LC410591

2004.09.07

Charge Pump White LED Supply

General Description

The LC410591 is a White LED Supply that provides four regulated current sources with a fractional charge pump DC-DC converter. It accepts an input voltage range from 2.7V to 5.5V and maintains a constant current. An external sense resistor determines 100% full scale LED current.

The LC410591 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. It operates with 600kHz fixed-frequency switching without inductors, therefore the EMI noise is very limited.

By pulsing the BRGT input, the LED brightness can be controlled in multiple steps down to 5%. Once the desired brightness is set, LC410591 maintains the brightness as long as the BRGT input keeps high. If an BRGT input is kept low for more than 2ms, it enters shutdown mode. The LC410591 is available in a FLGA (WL-CSP), VQFN packages.

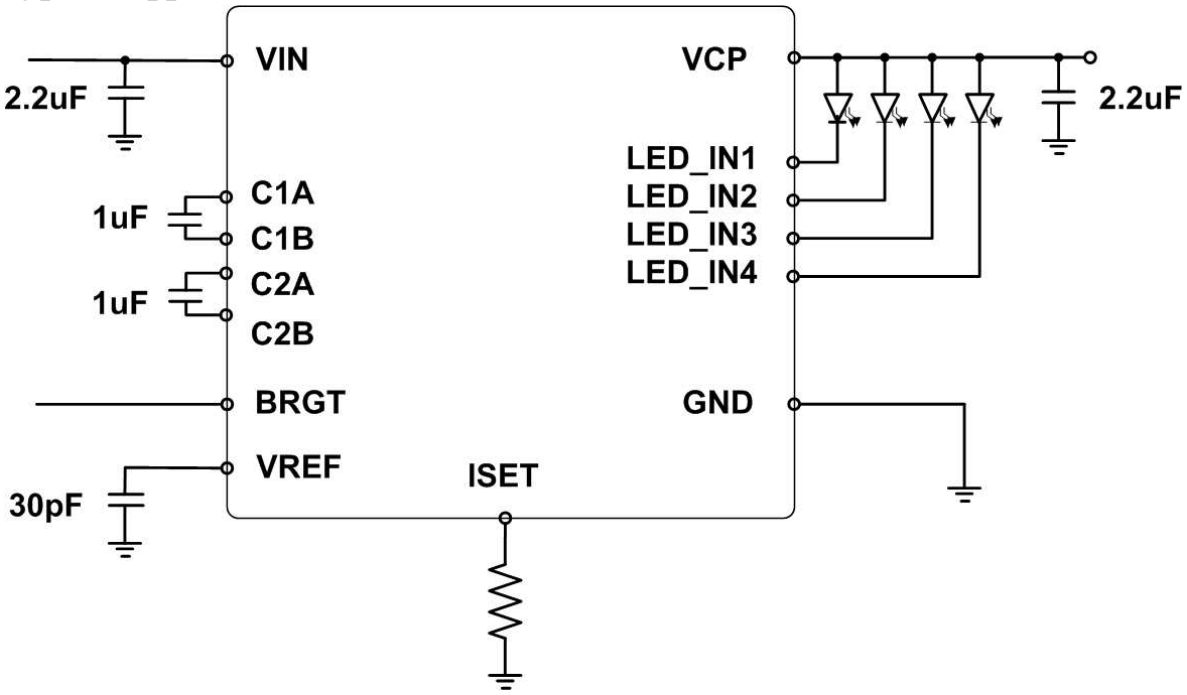
Features

- Low noise, high efficiency CMOS charge pump
- 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 and 1.5 boost mode)
- Typical +-1.5% current matching of any two LED outputs
- Soft start limits inrush current
- Charge pump frequency 600kHz
- 5% to 100% Brightness control through single-wire serial 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

