Powering LumiLEDs PWF4 with SP7685 1.2A Capable Charge Pump DC/DC

The SP7685 Buck/Boost Charge Pump LED driver is designed for powering high brightness white LEDs for camera flash applications. This application highlights the capabilities of the SP7685 to drive two of the LumiLEDs PWF4 Flash LEDs to 1.2A total current. The total solution size as shown in figure 1 is only 5.7mm x 5.9mm, much smaller than any inductor based DC/DC solution. Additionally, using a charge pump eliminates the inductor and its EMI issues, and involves less expense, footprint size and height restrictions.

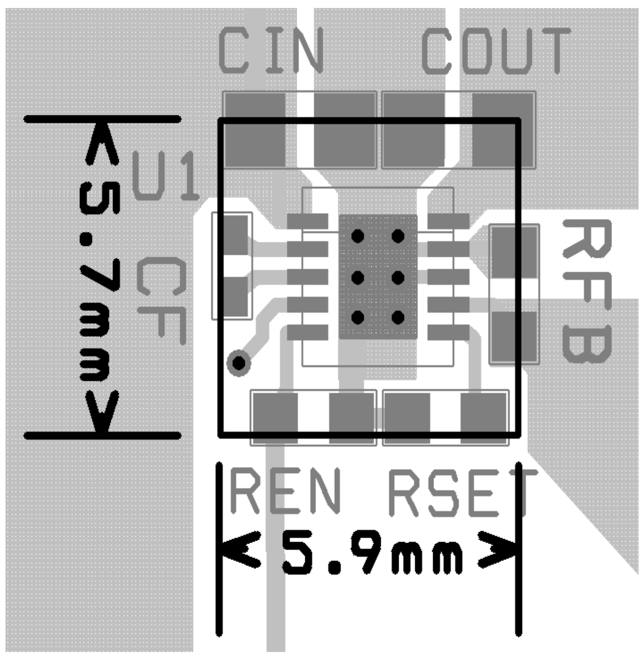


Figure 1. Solution Layout and Size

Circuit Description:

This application has been designed for a single Li-Ion battery input to drive two PWF4 LEDs connected in parallel for a 1.2A Flash that requires high LUX output, small size and low output ripple. The input voltage range is from 2.7V to 4.2V and is boosted up in 2X charge pump mode or bucked down in 1X Linear regulator mode to drive the two parallel PWF4 LED outputs. The two PWF4s as shown in figure 2 schematic each have a series 0.047ohm resistor for the purpose of monitoring LED individual currents and helping to balance the two LED currents. The input power supply circuit used is called a battery simulator and is designed with large bulk electrolytic capacitance of 10,000uF in parallel with 300uF of X5R ceramic capacitance to simulate the current delivery capability of a cellphone Li-Ion battery. The ESR of the battery is included with 0.1ohm SM metal film resistor and the resistance of the battery wires and connector is included in the Rwire resistance of 0.05ohm SM metal film resistance. The SP7685 circuit includes CIN consisting of two 10uF X5R 0603 size input bypass capacitors, one Cf 1uF X5R fly capacitor and one COUT 10uF X5R output capacitor. The LEDs are connected between the SP7685 VOUT pin and VFB pin, and a RFB resistor of 0.22ohm 0603 size MF resistor connects from VFB to GND.

