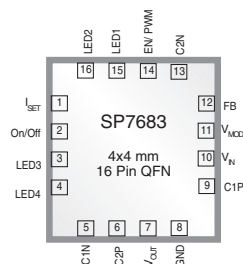


## Four Channel Charge Pump Regulator LED Driver

### FEATURES

- 2.7V to 5.5V Input Voltage Range
- Up to 4 LEDs with matching currents
- LEDs can be Driven from the Charge Pump Output
- 1X and 1.5X Mode Charge Pump
- High Efficiency Operation
- 1.2 MHz Switching Frequency
- Programmable LED Drive Capablility
- PWM Dimming Control
- Low 0.5 $\mu$ A Shutdown Current
- Soft-Start Limits Inrush Current
- Output Overvoltage Protection
- Thermal Shutdown Protection
- QFN (4mm x 4mm) package



*Now Available in Lead Free Packaging*

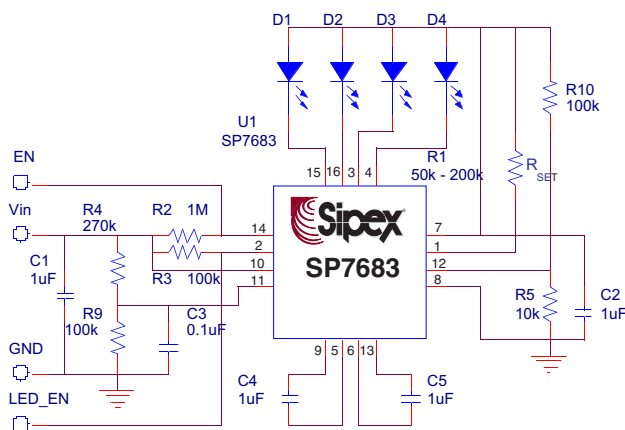
### APPLICATIONS

- Smart Phones
- Cell Phones
- PDA's
- Digital Cameras
- MP3 Players
- Other Portables

### DESCRIPTION

The SP7683 is high efficiency Charge Pump which regulates up to four white LEDs with matching current. Based on the supply headroom available for the four precision current sinks, SP7683 automatically switches between 1X and 1.5X modes. The part powers up in 1X mode, with low quiescent current of 70 $\mu$ A (typ) and remains in 1X mode as long as the LED current has not decreased by more than 0.5%. If the current decreases, then it switches into 1.5X mode where it regulates the lowest of the LED cathode voltages to 0.1V. Other features include soft-start, over current protection, overvoltage protection and thermal shutdown at 140°C. Offered in 4X4 pin QFN.

### TYPICAL APPLICATION SCHEMATIC



## ABSOLUTE MAXIMUM RATINGS

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.

I<sub>SET</sub> Voltage to GND.....0.5V  
 IN, OUT, EN1, EN2 to GND.....-0.3V to 6V  
 SET, LED1, LED2, LED3, LED4 to GND -0.3V to IN+0.3V  
 C1N, C2N to GND.....-0.3 to IN+1V  
 C1P, C2P to GND - 0.3V to greater than IN+1 or OUT+1V

OUT Short Circuit to GND.....Continuous  
 Storage Temperature .....-65°C to 150°C  
 Operating Temperature.....-40°C to +85°C  
 Lead Temperature (Soldering, 10 sec).....300°C

## ELECTRICAL CHARACTERISTICS

Unless otherwise specified: V<sub>IN</sub> = 3.6V, MODE = 0V, ILX = 0mA, T<sub>A</sub> = -40°C to +85°C, typical values at 27° unless otherwise noted.

