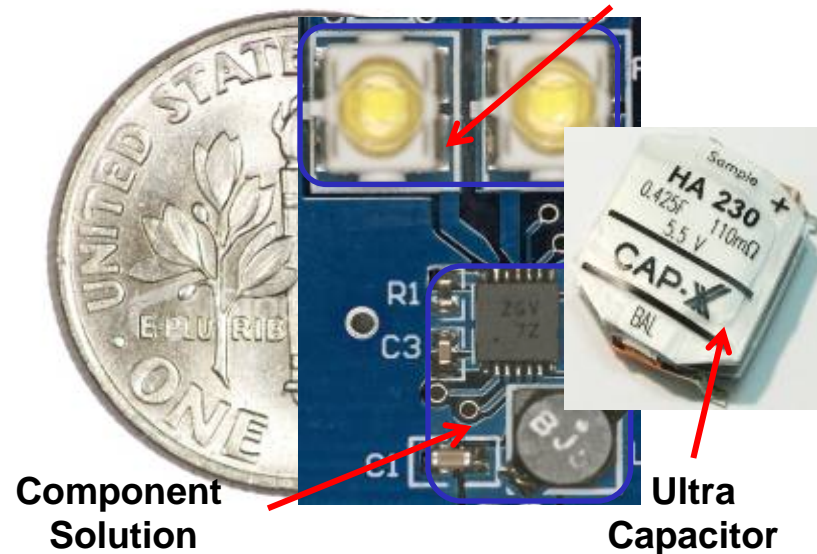
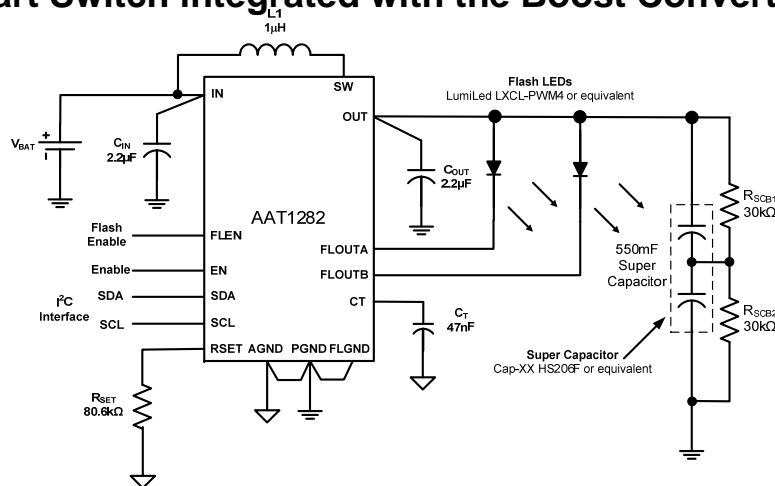
High current Flash LED application for camera or cell phone

