Sitronix

ST1208

3-Channel White LED Driver

■ Features

- **High Efficiency Operation (P_{LEDs} / P_{BATT})**
  -- Extends battery life
  -- Peak efficiency over 88 %
- **1 / 1.5x Fractional Charge Pump Circuits**
  -- extends voltage operate range
- **Range of LED Driver Power**
  -- 2.7 to 5.0V
- **Drivability 30 mA/LED with Li-Ion Battery Operating Range**
- **Shutdown Mode Draws Less Than 1 uA**
- **Regulated to ± 3 % Output Current Matching**
- **Soft-Start Function To Limit Inrush Current**
- **Dimming Control by Logic or PWM**
- **No external Schottky Diode and Inductor Required**
- **Low Input Ripple and EMI**
- **Short Circuit and Over-Temperature Protection**
- **2KV ESD Rating**
- **Thin QFN (4 mm X 4 mm), Small TSSOP-16L Packages and Bare Chip**

■ Ordering Information

Ordering No.	Package
ST1208-Q	QFN-16
ST1208-T	TSSOP-16L
ST1208-B	Bare Chip

■ Description

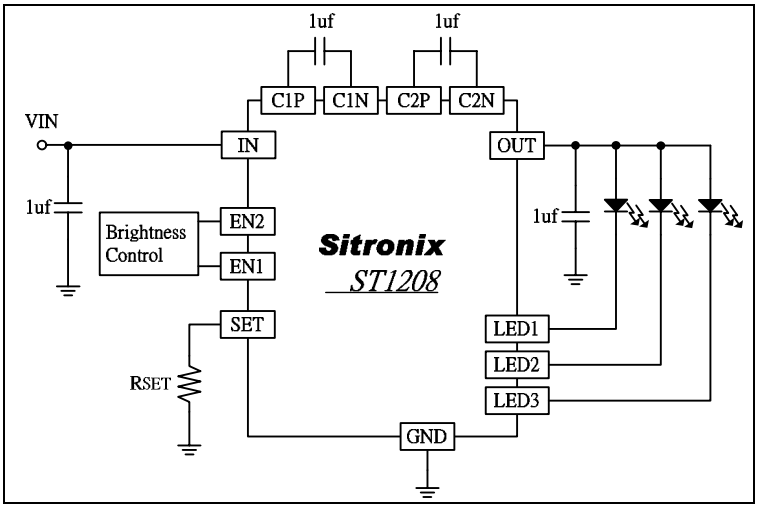
The ST1208 is a versatile change pump designed for use in battery operated power supply application. The wide input range is matched for Li-Ion battery applications.

The ST1208 LED drivers feature a fractional change pump implementation with efficiency comparable to a switching regulator without costly inductors. Only four tiny ceramic capacitors are required, and no external inductor is required for operation that provides a reduced-EMI solution. Proprietary low noise mode switching circuit and constant output current allow the use of extremely small input and output capacitor.

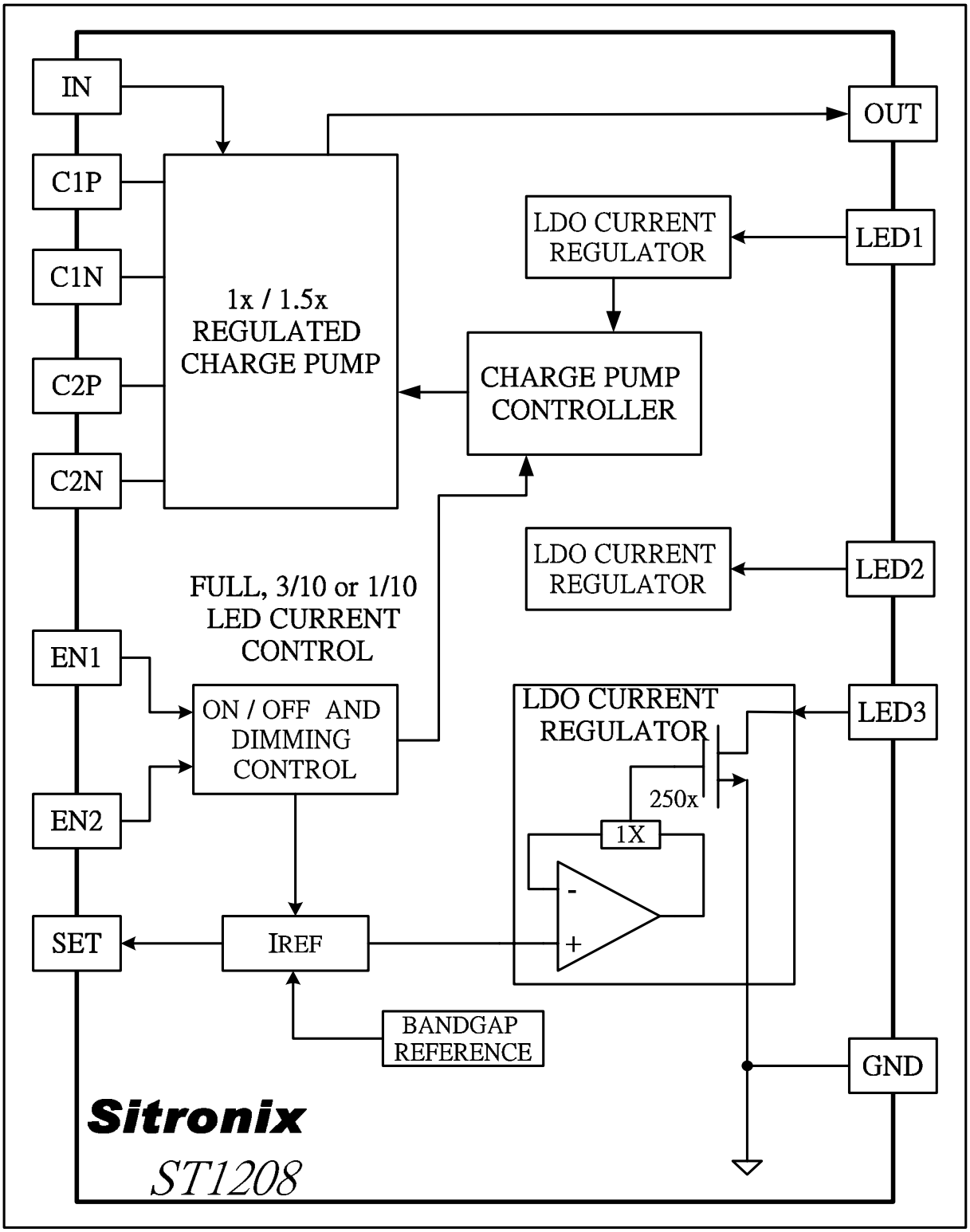
The ST1208 contains a thermal management circuit to protect the device under continuous output short circuit condition.

