

## 1x/1.5x Auto-Adjust Charge Pump 4-Channel White LED Driver with Two Dimming Modes

### GENERAL DESCRIPTION

The PT4303 is a 4-channel 1x/1.5x auto-adjust charge pump white LED driver with two dimming modes. Auto-adjust charge pump achieves high efficiency for Li-Ion battery supply. The two LED dimming modes enable users to dim the four LEDs all together or individually. Only a few external components (two flying capacitors and two filter capacitors at  $V_{IN}$  and  $V_{OUT}$ ) are needed, which makes the PT4303 ideally suited for mobile applications.

The current through the LED can be set by an external resistor. The four LEDs can be turned on and off individually or in a group of two to four through the two control terminals, which can also be used to dim the LEDs by applying PWM control signals.

Built-in soft-start circuit prevents the inrush current from the power supply during power on and 1x/1.5x mode change. The thermal shutdown and current limiter prevent the PT4303 from being damaged by a high-level current through it. A shutdown current of less than 1uA makes the battery last longer. The PT4303 is available in QFN-16 package.

### FEATURES

- 3V-5.5V input voltage
- 1x/1.5x auto-adjust charge pump
- Set LED current by external resistor
- Dimming LED by PWM signal through 2 control terminal
- LED fault detection
- <3% current mismatch
- No inductor
- Less than 1uA shutdown current
- Built-in soft-start and soft mode decision

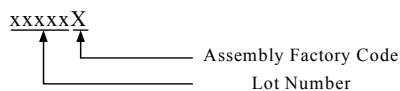
### APPLICATIONS

- Cell phones
- Laptop computers and PDAs
- Digital cameras
- Small LCD displays

### ORDERING INFORMATION

PACKAGE	TEMPERATURE RANGE	ORDERING PART NUMBER	TRANSPORT MEDIA	MARKING
QFN-16 (3x3)	-40 °C to 85 °C	PT4303EQFN	Tape and Reel 3000 units	PT4303 xxxxxX

Note:



### TYPICAL APPLICATION CIRCUIT

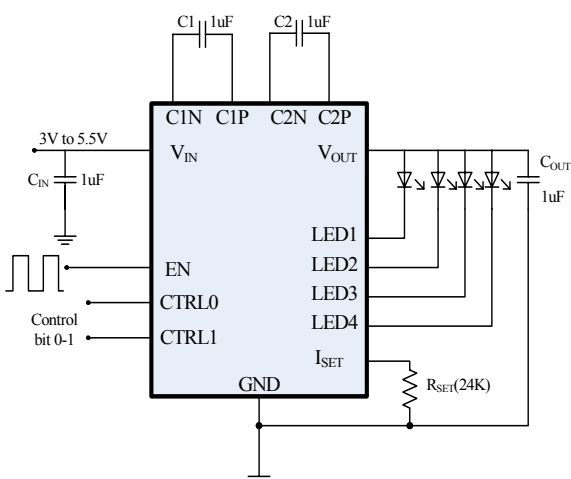


Figure 1. Li-Ion Battery Driving 4 White LEDs

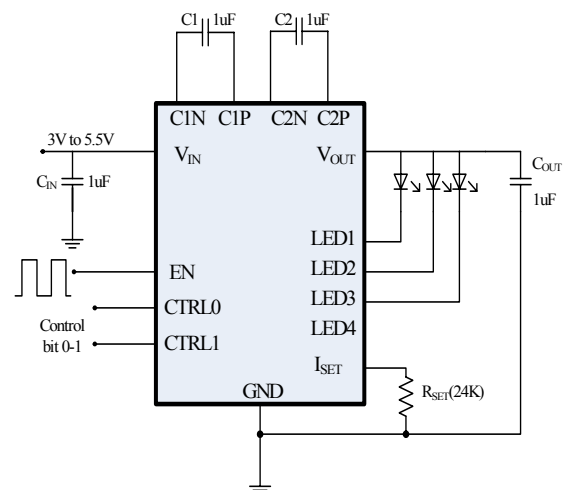
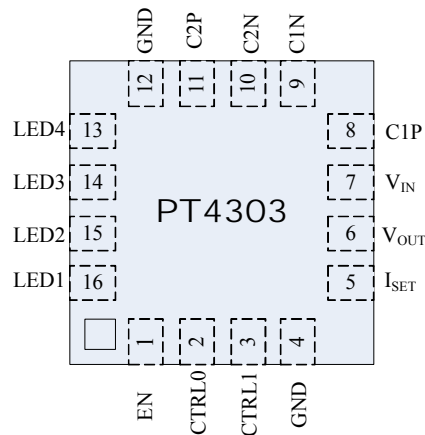