Smart Switch plus Boost Converter - Supercap provides the Flash Current



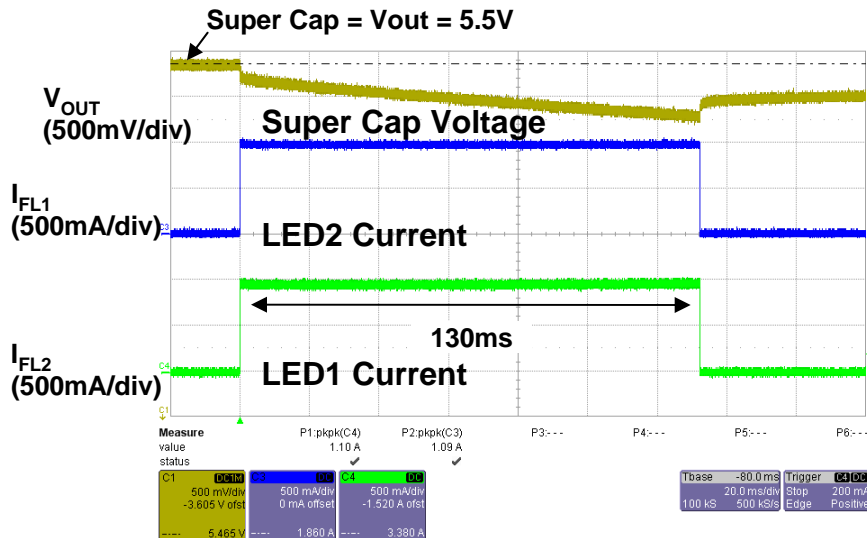
2 x WLED Flash With Lens

Smart Switch integrated with the Boost Converter

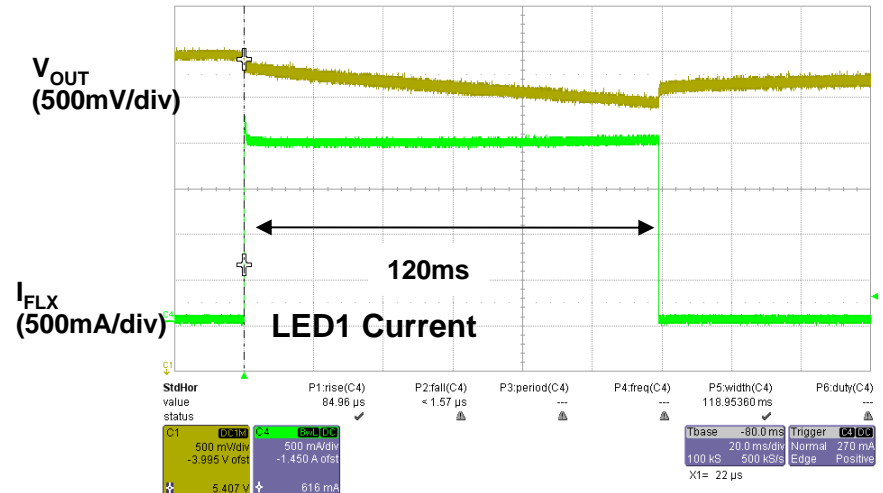


Component Solution

Ultra Capacitor

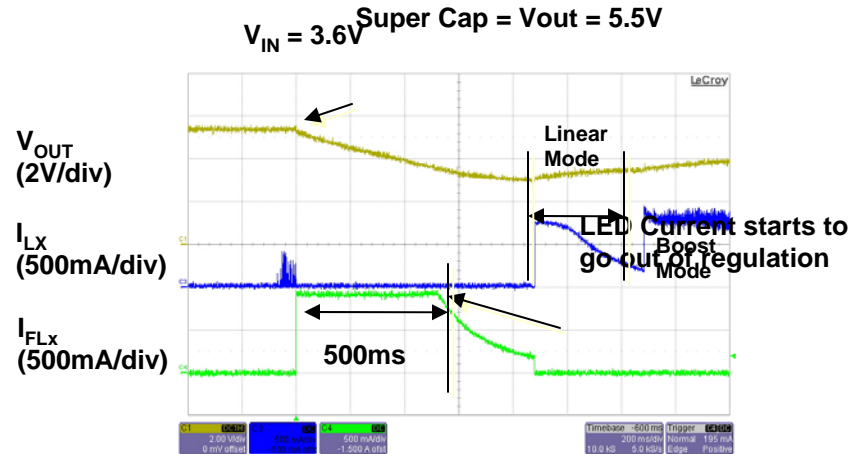
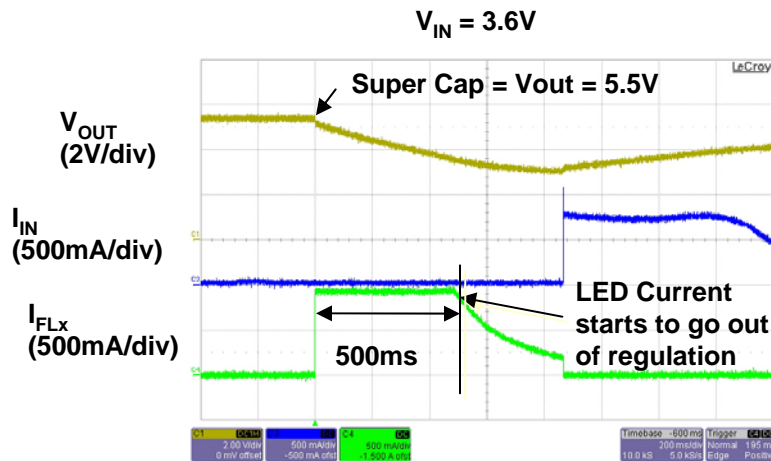