PARAMETER	MIN	TYP	MAX	UNITS	CONDITIONS
Input Voltage	2.7		5.5	V	
Quiescent Current		.5	3	mA	V <sub>IN</sub> = 3V - 5.5V, V <sub>OUT</sub> = 3.6V, I <sub>OUT</sub> = 100μA
Shutdown Current		.5	1.5	μA	V <sub>EN</sub> /PWM = 0V, V <sub>IN</sub> = 5.5V
Maximum Load Current		200		mA	V <sub>IN</sub> = 4.2V, V <sub>OUT</sub> = 3.6V
V <sub>OUT</sub> Turn-on Time		250	500	μs	FB within 90% regulation 1.5X Mode, V <sub>OUT</sub> = 3.6, I <sub>OUT</sub> = 100μA
Output Current Multiplication Ratio (Note 1)	140	200	260		I <sub>SET</sub> = 100μA, V <sub>LED</sub> = .3V
LED Current Matching	-3	0.8	3	%	Any 2 LEDs
LED Cathode Voltage		0.5		V	LEDs D1-D4
Current in OFF Mode		0.01	1	μA	V <sub>EN</sub> = 0V
Oscillator Frequency	.7	1.2	1.5	MHz	V <sub>IN</sub> = 2.7V - 5.5V
FB Reference Voltage	.277	.310	.342	V	I <sub>OUT</sub> = 20mA, V <sub>OUT</sub> = 3.6V, 1.5X MODE
FB Pin Current		0.01	0.5	μA	V <sub>FB</sub> = 1V
Output Resistance		8	15	Ohms	1.5X MODE, 100mA load
		3	7		1X MODE, 100mA load
V <sub>MODE</sub> Threshold Voltage	1	1.25	1.5	V	V <sub>IN</sub> falling
V <sub>MODE</sub> Hysteresis		30		mV	
V <sub>MODE</sub> Pin Current		0.01	0.5	μA	V <sub>MODE</sub> = 1.25V
ENABLE/PWM Logic High	1.6			V	
ENABLE/PWM Logic Low			0.4	V	
Enable/ PWM Pin Current		0.01	0.5	μA	V <sub>EN</sub> / PWM = 4.2V

Note 1: Output current Multiplication Ratio (I<sub>LED</sub>/I<sub>SET</sub>) is not linear. For actual ratio and I<sub>LED</sub> please refer to typical performance characteristics @ page 4 and page 5 of SP7614 datasheet.

## ELECTRICAL CHARACTERISTICS

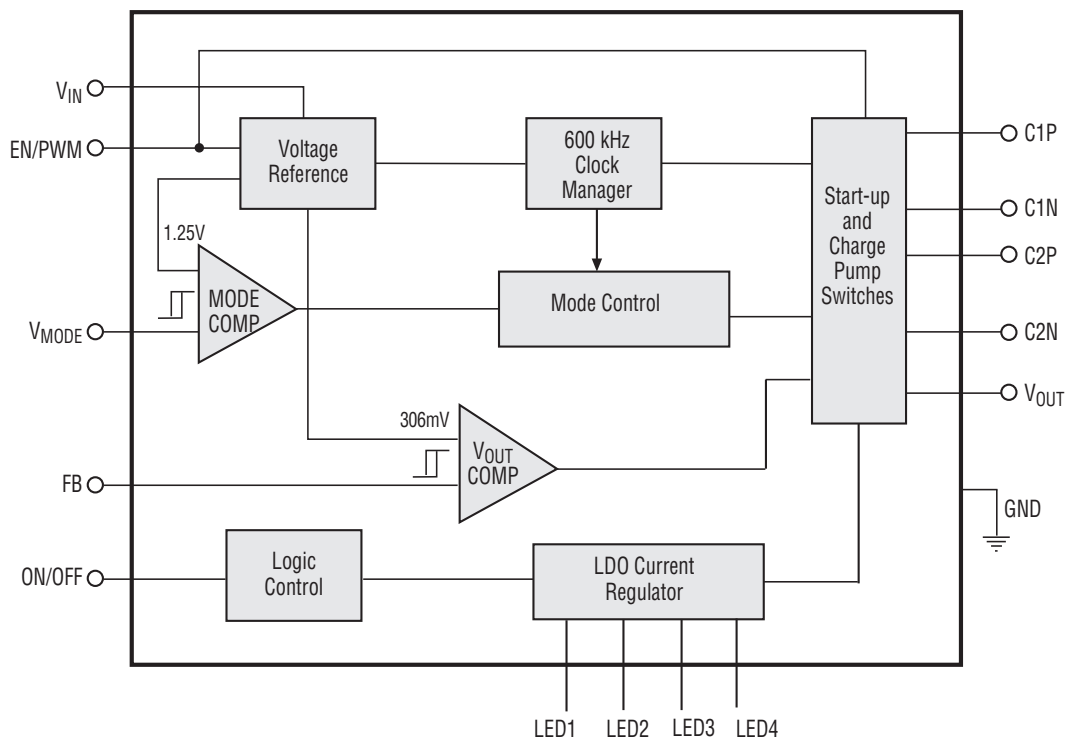
Unless otherwise specified:  $V_{IN}=3.6V$ ,  $MODE=0V$ ,  $ILX=0mA$ ,  $T_A=-40^{\circ}C$  to  $+85^{\circ}C$ , typical values at  $27^{\circ}$  unless otherwise noted.

