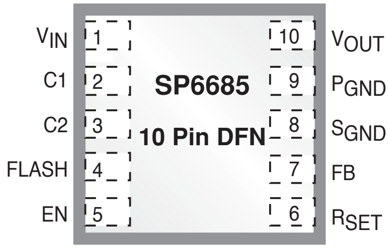
# SP6685

## 700mA Buck/Boost Charge Pump LED Driver

### FEATURES

- Output Current up to 700mA
- Up to 94% Efficiency in Torch Mode
- Adjustable FLASH Mode Current
- Minimum External Components: No Inductors
- Automatic Buck/Boost Mode Switchover
- Wide $V_{IN}$ Range: 2.7V to 5.5V
- High Frequency Operation: 2.4 MHz
- Low 50mV Reference for low Loss Sensing
- $I_Q < 1\mu A$ in Shutdown
- PWM Dimming Control
- Automatic Soft Start Limits Inrush Current
- Overvoltage Protection on Output
- Overcurrent/Temperature Protection
- Low Ripple and EMI
- Ultra-low Dropout Voltage in Buck Mode
- Space Saving 10-pin 3mm x 3mm DFN Package




*Now Available in Lead Free Packaging*

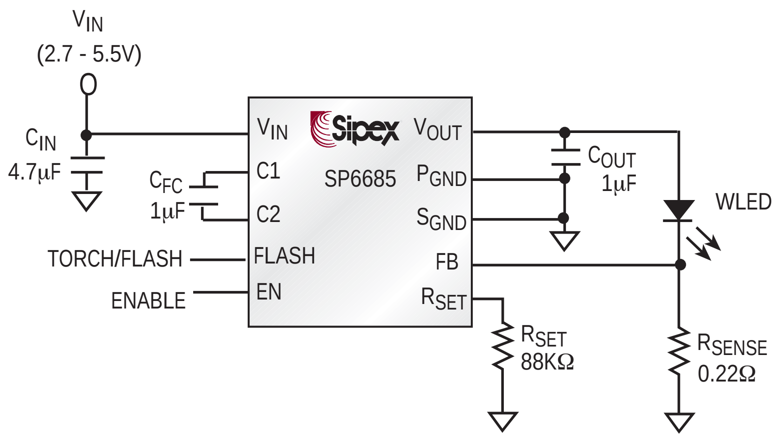
### APPLICATIONS

- White LED Torch/Flash for Cell Phones, DSCs, and Camcorders
- White LED Backlighting
- Generic Lighting/Flash/Strobe Applications
- General Purpose High Current Boost

### DESCRIPTION

The SP6685 is a current-regulated charge pump ideal for powering high brightness LEDs for camera flash applications. The charge pump can be set to regulate two current levels for FLASH and TORCH modes. The SP6685 automatically switches modes between step-up and step-down ensuring that LED current does not depend on the forward voltage. A low current sense reference voltage (50mV) allows the use of small 0603 current sensing resistors. The SP6685 is offered in the 10-pin DFN package.

### TYPICAL APPLICATION CIRCUIT



# ABSOLUTE MAXIMUM RATINGS

$V_{IN}$ , $V_{OUT}$ .................. -0.3V to 6V
Output Current Pulse (Flash) .................. 1A
Output Current Continuous (Torch) .................. 0.4A
Storage Temperature .................. -65°C to +150°C
Operating Temperature .................. -40°C to +85°C
$V_{EN}$ .................. 0.0V to 7V
3mmx3mm 10 DFN ..................$\Theta_{JA}$ = 57.1°C/W
ESD Rating. .................. 2kV HBM

These are stress ratings only and functional operation of the device at these ratings or any other above those indicated in the operation sections of the specifications below is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

# ELECTRICAL CHARACTERISTICS

$T_A$ = -40°C to +85°C, $V_{IN}$ = 3.6V, $C_{IN}$ = 4.7µF, $C_{FC}$ = $C_{OUT}$ = 1.0µF. $V_{SHDN}$ = $V_{IN,}$ typical values at 25°C. The ♦ denotes the specifications which apply over the full operating temperature range unless otherwise noted.

| PARAMETER | MIN. | TYP. | MAX. | UNITS | | CONDITIONS |
|---|---|---|---|---|---|---|
| Operating Input Voltage | 2.7 | | 5.5 | V | ♦ | |
| Quiescent Current | | 0.5 | 3 | mA | ♦ | $V_{IN}$ = 2.7 - 5.5V FLASH = 0.0V, $I_{LOAD}$ = 100µA |
| | | 2 | | | | FLASH = $V_{IN,}$ 2x mode |
| Shutdown Current | | | 1 | µA | | $V_{IN}$ = 5.5V, $V_{EN}$ = 0.0V |
| Oscillator Frequency | | 2.4 | | MHz | | |
| Charge Pump Equivalent Resistance (x2 mode) | | 5 | | | | $V_{FB}$ = 0.0V, $V_{IN}$ = 3.6V |
| Charge Pump Equivalent Resistance (x1 mode) | | 0.6 | 0.8 | | | $V_{IN}$ = 3.6V |
| FB Reference Voltage | 138 | 150 | 162 | mV | ♦ | FLASH = $V_{IN}$ $R_{SET}$ = 88.7K |
| FB Reference Voltage | 45 | 50 | 55 | mV | ♦ | FLASH = GND |
| FB Pin Current | | | 0.5 | µA | | $V_{FB}$ = 0.3V |
| EN, FLASH Logic Low | | | 0.4 | V | ♦ | |
| EN, FLASH Logic High | 1.3 | | | V | ♦ | |
| EN, FLASH Pin Current | | | 0.5 | µA | ♦ | |
| $V_{OUT}$ Turn-on Time | | 250 | 500 | µs | ♦ | $V_{IN}$ = 3.6V, FB within 90% of regulation |
| Thermal Shutdown Temperature | | 145 | | °C | | |

| PIN NUMBER | PIN NAME | DESCRIPTION |
|---|---|---|
| 1 | $V_{IN}$ | Input Voltage for the charge pump. Decouple with 4.7μF ceramic capacitor close to the pins of the IC. |
| 2 | C1 | Positive input for the external fly capacitor. Connect a ceramic 1μF capacitor close to the pins of the IC. |
| 3 | C2 | Negative input for the external fly capacitor. Connect a ceramic 1μF capacitor close to the pins of the IC. |
| 4 | FLASH | Logic input to toggle operation between FLASH and TORCH mode. In TORCH mode FB is regulated to the internal 50mV reference. In FLASH mode FB reference voltage can be adjusted by changing the resistor from $R_{SET}$ pin to ground. Choose the external current sense resistor ($R_{SENSE}$) based on desired current in TORCH mode. |
| 5 | EN | Shutdown control input. Connect to $V_{IN}$ for normal operation, connect to ground for shutdown. |
| 6 | $R_{SET}$ | Connect a resistor from this pin to ground. When in FLASH mode (FLASH = High) this resistor sets the current regulation point according to the following: $V_{FB} = (1.26V/ R_{SET})*11.2K\Omega$. |
| 7 | FB | Feedback input for the current control loop. Connect directly to the current sense resistor. |
| 8 | $S_{GND}$ | Internal ground pin. Control circuitry returns current to this pin. |
| 9 | $P_{GND}$ | Power ground pin. Fly capacitor current returns through this pin. |
| 10 | $V_{OUT}$ | Charge Pump Output Voltage. Decouple with an external capacitor. At least 1μF is recommended. Higher capacitor values reduce output ripple. |

$V_{IN}$ = 3.6V, Typical Application Circuit, D1 = Luxeon LXCL-PWF1, $T_A$ = 25°C unless otherwise noted.

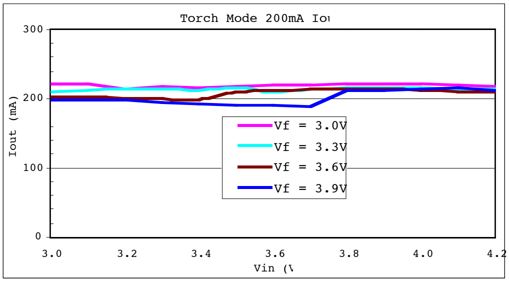



Figure 1. Torch Mode Output Current

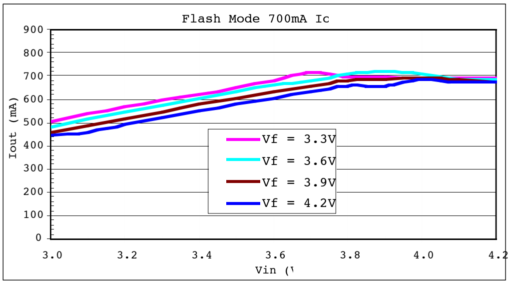



Figure 2. Flash Mode Output Current

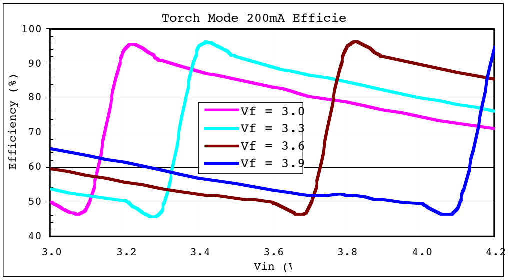



Figure 3. Torch Mode Efficiency

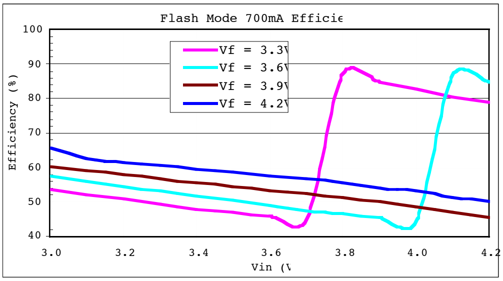



Figure 4. Flash Mode Efficiency

$V_{IN}$ = 3.6V, Typical Application Circuit, D1 = Luxeon LXCL-PWF1, $T_A$ = 25°C unless otherwise noted.

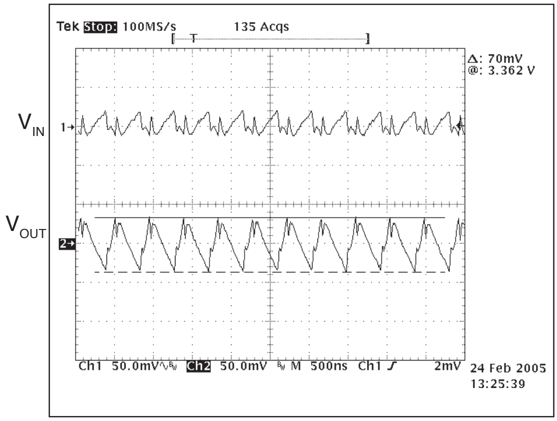



Figure 5. PWF1 Ripple 1X Flash 700mA Ch1 = $V_{IN,}$ Ch2 = $V_{OUT,}$ $V_{IN}$ = 4.2V, $C_{IN}$ = 10μF, $C_{FC}$ = 1μF, $C_{OUT}$ = 4.7μF

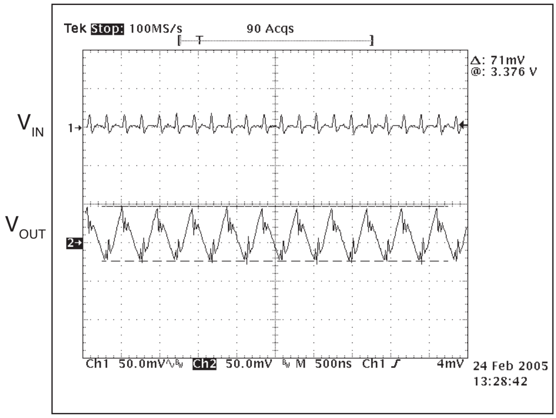



Figure 6. PWF1 Ripple 2X Flash 700mA Ch1 = $V_{IN,}$ Ch2 = $V_{OUT,}$ $V_{IN}$ = 3.6V, $C_{IN}$ = 10μF, $C_{FC}$ = 1μF, $C_{OUT}$ = 4.7μF