- $V_{in} = 3.62V$ (875mA/hr Li-Ion Polymer battery cell)
- Flash Time-out set for 130ms
- LEDs = Lumiled PWM-4
- Super Cap = Cap-XX, HS206F - 0.55F - 85m Ω ESR

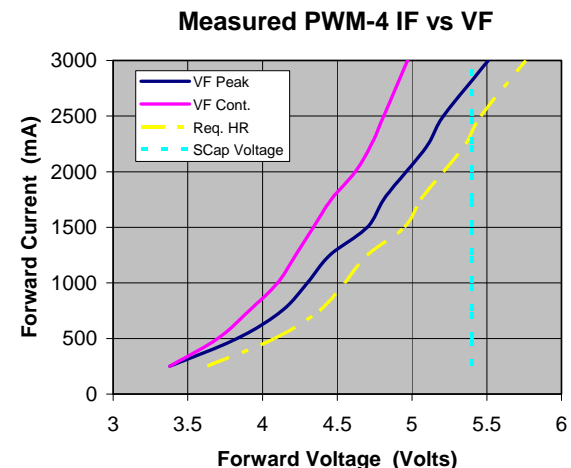


- $V_{in} = 3.62V$ (875mA/hr Li-Ion Polymer battery cell)
- Flash Time-out set for 120ms
- LED = Lumiled PWM-4
- Super Cap = Cap-XX, HS206F - 0.55F - 85m Ω ESR

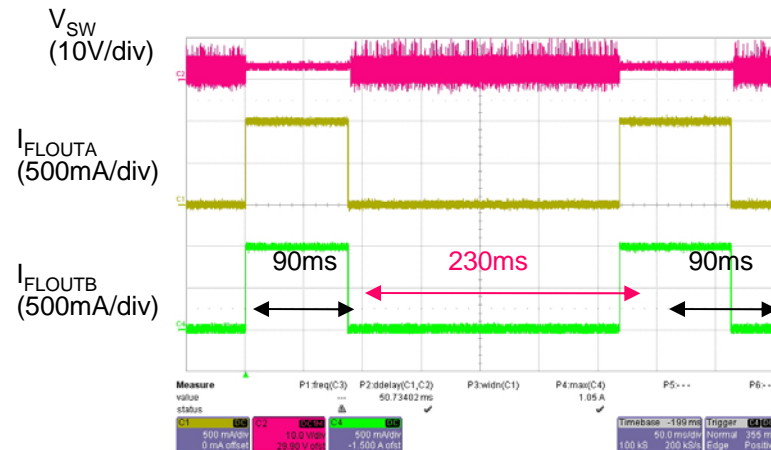
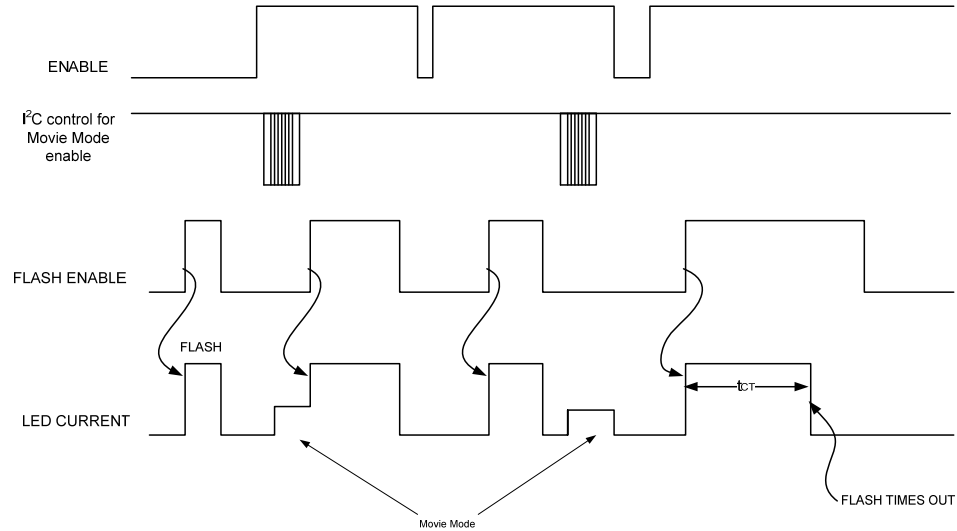
1A/LED Flash Operation Test Results – Long Duration Flash



