

LC410591FN

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 the LED current.

The LC410591 drives up to 105mA of load current to drive one, two, three, or four white LEDs. When it drives four LEDs, maximum current 26mA of each LED is available. When it drives three LEDs, maximum current 35mA of each LED is available. It operates with 600kHz fixed-frequency switching without inductors, therefore the EMI noise is very limited.

LED brightness can be controlled by pulsing a PWM signal on the BRGT pin. When BRGT pin is fixed to Low level for 22ms or more, the LC410591 is into Shutdown mode. And then all LEDs are turned off. The LC410591 is available in a VQFN16(4mm x 4mm) packages.

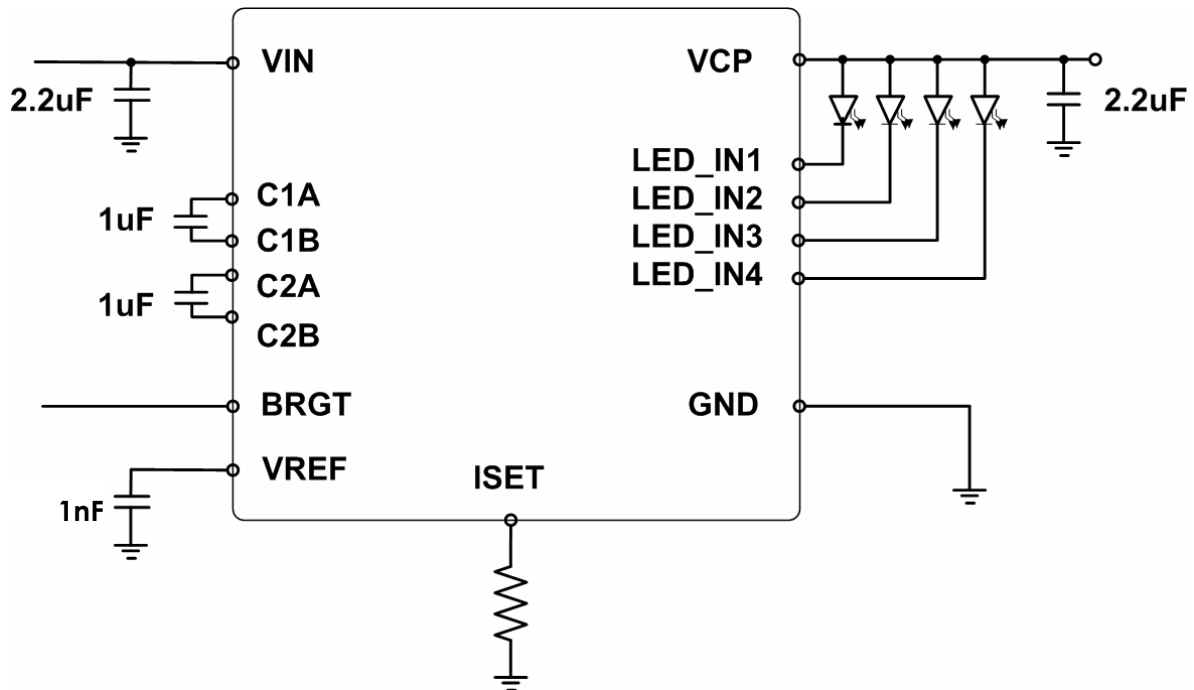
Features

- 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 $\pm 1.5\%$ current matching of any two LED outputs
- Soft start limits inrush current
- Charge pump frequency 600kHz
- Brightness control by PWM ($\sim 50\text{kHz}$)
- Maximum 1uA shutdown current

