

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 become 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:

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

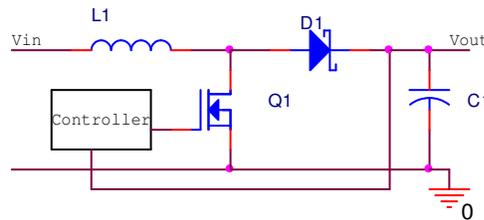
Where, V_{OUT} is the output voltage of the LED driver. V_F is the forward voltage of the LED. R is the value of the resistor that is connected to the LED in series. So, I_{LED} is determined by three parameters: V_{OUT} , V_F , R .

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.

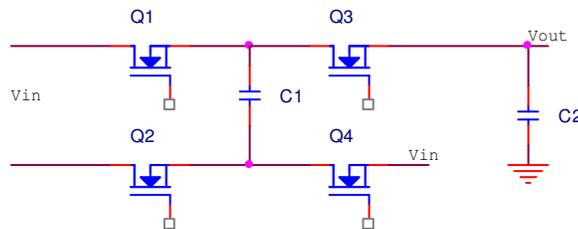
Boost and charge pump. Generally, the input range of a Li-Ion battery is 3.2V~4.2V, and the forward voltage is 3V~4.6V. So as the input is low, such as 3.6V and the output needs be high, such as 4.6V, a step-up circuit will be needed to drive the LED. There are two modes to step up the voltage. One is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



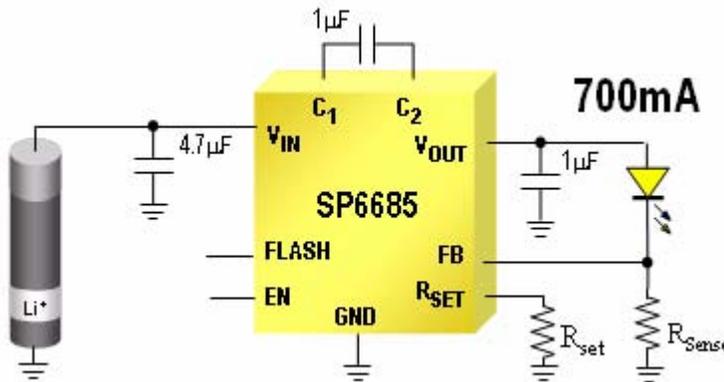
There is no inductor used in the charge pump topology, so it doesn't contain inductor related EMI components and the driver solution area can be less than a boost circuit, with a lower parts count. But compared with an inductive-based boost DC/DC circuit, the charge pump has a weakness in efficiency 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. RSET is used to set up the current of flash mode and RSENSE is for torch current. Due to the fast switching speeds, the component heights, including capacitors are kept at a minimum.

SP6685 torch mode

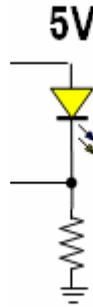
For the torch mode, SP6685 works in CC mode. In torch mode (Flash pin is low), the voltage of the FB pin is 50mV (typical value). So the current that flows through the LED can be calculated as:

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

There is a point that should be clarified here. Because the VFB is 50mV and even if the maximum current (200mA) goes through the LED, the power on the RSENSE resistor is:

$$P_{SENSE} = 50\text{mV} \bullet 200\text{mA} = 0.01\text{W}$$

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:

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

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:

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

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:

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

Where 1.26 is the internal bandgap reference and 11.2K Ω 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 RSET, so little power will be consumed on RSET. Therefore, an 0603 or 0402 package is enough for RSET.

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
I _{OUT} (Flash mode)	780mA/ 400mA	350mA	400mA	480mA	120mA	300mA	1A
I _{OUT} (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
V _{OUT}	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
θ _{JA}	57.1°C/W	68.5°C/W	55°C/W	100°C/W	68°C/W	150°C/W	37.3°C/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
tel: (408) 934-7500
faX: (408) 935-7600

Sipex Corporation reserves the right to make changes to any products described herein. Sipex does not assume any liability arising out of the application or use of any product or circuit described herein; neither does it convey any license under its patent rights nor the rights of others.