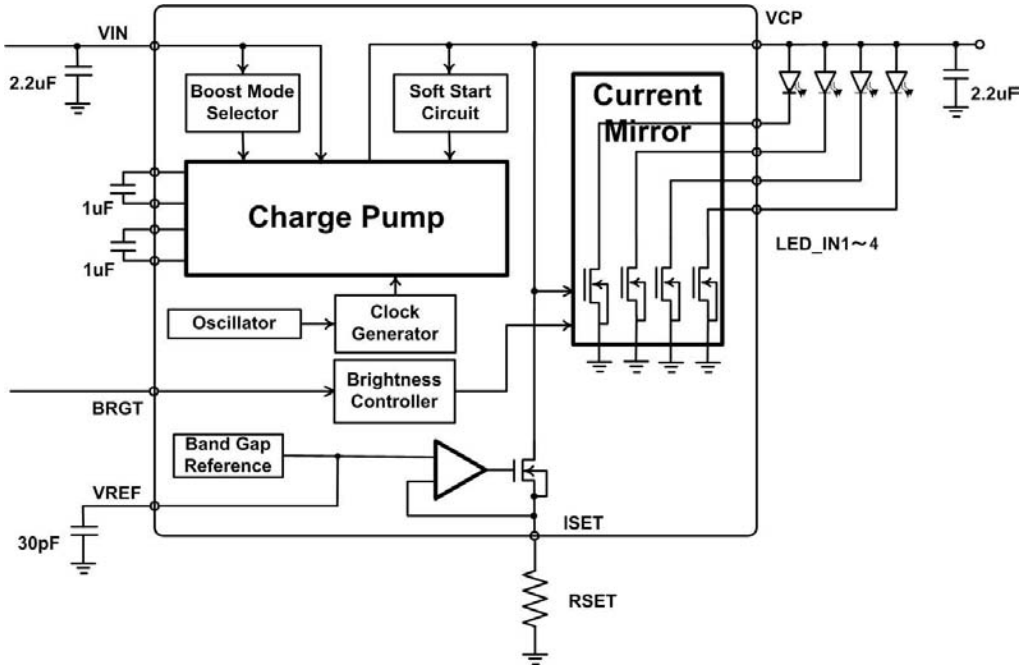
Typical Application Circuit



Pin Assignment

Pin name	Function
VIN	Power Supply Input. Bypass VIN to GND with a 2.2uF capacitor.
C1A	Flying Capacitor (1) +
C1B	Flying Capacitor (1) -
C2A	Flying Capacitor (2) +
C2B	Flying Capacitor (2) -
BRGT	Brightness Control Input. The first time, BRGT must be pulsed for reset. The second time it goes high(120us min), then the LEDs turn on at a 100% brightness. Pulsing BRGT low controls the LED current in multiple steps. If BRGT is kept low for more than 2ms, the LC410591 enters shutdown mode and LEDs turn off. Please see "Brightness Control" chapter.
ISET	External Resistor. Maximum LED current is determined by $I_{LED}(mA)=48/R_{SET}(k\Omega)$
VREF	VREF output (typically 1.2V). Bypass VREF to GND with a 30pF capacitor. VREF output must be kept high-impedance.
GND	Power Supply Ground. Charge pump switching current flows through this pin.
LED_IN1~4	Connect a LED between VOUT and LED_IN1~4.
VCP	Charge Pump Output. Bypass VCP to GND with a 2.2uF capacitor.
TEST	Not use. Must be open.

Block Diagram



Absolute Maximum Ratings

Maximum Supply Voltage(VDD)= -0.3V ~ 7.2V, Maximum Supply Voltage(VSS)= -0.3V ~ 0.3V

Storage Temperature -55°C ~ 125°C

Electrical Characteristics

Supply Voltage(V_{IN})=3.6V, R_{SET}=3.2kΩ, LED Forward Voltage(V_F)=3.2V,
Bypass capacitor(C_{IN})=2.2uF, Output Capacitor(C_{CP})=2.2uF, Flying Capacitors(C1, C2)=1uF
T_A=-40°C~ 85°C(note1)
(Unless specified, typical values are at T_A=25°C)

