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LC41059

Current Regulated White LED Supply with Brightness Control

///// General Description /////

The LC41059 is a fractional charge pump DC-DC converter with a regulator that provides four regulated current sources. It accepts an input voltage range from 2.7V to 5.5V and maintains a constant current determined by an external sense resistor.

The LC41059 delivers up to 105mA of load current to drive one, two, three, or four White LEDs. When it drives four LEDs, maximum 26mA of each LED is available. When it drives three LEDs, maximum 35mA of each LED is available. Current of each LEDs are highly matched regardless of the input voltage range from 2.7V to 5.5V, or the LED forward voltage range from 3V to 4V. It operates with 500kHz fixed-frequency switching without inductors, therefore the EMI noise is very limited, the pictures or tones generated in the device will not disturbed.

LED brightness can be controlled by both analog voltage input and pulse input. A voltage between 0V to 1.25V may be applied to the BRGT pin to vary the LED current linearly. Alternatively, a pulse signal can be applied to the SD pin to vary the perceived LED brightness. An active-low input to the SD pin will shutdown all the circuit, and the LED will turned off.

The LC41059 is available on WL-CSP, QFN or other packages.

///// Features /////

- Low noise, high efficiency CMOS charge pump
- Built-in current mirror with excellent accuracy
- Built-in constant current circuit
- 2.7V to 5.5V input voltage
- Drives one, two, three or four white LEDs with maximum total current 105mA
- Self-changing of charge pump mode (Pass mode, 3/2 boost mode, 2 boost mode)
- +-0.5% current matching of any two LED outputs
- Soft start limits inrush current
- Charge pump frequency 500kHz
- Brightness control with Analog voltage input or Pulse voltage input
- Maximum 1uA shutdown current

///// Applications /////

- White LED display backlights
- White LED keypad backlights
- 1-Cell Li-Ion battery-operated equipment including PDAs, hand-held PCs, cellular phones
- Flat panel displays

///// Package /////

WL-CSP, QFN or other packages are available

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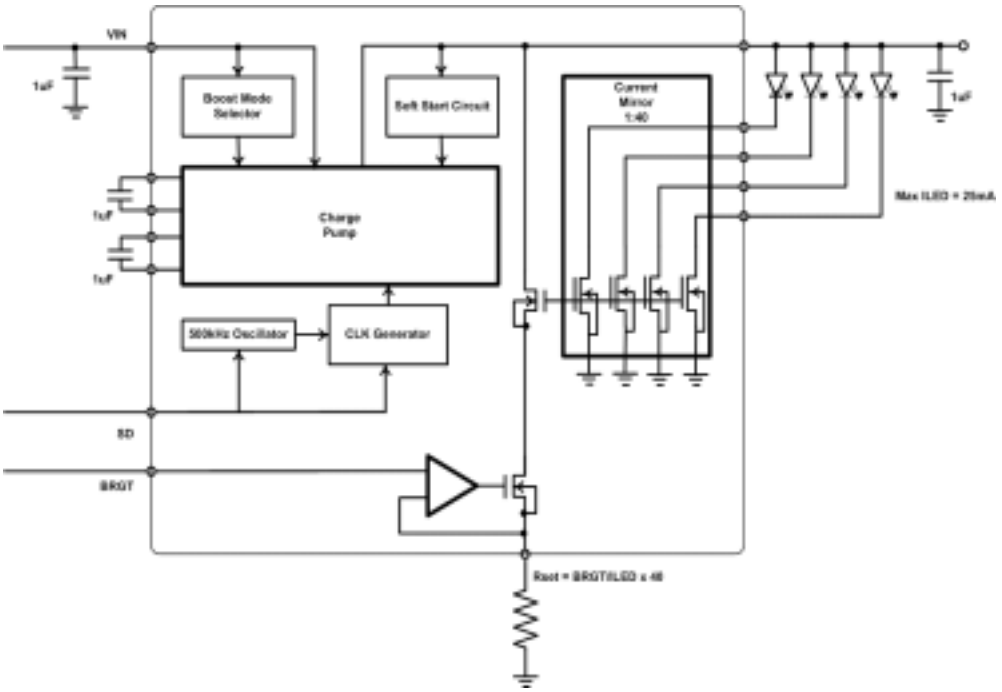
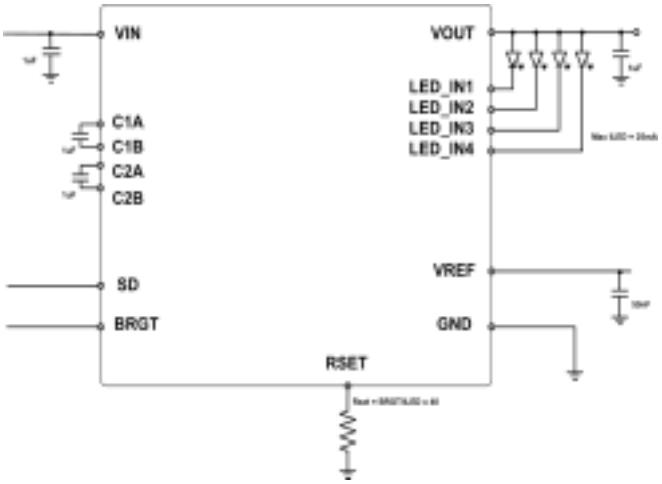
///// Block Diagrams /////