■ Applications

- **Cellular phones**
- **PDAs**
- **Portable communication devices**
- **LED/Display backlight driver**
- **Digital Cameras**
- **Handheld Electronics**
- **Flash LED driver**



■ Block Diagram



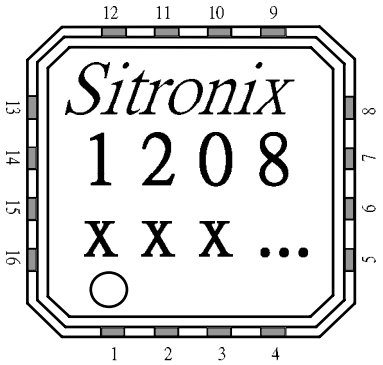
■ Pin Description

Name	Function
GND	Ground
IN	Supply voltage input pin (2.7 ~ 5.0 V). Bypass IN to GND with a ceramic capacitor.
OUT	Charge pump output pin. Bypass to GND with a ceramic capacitor. Connect to the anodes of all the LEDs. OUT is high impedance during shutdown.
SET	Variable output current pin by changing the resistant value. Connect a resistor from SET to GND to set the LED bias current. I_{SET} = 0.6V / R_{SET}
EN1	Enable, Dimming Control Input. EN1 and EN2 control shutdown and the LED current. See the Applications Information section for brightness control.
EN2	
LED1	LED cathode connection and charge-pump feedback. The charge pump regulates to the lowest voltage on the LED1. Therefore, LED1 must be used at least.
LED2	LED cathode connection. Connect LEDx to the cathode of one output LED. Let the LEDx floating if this LED is not populated.
LED3	
C1P	Charge Pump Capacitor 1 positive connection.
C1N	Charge Pump Capacitor 1 negative connection.
C2P	Charge Pump Capacitor 2 positive connection.
C2N	Charge Pump Capacitor 2 negative connection.

■ Pin Assignment

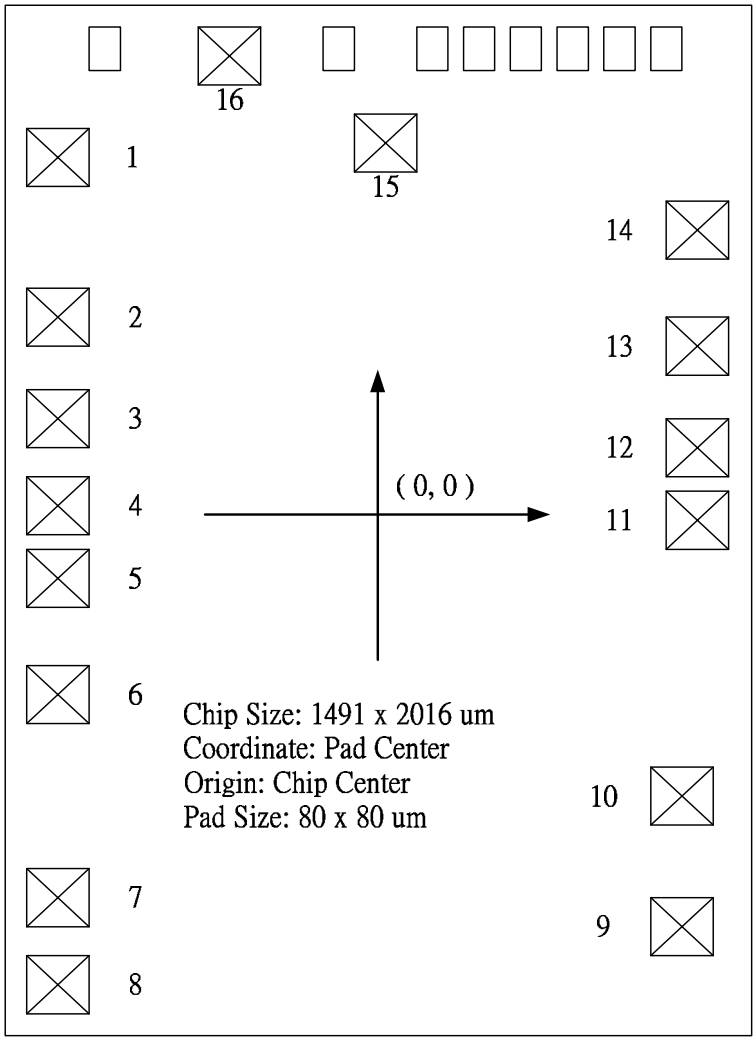
Pin (Pad) Number	Pin (Pad) Name		
	TSSOP-16	QFN-16	Bare Chip
1	LED1	C2N	LED1
2	LED2	VDD	LED2
3	LED3	VDD	LED3
4	GND	EN1	GND
5	GND	EN2	GND
6	C1P	SET	C1P
7	C2P	NC	C2P
8	C1N	LED1	C1N
9	VOUT	LED2	VOUT
10	C2N	LED3	C2N
11	IN	GND	IN
12	IN	GND	IN
13	EN1	C1P	EN1
14	EN2	C1N	EN2
15	SET	C2P	SET
16	NC	VOUT	NC