PARAMETER	MIN	TYP	MAX	UNITS	CONDITIONS
Min ON/OFF "On Voltage" Logic High (Note 2)	3			V	
Max ON/OFF "Off Voltage" Logic Low (Note 2)			0.5	V	

Note 2: "ON" is  $V_{ON/OFF}$  where  $I_{LED1} > 20mA$  @  $V_{LED1} = 0.3V$ .  
"OFF" is  $V_{ON/OFF}$  where  $I_{LED1} < 1\mu A$  @  $V_{LED1} > 0.3V$ .

## PIN DESCRIPTION

PIN #	PIN NAME	DESCRIPTION
1	$I_{SET}$	A pull up resistor attached between $V_{OUT}$ and this pin sets the output current by the relationship. $I_{LED} = 200(V_{OUT} - V_{ISET}) / R_{SET}$
2	ON/OFF	LED ON/OFF control (LED1 - LED4).
3	LED3	Cathode Connection for LED4. In 1.5X Mode the charge pump regulates $V_{OUT}$ so that the lowest of LED1, LED2, LED3, and LED4 voltages is 150mV. Connect to $V_{OUT}$ if not used.
4	LED4	Cathode Connection for LED3. In 1.5X Mode the charge pump regulates $V_{OUT}$ so that the lowest of LED1, LED2, LED3, and LED4 voltages is 150mV. Connect to $V_{OUT}$ if not used.
5	C1N	Flying Capacitor 1 Negative terminal.
6	C2P	Flying Capacitor 2 Positive Terminal
7	$V_{OUT}$	Output. Drives the anodes of all LEDs. Bypass to GND with a $1\mu F$ capacitor. High Impedance Shutdown
8	GND	Ground Connection
9	C1P	Flying Capacitor 1 Postive terminal.
10	$V_{IN}$	Supply voltage input. Bypass with a $1\mu F$ ceramic capacitor to GND
11	$V_{MODE}$	Charge pump mode program pin. When Vmode is greater than 1.25V, a X1 charge pump is used. Otherwise, charge pump switches to X1.5 mode. A voltage divider shown in typical application circuit programs the Vin threshold for charge pump mode switching.
12	FB	This is the feedback pin for output current or voltage regulation. The voltage of this pin is compared with an internal 306mV reference.
13	C2N	Flying Capacitor 2 Negative terminal.
14	EN/PWM	Enable/PWM dimming control input.
15	LED1	Cathode Connection for LED1. In 1.5X Mode the charge pump regulates $V_{OUT}$ so that the lowest of LED1, LED2, LED3, and LED4 voltages is 150mV. Connect to $V_{OUT}$ if not used.
16	LED2	Cathode Connection for LED2. In 1.5X Mode the charge pump regulates $V_{OUT}$ so that the lowest of LED1, LED2, LED3, and LED4 voltages is 150mV. Connect to $V_{OUT}$ if not used.