Parameter	Conditions	Min	Typ	Max	Unit
Supply Voltage (V_{IN})		2.7		5.5	V
Maximum Output Current	T_A=25°C	105			mA
Maximum LED Current (per one LED)	T_A=25°C, 4 LEDs	26			mA
	T_A=25°C, 3 LEDs	35			mA
No Load Supply Current (at I_{LED} 100% setting)	V_{IN} = 4.1 to 5.5V (When pass mode)		2		mA
	V_{IN} = 2.7 to 4.1V (When 1.5 boost mode)		5		mA
Charge Pump Frequency			600k		Hz
Input Charge Pump Mode Threshold	Pass mode to 1.5 boost mode		4.1		V
Input Charge Pump Mode Hysterysis			0.5		V
VREF Output Voltage			1.2		V
ISET Bias Voltage			1.2		V
LED Current Accuracy			+-3		%
LED to LED Current Matching			+-1.5		%
Shutdown Supply Current	V_{IN} = 2.7 to 5.5V, T_A=25°C			1	uA
BRGT Set Low Time(tLO)		0.5		500	us
Minimum BRGT Set High Time(tHI)		0.5			us
	Only when waking up from shutdown mode(Initial tHI)	150			us
BRGT Shutdown timeout(tSTDN)			2		ms
BRGT Threshold High	V_{IN} = 4.5 to 5.5V	3			V
	V_{IN} = 2.7 to 4.5V	2.5			V
BRGT Threshold Low	V_{IN} = 2.7 to 5.5V			0.5	V
BRGT Input Current	V_{IN} = 2.7 to 5.5V, T_A=25°C			1	uA

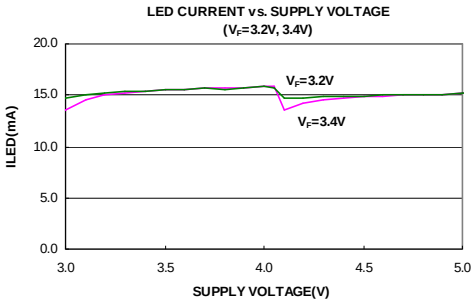
Note1: Specifications to -40°C are guaranteed by design and not production tested.

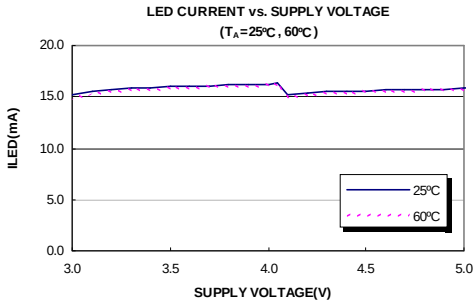
Typical Characteristics

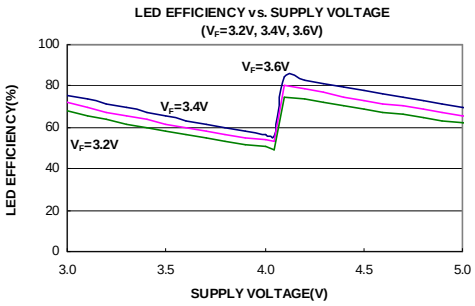
Unless otherwise specified;

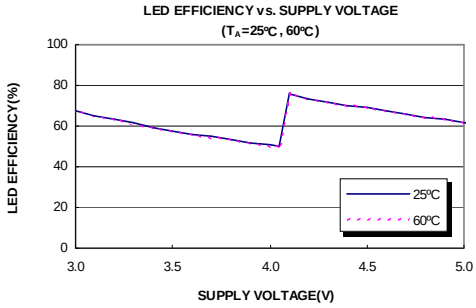
Supply Voltage(V_{IN})=3.6V, R_{SET}=3.2kΩ, LED Forward Voltage(V_F)=3.2V, T_A=25ºC, Drive 4 LEDs

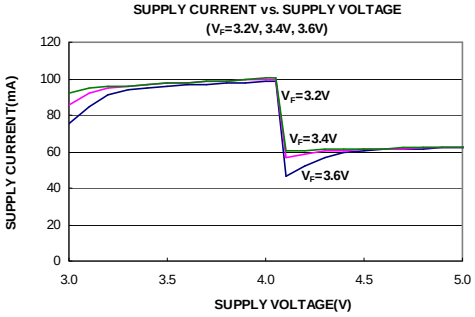
Bypass capacitor(C_{IN})=2.2uF, Output Capacitor(C_{CP})=2.2uF, Flying Capacitors(C1, C2)=1uF