TSSOP-16



QFN-16

■ Bare Chip Pad Arrangement



Substrate Connect to GND.

■ Bare Chip Pad Location Coordinates

Pad No.	Function	X	Y
1	**LED1**	-641.5	718
2	**LED2**	-641.5	386
3	**LED3**	-641.5	163
4	**GND**	-641.5	28
5	**GND**	-641.5	-72
6	**C1P**	-641.5	-318
7	**C2P**	-641.5	-750
8	**C1N**	-641.5	-900
9	**VOUT**	609.5	-777.3
10	**C2N**	609.5	-546
11	**IN**	640.5	9
12	**IN**	640.5	109
13	**EN1**	640.5	320
14	**EN2**	640.5	547
15	**SET**	103.5	769
16	**NC**	-189.5	903

■ Function Description

The ST1208 is a complete charge-pump buck-boost converter which is requiring only four small ceramic capacitors. In order to regulated constant current for uniform intensity, the ST1208 utilizes a proprietary 1x/1.5x fractional charge-pump topology to drive up three white LEDs. While two digital inputs control on/off and provide brightness control, an external resistor (R_{SET}) programs the full-scale LED current. The ST1208 operates with a 1MHz fixed frequency.

Output Regulation

The ST1208 operates in 1x mode until just above dropout. Then the ST1208 switches to 1.5x charge pump mode to regulate the LED1 to 300mV and maintain constant LED brightness even at very low battery voltages. Using this topology, there is no LED brightness change from 1x to 1.5x. which guarantees no flicker on the display.

The 1x mode produces almost no ripple, while the 1.5x mode regulates the output voltage by controlling the rate at which the charge pump capacitors are charged. In this way, the switching frequency remains constant for reduced input ripple and stable noise spectrum.

Shutdown Mode

When EN1 and EN2 are grounded, the ST1208 is in shutdown. The shutdown current is less than 1uA.

ST1208 which is out of shutdown will be operated in 1x mode while the input voltage is higher than output voltage.

Thermal Shutdown

The ST1208 includes a thermal-limit circuit that shutdown the IC at about +160°C. Turn-on occurs after the IC cools by approximately 20°C.

Setting the Output Current

SET control the LED bias current. Current into LED1, LED2 and LED3 is a multiple of the current flowing out of SET. Set the output current as follows:

$$I_{LEDx} = K \times (0.6 / R_{SET})$$

Where K = 160, 48 or 16 (depending upon EN1 and EN2. see Table1), and R_{SET} is the resistor connected between SET and GND.

Soft Start

The ST1208 includes soft-start circuitry to limit inrush current at turn-on. When starting up with an output voltage that is not near the input voltage, the output capacitor is charged directly from the input with a ramped current source until the output voltage is near the input voltage. Once this occurs, the charge pump determines if 1x or 1.5x mode is required. In the case of 1x mode, the soft start is terminated and normal operation begins. In the case of 1.5x mode, soft-start operates until the LED1 reaches regulation.

■ Applications Information

Dimming Using EN1 and EN2 (See Figure 1.)

Use EN1 and EN2 inputs as a digital 2-bit number to control on/off, 1/10, 3/10 and full current (see Table1). RSET programs the full current level (see the *Setting the Output Current* section).

EN1	EN2	BRIGHTNESS	LED CURRENT
0	0	Shutdown	I_{LED} = 0
0	1	1/10 Brightness	I_{LED} = 16 X I_{SET}
1	0	3/10 Brightness	I_{LED} = 48 X I_{SET}
1	1	Full Brightness	I_{LED} = 160 X I_{SET}

Table 1. Brightness Control

Dimming Using PWM into EN1 (See Figure 2.)

Use EN2 for shutdown and drive EN1 with a PWM signal. Current can be varied from 1/10 to full. The maximum frequency of PWM is 10 KHz.

$$I_{LED} = K \cdot I_{SET} \cdot (0.9 \cdot PWM + 0.1)$$

Where K = 160, PWM = 0% ~ 100%.

Dimming Using a Filtered PWM Signal (See Figure 3.)

Use a high-frequency PWM signal to drive an R-C-R filter on the SET pin. A 0% PWM duty cycle corresponds to 20mA/LED, while a 100% PWM duty cycle corresponds to 0mA/LED. At PWM frequencies above 5 KHz, C may be reduced.

Input Ripple (See Figure 4.)

For LED drivers, input ripple is more important than output ripple. Input ripple depends on the source supply's impedance. Adding a lowpass filter to the input further reduce input ripple. Figure 4 shows a C-R-C filter used to reduce input ripple to less than 2mVp-p when driving a heavy load or flash LED.