///// Pin Assignment /////



Pin name	Function
VIN	Battery Voltage In
C1A	Flying Capacitor (1) +
C1B	Flying Capacitor (1) -
C2A	Flying Capacitor (2) +
C2B	Flying Capacitor (2) -
SD	Shutdown Signal Input PWM Input
BRGT	Analog Brightness Control
RSET	External Resistor
GND	Ground
VREF	VREF Output
LED_IN1	White LED Input (1)
LED_IN2	White LED Input (2)
LED_IN3	White LED Input (3)
LED_IN4	White LED Input (4)
VOUT	Charge Pump Output

SD: A low level input will disable the device, and turn off LEDs. A high level input (=V_{IN}) will enable the device, and turn on LEDs. Pulse input on the SD pin makes LEDs flickering in synchronization with the pulse, so the brightness can be controlled by the duty cycle.

BRGT: Analog brightness control input. It accepts an input voltage range from 0V to 1.25V. Rset resistance and BRGT input voltage determine the LED current.

RSET: Connect a resistor. Rset resistance and BRGT input voltage determine the LED current.

VREF: 1.2V of internally generated VREF is available. VREF can be used for a BRGT input voltage.

(See “Operation” chapter for more details)

///// Electrical Characteristics /////

(Unless otherwise specified, VIN=3.6V, IOUT=80mA, Ta=27C)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input Voltage	VIN		2.7	3.6	5.5	V
Total Output Current	IOUT	VIN = 2.7 to 5.5V		60~80 20mA x4LEDs) 20mA x3LEDs)	105 (26mA x4LEDs) (35mA x3LEDs)	mA
Charge Pump Frequency	FCLK			500k		Hz
Input Charge Pump Mode Threshold	VCPH	Pass mode to 3/2 boost mode		4.6		V
	VCPL	3/2 boost to 2 boost mode		3.5		V
Input Charge Pump Mode Hysterysis	VCPY			0.1		V
LED Current Accuracy (LED Current variation caused by VIN degradation or VF variation)		VIN = 2.7 to 5.5V VF = 3.0 to 4.0V Total Output Current = 80mA			+-3	%
		VIN = 3.0 to 5.5V VF = 3.0 to 4.0V Total Output Current = 105mA			+-3	%
		VIN = 2.7 to 3.0V VF = 3.0 to 4.0V Total Output Current = 105mA			+-5	%
LED Current Matching between any two outputs	ID-MATCH	VIN = 2.7 to 5.5V VF = 3.0 to 4.0V Total Output Current = 80mA			+-0.5	%
		VIN = 3.0 to 5.5V VF = 3.0 to 4.0V Total Output Current = 105mA			+0.5	%
		VIN = 2.7 to 3.0V VF = 3.0 to 4.0V Total Output Current = 105mA			+-3	%
Shutdown Supply Current	ISD	VIN = 2.7 to 5.5V SD = 0V			1	uA
LED Current Response against the SD signal input	TSDL	Shutdown Response VIN = 2.7 to 5.5V SD = Low input		0.1		usec
	TSDH	Start-up Response VIN = 2.7 to 5.5V SD = High input		4.0		usec
Recommended SD input Frequency (PWM)	FPWM	PWM Input to SD Pin to Control Brightness	100		2000	Hz
BRGT input	BRGT	Analog Input to BRGT Pin to Control Brightness	0	1.0	1.25	V