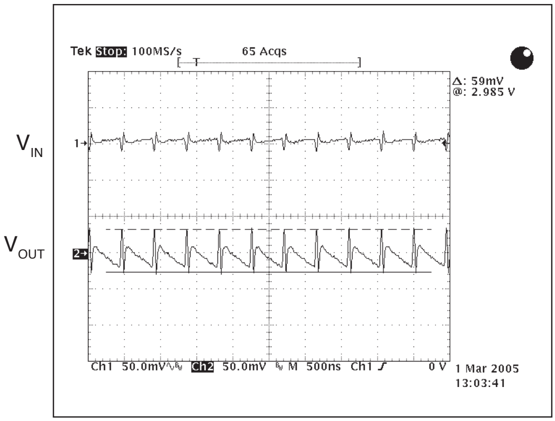



Figure 7. PWF1 Ripple 1X Torch 200mA $V_{IN}$ = 4.2V, $C_{IN}$ = 10μF $C_{FC}$ = 1μF, $C_{OUT}$ = 4.7μF

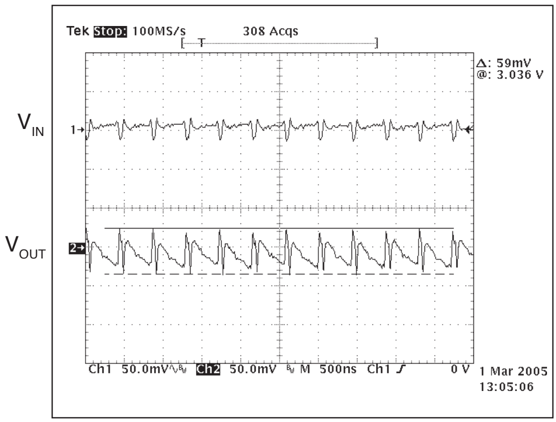



Figure 8. PWF1 Ripple 2X Torch 200mA $V_{IN}$ = 3.0V, $C_{IN}$ = 10μF $C_{FC}$ = 1μF, $C_{OUT}$ = 4.7μF

$V_{IN}$ = 3.6V, Typical Application Circuit, D1 = Luxeon LXCL-PWF1, $T_A$ = 25°C unless otherwise noted.

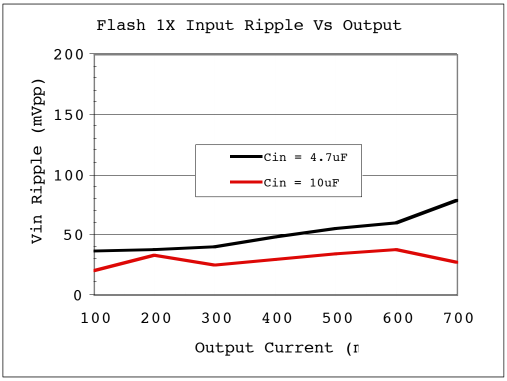



Figure 9. $C_{OUT}$ = 4.7µF

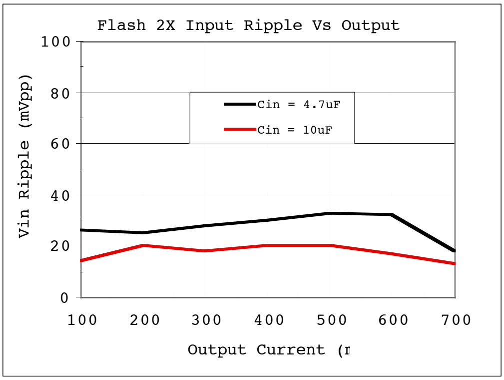



Figure 10. $C_{OUT}$ = 4.7µF

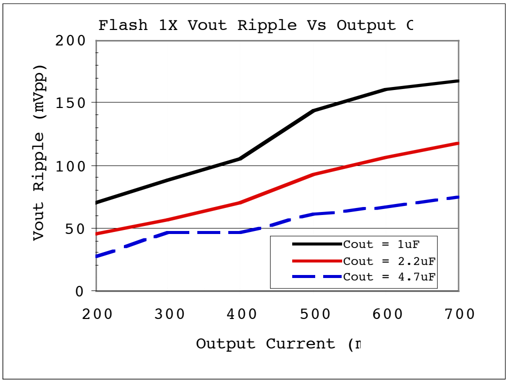



Figure 11. $C_{IN}$ = 10µF

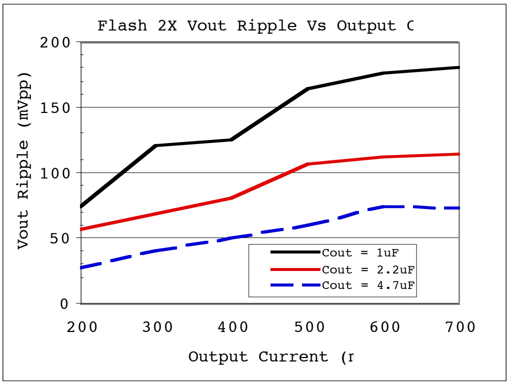



Figure 12. $C_{IN}$ = 10µF

D1 = Luxeon LXCL-PWFI LED, Rsense = 0.22ohms, $R_{SET}$ = 88.7K, $C_{IN}$ = 4.7µF, $C_{FC}$ = 1.0µF, $C_{OUT}$ = 1.0µF

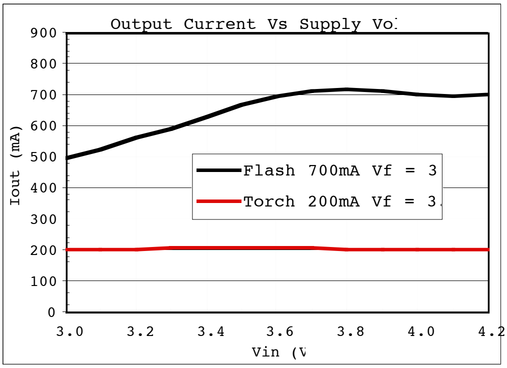



Figure 13.

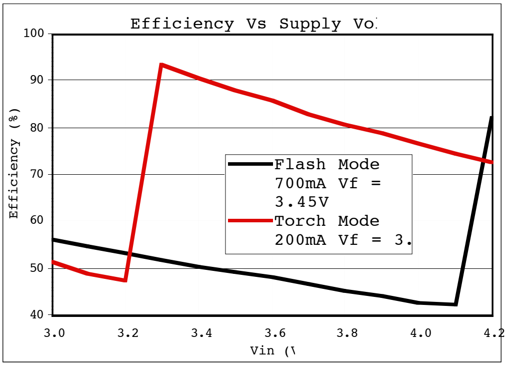



Figure 14.

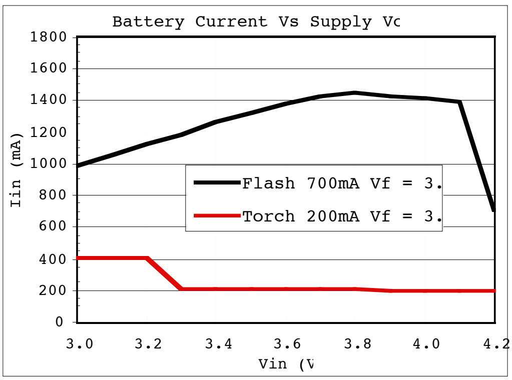



Figure 15.

Note: diode, resistor, and capacitor settings apply to figures 13, 14, and 15.

D1 = AOT 3228HPW0303B LED, Rsense = 0.33ohms, $R_{SET}$ = 162K, $C_{IN}$ = 4.7µF, $C_{FC}$ = 0.47µF, $C_{OUT}$ = 1µF

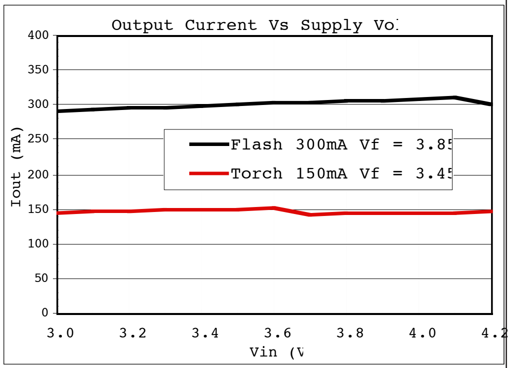



Figure 16.

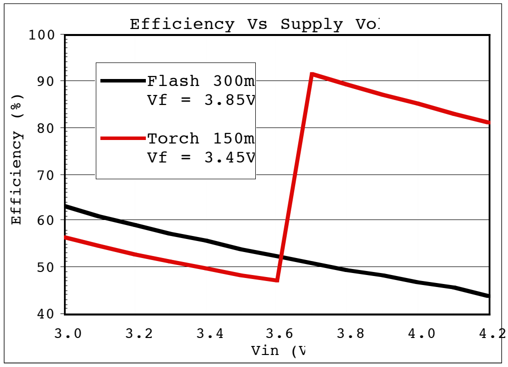



Figure 17.

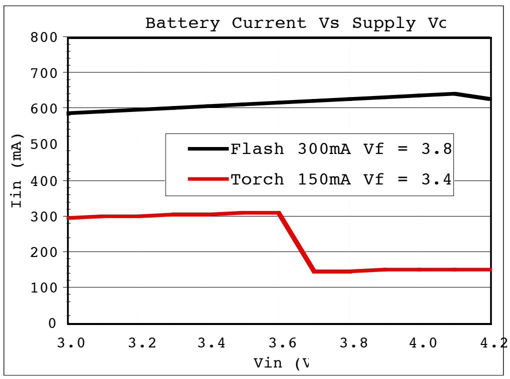



Figure 18.

Note: diode, resistor, and capacitor settings apply to figures 16, 17, and 18.

DI = AOT 6060HPW0305BD LED, Rsense = 0.33ohms, $R_{SET}$ = 75K, $C_{IN}$ = 4.7µF, $C_{FC}$ = 1.0µF, $C_{OUT}$ = 1.0µF

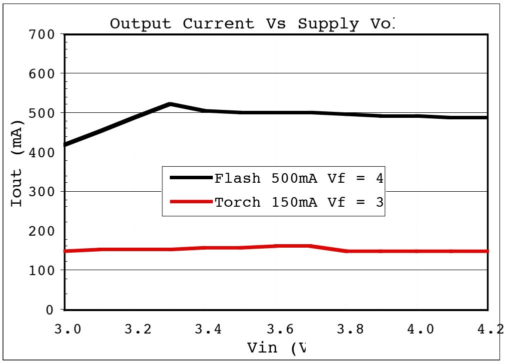



Figure 19.

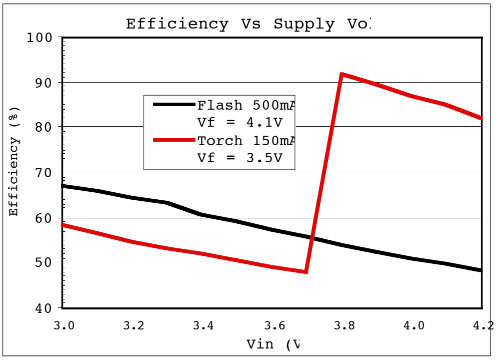



Figure 20.

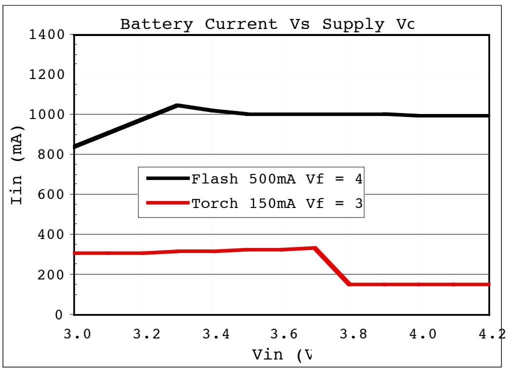



Figure 21.