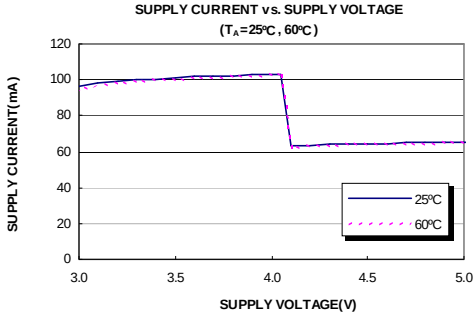


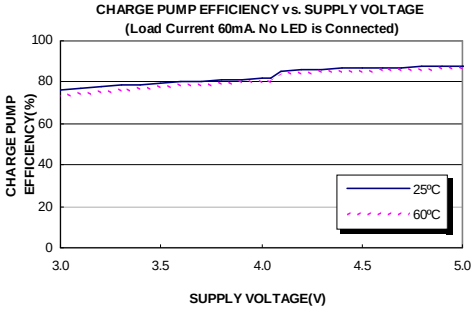


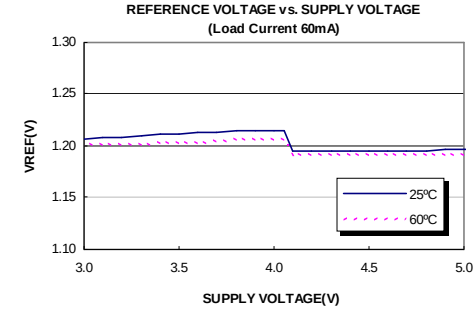










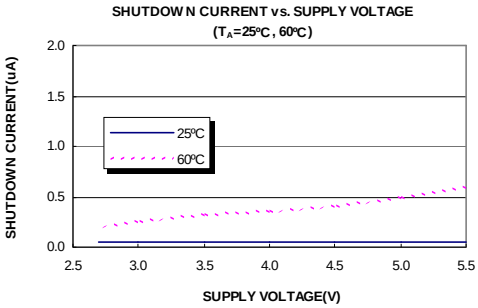


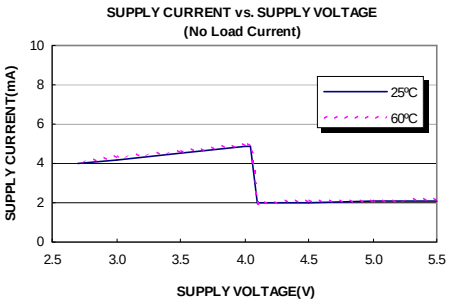
Typical Characteristics

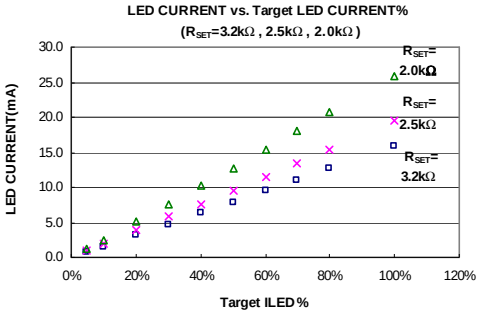
Unless otherwise specified;

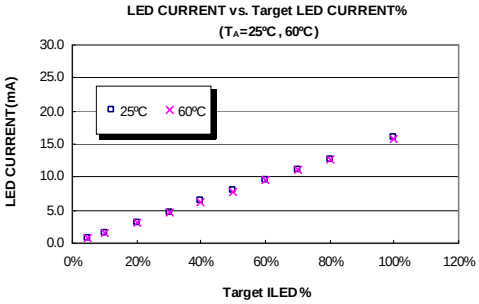
Supply Voltage(V_{IN})=3.6V, R_{SET}=3.2kΩ , LED Forward Voltage(V_F)=3.2V, T_A=25ºC, Drive 4 LEDs

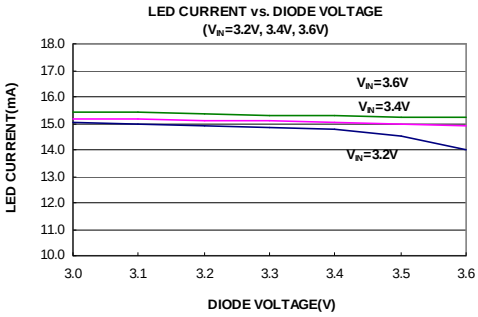
Bypass capacitor(C_{IN})=2.2uF, Output Capacitor(C_{CP})=2.2uF, Flying Capacitors(C1, C2)=1uF