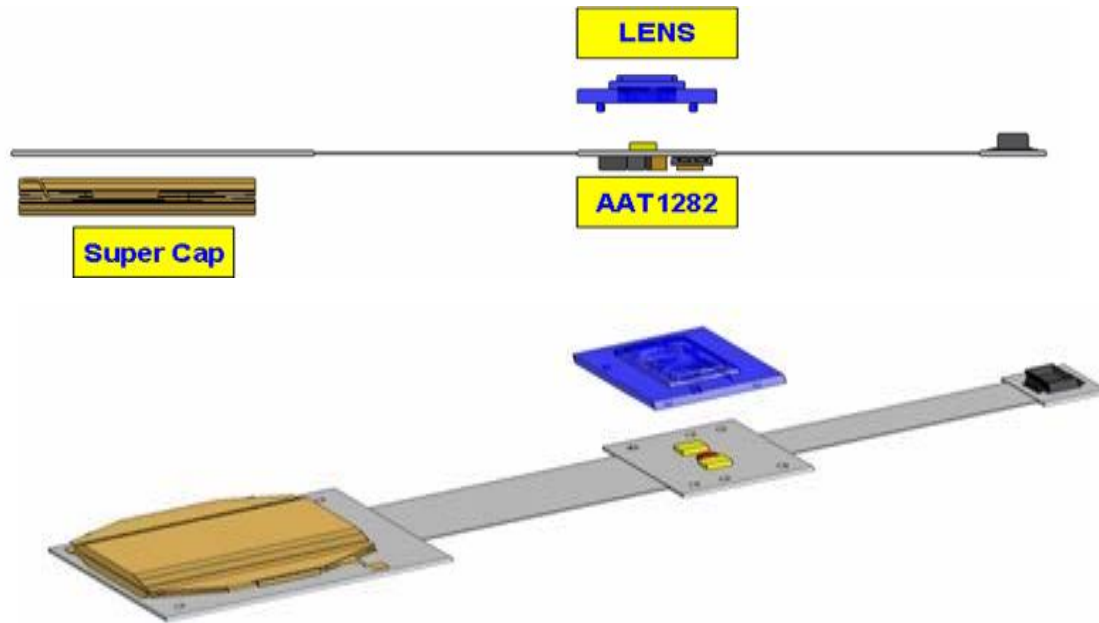
- V_{out} droops to LED VF
 - Limits Flash time
- $IR \text{ drop} = V_{out} - V_{minstep} = (5.5 - 5.4) = 100mV$
- $R = 100mV / 1A = 100m\Omega$
- Voltage drop on C = $(V_{minstep} - V_{mindroop})$
- $C = (5.4 - 4.5) = 900mV$
- $C_{min} = 1A(450ms) / 900mV = 0.5F$