Note: diode, resistor, and capacitor settings apply to figures 19, 20, and 21.

D1 = AOT 2015HPW-1915B LED, Rsense = 0.22ohms, $R_{SET}$ = 80.6K, $C_{IN}$ = 4.7µF, $C_{FC}$ = 1.0µF, $C_{OUT}$ = 1.0µF

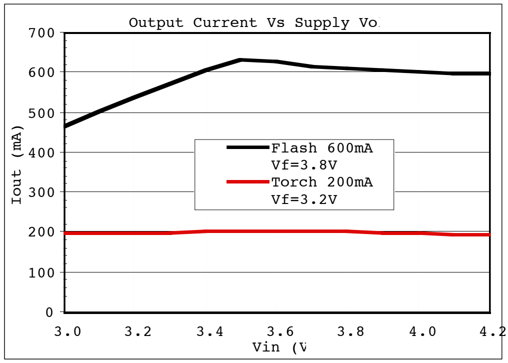



Figure 22.

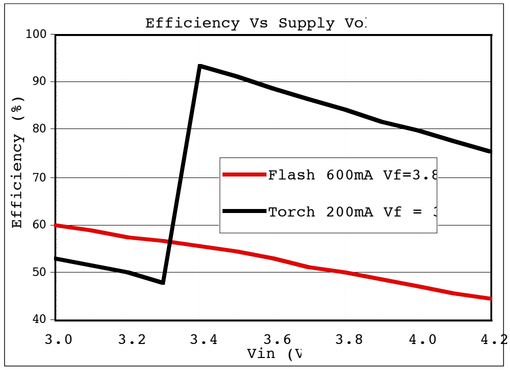



Figure 23.

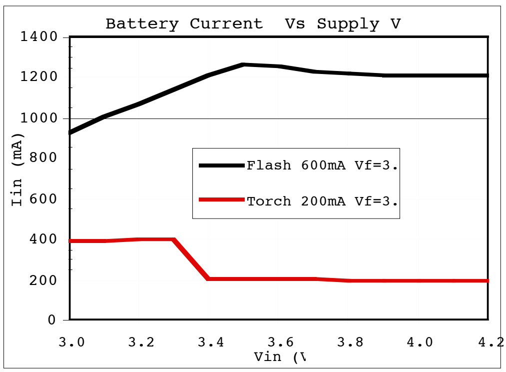



Figure 24.

Note: diode, resistor, and capacitor settings apply to figures 22, 23, and 24.

$V_{IN}$ = 3.6V, Typical Application Circuit, D1 = Luxeon LXCL-PWF1, $T_A$ = 25°C unless otherwise noted.

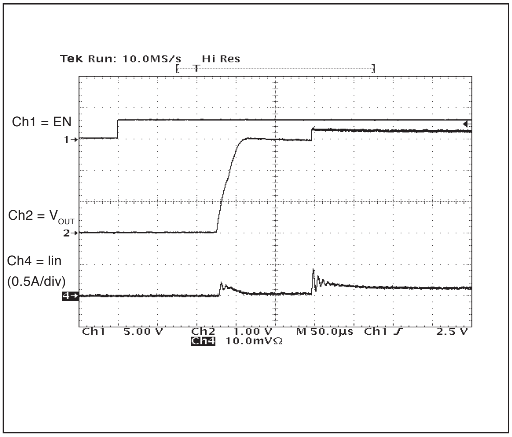



Figure 25. Startup 200mA Torch,
$V_{IN}$ = 3.6V, $V_{OUT}$ = 3.2V

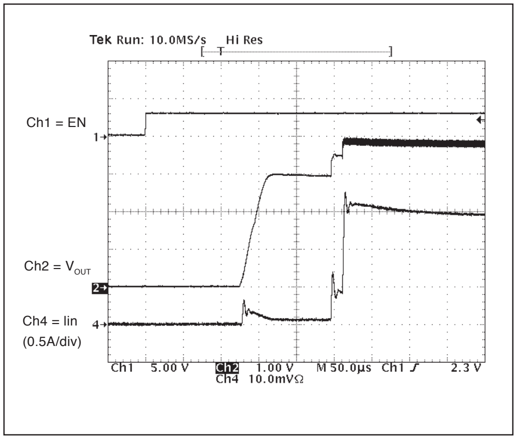



Figure 26. Startup 700mA Flash,
$V_{IN}$ = 3.6V, $V_{OUT}$ = 3.6V

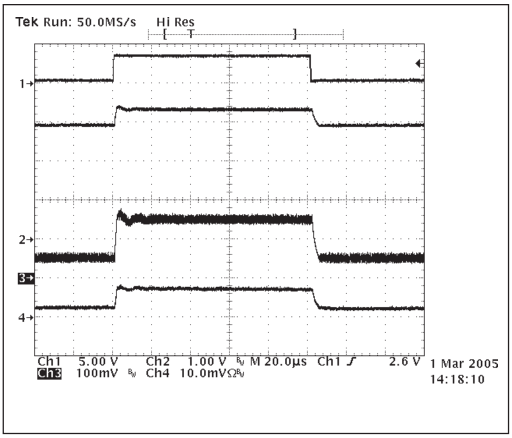



Figure 27. Torch in 1X to Flash in 1X Mode $V_{IN}$ = 4.2V.
CH1 = FLASH, CH2 = $V_{OUT}$, CH3 = $V_{FB}$, CH4 = $I_{OUT}$ 1A/div.

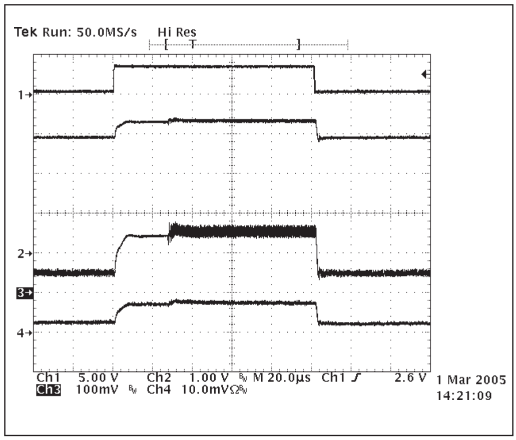



Figure 28. Torch in 1X to Flash in 2X Mode $V_{IN}$ = 3.6V.
CH1 = FLASH, CH2 = $V_{OUT}$, CH3 = $V_{FB}$, CH4 = $I_{OUT}$ 1A/div.

Application Circuit = Figure 31, $T_A$ = 25°C.

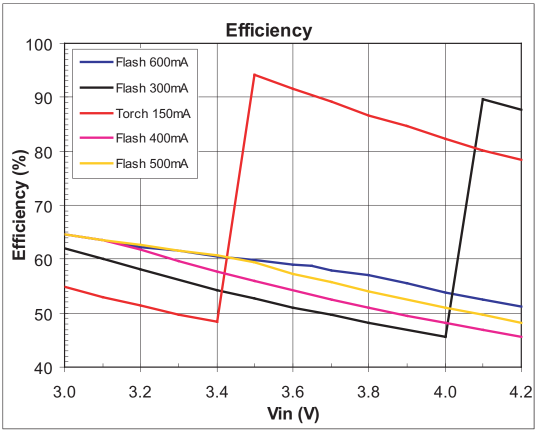



Figure 29. Efficiency vs. VIN.

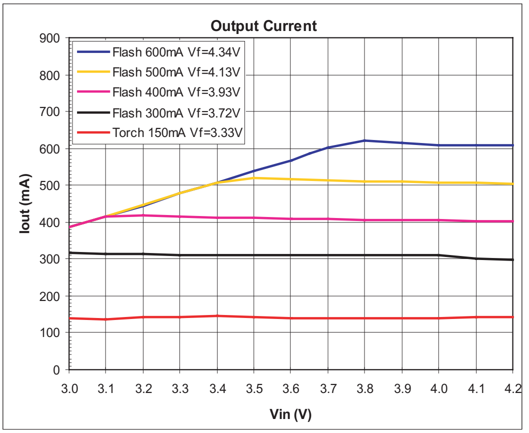



Figure 30. Output Current vs. VIN.

## APPLICATION INFORMATION

The SP6685 can be used with multiple LEDs in parallel as shown in figure 31. For best performance, the LEDs should be in a single package, preferably from a single die to have better matching for forward voltage $V_f$ for a given forward current $I_f$. In practice, if the $V_f$ of one LED is higher than the others, it will consume a larger $I_f$, which will raise its temperature which will then cause its $V_f$ to reduce, correcting the imbalance. The overall current will be the sum of the individual currents, for example $I_{total} = 4*I_{LED}$.

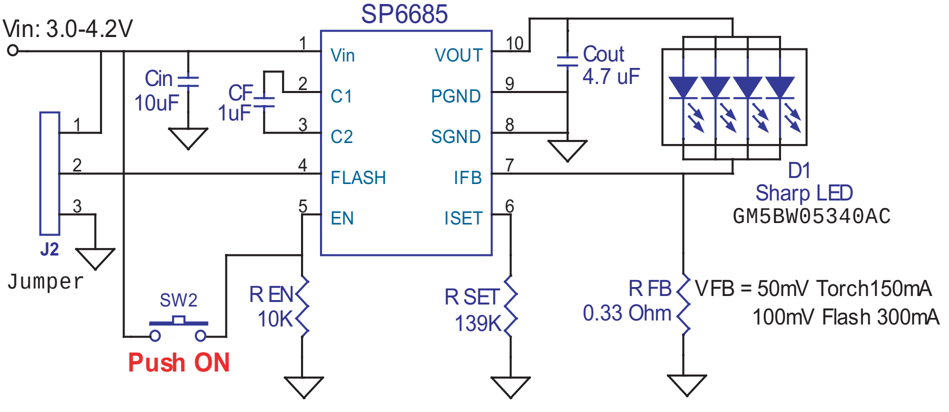
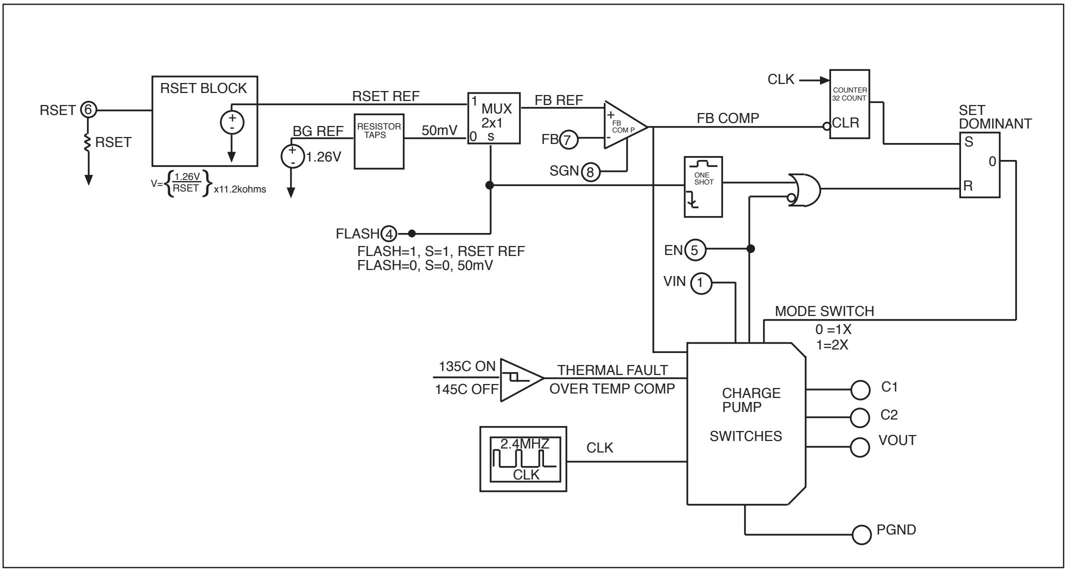



Figure 31. MULTIPLE LED FLASH CIRCUIT.