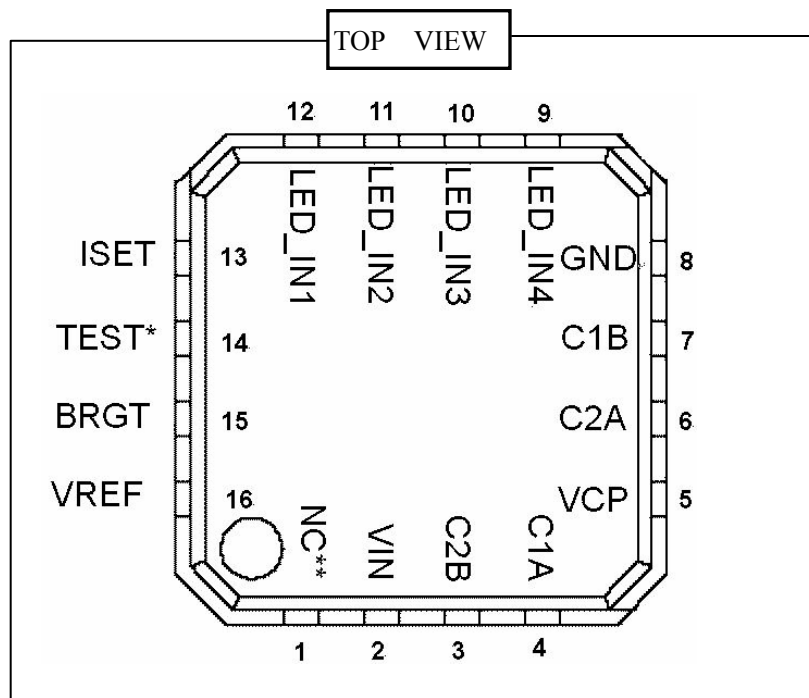
Applications

- 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



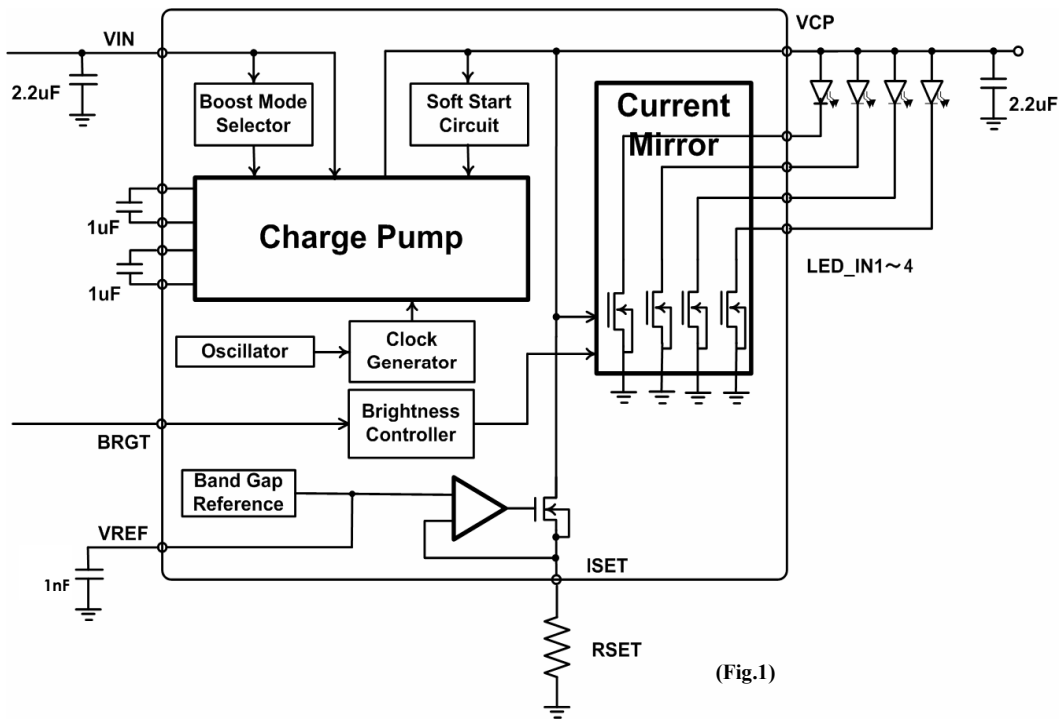
Pin Arrangement



Pin Assignment

Pin #	Pin name	Function
2	VIN	Power supply input. Bypass VIN to GND with a 2.2uF capacitor.
4	C1A	Flying capacitor (1) +
7	C1B	Flying capacitor (1) -
6	C2A	Flying capacitor (2) +
3	C2B	Flying capacitor (2) -
15	BRGT	Brightness control and shutdown input. A PWM signal (~50kHz) controls the LED brightness. A low level inhibits the device operation.
13	ISET	External resistor. Maximum LED current is determined by $I_{LED}(mA)=48/R_{SET}(k\Omega)$
16	VREF	VREF output (typically 1.2V). Bypass VREF to GND with a 1nF capacitor. VREF output must be kept high-impedance.
8	GND	Power supply ground. Charge pump switching current flows through this pin.
12	LED_IN1	Connect a LED between VCP and LED_IN1.
11	LED_IN2	Connect a LED between VCP and LED_IN2.
10	LED_IN3	Connect a LED between VCP and LED_IN3.
9	LED_IN4	Connect a LED between VCP and LED_IN4.
5	VCP	Charge pump output. Bypass VCP to GND with a 2.2uF capacitor.
1	NC	Not use. **This pin should be open, or connected to GND or VIN.
14	TEST	Not use, but internally connected. *This pin must be open.

Block Diagram



(Fig.1)

Absolute Maximum Ratings

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