PCB Layout and Routing

The ST1208 is a high-frequency switched-capacitor voltage regulator. For best circuit performance, use a solid ground plane and place CIN and COUT as close to the ST1208 as possible. Also, place their ground pads close together and as close as possible to GND. Making the bias current clear can enhance stability of the LED output current,

Component Selection

For high efficiency performance, how to choose the component is the most important.
Low ESR capacitor can reduce the output voltage ripple and increase the voltage of charge pump. The ceramic capacitor with an X5R or X7R is the best.
The efficiency of 1x mode is over 15% higher than 1.5x mode. Therefore, higher input voltages or the low forward voltage of LED can make the ST1208 switch to 1x mode.

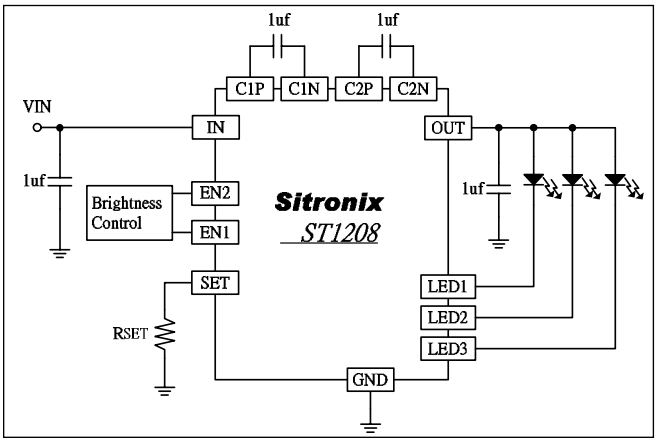


Figure 1. Typical Operating Circuit

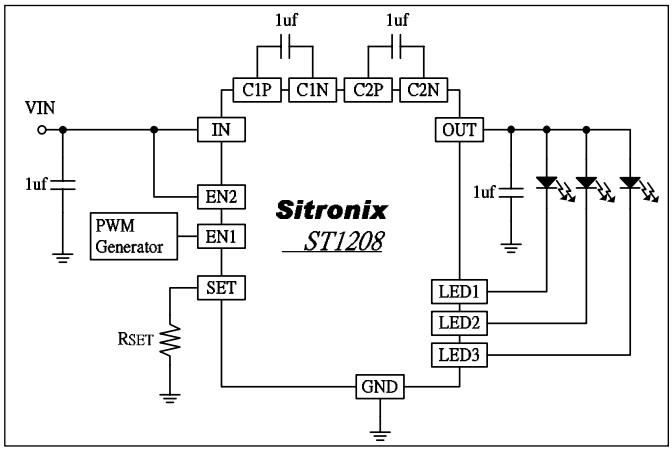


Figure 2. Dimming Using PWM Signal into EN1

■ Applications Information…… (Continued)