## THEORY OF OPERATION

The SP6685 is a charge pump regulator designed for converting a Li-Ion battery voltage of 2.7V to 4.2V to drive a white LED used in digital still camera Flash and Torch applications. The SP6685 has two modes of operation which are pin selectable for either Flash or Torch. Flash mode is usually used with a pulse of about 200 to 300 milliseconds to generate a high intensity Flash. Torch can be used continuously at a lower output current than Flash and is often used for several seconds in a digital still camera "movie" mode.

The SP6685 also has two modes of operation to control the output current: the 1X mode and 2X mode. Operation begins after the enable pin EN receives a logic high, the bandgap reference wakes up after 200μsec, and then SP6685 goes through a soft-start mode designed to reduce inrush current. The SP6685 starts in the 1X mode, which acts like a linear regulator to control the output current by continuously monitoring the feedback pin FB. In 1X mode, if the SP6685 auto detects a dropout condition, which is when the FB pin is below the regulation point for more than 32 cycles of the internal clock, the SP6685 automatically switches to the 2X mode. The SP6685 remains in the 2X mode until one of four things happens: 1) the enable pin EN has been toggled, 2) the Flash pin has changed from high to low, 3) $V_{IN}$ is cycled or, 4) a thermal fault occurs.

The 2X mode is the charge pump mode where the output can be pumped as high as two times the input voltage, provided the output does not exceed the maximum voltage for the SP6685, which is internally limited to about 5.5V. In the 2X mode, as in the 1X mode, the output current is regulated by the voltage at the FB pin.

In the Torch mode, (Flash = GND) the Flash pin is set to logic low and the SP6685 FB pin regulates to 50mV output:

$V_{FB}$ = 50mV (Torch Mode)

When in Flash mode, (Flash = $V_{IN}$), the FB regulation voltage is set by the resistor $R_{SET}$ connected between the $R_{SET}$ pin and $S_{GND}$ and the equation:

$V_{FB}$ = (1.26V/ $R_{SET}$)*11.2KΩ (Flash Mode)

Where 1.26V is the internal bandgap reference voltage and 11.2KΩ is an internal resistance used to scale the $R_{SET}$ current. Typical values of $R_{SET}$ are 40KΩ to 180KΩ for a range of $V_{FB}$ = 300mV to 75mV in Flash mode.

The output current is then set in either Flash or Torch mode by the equation:

$I_{OUT} = V_{FB} / R_{SENSE}$

### OVERTEMPERATURE PROTECTION

When the temperature of the SP6685 rises above 145 degrees Celsius, the over temperature protection circuitry turns off the output switches to prevent damage to the device. If the temperature drops back down below 135 degrees Celsius, the part automatically recovers and executes a soft start cycle.

### OVERVOLTAGE PROTECTION

The SP6685 has over voltage protection. If the output voltage rises above the 5.5V threshold, the over voltage protection shuts off all of the output switches to prevent the output voltage from rising further. When the output decreases below 5.5V, the device resumes normal operation.

### OVERCURRENT PROTECTION

The over current protection circuitry monitors the average current out of the $V_{OUT}$ = 50mV (Torch Mode) pin. If the average output current exceeds approximately 1Amp, then the over current protection circuitry shuts off the output switches to protect the chip.

### COMPONENT SELECTION

The SP6685 charge pump circuit requires 3 capacitors: 4.7μF input, 1μF output and 1μF fly capacitor are typically recommended. For the input capacitor, a larger value of 10μF will help reduce input voltage ripple for applications sensitive to ripple on the battery voltage. All the capacitors should be surface mount ceramic for low lead inductance necessary at the 2.4MHz switching frequency of the SP6685 and to obtain low ESR, which improves bypassing on the input and output and improves output voltage drive by reducing output resistance. Ceramic capacitors with X5R or X7R temperature grade are recommended for most applications. A selection of recommended capacitors is included in Table 1 below.

| Manufacturers Website | Part Number | Capacitance/ Voltage | Capacitor Size/Type/Thickness | ESR at 100KHz |
|---|---|---|---|---|
| TDK/www.tdk.com | C1005X5R0J105M | 1uF/6.3V | 0402/X5R/0.5mm | 0.03 |
| TDK/www.tdk.com | C1608X5R0J475K | 4.7uF/6.3V | 0603/X5R/0.9mm | 0.02 |
| TDK/www.tdk.com | C2012X5R0J106M | 10uF/6.3V | 0805/X5R/1.35mm | 0.02 |
| Murata/www.murata.com | GRM155R60J105KE19B | 1uF/6.3V | 0402/X5R/0.55mm | 0.03 |
| Murata/www.murata.com | GRM188R60J475KE19 | 4.7uF/6.3V | 0603/X5R/0.9mm | 0.02 |
| Murata/www.murata.com | GRM21BR60J106KE19L | 10uF/6.3V | 0805/X5R/1.35mm | 0.02 |

Table 1: Recommended Capacitors

The input and output capacitors should be located as close to the $V_{IN}$ and $V_{OUT}$ pins as possible to obtain best bypassing, and the returns should be connected directly to the $P_{GND}$ pin or to the thermal pad ground located under the SP6685. The fly capacitor should be located as close to the C1 and C2 pins as possible. See typical circuit layout (page 13) for details on the recommended layout.

To obtain lower output ripple, the $C_{OUT}$ value can be increased from 1µF to 2.2µF or 4.7µF with a corresponding decrease in output ripple as shown in the Typical Performance Characteristic curves. For output currents of 500mA to 700mA, the recommended $C_{FC}$ fly capacitor value of 1µF should be used. Output currents in Flash of 100mA to 400mA can use a 0.47µF $C_{FC}$ but a minimum 1µF $C_{OUT}$ is still needed.

## RESISTOR SELECTION

The sense resistor $R_{SENSE}$ is determined by the value needed in the Torch mode for the desired output current by the equation:

$R_{SENSE} = V_{FB} / I_{OUT}$ where $V_{FB}$ = 50mV (Torch Mode)

Once the $R_{SENSE}$ resistor has been selected for Torch mode, the $V_{FB}$ voltage can be selected for Flash mode using the following equation:

$V_{FB} = I_{OUT} * R_{SENSE}$ (Flash Mode) where $I_{OUT}$ is for Flash Mode.

Next, the $R_{SET}$ resistor can be selected for Flash mode using the following equation:

$R_{SET} = (1.26V/ V_{FB})*11.2K\Omega$ (Flash Mode)

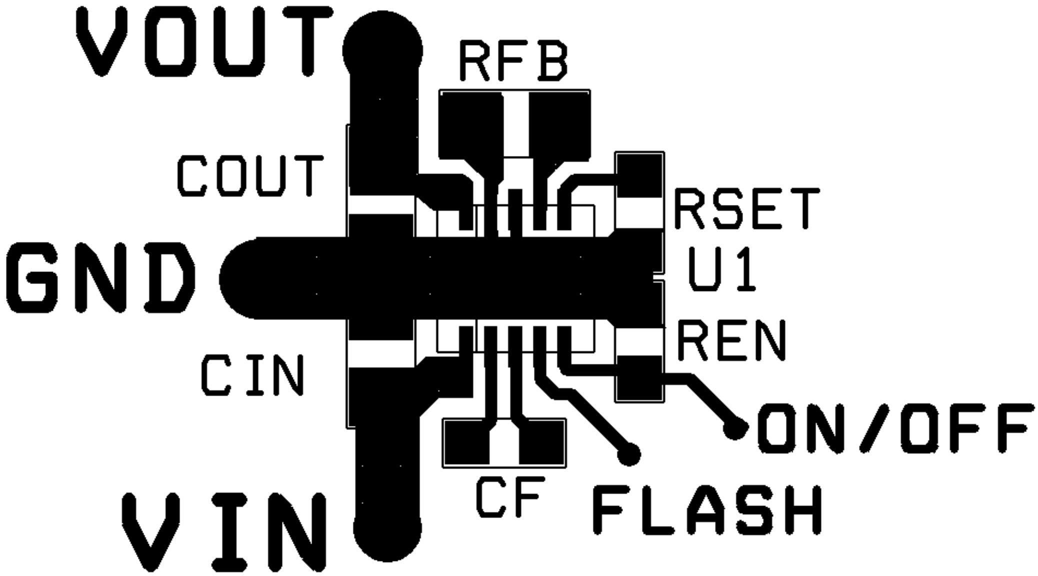
For an example of 200mA Torch mode and 600mA Flash mode, the values $R_{SENSE}$ = 0.25Ω, $V_{FB}$ = 150mV (Flash Mode), and $R_{SET}$ = 94KΩ are calculated. The power obtained in the Flash mode would be:

$P_{FLASH} = V_{FB} * I_{OUT}$ = 150mV*600mA = 90mW.

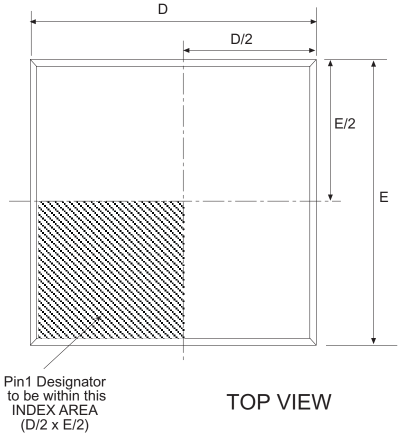
The typical 0603 surface mount resistor is rated 1/10 Watt continuous power and 1/5 Watt pulsed power, more than enough for this application. For other applications, the $P_{FLASH}$ power can be calculated and resistor size selected. The $R_{SENSE}$ resistor is recommended to be size 0603 for most applications. The range of typical resistor values and sizes are shown here in Table 2.

| Part Reference | Value | Tolerance | Size | Manufacturers |
|---|---|---|---|---|
| RSET | 68k | 5% | 0402 | any |
| RSET | 75k | 5% | 0402 | any |
| RSET | 82k | 5% | 0402 | any |
| RSET | 91k | 5% | 0402 | any |
| RSET | 100k | 5% | 0402 | any |
| RSET | 110k | 5% | 0402 | any |
| RSET | 120k | 5% | 0402 | any |
| RSET | 130k | 5% | 0402 | any |
| RSET | 140k | 5% | 0402 | any |
| RSET | 150k | 5% | 0402 | any |
| RSENSE | 0.22 | 5% | 0603 | Panasonic or Vishay |
| RSENSE | 0.27 | 5% | 0603 | Panasonic or Vishay |
| RSENSE | 0.33 | 5% | 0603 | Panasonic or Vishay |
| RSENSE | 0.39 | 5% | 0603 | Panasonic or Vishay |
| RSENSE | 0.47 | 5% | 0603 | Panasonic or Vishay |

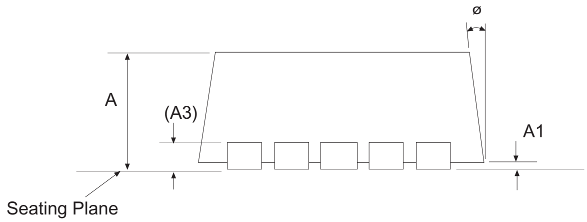
Table 2: Resistor values and sizes


VOUT
RFB
COUT
RSET
GND
U1
REN
CIN
ON/OFF
VIN
CF
FLASH

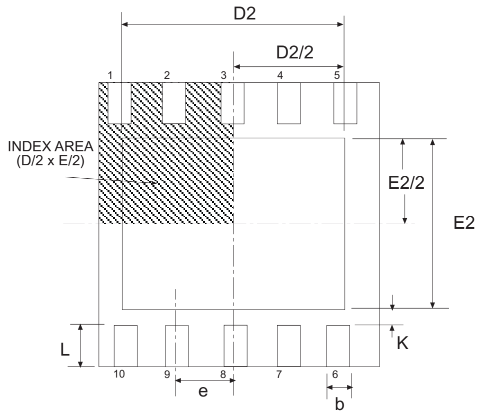
 




TOP VIEW




SIDE VIEW




BOTTOM VIEW

| 3x3 10 Pin DFN JEDEC MO-229 VARIATION VEED-5 | | | | | | |
|---|---|---|---|---|---|---|
| SYMBOL | Dimensions in Millimeters: Controlling Dimension | | | Dimensions in Inches Conversion Factor: 1 Inch = 25.40 mm | | |
| | MIN | NOM | MAX | MIN | NOM | MAX |
| A | 0.80 | 0.90 | 1.00 | 0.032 | 0.036 | 0.039 |
| A1 | 0.00 | 0.02 | 0.05 | 0.000 | 0.001 | 0.002 |
| A3 | 0.20 REF | | | 0.008 REF | | |
| K | 0.20 | - | - | 0.008 | - | - |
| ø | 0º | - | 14º | 0º | - | 14º |
| b | 0.18 | 0.25 | 0.30 | 0.008 | 0.010 | 0.012 |
| D | 3.00 BSC | | | 0.119 BSC | | |
| D2 | 2.20 | - | 2.70 | 0.087 | - | 0.106 |
| E | 3.00 BSC | | | 0.119 BSC | | |
| E2 | 1.40 | - | 1.75 | 0.056 | - | 0.069 |
| e | 0.50 BSC | | | 0.020 BSC | | |
| L | 0.30 | 0.40 | 0.50 | 0.012 | 0.016 | 0.020 |
| SIPEX Pkg Signoff Date/Rev: | | | | JL Aug09-05 / RevA | | |

| Part Number | Operating Temperature Range | Package Type |
|---|---|---|
| SP6685ER | -40°C to +85°C | 10 Pin DFN |
| SP6685ER/TR | -40°C to +85°C | 10 Pin DFN |

Available in lead free packaging. To order add "-L" suffix to part number.