Storage Temperature -55°C ~ 125°C

Electrical Characteristics

Supply voltage(V_{IN})=3.6V, R_{SET} =3.2k Ω , LED forward voltage(V_F)=3.2V,

Bypass capacitor(C_{IN})=2.2 μ F, Output capacitor(C_{CP})=2.2 μ F, Flying capacitors($C1, C2$)=1 μ F,

VREF capacitor=1nF, $V_{BRGT}=V_{IN}$, T_A =-40°C~ 85°C(note1)

Unless specified: at V_{IN} =3.6V, T_A =25°C (typical values)

Parameter	Conditions	Min	Typ	Max	Unit
Supply Voltage (V_{IN})		2.7		5.5	V
Maximum Output Current	T_A =25°C, R_{SET} =1.8k Ω	105			mA
Maximum LED Current (per one LED)	T_A =25°C, 4 LEDs, R_{SET} =1.8k Ω	26			mA
	T_A =25°C, 3 LEDs, R_{SET} =1.3k Ω	35			mA
No Load Supply Current	V_{IN} = 4.1 to 5.5V (Pass mode)		2		mA
	V_{IN} = 2.7 to 4.1V (1.5 boost mode)		5		mA
Charge Pump Frequency			600		kHz
Input Charge Pump Mode Threshold	Pass mode to 1.5 boost mode		4.1		V
Input Charge Pump Mode Hysteresis	Pass mode to 1.5 boost mode, or 1.5 boost mode to pass mode		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	T_A =25°C			1	μ A
BRGT PWM Frequency	T_A =25°C	100		50k	Hz
BRGT Threshold High	T_A =25°C, V_{IN} = 4.5 to 5.5V	3			V
	T_A =25°C, V_{IN} = 2.7 to 4.5V	2.5			V
BRGT Threshold Low	T_A =25°C			0.5	V
BRGT Input Current(Hi Level)	T_A =25°C, Input voltage is V_{IN}			1	μ A
BRGT Input Current(Lo Level)	T_A =25°C, Input	-1			μ A