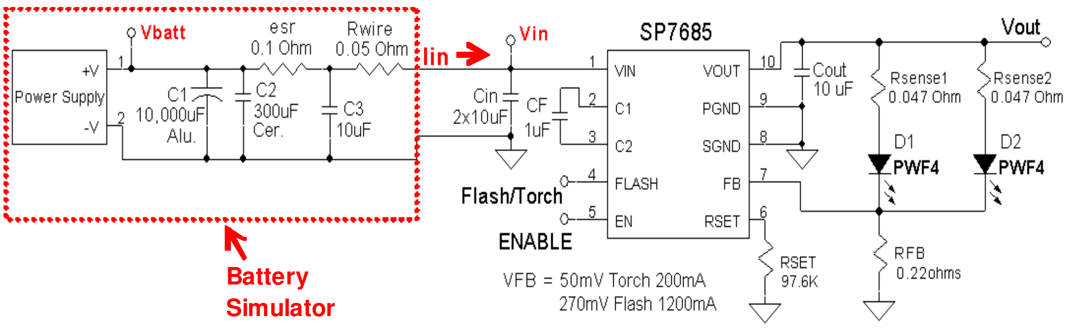


Figure 2. Schematic for SP7685 1.2A Flash driving two PWF4 LEDs

Resistor Selection for Torch/Flash output Current

The VFB pin is set to 50mV in Torch mode by a logic Low on the FLASH pin and Logic High on ENABLE. For 220mA Torch mode the RFB resistor is calculated by the expression:

RSENSE = VFB/IOUT = 50mV/220mA = 0.22ohm in Torch Mode

In Flash mode the FLASH pin is set to logic High and logic High is applied to the ENABLE pin. The VFB pin voltage needed in Flash Mode is:

VFB = RSENSE* IOUT = 0.22ohm*1.2A = 264mV

The VFB pin value is set in Flash mode by the RSET resistor value and the equation:

RSET = VFB*5/14uA = 264mV*5/14uA = 94Kohms

The actual value of 97.6KΩ was the standard value used.

Flash Output Data

The Flash output current data is shown in Table 1 & figure 3. For high VBATTERY values the individual LED currents are about 600mA each for LED, with the total of LED current of 1200mA. The input current matches the output current for high VIN, since when VIN is much greater than VOUT the charge pump operates in the

1X mode where I_{IN} and I_{OUT} match (there is some quiescent current, but at 2mA it can be ignored). When V_{IN} is 3.8V and lower, the charge pump cannot keep the output regulated in 1X mode and the SP7685 switches to 2X Mode, where the output can be boosted 2 times. The limit on how much current can be delivered in Flash mode is determined by the V_{OUT} and I_{OUT} needed for the application and the R_{OUT} or output resistance of the charge pump. In 1X mode the output resistance is typically 0.4ohms, while in 2X mode it is about 4ohms. For the PWF4s driven at about 600mA, the data in table 1 shows Vout = 3.3V is needed.

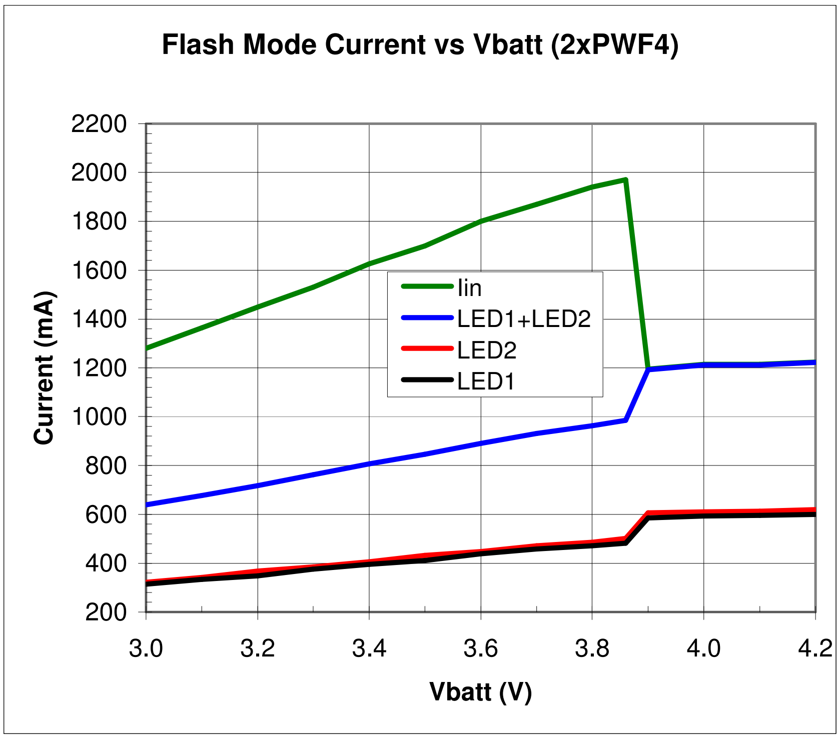


Figure 3. Flash Mode Current Output

The expression below shows how much current can be delivered for Vin = 3.8V and Vout = 3.31V for 1X mode:

$$I_{OUT} = (V_{IN} – V_{OUT})/ R_{OUT} = (3.8 – 3.31)/0.4ohm = 1.2A$$

This shows that below V_{IN} = 3.8V the part will need to switch to 2X mode. The SP7685 when enabled will start in 1X mode, but after softstart finishes and if VFB is below the regulation point for 32usec, it will switch to 2X mode. Once in 2X mode the output current that can be supplied depends on 2* V_{IN} and R_{OUT} (which is now 4ohms in 2X mode):

$$I_{OUT} = (2V_{IN} – V_{OUT})/ R_{OUT} = (2*3.7 – 3.31)/4ohm = 1.02A$$

This shows that in 2X mode and output set for 1.2A the output current will actually drop because IOUT * ROUT is too large. For many cellphone batteries, it is actually desirable that the output current will drop in 2X mode because the battery will not be able to provide the increased current demands at low battery voltage. Note, for a charge pump in 2X mode, since the output capability is increased by 2X, the input current needs to be 2 times the output. In this case the maximum input current measured was 1.97A for an output current of 984mA.

Vbat	Vin	Vin ripple	Iin	Vout	Vo ripple	VFB	Iout	VR_{SENSE} 1	VR_{SENSE} 2	I_{LED} 1	I_{LED} 2	Effi
(V)	(V)	(mV)	(mA)	(V)	(mV)	(mV)	(mA)	(mV)	(mV)	(mA)	(mA)	(%)
4.2	4.00	110	1224	3.31	125	276	1222.1	28.0	28.9	599.6	618.8	75.74
4.1	3.90	100	1215	3.31	125	273	1211.9	27.8	28.6	595.3	612.4	77.66
4.0	3.80	90	1214	3.31	120	273	1211.4	27.7	28.5	593.1	610.3	79.74
3.9	3.71	70	1195	3.31	125	269	1192.4	27.3	28.3	584.6	606.0	81.79
3.86	3.52	140	1970	3.25	70	222	984.0	22.5	23.4	481.8	501.1	42.97
3.8	3.49	125	1940	3.24	100	217	961.9	22.0	22.7	471.1	486.1	42.95
3.7	3.40	120	1870	3.22	65	210	930.9	21.4	22.0	458.2	471.1	44.07
3.6	3.31	110	1800	3.21	60	201	891.0	20.5	20.9	439.0	447.5	45.00
3.5	3.23	110	1700	3.20	55	191	846.6	19.2	20.2	411.1	432.5	46.39
3.4	3.14	105	1625	3.18	55	182	806.7	18.5	19.0	396.1	406.9	47.40
3.3	3.06	100	1530	3.15	50	172	762.4	17.6	18.0	376.9	385.4	48.50
3.2	2.97	100	1450	3.13	50	162	718.1	16.3	17.2	349.0	368.3	49.49
3.1	2.89	90	1365	3.12	50	153	678.2	15.6	16.0	334.0	342.6	51.01
3.0	2.80	90	1280	3.10	45	144	638.3	14.6	15.0	313.3	321.2	52.65

Table 1. Flash Output Data

The Flash turn-on waveforms in figures 4 & 5 show that IIN rises to about 2A for 2X mode as expected.