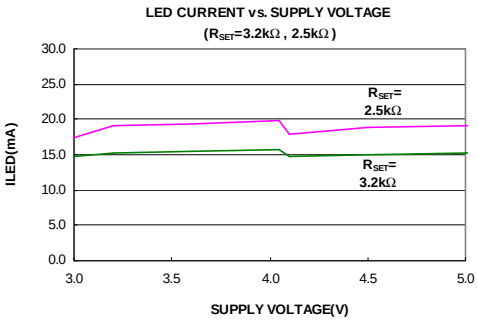


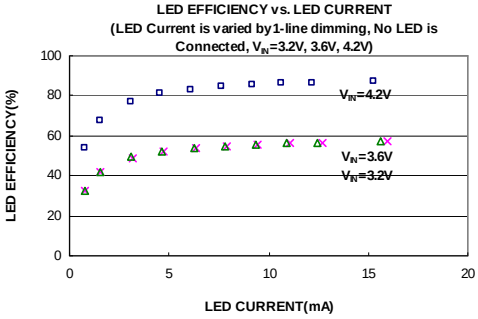


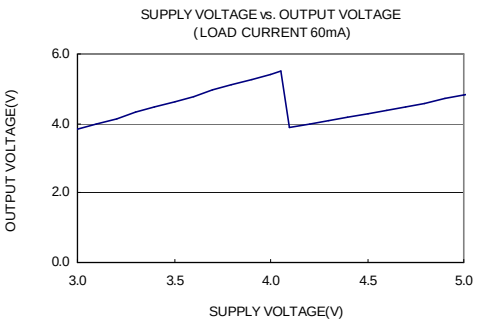












Operation

Circuit Description

The LC410591 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 LC410591 employs a charge pump to step up the output voltage to 1.5 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 an internal standard voltage generation source(VREF≒1.2) 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 $I_{RSET} = V_{REF} / R_{SET}$. LC410591 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_{REF}= 1.2V, R_{SET}= 2kΩ, 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. This term does not include the tolerance of the external resister R_{SET}. If precision LED current accuracy is required, a precision resister is needed (ex. 1% tolerance resister).

The LED brightness can be controlled by serial signal input.

Shutdown Mode

BRGT input is kept low for more than 2ms, it enters shutdown mode, and reduce the quiescent current to 1μA maximum.

Soft Start

LC410591 requires a pulse(>20ns) and a low input more than 2ms to wake up from the shutdown mode. Then, if a high input (>120us) is supplied on BRGT, LC410591 starts with 100% LED current mode with soft start mode 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 output capacitors.

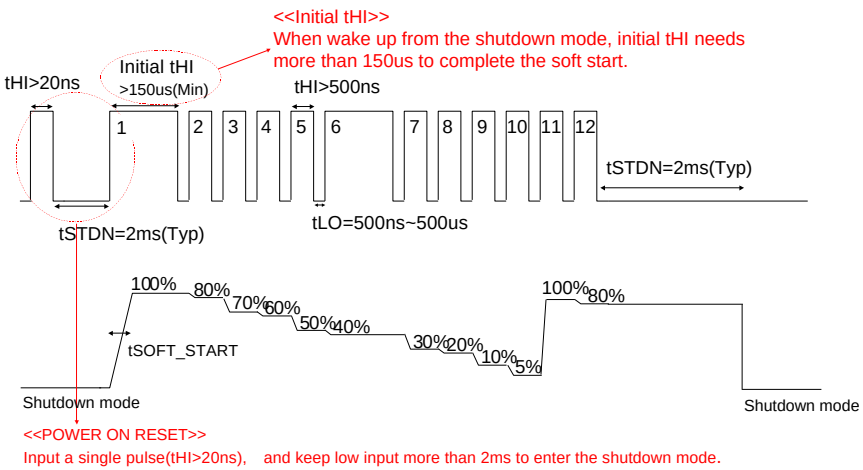
Brightness Control

Use BRGT inputs as a serial signal to control ten levels of LED brightness by adjusting the amount of LED current. If the low level input continues more than 2ms, it will go into the shutdown mode.