Example: SP6685ER/TR = standard; SP6685ER-L/TR = lead free

/TR = Tape and Reel

Pack quantity is 3,000 for DFN.

**Sipex Corporation**

**Headquarters and Sales Office**
233 South Hillview Drive
Milpitas, CA 95035
TEL: (408) 934-7500
FAX: (408) 935-7600

# Appendix and Web Link Information

For further assistance:

Email: Sipexsupport@sipex.com
WWW Support page: http://www.sipex.com/content.aspx?p=support
Sipex Application Notes: http://www.sipex.com/applicationNotes.aspx
Product Change Notices: http://www.sipex.com/content.aspx?p=pcn

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faX: (408) 935-7600



**The following sections contain information which is more changeable in nature and is therefore generated as appendices.**

1) **Package Outline Drawings**
2) **Ordering Information**

**If Available:**

3) **Frequently Asked Questions**
4) **Evaluation Board Manuals**
5) **Reliability Reports**
6) **Product Characterization Reports**
7) **Application Notes for this product**
8) **Design Solutions for this product**

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Part Number S
PartnerNet Keyword Sear

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## Product Lines

### Power Management

- Boost Regulators
- Buck Regulators
- Charge Pumps
- LED Drivers
- Linear Regulators
- Power Blox™
- PWM Controllers
- References
- Supervisors
- USB Vbus Switches

### Interface

- Multiprotocol
- RS232
- RS422
- RS485
- USB

### Optical Storage

- Advanced Power Control
- Photo Detector IC

## SP6685 product details

You are here : Home : Products : Charge

### 700mA Charge Pump LED Driver For Camera Flash

### Features

- Output Current up to 700mA
- Up to 94% Efficiency in Torch Mode
- Adjustable FLASH mode current
- Minimum External Components: No Inductors
- Automatic buck/boost mode switchover
- Wide VIN Range: 2.7V to 5.5V
- High Frequency Operation: 2.4 MHz
- Low 50mV reference for low loss sensing
- IQ < 1μA in shutdown
- PWM Dimming Control
- Automatic Soft Start limits inrush current
- Over voltage protection on output
- Over current/temperature protection
- Low Ripple and EMI
- Ultra low dropout voltage in buck mode
- Space Saving 10-pin 3mm x 3mm DFN Package

### Quick Links

- Download Datasheet
- Check Price Availability

### Design-In Supp

- Email: Tech
- Charge Pum Product Sele
- Applications
- Evaluation E
- Quality Infor
- Part Nomen
- SP6685 FAQ

### Ordering Part Number

| Part Number | Package Code | RoHS | MIN. Temp. (°C) | MAX. Temp. (°C) | Status | Buy | Samples |
|---|---|---|---|---|---|---|---|
| CHARGE PUMP **SP6685** | | | | | | | |
| LED DRIVER **SP6685** | | | | | | | |
| **SP6685**ER-L | DFN10 | ▪ | -40 | 85 | Active | Buy Now | Order Sa |
| **SP6685**ER-L/TR | DFN10 | ▪ | -40 | 85 | Active | Buy Now | Order Sa |
| **SP6685**EB | Board | | 0 | 70 | Active | Buy Now | Order Sa |
| **SP6685**ER-ES-L | DFN10 | ▪ | 0 | 70 | EOL | | |
| **SP6685**ER | DFN10 | | -40 | 85 | EOL | Buy Now | |
| **SP6685**ER/TR | DFN10 | | -40 | 85 | EOL | Buy Now | |
| **SP6685**ER-ES | DFN10 | | -40 | 85 | EOL | | |
| **SP6685**ER-ES/TR | DFN10 | | 0 | 70 | EOL | | |
| **SP6685**W | Wafer | | 0 | 70 | EOL | Buy Now | |

**Part Status Legend**

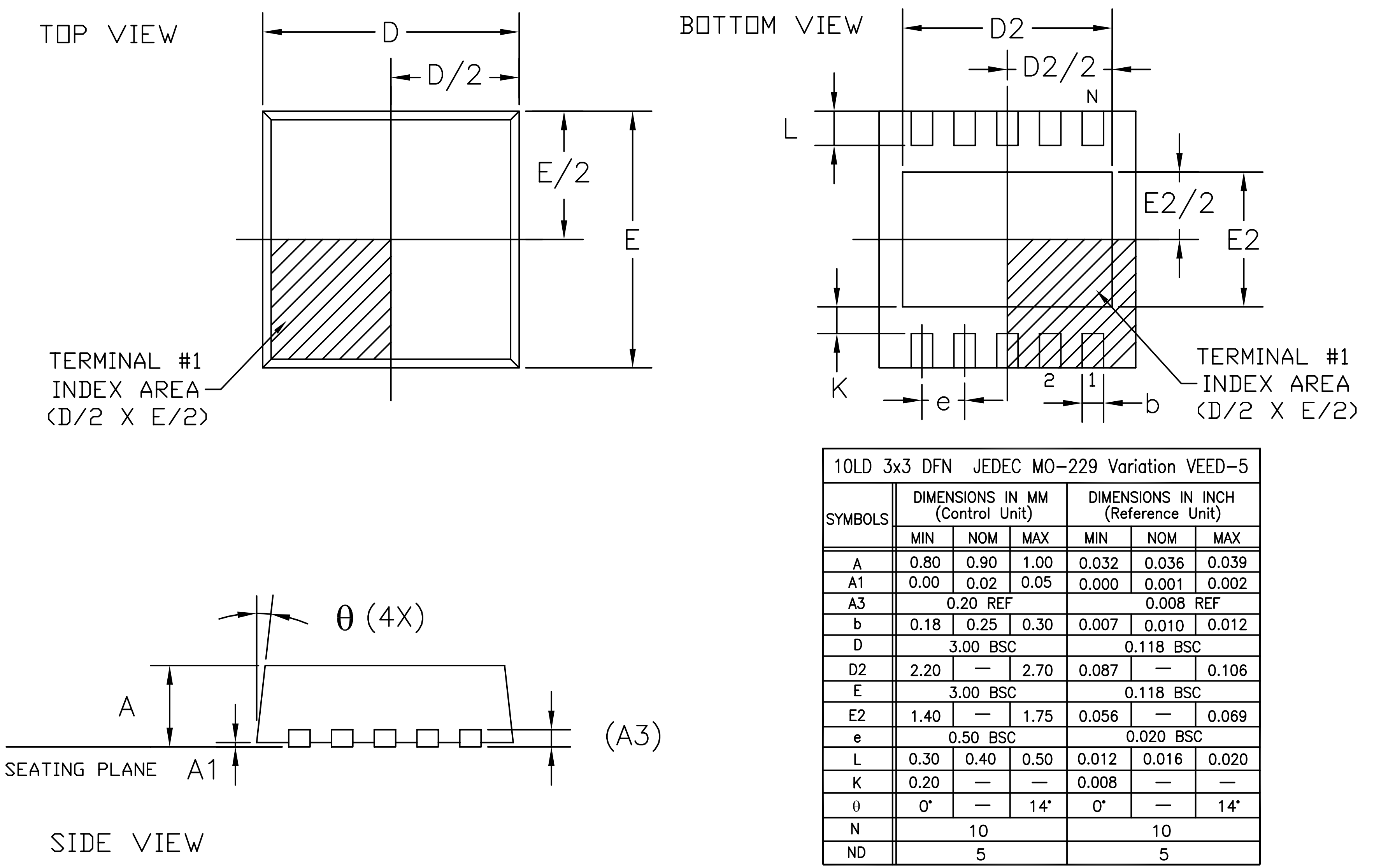
**Active** - the part is released for sale, standard product.

**EOL (End of Life)** - the part is no longer being manufactured, there may or may not be inventory still in stock.

**CF (Contact Factory)** - the part is still active but customers should check with the factory for availability. Longer lead-times may apply.

**PRE (Pre-introduction)** - the part has not been introduced or the part number is an early version available for sample only.
**OBS (Obsolete)** - the part is no longer being manufactured and may not be ordered.
**NRND (Not Recommended for New Designs)** - the part is not recommended for new designs.

| REVISION HISTORY | | | |
|---|---|---|---|
| REV. | DISCRIPTION | DATE | APP'D |
| A | DRAWING ORIGINATION | 08/09/05 | JL |
| B | MODIFY DRAWING FORMAT | 07/10/06 | JL |




| 10LD 3x3 DFN JEDEC MO-229 Variation VEED-5 | | | | | | |
|---|---|---|---|---|---|---|
| SYMBOLS | DIMENSIONS IN MM (Control Unit) | | | DIMENSIONS IN INCH (Reference Unit) | | |
| | MIN | NOM | MAX | MIN | NOM | MAX |
| A | 0.80 | 0.90 | 1.00 | 0.032 | 0.036 | 0.039 |
| A1 | 0.00 | 0.02 | 0.05 | 0.000 | 0.001 | 0.002 |
| A3 | 0.20 REF | | | 0.008 REF | | |
| b | 0.18 | 0.25 | 0.30 | 0.007 | 0.010 | 0.012 |
| D | 3.00 BSC | | | 0.118 BSC | | |
| D2 | 2.20 | — | 2.70 | 0.087 | — | 0.106 |
| E | 3.00 BSC | | | 0.118 BSC | | |
| E2 | 1.40 | — | 1.75 | 0.056 | — | 0.069 |
| e | 0.50 BSC | | | 0.020 BSC | | |
| L | 0.30 | 0.40 | 0.50 | 0.012 | 0.016 | 0.020 |
| K | 0.20 | — | — | 0.008 | — | — |
| θ | 0° | — | 14° | 0° | — | 14° |
| N | 10 | | | 10 | | |
| ND | 5 | | | 5 | | |

| | |
|---|---|
| Solved by Sipex | SIPEX CORPORATION |
| | 10 PIN 3x3 DFN PACKAGE OUTLINE |
| Packaging Approval: | Drawing No: 10–PIN 3x3 DFN |
| By: JL Date: 07/10/06 | Revision: B Sheet: 1 OF 1 |

APPLICATION NOTE ANP10

# Using SP6685 to Provide a Tiny, Efficient, High Power LED Camera Flash Solution

## Introduction

Feature sets for new cell phones and PDAs are expanding with the latest models including built-in cameras and video cameras. Today's cell phones now offer megapixel resolution cameras whichthen necessitate more sophisticated flash technology. At the same time, consumers demand increasingly smaller form factors and longer battery life, making the circuit design challenging.