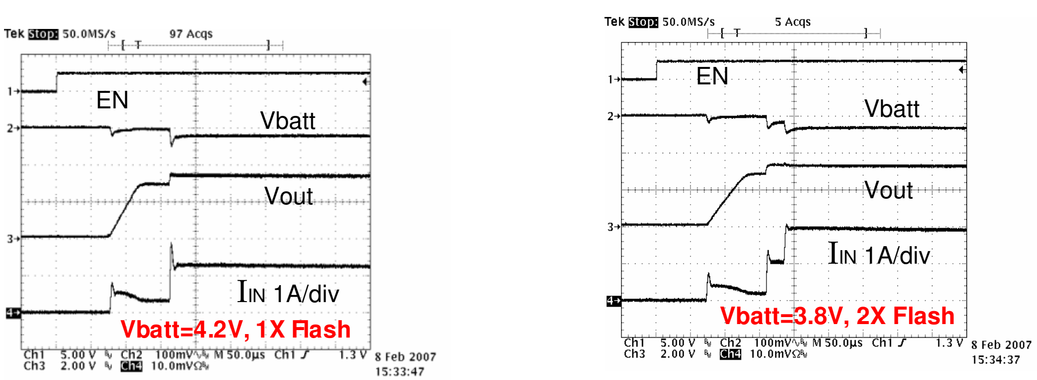


Figure 4 & 5: Flash Mode Turn-on Waveforms

The ripple waveforms for Flash Mode in figures 6 & 7 have about 2MHz frequency and 100 mVpp amplitude on the input which should not pose any real problems to devices running on the cellphone battery.

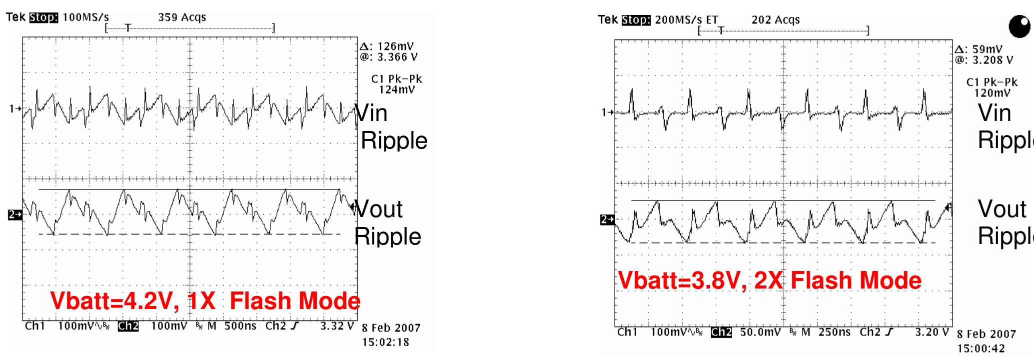


Figure 6 & 7: Flash Mode Input & Output Ripple

Light Delivery in Flash

In Flash mode, efficiency is not a key criterion, since the LED is only on for as much as 200msec and off most of the time. The key performance requirement in Flash is current delivery, for this is what enables getting the most light from the Flash LED. From figure 4 we can see that the light output of a PWF4 at 600mA current for the high uniformity option, which LumiLEDs recommends for cellphone Flash, is about 70 lux per LED. For 2 PWF4s this produces a total of 140 lux at 1m. Other output current data points can be determined, for example, at 3.3V V_{IN} the output current per LED is 440mA per LED or 55 lux per LED for a total of 110 lux at 1m. For a cellphone application, 110 to 140 lux at 1m is a very good Flash light output.