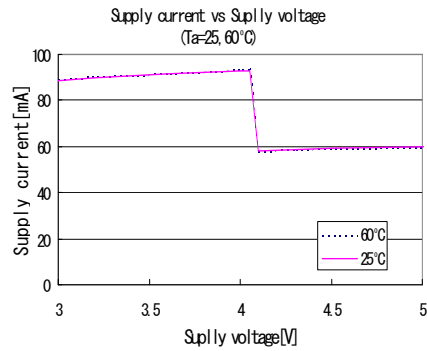
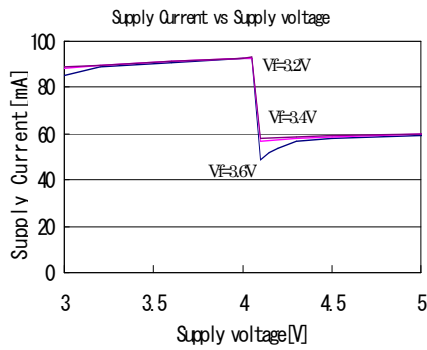
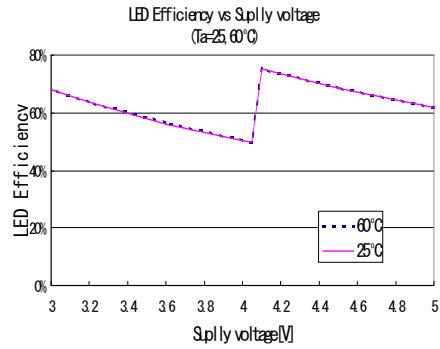
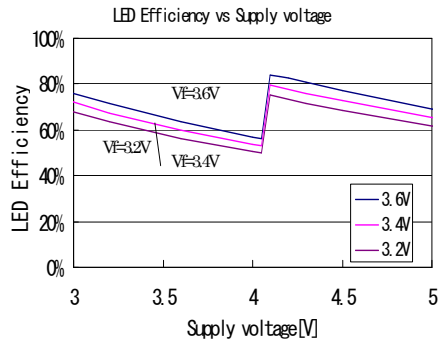
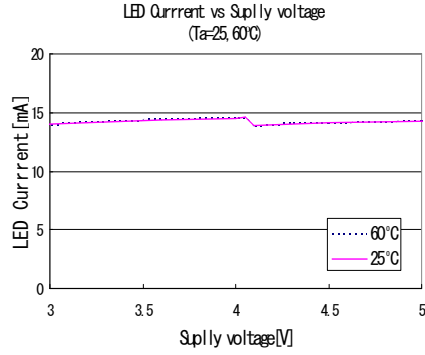
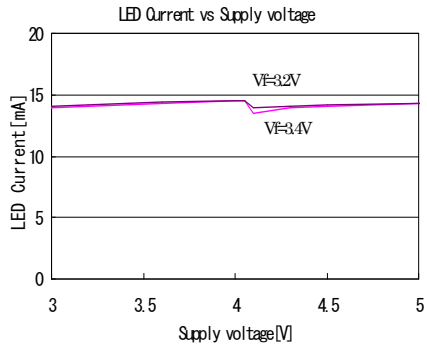
Note1: Specifications to -40°C, 85°C are guaranteed by design and not production tested.

Typical Characteristics

Unless otherwise specified;

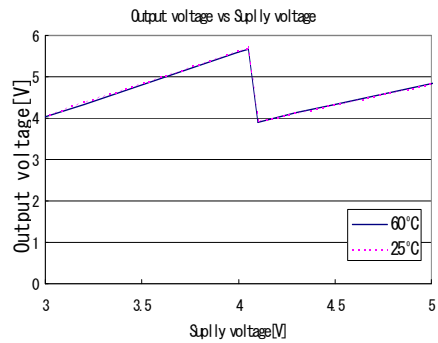
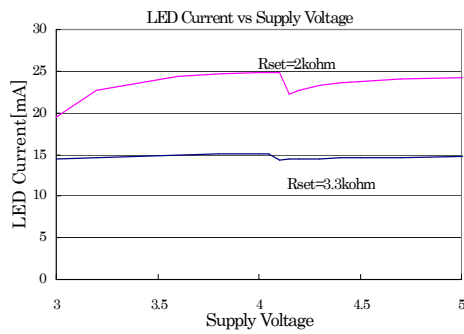
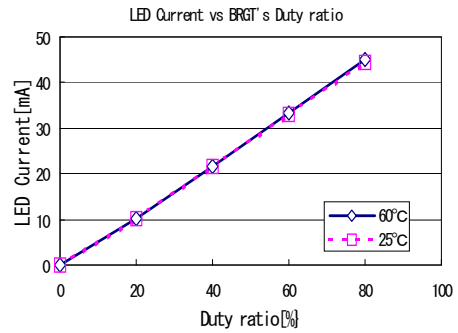
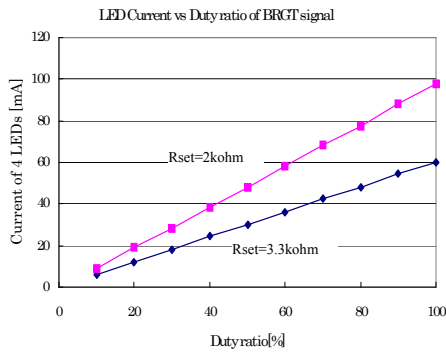
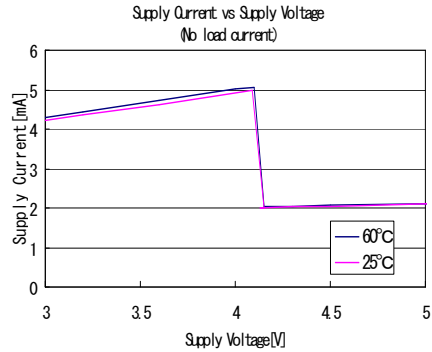
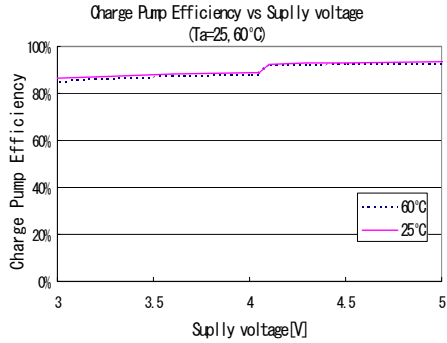
Supply Voltage(V_{IN})=3.6V, R_{SET} =3.2k Ω , LED Forward Voltage(V_F)=3.2V, T_A =25°C, Drive 4 LEDs