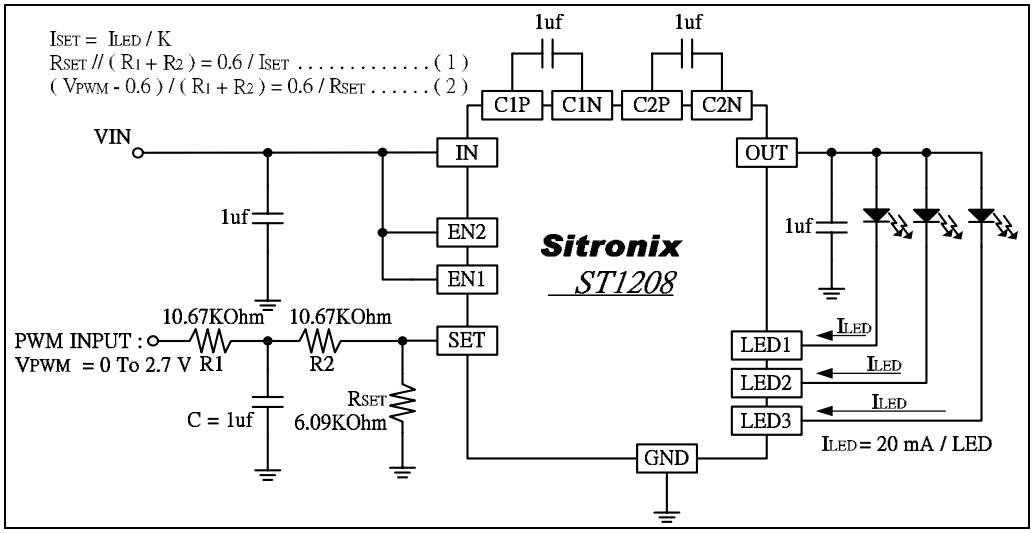


Figure 3. Dimming Using Filtered PWM Signal

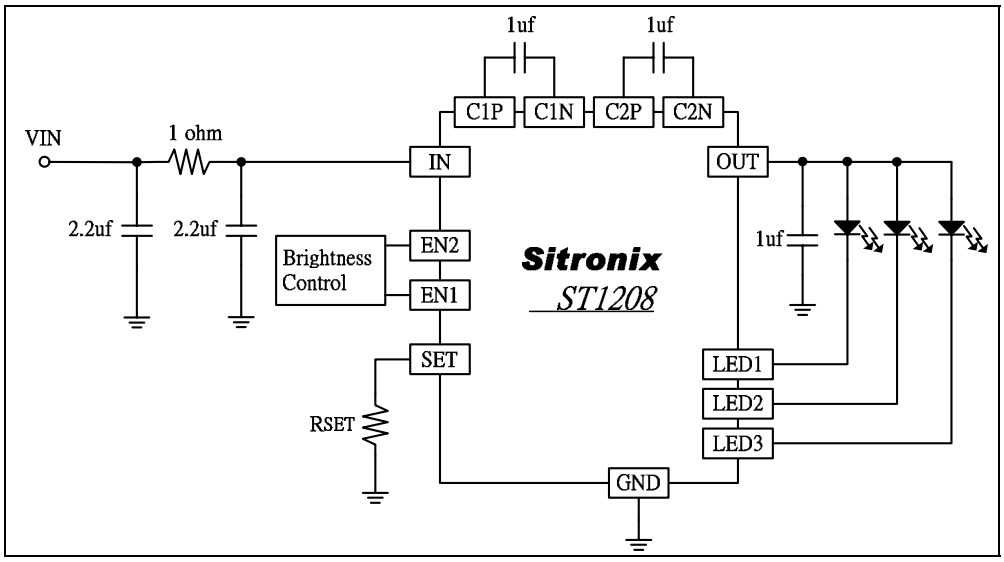


Figure 4. C-R-C Filter Reduces Input Ripple

■ Absolute Maximum Ratings

IN, OUT, EN1, EN2 to GND ..... -0.3V to + 6.0V
SET, LED1, LED2, LED3 to GND ..... -0.3V to (VIN + 0.3V)
C1N, C2N to GND ..... -0.3V to (VIN + 1V)
C1P, C2P to GND ..... -0.3V to greater of (VOUT + 1V) or (VIN + 1V)

Continuous Power Dissipation (TA = +70°C)
16-Pin QFN (de-rate 17 mW/°C above +70°C) 1350 mW
16-Pin TSSOP (de-rate 18 mW/°C above +70°C) 1500 mW
Operating Temperature Range .....-40°C to +85°C
Storage Temperature Range .....-40°C to +125°C

■ Electrical Characteristics

Condition: VIN = VEN1 = VEN2 = 3.6 V, CIN = C1 = C2 = COUT = 1 uf, dropout current is 60 mA. (20 mA / LED X 3), LED Vf = 3.3 V, ISET = 125 uA, Charge pump switching

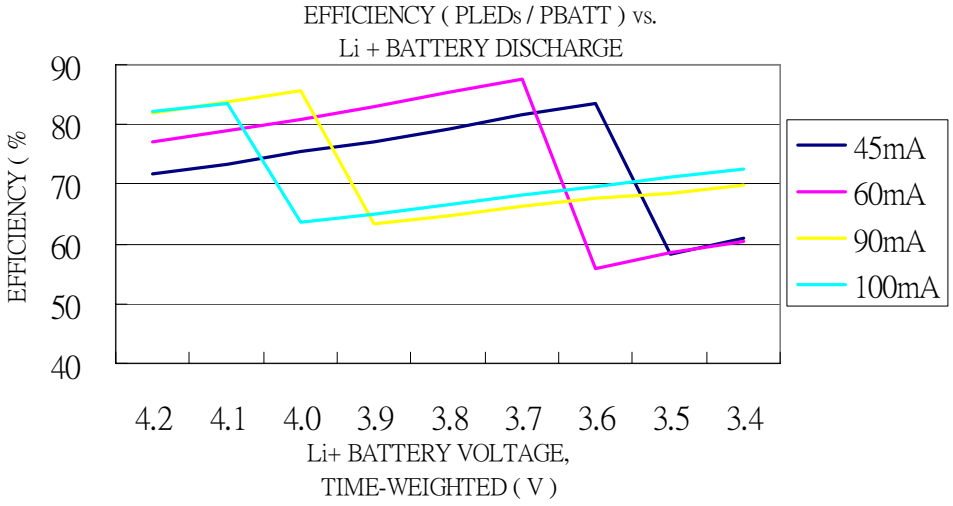
(TA = +25℃)