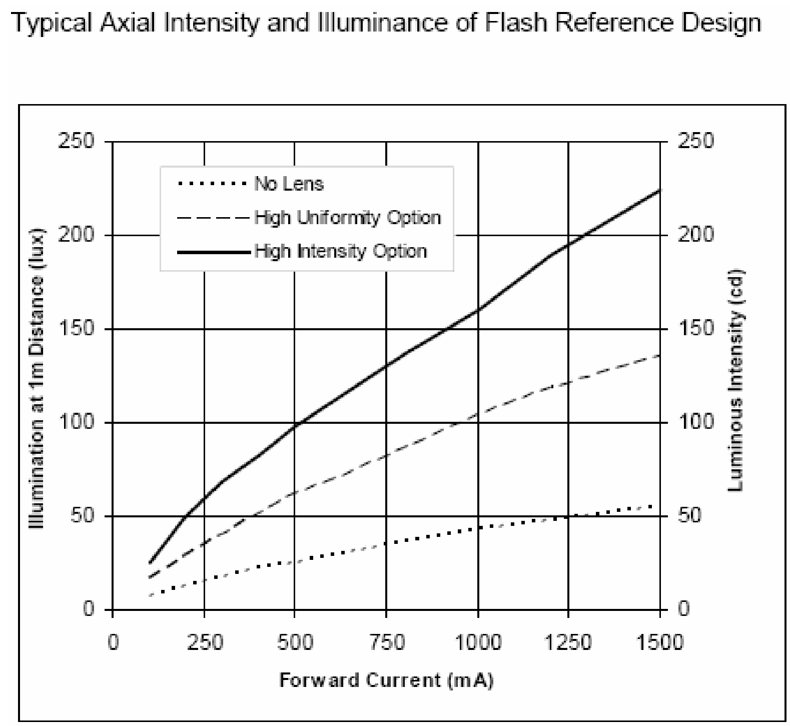


Figure 8. Flash Mode Light Output LCXL-PWF4

Torch Output Data

The SP7685 in Torch mode has a very low VFB regulation voltage of 50mV. This provides more efficiency in the Torch mode by allowing the charge pump to remain in 1X mode for most of the Li-Ion range. From Table 2 and Figure 9 the input current is the same as the output current for V_{BATT} voltages of 4.2V down to 3.0V. This provides the highest efficiency in Torch mode where it is needed most when the LED can remain on for many seconds if used in “Movie Mode”. From figure 10 the Torch efficiency of 67% up to 95% was achieved from 4.2V to 3.0V input.

Torch Mode, 2 x PWF4												
Vbat	Vin	Vin ripple	Iin	Vout	Vo ripple	VFB	Iout	VR_{SENSE} 1	VR_{SENSE} 2	I_{LED} 1	I_{LED} 2	Effi
(V)	(V)	(mV)	(mA)	(V)	(mV)	(mV)	(mA)	(mV)	(mV)	(mA)	(mA)	(%)
4.2	4.15	200	262	2.91	100	57.9	256.6	5.90	6.02	125.5	128.1	67.32
4.1	4.05	200	261	2.91	95	57.8	256.2	5.88	6.01	125.1	127.9	69.13
4.0	3.96	180	257	2.91	85	57.0	252.7	5.78	5.93	123.0	126.2	70.83
3.9	3.86	180	258	2.91	100	57.3	254.0	5.82	5.96	123.8	126.8	72.76
3.8	3.76	160	257	2.91	90	57.0	252.7	5.78	5.93	123.0	126.2	74.60
3.7	3.66	140	253	2.91	90	56.2	249.1	5.72	5.84	121.7	124.3	76.77
3.6	3.56	110	249	2.90	70	55.5	246.0	5.64	5.77	120.0	122.8	78.94
3.5	3.46	100	248	2.90	60	55.3	245.1	5.62	5.74	119.6	122.1	81.26
3.4	3.36	80	242	2.90	50	54.0	239.4	5.48	5.60	116.6	119.1	83.78
3.3	3.26	60	236	2.90	60	52.7	233.6	5.35	5.48	113.8	116.6	86.45
3.2	3.16	40	233	2.90	50	52.0	230.5	5.31	5.42	113.0	115.3	89.16
3.1	3.06	30	231	2.90	40	51.7	229.2	5.25	5.37	111.7	114.3	92.34
3.0	2.97	20	223	2.89	20	50.0	221.6	5.11	5.19	108.7	110.4	95.04
2.99	2.92	60	443	2.89	95	49.4	219.0	5.04	5.12	107.2	108.9	48.09
2.80	2.74	50	451	2.89	80	50.5	223.8	5.17	5.25	110.0	111.7	51.44