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



Unless otherwise specified;

Supply Voltage(V_{IN})=3.6V, R_{SET} =3.2k Ω , LED Forward Voltage(V_F)=3.2V, T_A =25 $^{\circ}$ C, Drive 4 LEDs
Bypass capacitor(C_{IN})=2.2 μ F, Output Capacitor(C_{CP})=2.2 μ F, Flying Capacitors($C1, C2$)=1 μ F



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 3.2~3.6V typically. So when the battery output voltage degrades less than V_F , 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 and changes the boost mode automatically.

The LED current (I_{LED}) is determined by the external resistor. The internal reference voltage ($V_{REF} \cong 1.2V$) is forced on the external resistor with high accuracy by an internal Op-Amp, then the current flowing through the external resistor (I_{RSET}) will be $I_{RSET} = V_{REF} / R_{SET} = 1.2 / R_{SET}$. The 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. Then, the LED current will be;

$$I_{LED} = 1.2 / R_{SET} * 40 \dots\dots\dots (1)$$

For example, when $R_{SET} = 2.4k\Omega$, then $I_{LED} = 20mA$. If four LEDs are connected, the device drives up a total of $20mA * 4 = 80mA$ to the LEDs. This term does not include the tolerance of the external resistor R_{SET} . If precision LED current accuracy is required, a precision resistor is needed (ex. 1% tolerance resistor).

The LED brightness can be controlled by a PWM signal.

Shutdown Mode

Applying a low level to the BRGT pin for 22ms or more inhibits the device, turns off all the LEDs, and reduces the quiescent current to 1 μ A maximum.

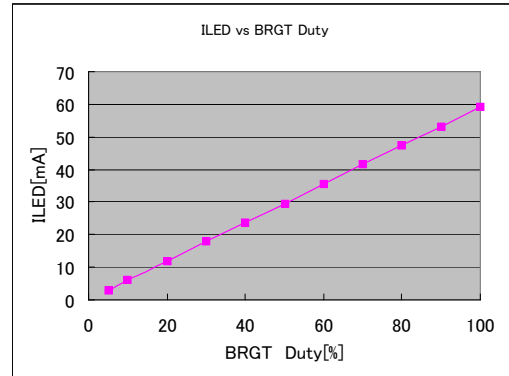
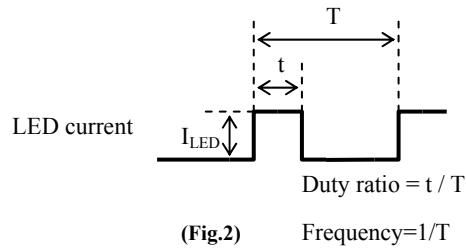
Soft Start

LC410591 includes a soft start function to reduce the inrush current. Inrush current will be generated when the charge pump operates with flying capacitors discharged. On this occasion, the charge pump circuit becomes low impedance, and 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.