Xenon flash lamps could provide high lumen flash capability but are not used in cell phones and PDAs because they are too bulky. LED solutions are more suited to the form factor requirements of cell phones and PDAs, not only for their small size but also because they operate in "torch" or video mode. Until recently, LED solutions were only popular in sub 1 megapixel digital cameras, but improvements in LED technology made them viable solutions for 1 megapixel and higher cell phone cameras.

Sipex offers the highest performance, extremely compact solution for driving the latest high light output LEDs, including Lumileds Luxeon Flash LEDs. Luxeon LEDs are up to 12 times brighter than conventional LEDs and are ideal for applications in cell phones, PDAs, digital still cameras
and digital camcorders.

## Requirements for LED Drivers in Portable Electronics

While switcher based DC-DC converters offer the efficiency and small size required for highcurrent LED drivers used in battery operated portable equipment, they have one fundamental drawback. Traditional switchers are designed to provide a regulated voltage for varying load currents. However, LEDs must be driven with a constant current to generate a predictable light output. If a typical switcher were to be used for such an application, it would require using an opamp and additional circuitry, which is undesirable in space constrained applications. Besides the constant current requirement, the solution must also be able to either step-up or step down the input voltage from the Lithium-ion battery depending on where the Li-ion battery is in its discharge cycle.

## The SP6685 Charge Pump Solution

The SP6685 operates in either the 1x or 2x mode, providing constant current to the LED with either a step-up or step-down in voltage. The SP6685 eliminates the need for the inductor because of the charge pump operation. With an industry leading switching frequency of 2.4MHz, the SP6685 offers the smallest solution size. The device is available in a space saving 10 pin DFN package and requires only 3 small capacitors and 2 small resistors (0603 and 0402 size), making it the ideal choice for small form factor applications

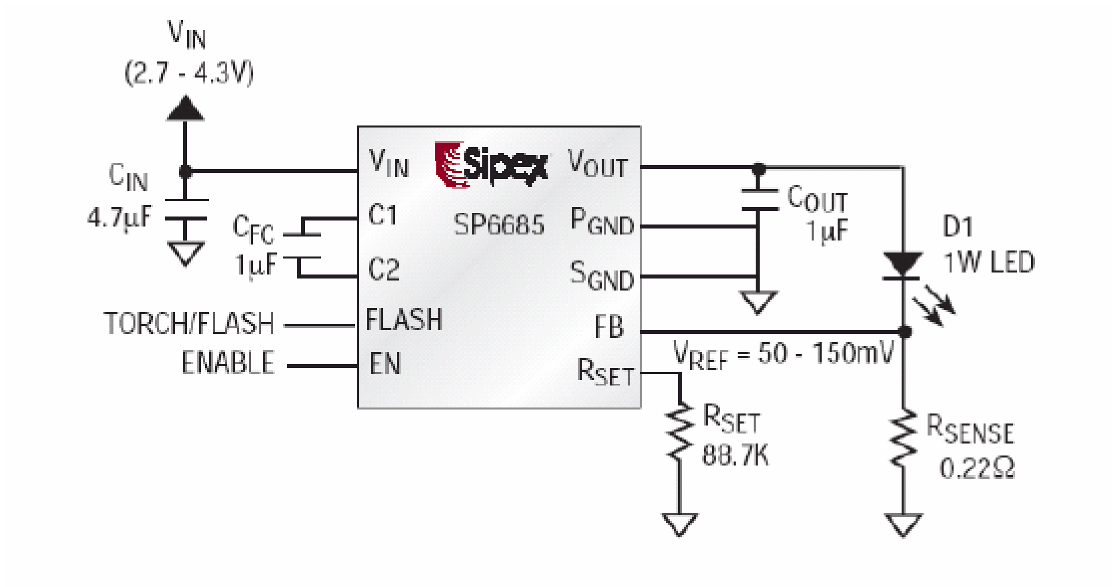



**Figure 1. Small, Efficient LXCL-PWF1 Luxeon Flash Driver using the SP6685.**

This charge pump based design eliminates the need of an inductor and requires just 5 small external components to realize a 700mA solution in flash mode and 200mA in torch mode.

The SP6685 delivers up to 92% efficiency thanks to a proprietary feature that enables the IC to automatically transition from the buck mode to the boost mode based on the battery input voltage. This also ensures the current does not depend on the LED forward voltage. An extremely low output equivalent resistance and reference voltage allow for the highest white LED flash brightness and an ultra low dropout voltage. The SP6685 also features a very low shutdown current, an automatic soft-start mode to limit inrush current, as well as over current, over voltage and thermal-shutdown control.

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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# APPLICATION NOTE ANP17

## Design Considerations For Cell Phone Camera Flash Drivers

## Introduction

Hundreds of kinds of cell phones are appearing on the market every year and they all have the same major function—communication. In the case of GSM handsets, they are using the same, or similar, chipsets to achieve those functions. The difference among them is in the peripheral functions, such as appearance, color and brightness of the LCD. Other differentiating features include multimedia capabilities, Bluetooth enablement, digital camera, and other peripheral functions. A cell phone camera function is the fastest growing segment of the new handset feature sets. Due to this, the Flash LED performance for cameras has becomes an important differentiator.

LED flash is used popularly in the cell phone field. In contrast to the high voltage necessary for Xenon lamps, LED flash only needs 3.5V-4.6V constant voltage. And 2000mcd- 7500mcd brightness can be achieved with as little as 120-250mA LED current. LEDs are a good choice for cell phone, digital camera and other portable equipment, because LED flash has the following advantage: high efficiency, low cost, and small PCB area.

## Solution for LED flash driver

LED flash driver circuits can be sorted into CV mode (constant voltage) and CC mode (constant current) power circuits, according to the different output characteristic of each mode. Furthermore, the LED driver power solutions can again be sorted into the boosting circuit and the charge pump circuit according to the different step up modes.

**CV mode and CC mode**. The LED brightness relies on the current that goes through it. The forward voltage doesn't influence the brightness. In CV mode, a resistor is needed to be connected to the LED in series. The current through the LED can be calculated by the following function:

$$I_{LED}=(V_{OUT}-V_F)/R$$

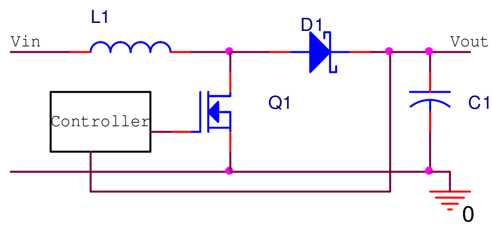
Where, $V_{OUT}$ is the output voltage of the LED driver. $V_F$ is the forward voltage of the LED. R is the value of the resistor that is connected to the LED in series. So, $I_{LED}$ is determined by three parameters: $V_{OUT}$ ,$V_F$ ,R.

$V_{OUT}$ and R are fixed and the range of $V_F$ is 3V-4.6V. The LED current as well as the LED brightness will be different if the LEDs have the different values of $V_F$. This is the disadvantage of CV mode.

In CC mode, the voltage on the resistor that is connected to LED in series is fixed. And R is fixed, too. Thus, the current that goes through the LED and resistor is constant. So the anticipated LED brightness can be calculated.

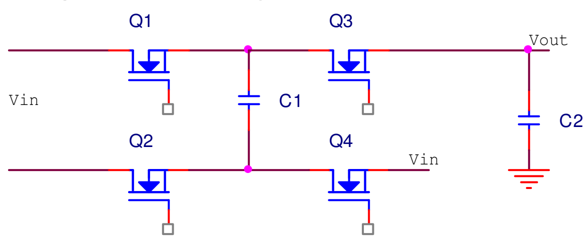
**Boost and charge pump**. Generally, the input range of a Li-Ion battery is 3.2V~4.2V, and the forward voltage is 3V~4.6V. So as the input is low, such as 3.6V and the output needs be high, such as 4.6V, a step-up circuit will be needed to drive the LED. There are two modes to step up the voltage. One is the boost circuit that uses an inductor to transfer power and another is the charge pump that uses a capacitor to transfer power.

Generally, the inductive based boost DC/DC LED driver provides higher efficiency than the charge pump solution. A typical schematic can be found below.




In most of LED driver ICs used for boost DC/DC circuits, the controller and MOSFET are integrated. But the inductor and Schottky diode are peripheral components. So, the total BOM cost and solution PCB area can be larger than the charge pump solution. The circuit also becomes more complex and considerations of EMI induced by inductor action might come into consideration for handset communications interference. Because the flash driver, LCD driver, and mobile antenna are all located on the top side of the cell phone, and they are all close to the RF circuit, it is a very important problem to prevent RF emissions from the inductor on the driver circuit.

A typical Charge Pump function diagram can be found as below:

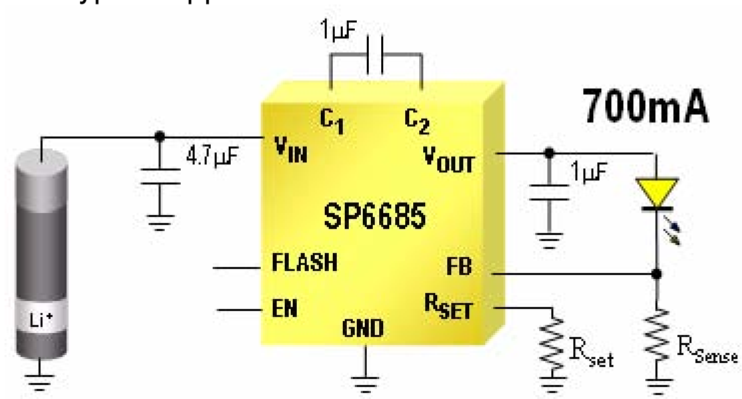



There is no inductor used in the charge pump topology, so it doesn't contain inductor related EMI components and the driver solution area can be less than a boost circuit, with a lower parts count. But compared with an inductive-based boost DC/DC circuit, the charge pump has a weakness in efficiency in some operating modes. However, the flash time is very short, only lasting 100~300ms generally, so the low efficiency issue isn't a critical factor for the cell phone battery. In torch mode operation, efficiency can become a consideration, but usually the conversion is a higher efficiency buck, in both circuit type cases. The main consideration for efficiency in boosting modes (during Flash mode) will come into play when considering the inrush current pulled from the battery, which may be higher in the case of the charge pump, but approaches instantaneous. If the current pulled out of the battery input increased, some handset vendors disable the flash function when the battery reaches a low level, 3.4V for example. However, the life percentage of a Lithium-Ion cell is very short when it falls below 3.5V, so the end user does not often see this depleted functionality, and if so, would probably welcome the power savings decision when the battery itself is about to reach its end of charge. The talk time at the last 5% of battery life will usually be preferred over taking a flash-based picture.

## Sipex LED flash driver series

Due to the inherent advantages of the charge pump solution for LED driving, Sipex announced a series of flash drivers: SP6686, SP6685, and SP7685. The output currents are up to 400mA, 700mA, and 1.2A respectively. They are all pin-compatible to each other; the only difference among them is the output current, except for timeout features added to the SP7685 device that assure 1.2A is not driven into an LED continuously. The 700mA-capable SP6685 is the most popular device among these introduced products, supporting CCDs of 3Megapixels and higher.

The typical application circuit of SP6685 can be found as below:




Few peripheral components are needed except 3 capacitors and 2 resistors. $R_{SET}$ is used to set up the current of flash mode and $R_{SENSE}$ is for torch current. Due to the fast switching speeds, the component heights, including capacitors are kept at a minimum.