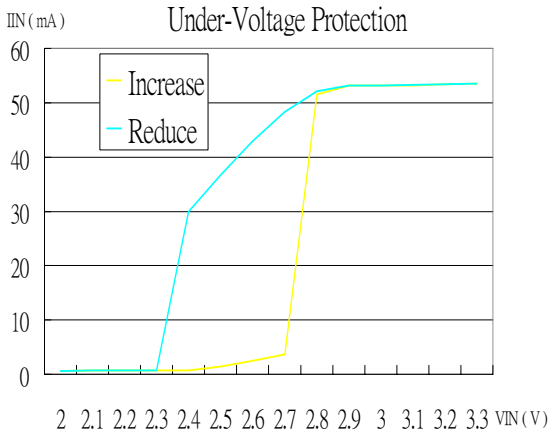
Symbol	Parameter	Test Condition		Min.	Typ.	Max.	Unit
V_{IN}	IN Operating Voltage	-		2.7	-	5.0	V
I_{IN}	Power Supply Current	Switching, no load		-	2.0	4.0	mA
I_{OUT}	Maximum OUT Current	VIN >=3.6 V, EN1 = EN2 = IN		100		-	mA
I_{LED}	Maximum LEDx Sink Current	VIN >=3.3 V, I_{SET} = 190 uA, EN1 = EN2 = IN		28	30	-	mA
I_{INS}	Shutdown Supply Current	EN1 = EN2 = GND		-	1	3	uA
I_{LSS}	SET Leakage in Shutdown	EN1 = EN2 = GND, TA = 25℃		-	0.01	0.1	uA
I_{LLS}	LED Leakage in Shutdown	EN1 = EN2 = GND, TA = 25℃		-	0.01	0.1	uA
I_{SET}	SET Current Range			30	-	200	uA
V_{IH}	EN1, EN2 Logic High Voltage	VIN=2.7 V to 5.0 V		0.7 V_{IN}	-	V_{IN}	V
V_{IL}	EN1, EN2 Logic Low Voltage	VIN=2.7 V to 5.0 V		0	-	0.2 V_{IN}	V
I_{EN}	EN1, EN2 Input Current	VENx = GND or 5.0 V, TA = 25℃		-	0.5	1.0	uA
V_{LED}	LEDx Minimum Regulation Voltage (1.5x Mode)	EN1 = EN2 = IN, I_{SET} = 125 uA		200	300	400	mV
V_{DP}	LEDx Dropout Voltage	I_{SET} = 125 uA		-	20	30	mV
R_{OUT}	Open-Loop OUT Resistance	1x mode (1 X V_{IN} - V_{OUT}) / I_{OUT} @ VIN = 4.2 V, IOUT = 60 mA		-	7	10	Ohm
		1.5x mode (1.5 X V_{IN} - V_{OUT}) / I_{OUT} @ VIN = 3.6 V, IOUT = 60 mA		-	11	15	
f_{SW}	Switching Frequency	± 20%		0.8	1.0	1.2	MHz
T_{TS}	Thermal-Shutdown Threshold	20℃ hysteresis		130	160	190	℃
V_{UV}	Undervoltage Lockout Threshold	VIN rising or falling, 0.25V hysteresis		2.2	2.3	2.6	V
K	SET to LEDx Current Ratio (ILED / ISET)	I_{SET}= 125 uA	EN1 = EN2 = IN	145	160	175	A/A
			EN1 = IN, EN2 = GND	43	48	52	
			EN1 = GND, EN2 = IN	14	16	17	
A	LEDx Current Accuracy	EN1 = EN2 = IN, R_{SET} = 4.8KOhm, TA = 0℃ ~ 85℃		-	±3	-	%
M	LEDx Current Matching	EN1 = EN2 = IN, I_{SET} = 125 uA, TA = 0℃ ~ 85℃ (Note 1)		-	±3	-	%
η	Peak efficiency in 1x mode	I_{OUT} = 60 mA, P_{LEDs} / P_{IN} X 100 %		80	88	-	%

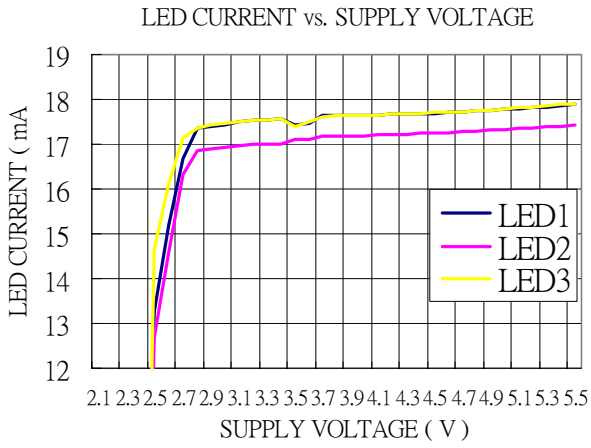
Note1: LEDx current matching is define as : (I_{LEDX} - I_{AVG}) / I_{AVG} X 100 %.

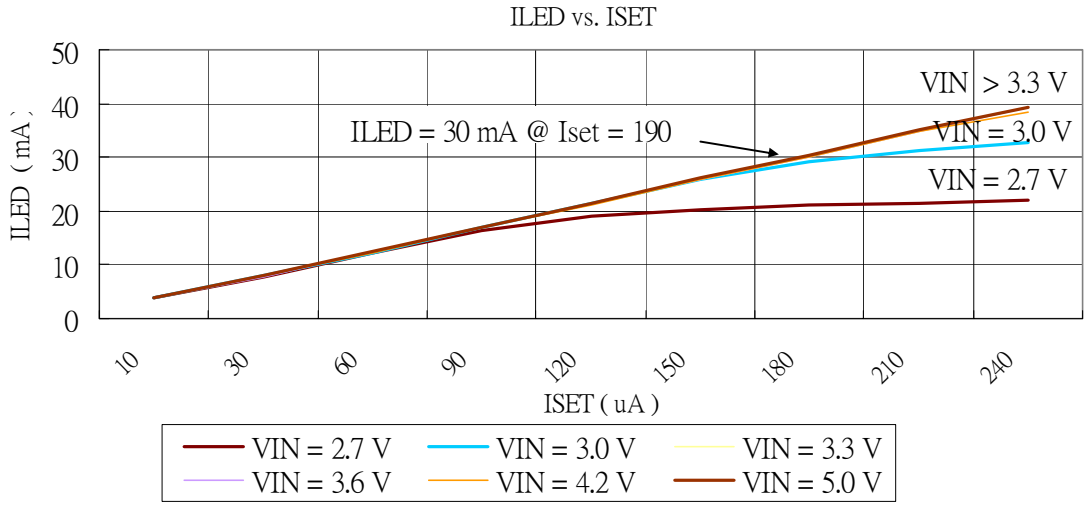
■ Typical Operating Characteristics

Condition: VIN = VEN1 = VEN2 = 3.6 V, CIN = C1 = C2 = COUT = 1 uf, dropout current is 60 mA. (20 mA / LED X 3), LED forward voltage Vf = 3.3 V, ISET = 125 uA