The SP7683 is comprised of two stages. First is a regulated charge pump to convert the input voltage  $V_{IN}$  into a stable output voltage or current depending on the mode used. The second stage is a low dropout current matching regulator that provides stable identical currents in all four channels to drive LED1 - LED4. The first stage can drive an additional four LEDs that are connected in parallel to the  $V_{OUT}$  pin. It is recommended to use resistors in series with these additional diodes for current matching.

The SP7683 provides dimming control for the LEDs, with a constant ratio of brightness between them. It can also be used to turn off the LEDs completely.

### The Charge Pump

The regulated charge pump can operate in two modes  $1X V_{IN}$  and  $1.5X V_{IN}$  to optimize efficiency over the entire battery voltage range. The input voltage trip point at which the charge pump will automatically switch from a  $1X$  mode to  $1.5X$  mode is defined by an external voltage divider connected to  $V_{MODE}$  pin. Cycle-by-cycle regulation ensures that no mode change occurs during a switching cycle. To achieve better efficiency it is recommended that the  $V_{IN\_TRIP}$  is set at  $V_{IN\_TRIP} = V_F + 0.31 + M I_{LED} * R_{OUT}$  where  $V_F$  is the LED forward voltage and (M) is the number of LEDs connected to  $V_{OUT}$ .  $R_{OUT}$  is the output resistance.  $I_{LED}$  is the current per LED.

The charge pump may be configured in voltage mode or as a current source. When used as a voltage source the output voltage is determined by an external resistive divider connected to FB pin as:  $V_{OUT} = (1 + R10/R5) * V_{FB}$  (see Figure 2) where  $V_{FB} = 0.31V$ .

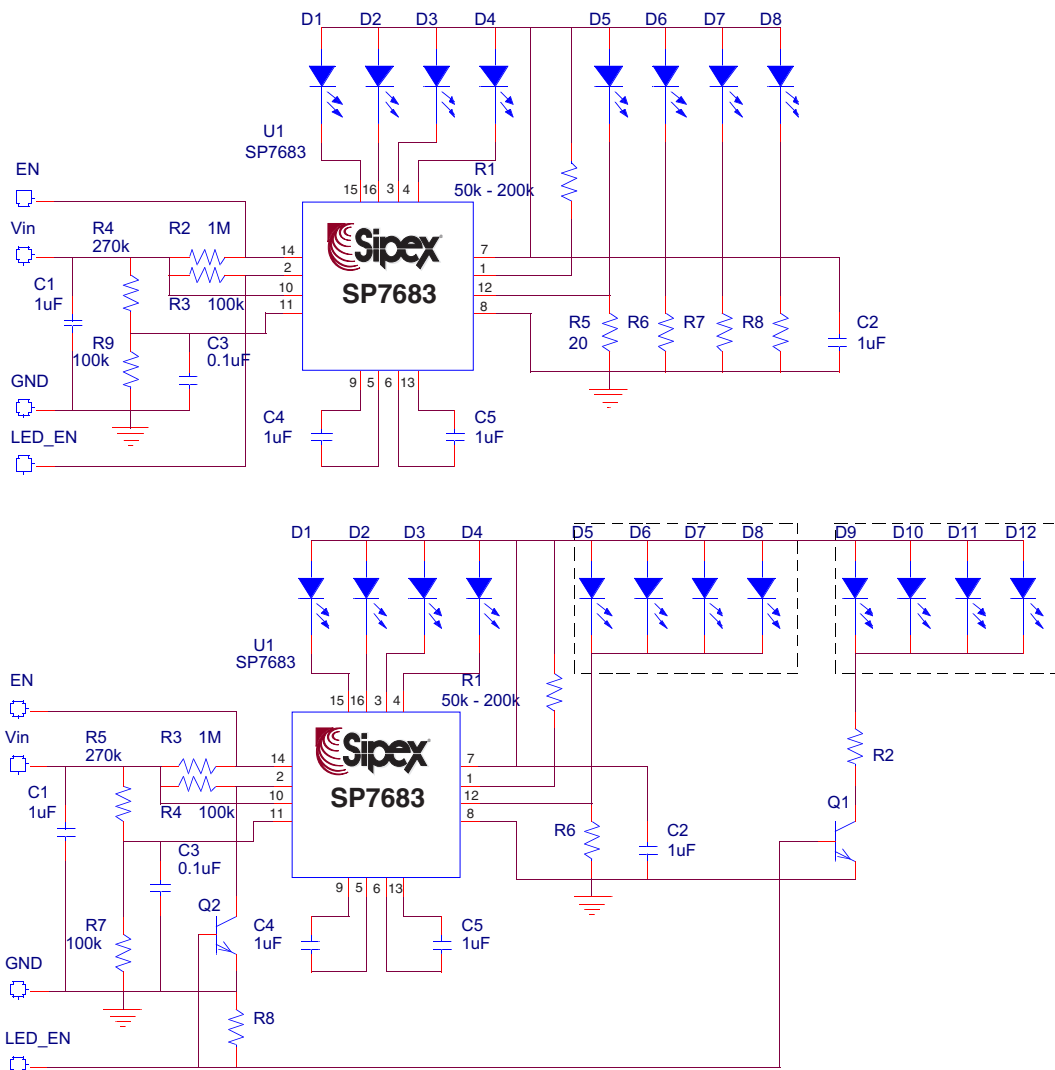
When used as a current source the current in one single LED (D5 - D8) may be set by series resistor  $R_S$  as  $I_{LED} = V_{FB} / R_S$ . The current in the remaining LEDs will track based on the ballast resistors. Three-wire LED modules with internal series resistors can also be driven in this way.