LC410591 requires a pulse(>20ns) and a low input more than 2ms to wake up from the shutdown mode. Then, If a high input (>120us) is supplied on BRGT, LC410591 starts with 100% LED current mode. Brightness control is done by pulsing BRGT low(500ns to 500us pulse width). Each pulse reduces the LED current. The 10th pulse reduces the current by 5%, and the 11th pulse sets the LED current back to 100%. Drive BRGT low more than 2ms to put the LC410591 in shutdown mode. Below figure shows a timing diagram.

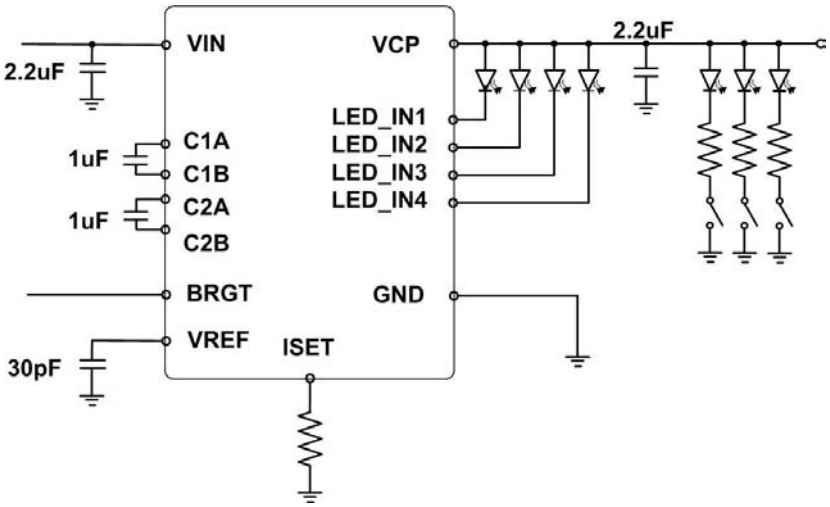
Capacitor Selection

For the input bypass capacitor, the output capacitor and the charge pump flying capacitors, we recommend to use the capacitors which have low equivalent series resistance (ESR), and low variation over temperature, such as X5R or X7R of the ceramic capacitors.

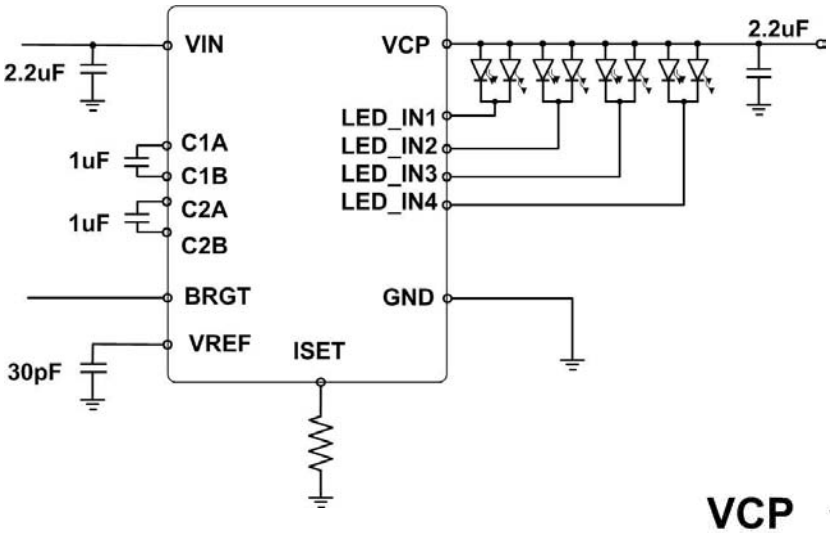


Additional LED driving

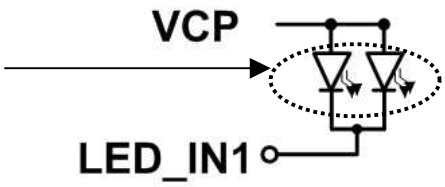
The LC410591 can drive additional LEDs by using the output voltage. The example circuit is below. Note if the total output current is larger than 105mA, the LC410591 may not meet the specification. The resisters and the switches should be connected in serial with the additional LEDs to control the sink current and to control the LEDs' on/off.