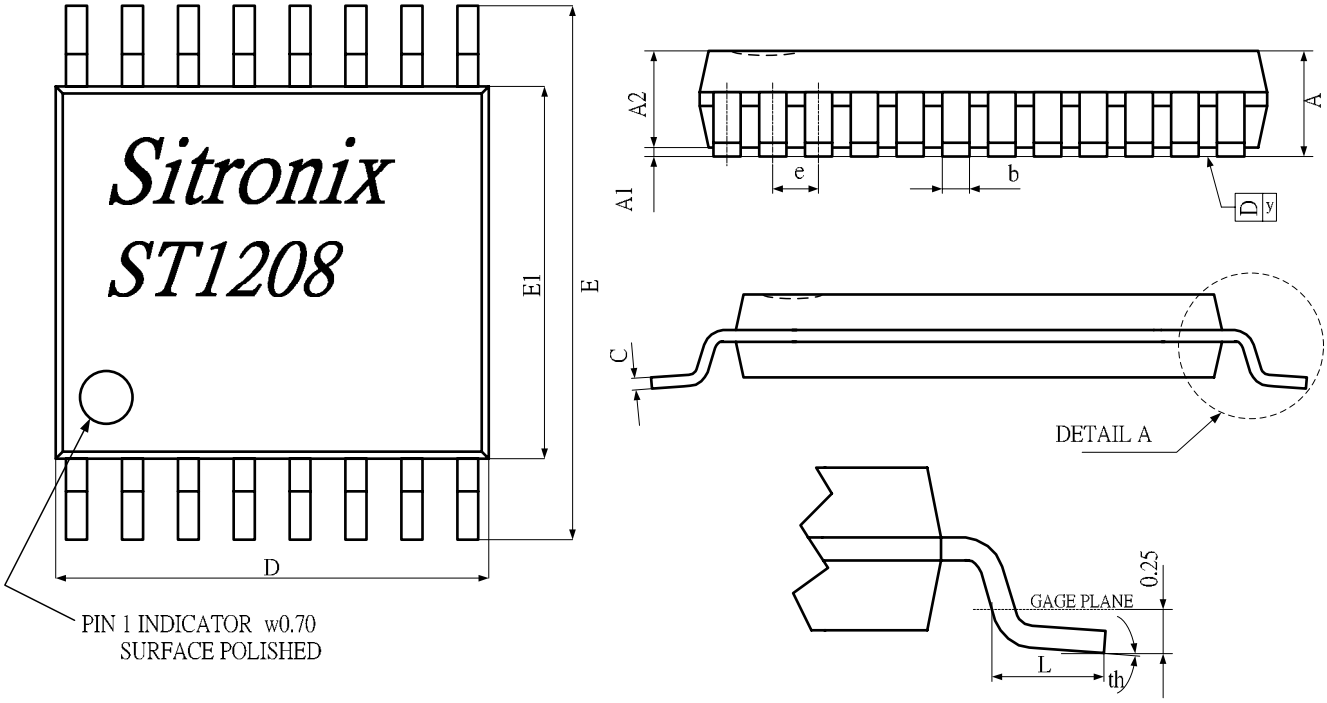






■ Package Information

TSSOP-16L



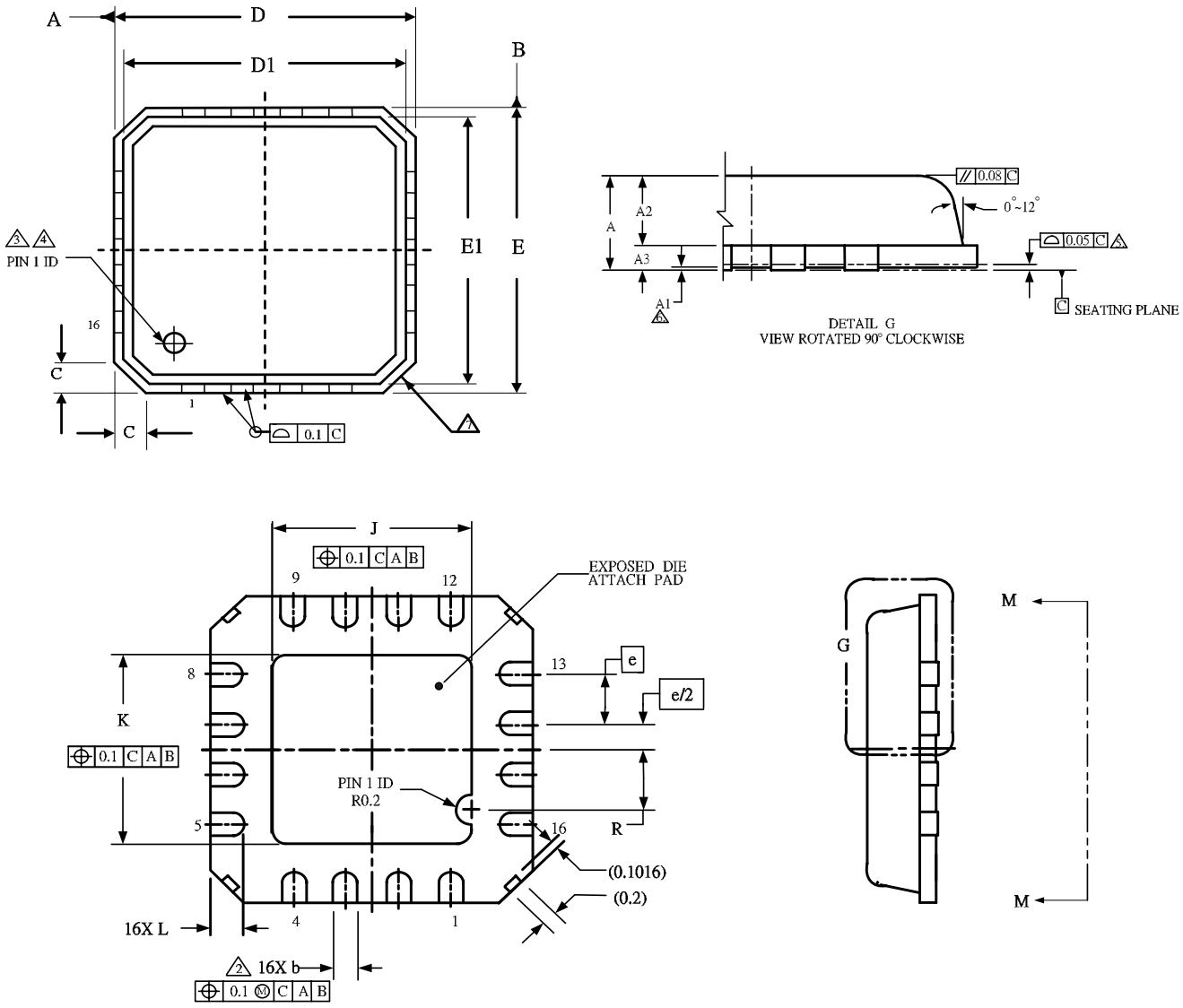
DETAIL A

NOTE:
1. CONTROLLING DIMENSION : mm
2. LEAD FRAME MATERIAL : OLIN C7025/EFTEC 64T
3. DIMENSION “D” DOES NOT INCLUDE MOLD FLASH, TIE BAR BURRS AND GATE BURRS. MOLD FLASH, TIE BAR BURRS AND GATE BURRS SHALL NOT EXCEED 0.006” [0.15mm] PER END DIMENSION “E1” DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010” [0.25mm] PER SIDE.
4. DIMENSION “b” DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.003” [0.08mm] TOTAL IN EXCESS OF THE “b” DIMENSION AT MAXIMUM MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE FOOT. MINIMUM SPACE BETWEEN PROTRUSION AND AN ADJACENT LEAD TO BE 0.0028 “ [0.07mm]
5. TOLERANCE: +/- 0.010” [0.25mm] UNLESS OTHERWISE SPECIFIED.
6. OTHERWISE DIMENSION FOLLOW ACCEPTABLE SPEC.
7. REFERENCE DOCUMENT : JEDEC SPEC MO-153

SYMBOLS	DIMENSIONS IN MILLIMETERS			DIMENSIONS IN INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	1.05	1.10	1.20	0.041	0.043	0.047
A1	0.05	0.10	0.15	0.002	0.004	0.006
A2	-	1.00	1.05	-	0.039	0.041
b	0.20	0.25	0.28	0.008	0.010	0.011
C	-	0.127	-	-	0.005	-
D	4.90	5.075	5.10	0.193	0.1998	0.200 (*1)
E	6.20	6.40	6.60	0.244	0.252	0.260
E1	4.30	4.40	4.50	0.170	0.173	0.177
e	-	0.65	-	-	0.026	-
L	0.50	0.60	0.70	0.020	0.024	0.028