Double Flash Operation (Recharge Super capacitor in between)



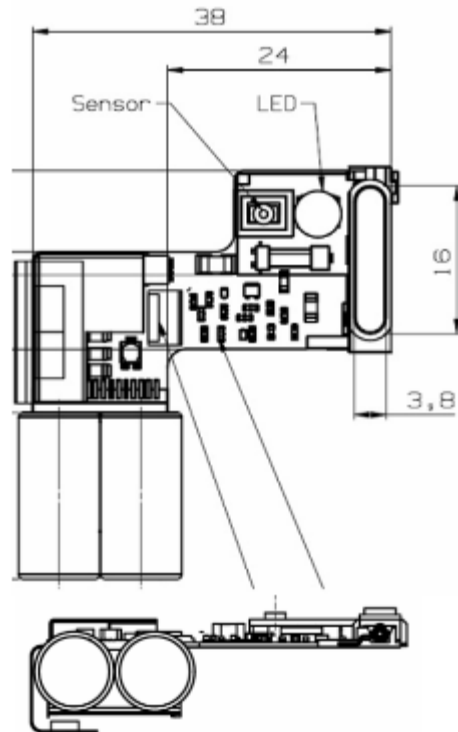
Boost stops switching during flash



<u>Mode 1</u>		<u>Mode 2</u>		<u>Mode 3</u>	
time duration	LED current	time duration	LED current	time duration	LED current
2 sec	50mA	2 sec	50mA	2 sec	50mA
140 msec	1A	70 msec	1.5A	40 msec	2A
100 msec	OFF	100 msec	OFF	100 msec	OFF
140 msec	1A	70 msec	1.5A	40 msec	2A

● Xenon Flash

- UC can provide LED flash better than Xenon flash in a fraction of the size and provide Torch Mode with true DSC performance



	Electrolytic
Capacitance	2 x 14 μ F = 28 μ F
Energy storage	$\frac{1}{2} \times 28\mu\text{F} \times (330\text{V}^2 - 100\text{V}^2) = 1.4\text{J}$
dimensions	2 x 7mm dia x 18mm long
Effective volume	1.76cc
Energy density	0.785J/cc

	Supercapacitor
Capacitance	1.1F/2 = 0.55F
Energy storage	$\frac{1}{2} \times 0.55\text{F} \times (5.5\text{V}^2 - 4.5\text{V}^2) = 2.75\text{J}$
dimensions	2 x 17mm x 28.5mm x 1mm
Effective volume	0.97cc
Energy density	2.835J/cc



	Xenon	Supercap
Light machine	Xe filled quartz tube 15x5x3mm = 0.225cc	Si LED 2x 1.6x2x0.7mm = 0.00448cc
Energy Storage	Electrolytic Cap 2x 7Øx18mm =1.766cc eff	Supercap 1 or 2 x 17x28.5x1mm =0.48 – 0.96cc
FPC circuit	10x30x0.2mm = 0.06cc	10x30x0.2mm = 0.06cc
Control chip	4x4x1= 0.016cc	4x4x1= 0.016cc
Transformer	5x5x4mm =0.1cc	n/a
Light sensor	3x3x1mm = 0.009cc	n/a
IGBT	1.5x1.5x0.8mm = 0.0018cc	n/a
Total	~2.2cc	~0.56 – 1.04cc

- **Using a Super/UltraCapacitor**
 - It is possible to drive very high LED currents for an ultra bright WLED flash.
- **2x Flash LEDs driven at 2A**
 - Deliver more light than a K800i xenon strobe
- **SC/UC Flash Solution is < 2mm thick**
- **SC/UC Can Enhance Other Features in a Phone**
 - Longer Talk Time and Better Audio
- **Limits peak current consumed by the battery**
- **A Current Limiting Smart Switch with Boost Converter**
 - Issues with Super/Ultra Caps and Flash LEDs Eliminated