Table 2. Torch Mode Output Data

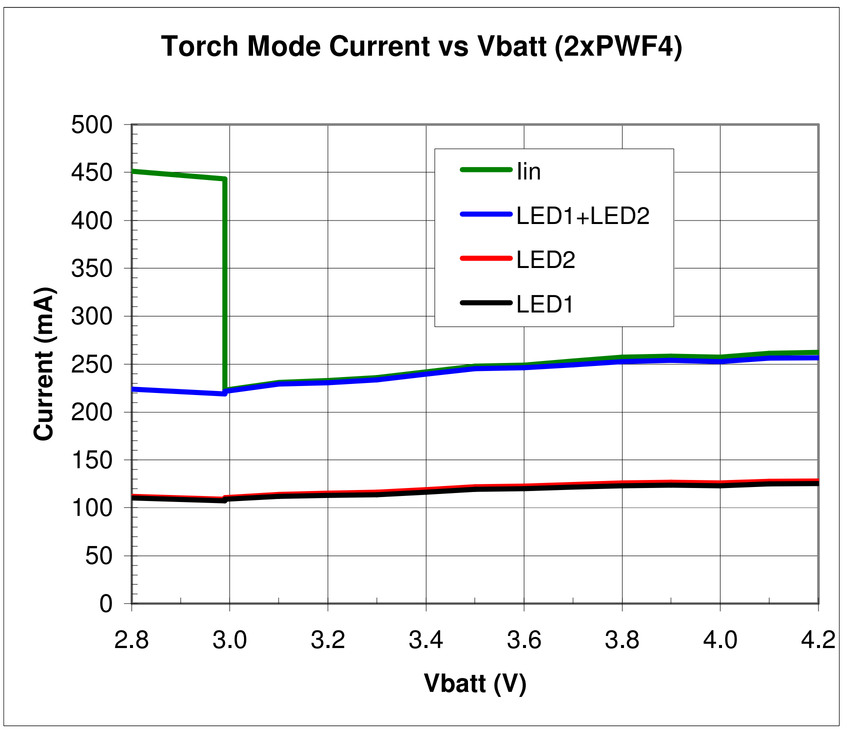


Figure 9. Torch Mode Current Output

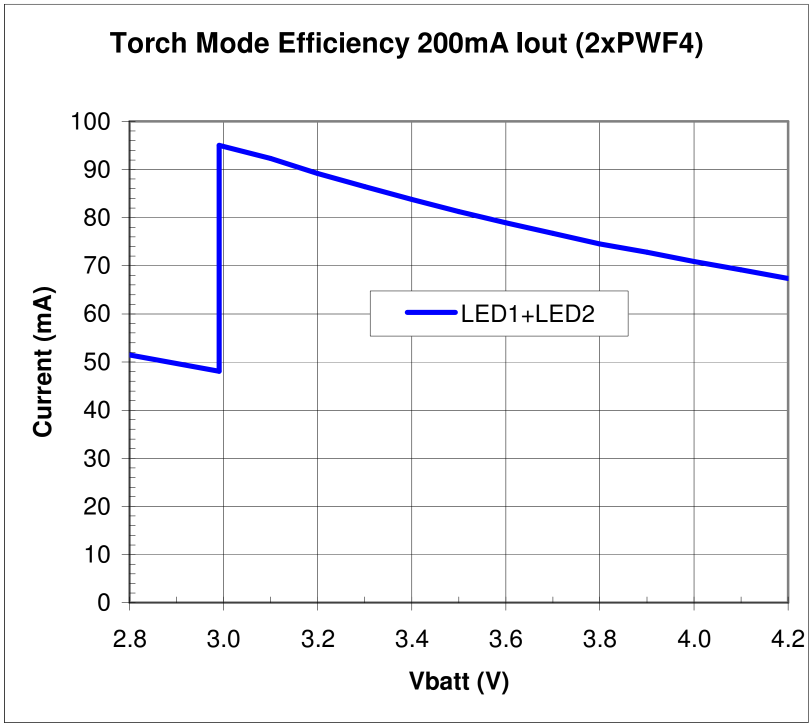


Figure 10. Torch Mode Efficiency

The Torch Mode turn-on waveforms in figures 11 & 12 show that IIN is well behaved and reaches at most 0.8A in startup.