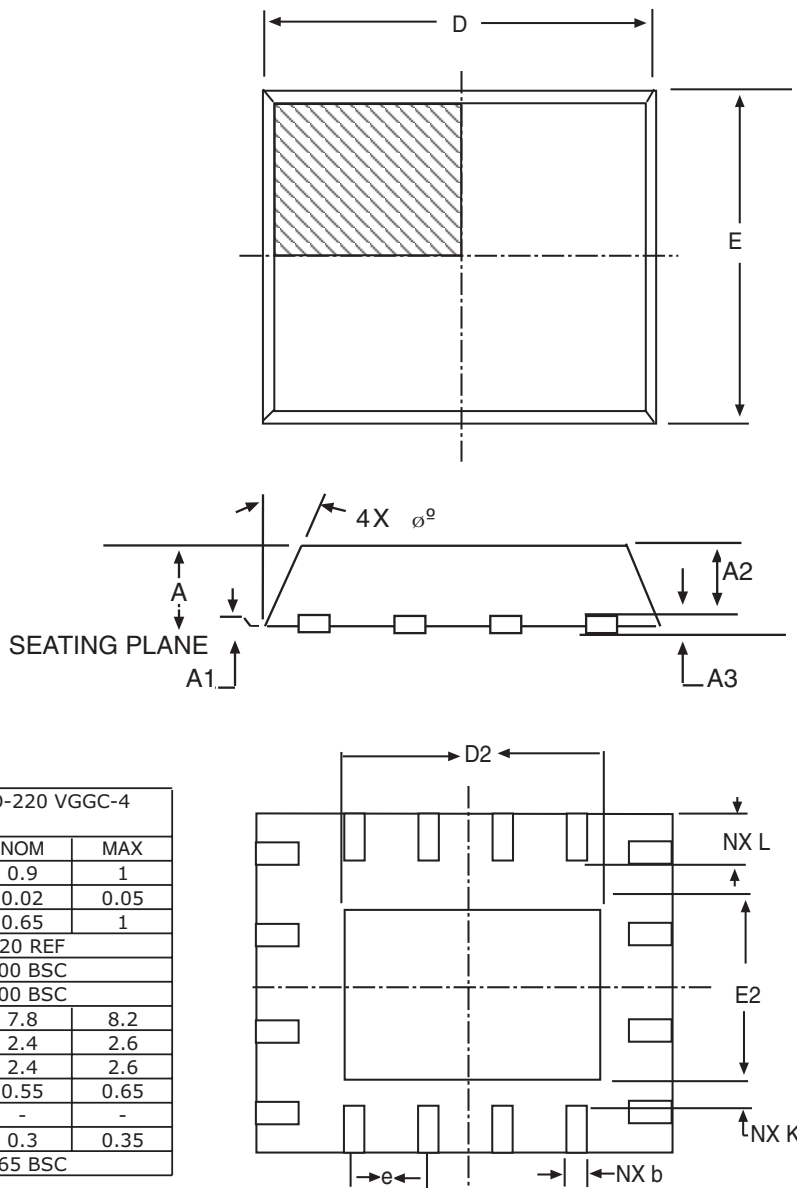
The flying capacitors C1 and C2 of the charge pump control the trade-off between the output voltage ripple and the output current capability. Decreasing the flying capacitors will reduce the output voltage ripple because less charge will be delivered to the output capacitor. However, smaller flying capacitors lead to larger output resistance, thus decreasing the output current handling capability and circuit efficiency. We recommend using ceramic capacitors in the range of  $1\mu F$  -  $4.7\mu F$  with low ESR, which helps reduce peak-to-peak output ripple and reduce high frequency noise spikes.