### SP6685 torch mode

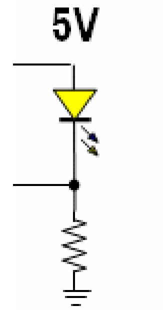
For the torch mode, SP6685 works in CC mode. In torch mode (Flash pin is low), the voltage of the FB pin is 50mV (typical value). So the current that flows through the LED can be calculated as:

$I_{LED}$=50mV/$R_{SENSE}$

There is a point that should be clarified here. Because the $V_{FB}$ is 50mV and even if the maximum current (200mA) goes through the LED, the power on the $R_{SENSE}$ resistor is:

$P_{SENSE}$=50mV●200mA=0.01W

So a resistor with 0603 SMD package can be used for $R_{SENSE}$ and it will save PCB area. However, in CV mode, a much bigger package will be needed for $R_{SENSE}$. Most driver circuit output voltages are 5V as shown below:




The LED forward voltage range is 3V-4.6V, as the output voltage is 5V, the voltage on the resistor will be 1V~2V. When the LED current is 200mA, $R_{SENSE}$ power will be:

$P_R = U \bullet I = (1V \sim 2V) \bullet 0.2A = 0.2W \sim 0.4W$

Four resistors with 1206 package size will be needed. Compared with the SP6685 solution (only one resistor with 0603 package), a CV mode solution needs more PCB area.

Compared with the charge pump in CV mode, the efficiency advantage of the SP6685 should be emphasized. The LED driver's efficiency (η) is influenced by 3 parameters: 1) input voltage ($V_{IN}$); 2) LED forward voltage ($V_F$); 3) step-up multiples (K=1X, 2X). The function is:

$\eta = V_F / (V_{IN} \bullet K)$

Because the Li-battery voltage range is 3.6V~4.2V and the output voltage should be 5V, the charge pump should be within the step-up mode. That is to say, K should be 1.5 or 2. In fact, when the Li-battery voltage is higher than the LED forward voltage, the charge pump can be in 1X mode. The efficiency of 1X mode is much higher than the efficiencies of 1.5X and 2X mode. So the efficiency of Sipex flash driver series is higher than the ICs that work in CV mode.

**SP6685 flash mode**

In flash mode (Flash pin is high), the voltage of FB ($V_{FB}$) is determined by $R_{SET}$. The function is:

$V_{FB} = (1.26V / R_{SET}) \bullet 11.2K\Omega$

Where 1.26 is the internal bandgap reference and 11.2KΩ is an internal resistance used to scale the $R_{SET}$ current.

The flash current can be calculated as:

$I_{LED} = V_{FB} / R_{SENSE}$

The LED current doesn't flow through $R_{SET}$, so little power will be consumed on $R_{SET}$. Therefore, an 0603 or 0402 package is enough for $R_{SET}$.

On the total solution, only 2 resistors with 0603 package and 3 capacitors with 0805 package are needed as peripheral components. So the solution area can be contained in an area of 5.4mm*3mm, which is very difficult for other flash drivers.

## The comparison of SP6685/SP6686 with other flash drivers

Table 1 is the comparison of SP6685/6696 with other flash drivers. The advantage of the Sipex flash driver can be seen from the sheet.

**Sipex Charge Pump Advantages: SP6685/SP6686/SP7685/SP7686**(Soon to Release)

1) The least components with the smallest package, resulting in the lowest cost solution.
2) The highest frequency means the smallest capacitor values for the input & output capacitor and flying capacitor.
3) No inductive based EMI concerns.
4) Highest efficiency among the charge pump ICs, since SP6685/6686/7685 can work in 1X mode and the feedback voltage is
5) low to 50mV.

| | SP6685 SP6686 | NCP5603 | LM2753 | MAX1576 | RT9362 | Max1583 | LM3551 LM3552 |
|---|---|---|---|---|---|---|---|
| **IOUT (Flash mode)** | 780mA/ 400mA | 350mA | 400mA | 480mA | 120mA | 300mA | 1A |
| **IOUT (Torch mode)** | 200mA | 200mA | 200mA | 30mA*8 | 120mA | 100mA | 200mA |
| **Operating mode** | 1X, 2X charge pump | 1X, 1.5X, 2X Charge pump | 1X，2X charge pump | 1X, 1.5X, 2X Charge pump | 1X, 1.5X, 2X Charge pump | Boost | Boost |
| **Frequency (Hz)** | 2.4M | 262K, 650K | 725K | 1M | 250K/1M | 1M | 1.25M |
| **VOUT** | CC mode (Note1) | 4.5V/5V | 5V | CC mode | CC mode | 24V, CC mode | adjustable |
| **Peripheral components quantity** | | 4 cap, 4 res(1206) | 3 cap 2 res(1206) | 5 cap, 2 res | 4 cap, 1 res | 3 cap 1 inductor 1 Schottky 3 res | 5 cap, 1 inductor 1 Schottky 3 res |
| **PACKAGE** | DFN10, 3x3 | DFN10, 3x3 | LLP10, 3x3 | QFN-24, 4x4 | VQFN16, 3x3 | TDFN-10, 3x3 | LLP14, 4x4 |
| **θJA** | 57.1℃/W | 68.5℃ /W | 55℃/W | 100℃ /W | 68℃ /W | 150℃/W | 37.3℃/W |

**Table 1: comparison of flash drivers**

Note 1:
CC mode means *constant current* mode

Comments :
1) NCP5603 and LM2753 should work in 1.5X or 2X mode, the efficiency will be decreased.
2) 4 resistors of 1206 size SMD will be needed on NCP5603 and 2 resistors of size 1206 SMD will be needed on LM2753. It costs more PCB area.
3) The frequency of SP6685/6686 (2.4MHz) is much higher than others. So the input and output capacitors and flying capacitor have smallest values.
4) MAX1583, LM3551/3552, MP1540 should have an inductor and Schottky diode as peripheral components.
5) The feedback voltage of LM3551/3552 is 1.265V, much higher than 50mV. Much power will be consumed on the sense resistor.
6) RT9326's output current is much less than SP6685/6686.
7) 2 sets of LEDs are needed by MAX1576 for flash and torch mode.

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
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faX: (408) 935-7600

# SP6685: FAQ

**Sipex Part: SP6685**
**Date:** June 2, 2006

## Question:
How do you choose the Torch mode for the SP6685? I connected pin 4 of the SP6685 to ground, but it does not work.

## Answer:
When you try to turn on the SP6685, you need to connect EN pin to Vin or to some logic high for the length of time that you need the LED to be on, in addition to connecting the Flash pin to GND. You also need to have selected a $R_{FB}$ resistor to sense the current through the LED, as shown in the typical application circuit on page 1 of the SP6685 datasheet. If you have further problems, please send Sipex.support@sipex.com your output requirements such as the forward voltage of the LED and the output current desired as well as the input voltage range.

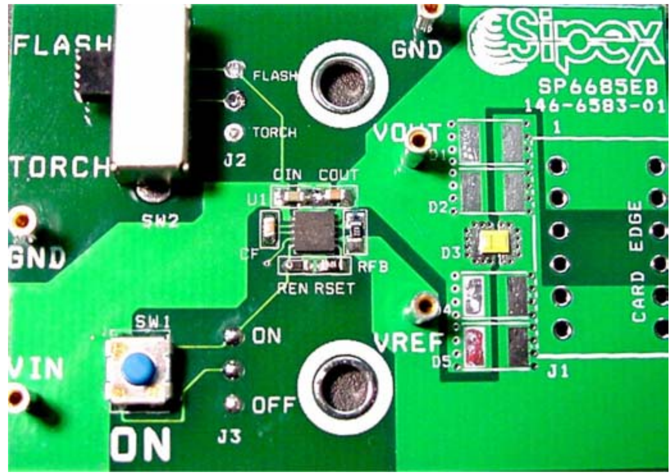
## Question:
I am having some problems with the SP6685 and would like to see some waveforms at the external fly capacitor pins. How do I know if the problem is the capacitor I currently have for the flying capacitor? It is a 1uF Y5U +80/-20 % tolerance. I have some X7R's on order but the datasheet does not show waveforms at the fly capacitor pins so I do not know what to expect.

## Answer:
If it were a too small value in the flying capacitor due to the temperature coefficient of the capacitor, the part would still work OK and may have a little more output resistance. Capacitor values on $V_{IN}$ and $V_{OUT}$ will affect the output ripple values. We would need you to describe in more detail the problems you are having and the conditions for $V_{IN}$, $V_F$ of the LED and $I_{OUT}$, and send Sipex.support@sipex.com your output requirements and questions.

# SP6685EB
# Evaluation Board Manual

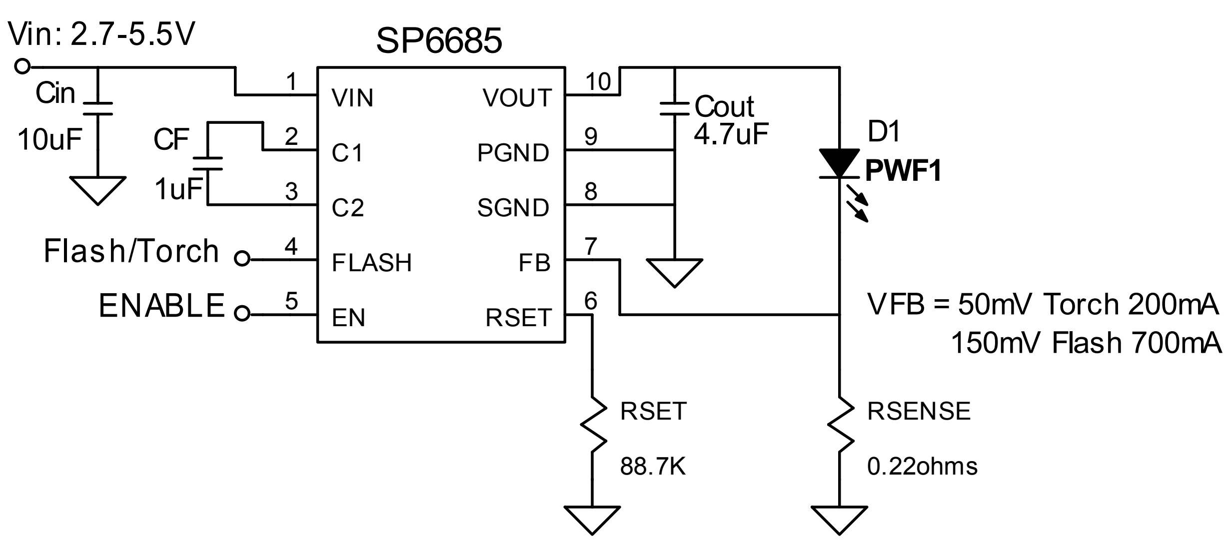
- 2.7V to 4.2V Input Range
- Typical 200mA Torch or 700mA Flash Output Current
- High Efficiency in 1X mode, high $V_{OUT}$ in 2X mode
- Small 3x3mm 10-Pin DFN Package
- 2.4MHz Switching Frequency Enables Small Components
- Integrated Design with Minimal Components.
- Use with 1 cell Lithium Ion Battery




## DESCRIPTION AND BOARD SCHEMATIC

The **SP6685EB Evaluation Board** is a compact circuit including the SP6685 in 3x3mm DFN and 3 small 0603 capacitors which can provide a stable drive current for a 1W LED such as the Lumi-LEDs Luxeon I or PWF1 type light sources. The evaluation board is a completely assembled and tested surface mount board which provides easy probe access points to all SP6685 inputs and outputs so that the user can quickly connect and measure electrical characteristics and waveforms.

**SP6685EB Schematic**




**TO GET STARTED:**

1. Connect VIN from VIN to GND (VIN range 2.7V to 4.2V).
2. Select mode between TORCH and FLASH by putting jumper into corresponding position.
3. Apply High to ON terminal to turn the LED on.