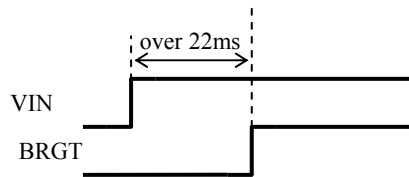
LED's Brightness Control

LC410591 can control LED's luminosity by PWM. When a PWM signal is applied on the BRGT pin, the LED current changes according to the PWM input. [LED average current = $I_{LED} * \text{Duty ratio}$] ---->(fig.2)
The current of LEDs change linearly to Duty ratio of BRGT input. (fig.3)
The LC410591 allows the PWM frequency up to 50kHz.

After VIN is turned on, please fix the BRGT to Low level 22ms or more. (fig.4)



Condition:
(Fig.3) VIN=3.6V, Rset=3.3kohm
(Reference data) BRGT=1kHz, 4LEDs



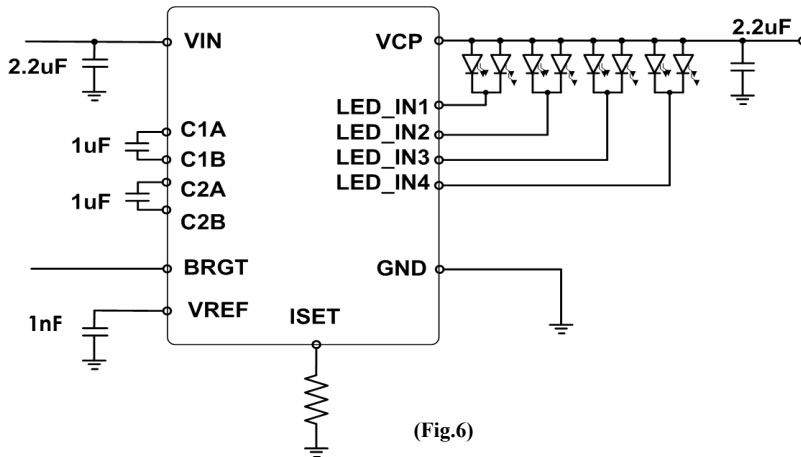
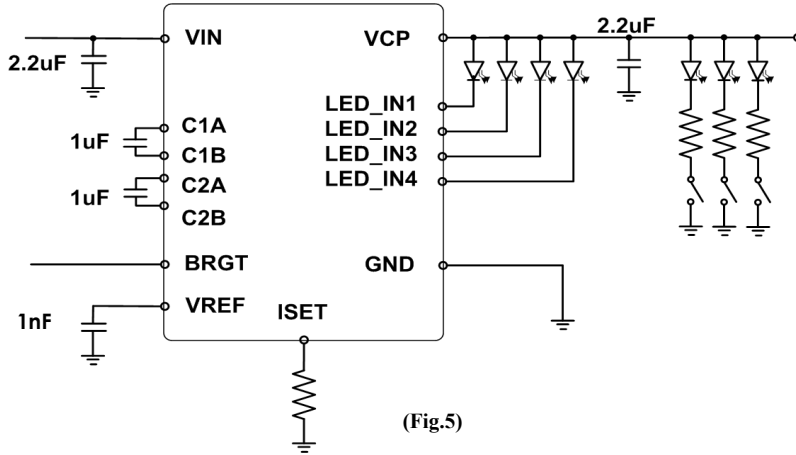
(Fig.4)

Capacitor Selection

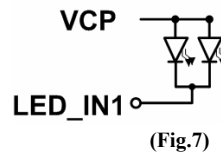
For the input bypass capacitor, the output capacitor and the charge pump flying capacitors, we recommend to use the capacitors which have low equivalent series resistance (ESR), and low variation over temperature, such as X5R or X7R of the ceramic capacitors.

Additional LED driving

The LC410591 can drive additional LEDs by using the output voltage. The example circuit is below.(Fig.5~6)
Note if the total output current is larger than 105mA, the LC410591 may not meet the specification. The resistors and the switches should be connected in serial with the additional LEDs to control the sink current and to control the LEDs' on/off.