///// Operation /////

1. Circuit Description

The LC41059 is a white LED supply which accepts the input voltage from the Li-Ion battery. While the Li-Ion battery has the output voltage range from 2.7 to 5.5V, the forward voltage (V_F) of the white LED is about 3.6V typically. So when the battery degrades the output voltage to about 3.6V, the higher voltage must be generated internally. The LC41059 employs a charge pump to step up the output voltage to 1.5 times or 2 times the input voltage. This charge pump selects the optimum boost mode, and changes the boost mode automatically.

LED current (I_{LED}) is determined by the BRGT input voltage and the resistance of the external resistor. Same voltage of BRGT (V_{BRGT}) is forced on the external resistor with high accuracy by an internal Op-Amp, so the current passing through the external resistor (I_{RSET}) will be $I_{RSET} = V_{BRGT} / R_{SET}$. LC41059 includes the current regulator to deliver the regulated current to the LEDs, which are composed of current mirrors with a 40 to 1 ratio. For example, when V_{BRGT}= 1.2V, R_{SET}= 2000ohms, then I_{RSET} =0.6mA, and I_{LED}= I_{RSET} x 40= 24mA . If four LEDs are attached, the device drive up a total of 24mA x 4= 96mA through the LEDs.

The LED brightness can be controlled by both analog and/or digital methods. The digital technique uses a PWM (Pulse Width Modulation) signal applied to the SD pin (see *4.Brightness Control Using PWM*). The analog technique applies an analog voltage to the BRGT pin (see *5.BRGT Pin*).

2. Soft Start

LC41059 includes a soft start function to reduce the inrush current. Inrush current will be generated when the charge pump operates with flying capacitors discharged. When the capacitors are being charged with low impedance, excess current may surge into the capacitors from the battery. Soft start is done to reduce stress on the battery and external components. During soft start, the switch resistances limit the inrush current used to charge the flying and hold capacitors.

3. Shutdown Mode

A shutdown pin is available to disable the LC41059 and reduce the quiescent current to 1µA maximum. During normal operation mode, applying a high level input to SD pin will enable the device. Pulling a low level input to SD pin will disable the device.

4. Brightness Control Using PWM

Brightness control can be implemented by pulsing a signal at the SD pin. The recommended frequency is between 100Hz to 2kHz. If the PWM frequency is much less than 100Hz, flicker may be seen in the LEDs. Likewise, if frequency is much higher, brightness in the LEDs will not be linear. Increasing and decreasing the duty cycle of the PWM signal control the brightness. Zero duty cycle will turn off the LED, and a 50% duty cycle waveform produces an average current of 10mA if R_{SET} is set to produce a maximum LED current of 20mA. So the LED current varies linearly with the duty cycle.

5. BRGT Pin

The BRGT pin can be used to smoothly vary the brightness of the White LEDs. In the LC41059, this voltage is fed to the Op-Amp that controls the current through the mirror resistor R_{SET}. The nominal range on BRGT is 0V to 1.25V. Care must be taken to prevent voltages on BRGT that cause LED current to exceed a total of 100 mA. Although this will not cause damage to the IC, it will not meet the guaranteed specifications listed in the “Electrical Characteristics” chapter.