Below application can be available also.

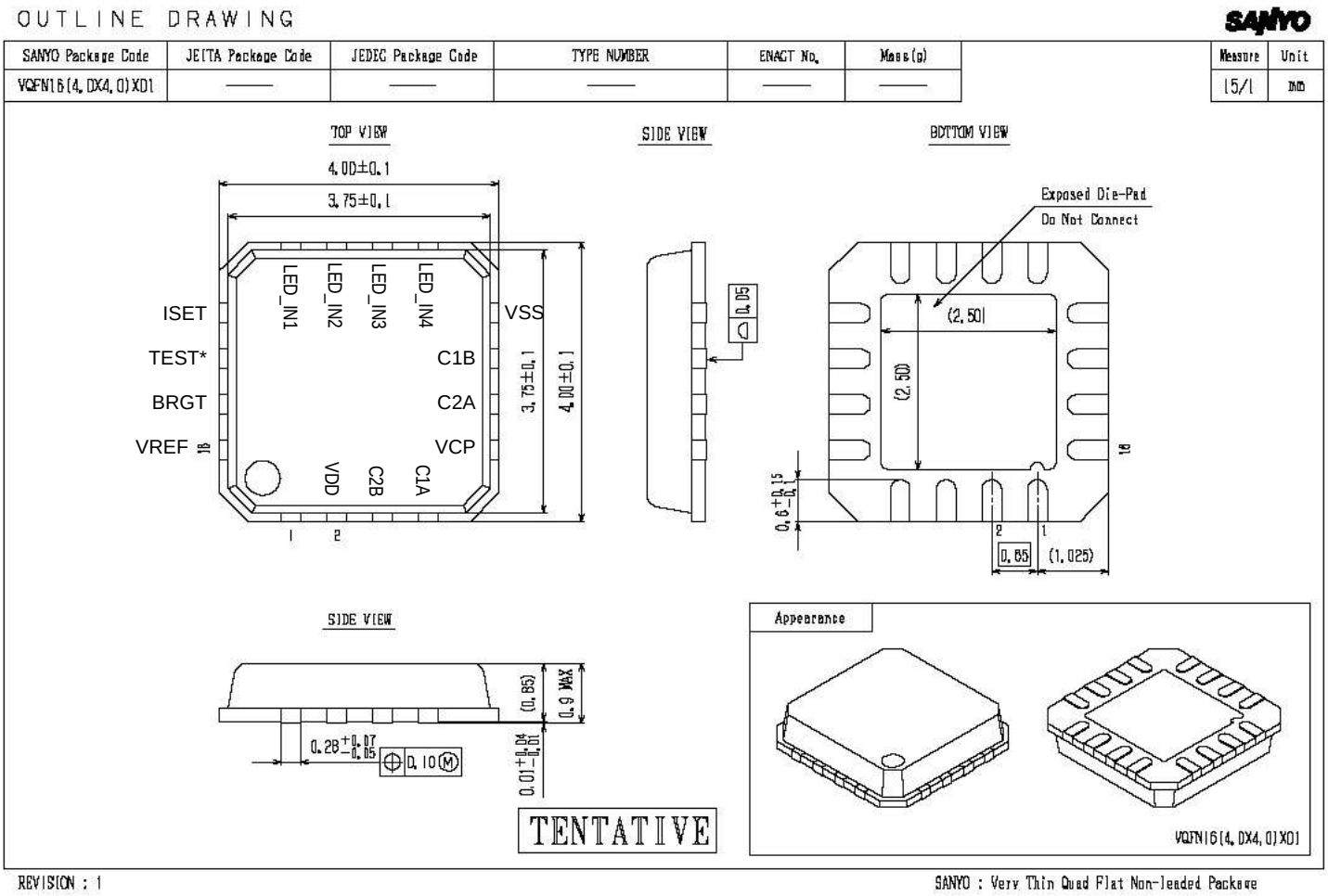


Notice when applying above application, the current difference of the LEDs that sink into the same LED_IN terminal, would not be regulated.



Package

1. VQFN16



* TEST pin must be open.