y	-	-	0.076	-	-	0.003
th	0°	4°	8°	0°	4°	8°

■ Package Information…… (Continued)

QFN-16



VIEW M—M

DIM.	MIN.	NOM.	MAX.	NOTES
A	0.8		0.9	1. DIE THICKNESS ALLOWABLE IS 0.305mm MAXIMUM (.012 INCHES MAXIMUM).
A1	0	0.02	0.05	2. DIMENSION APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.2 AND 0.25 mm FROM TERMINAL TIP.
A2	0.65		0.69	3. THE PIN #1 IDENTIFIER MUST BE EXISTED ON THE TOP SURFACE OF THE PACKAGE BY USING INDENTATION MARK OR OTHER FEATURE OF PACKAGE BODY.
A3		0.203 REF		4. EXACT SHAPE AND SIZE OF THIS FEATURE IS OPTIONAL.
b	0.25	0.3	0.35	5. APPLIED FOR EXPOSED PAD AND TERMINALS. EXCLUDE EMBEDDING PART OF EXPOSED PAD FROM MEASURING.
c	0.24	0.42	0.6	6. APPLIED ONLY THE TERMINALS.
D		4 BSC		7. EXACT SHAPE OF EACH CORNER IS OPTIONAL
D1		3.75 BSC		
E		4 BSC		
E1		3.75 BSC		
e		0.65 BSC		
J	2.37	2.47	2.57	
K	2.37	2.47	2.57	
L	0.3	0.4	0.5	
R	0.685	0.785	0.885	

UNIT	DIMENSION AND TOLERANCES	REFERENCE DOCUMENT
MM	ASME Y14.5M	98A0016PN004

ST1208 Serial Specification Revision History		
Version	**Date**	**Revision Description**
0.2c	**2004/05/05**	**1. Take off PHO function.** **2. Release TBD value.**
0.2e	**2004/07/26**	**1. Add the drawing of QFN package.** **2. Adjust the characteristic for ST1208.**
1.0	**2004/08/19**	**1. a-site release. (Ver0.2e → Ver1.0)**
1.1	**2004/10/27**	**1. Add the bare chip information.**