## POWER SUPPLY DATA

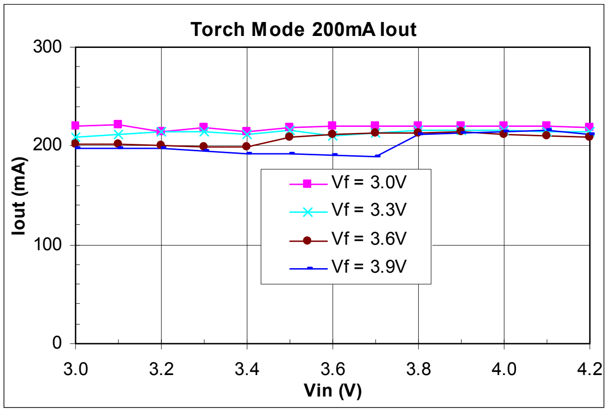



Figure 1. Torch Mode Output Current

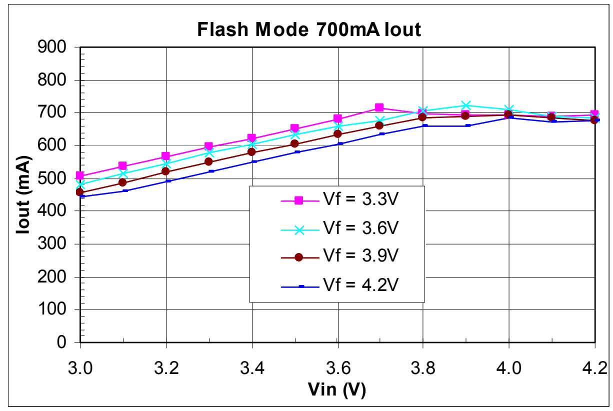



Figure 2. Flash Mode Output Current

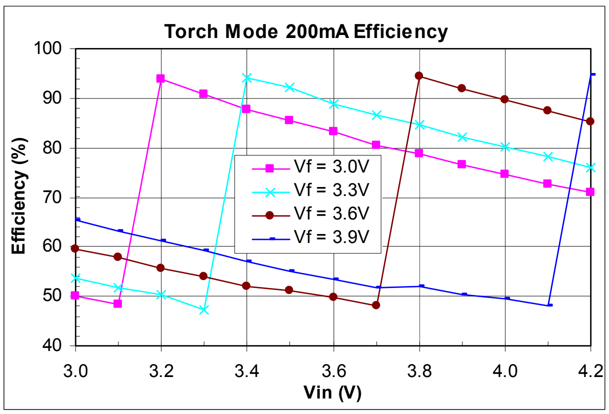



Figure 3. Torch Mode Efficiency

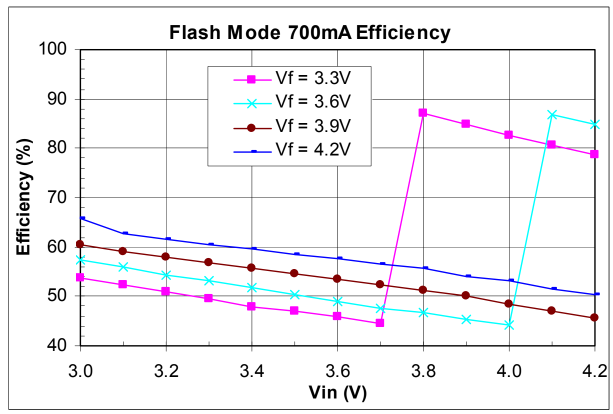
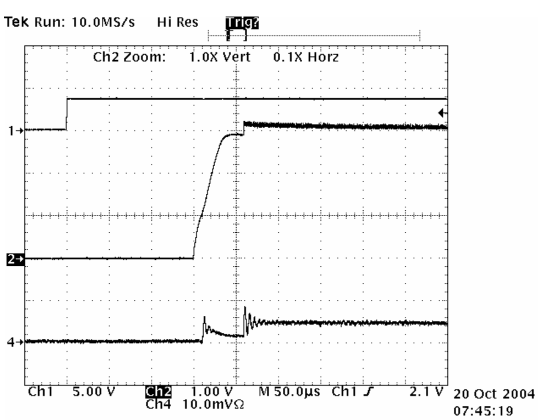



Figure 4. Flash Mode Efficiency




Ch1 = EN

Ch2 = Vout

Ch4 = Iin
(0.5A/div)

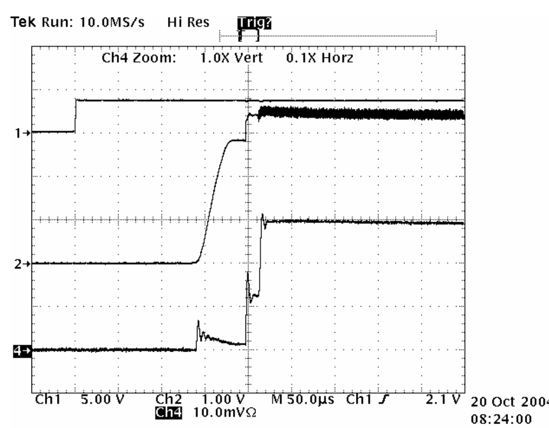
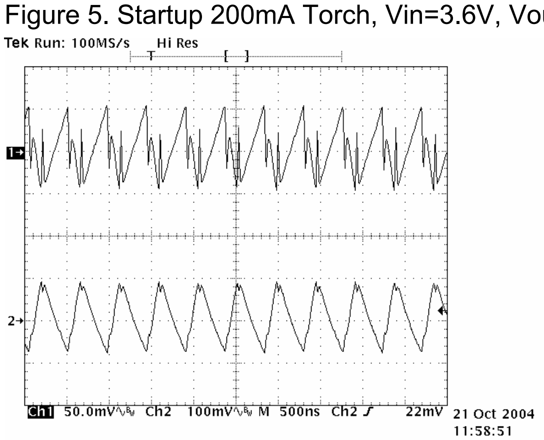



Figure 5. Startup 200mA Torch, Vin=3.6V, Vout=3.0V.

Figure 6. Startup 700mA Flash, Vin=3.6V, Vout=3.3V.




Ch1 = Vin (AC)
50mV/div

Ch2 = Vout (AC)
50mV/div

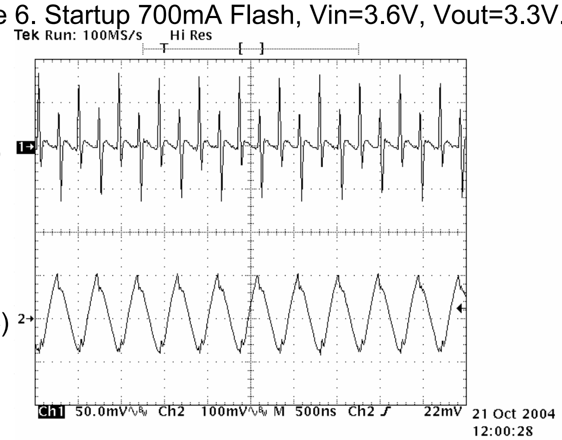



Figure 7. Ripple 200mA Torch, Vin=3.6V, Vout=3.15V.

Figure 8. Ripple 700mA Flash, Vin=3.6V, Vout=3.35V.

## EVALUATION BOARD LAYOUT

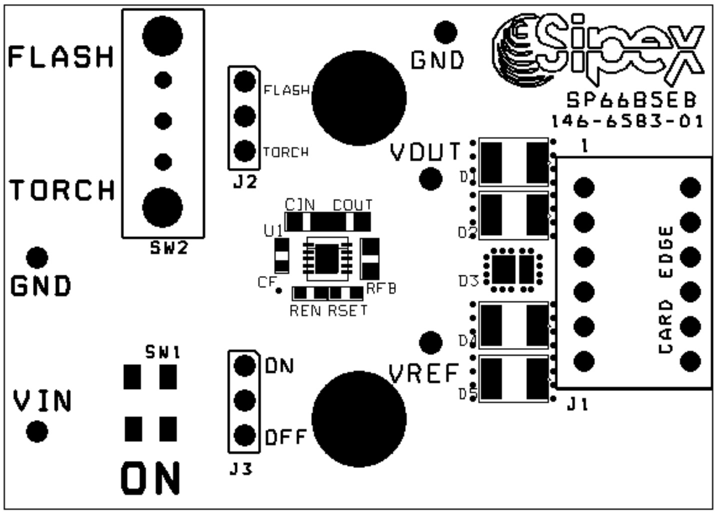



FIGURE 9: SP6685EB COMPONENT PLACEMENT

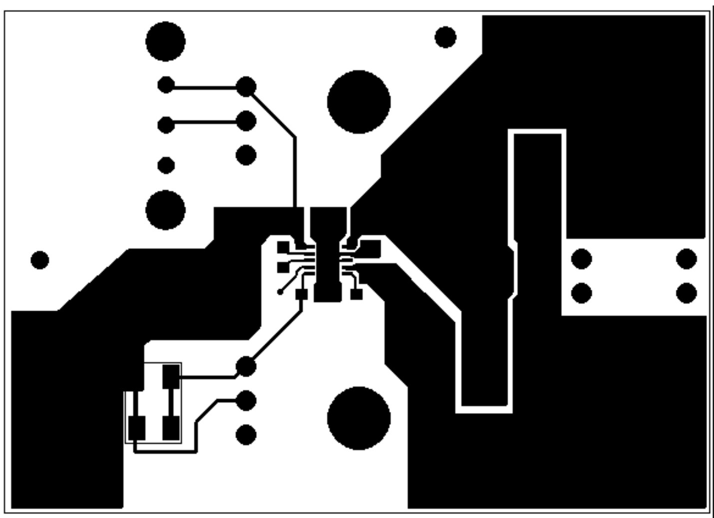


FIGURE 10: SP6685EB PC LAYOUT TOP SIDE

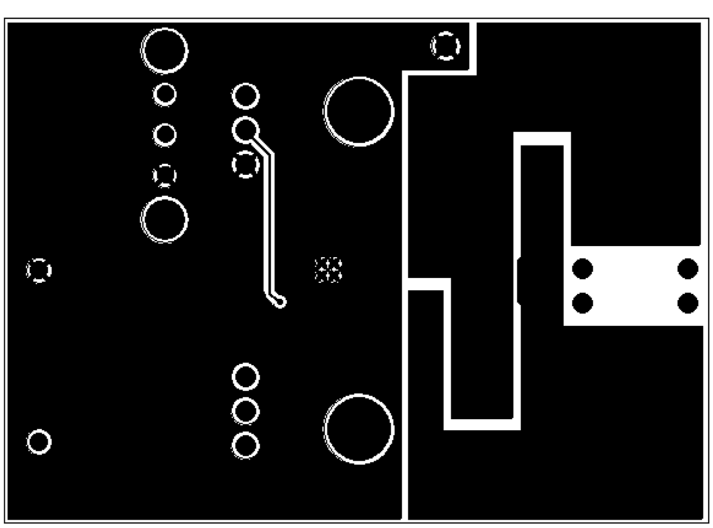


FIGURE 11: SP6685EB PC LAYOUT BOTTOM SIDE

## TABLE1: SP6685EB LIST OF MATERIALS

| Part Reference | Part Number | Value | Size | Manufacturers/ Website |
|---|---|---|---|---|
| U1 | SP6685ER | | 3x3mm DFN - 10 pin | Sipex/www.sipex.cpm |
| CIN | GRM21BR60J106KE19L | 10uF/6.3V | 0805/X5R/1.35mm ht | Murata/www.murata.com |
| CF | GRM155R60J105KE19B | 1uF/6.3V | 0402/X5R/0.5mm ht | Murata/www.murata.com |
| COUT | GRM188R0J475KE19 | 4.7uF/6.3V | 0603/X5R/0.9mm ht | Murata/www.murata.com |
| RSET | - | 88.7K | 0402 | Rohm www.rohm.com |
| | | | | Cyntec www.cyntec.com |
| RSENSE | - | 0.22ohms | 0603 | Cyntec www.cyntec.com |

## ORDERING INFORMATION

**Model** **Temperature Range** **Package Type**

SP6685EB............................. ……-40°C to +85°C...................SP6685EB Evaluation Board
SP6685ER....................................-40°C to +85°C..................................... 10-pin 3x3 DFN