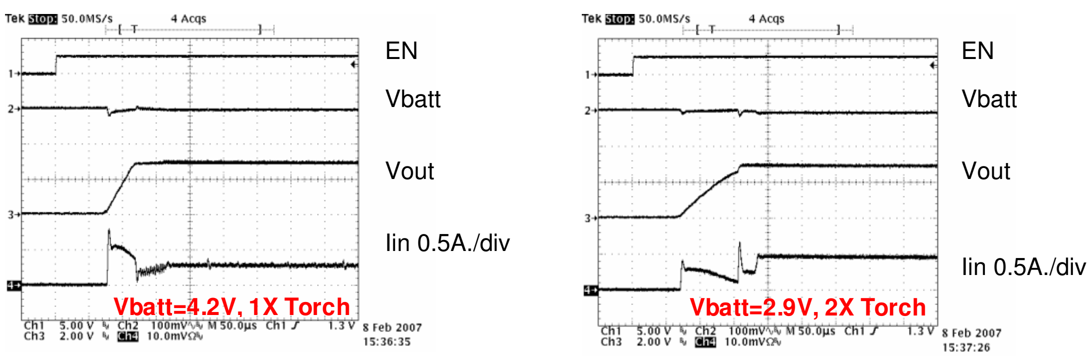
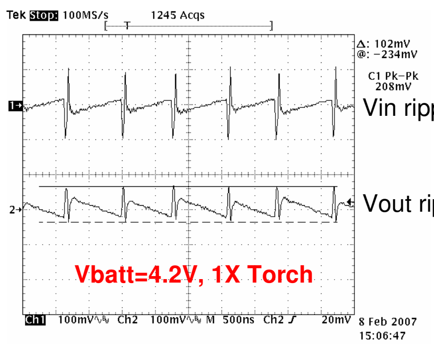


Figure 11 & 12. Torch Mode Turn-on Waveforms

The Torch Mode ripple is included in figures 13 & 14 and show that ripple frequency can vary from 1 to 2MHz with amplitude of input ripple at most of about 200mV which should not be an issue for devices running on the cellphone battery.



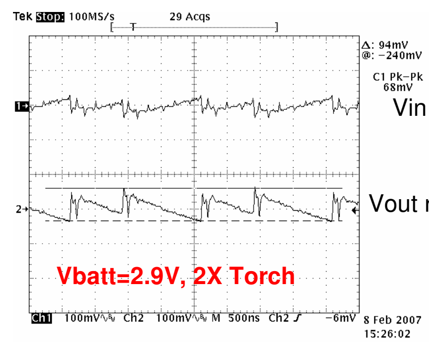


Figure 13 & 14. Torch Mode Input & Output Ripple

Summary

1) The SP7685 is capable of driving two of the latest LumiLEDs PWF4 LEDs in parallel in Flash mode to a total of 1.2A.

2) The total light output of the 2 PWF4's in 1.2A total current in Flash mode is 110 to 140 lux at 1m for the high uniformity option per LumiLED LCXL-PWF4 datasheet.

3) In Torch mode the SP7685 can deliver 200mA output current at efficiencies from 67% to 95% for 4.2V to 3.0V battery input.

4) The total solution size of the SP7685 is very small at about 5.7mm x 5.9mm, much smaller than any inductor based DC/DC solution.

5) Using a charge pump eliminates the inductor and its EMI issues, and involves less expense, footprint size and height restrictions.

For further assistance:

Email:	Sipexsupport@sipex.com
WWW Support page:	http://www.sipex.com/content.aspx?p=support
Live Technical Chat:	http://www.geolink-group.com/sipex/
Sipex Application Notes:	http://www.sipex.com/applicationNotes.aspx

Sipex Corporation
Headquarters and
Sales Office
233 South Hillview Drive
Milpitas, CA95035
tel: (408) 934-7500
faX: (408) 935-7600