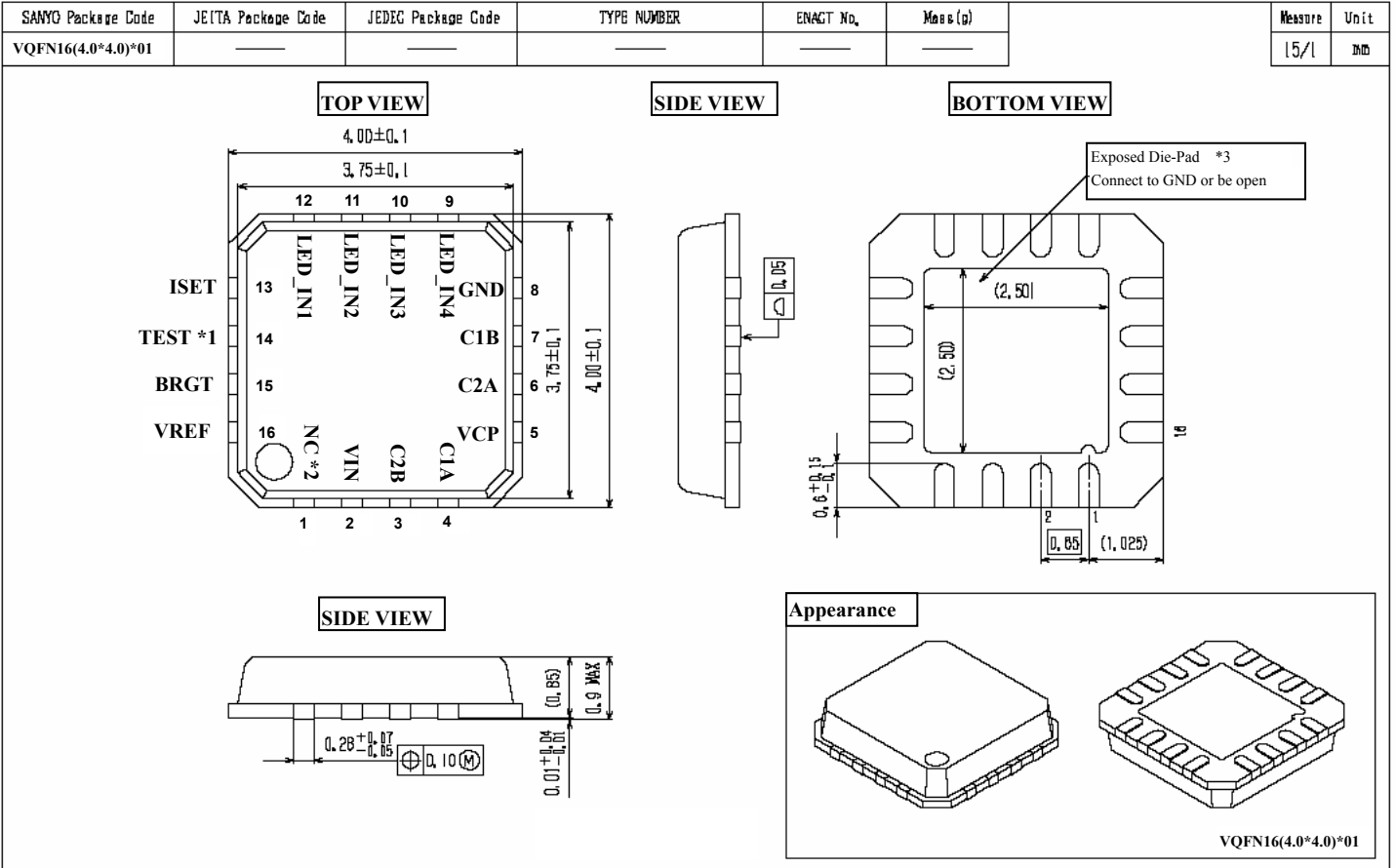


Notice when applying above application(Fig.6), the current difference of the LEDs that sink into the same LED_IN terminal, would not be regulated.(Fig.7)



1. VQFN16

OUTLINE DRAWING



REVISION : 1

- *1 TEST pin(14) must be open.
- *2 NC pin(1) should be open, or connected to GND or VIN.
- *3 Exposed Die-Pad should be open, or connected to GND.

SANYO : Very Thin Quad Flat Non-lead Package

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