Dimming control can be achieved by applying a PWM control signal to the EN/PWM pin. The brightness of the LEDs is controlled by varying the duty cycle of the PWM signal. PWM repetition rate from 60Hz - 700Hz. A repetition rate of at least 60Hz is required to prevent visible flickering. Applying a logic low signal to EN/PWM control input turns off the device resulting in supply current below  $1\mu A$  and high impedance state of the  $V_{OUT}$  pin.

The low dropout regulator provides matched currents into four LEDs. The current in the LED can be programmed by an external resistor connected between the V<sub>OUT</sub> and I<sub>SET</sub> pins. I<sub>LED</sub> = 200\*(V<sub>OUT</sub> - 0.5)/R<sub>SET</sub> where the 200 is the Output Current Multiplying Ratio and 0.5 is I<sub>SET</sub> voltage value.

To obtain the best performance from the SP7683, a printed circuit board with ground plane is required. High quality, low series resistance ceramic 0.1  $\mu$ F bypass capacitors should be used at the  $V_{IN}$  and  $V_{OUT}$  pins (pin 10 and 7). These capacitors and flying capacitors C1 and C2 must be located as close to the part as possible. The traces connecting the pins to these capacitors should be made as short and wide as possible.





16 Pin QFN JEDEC MO-220 VGGC-4 Variation			
SYMBOL	MIN	NOM	MAX
A	0.8	0.9	1
A1	0	0.02	0.05
A2	0	0.65	1
A3	0.20 REF		
D	4.00 BSC		
E	4.00 BSC		
E2	7.4	7.8	8.2
D2	2.2	2.4	2.6
E2	2.2	2.4	2.6
L	0.45	0.55	0.65
K	0.2	-	-
b	0.25	0.3	0.35
e	0.65 BSC		

Note: Dimensions in (mm)

## 16 PIN QFN

Part Number	Operating Temperature Range	Package Type
SP7683ER .....	-40°C to +85°C .....	16 Pin 4 x 4mm QFN
SP7683ER/TR .....	-40°C to +85°C .....	16 Pin 4 x 4mm QFN

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

Example: SP7683ER/TR = standard; SP7683ER-L/TR = lead free

/TR = Tape and Reel

Pack quantity is 2500 for QFN.

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