Figure 2. Li-Ion Battery Driving 3 White LEDs

**PIN ASSIGNMENT**

**Figure 3. QFN16(3x3) Top View**
**PIN DESCRIPTIONS**

QFN16 PIN No.	PIN NAMES	DESCRIPTION
1	EN	Chip enable pin
2 to 3	CTRL0 to 1	LED current control bit 0 to 1, (See table 1)
5	I <sub>SET</sub>	LED currents are set by the resistor Rset connected from the Iset pin to ground. The pin must not be shorted to ground because its voltage is set internally to 1.22V.
6	V <sub>OUT</sub>	Output voltage source connecting to the 1uF ceramic capacitor's positive and LED's anodes.
7	V <sub>IN</sub>	Power supply
8	CIP	Positive terminal of fly capacitor 1
9	C1N	Negative terminal of fly capacitor 1
10	C2N	Negative terminal of fly capacitor 2
11	C2P	Positive terminal of fly capacitor 2
4, 12	GND	Ground
13 to 16	LED1 to 4	Current sink for LED

**ABSOLUTE MAXIMUM RATINGS (Note 1)**

SYMBOL	ITEMS	VALUE	UNIT
V <sub>IN</sub>	Input Voltage	-0.3~6	V
V <sub>OUT</sub>	Output Voltage	-0.3~6	V
V <sub>EN</sub> , V <sub>CTRL0~1</sub>	The voltage of EN, CTRL0, and CTRL1 pin voltage	GND-0.3 ~V <sub>IN</sub> +0.3	V
PTR	Thermal Resistance, QFN-16 (3x3) $\Theta_{JA}$	68	°C /W
P <sub>DMAX</sub>	Power Dissipation (Note 2)	Internally Limited	W
T <sub>J</sub>	Operation Junction Temperature Range	-40 to 150	°C
T <sub>stg</sub>	Storage Temperature	-55 to 150	°C
T <sub>solder</sub>	Package Lead Soldering Temperature	260°C, 10s	
	ESD Susceptibility (Note 3)	2	kV

**1x/1.5x Auto-Adjust Charge Pump  
4-Channel White LED Driver with Two Dimming Modes**
**RECOMMENDED OPERATING RANGE**

SYMBOL	ITEMS	VALUE	UNIT
V <sub>IN</sub>	V <sub>IN</sub> Supply Voltage	+3 ~ +5.5	V
V <sub>LED</sub>	The LED Forward Voltage at 20mA	< 4	V
T <sub>OPT</sub>	Operating Temperature	-40 to +85	°C

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Range indicates conditions for which the device is functional, but does not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Range. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

**Note 2:** The maximum power dissipation must be derated at elevated temperatures and is dictated by T<sub>JMAX</sub>, θ<sub>JA</sub>, and the ambient temperature T<sub>A</sub>. The maximum allowable power dissipation is P<sub>DMAX</sub> = (T<sub>JMAX</sub> - T<sub>A</sub>) / θ<sub>JA</sub> or the number given in Absolute Maximum Ratings, whichever is lower.

**Note 3:** Human body model, 100pF discharged through a 1.5kΩ resistor.

**ELECTRICAL CHARACTERISTICS (Note 4, 5)**

V<sub>IN</sub>=3.5V, C1=C2=C<sub>IN</sub>=C<sub>OUT</sub>=1μF, T<sub>A</sub>=25 °C, unless specified otherwise.

SYMBOL	ITEMS	CONDITIONS	MIN.	TYP.	MAX.	UNIT
<b>Input Characteristics</b>						
V <sub>IN</sub>	Input Voltage		3		5.5	V
I <sub>OFF</sub>	Operating Current (Shutdown)	EN=0		0.1	1	μA
I <sub>q</sub>	Operating Current (Quiescent)	No load Current		2	4	mA
<b>Charge Pump</b>						
F <sub>CLK</sub>	Switching Frequency		0.7	1	1.3	MHz
T <sub>SS</sub> <sup>(note 6)</sup>	Soft-start time			550		μs
V <sub>15-1</sub>	The Threshold of 1.5X-> 1X	V <sub>LED1</sub> =V <sub>LED2</sub> =3.5V, I <sub>LED</sub> =20mA		4		V
V <sub>1-15</sub>	The Threshold of 1X-> 1.5X	V <sub>LED1</sub> =V <sub>LED2</sub> =3.5V, I <sub>LED</sub> =20mA		3.8		V
<b>Output Characteristics</b>						
I <sub>OUT</sub>	Maximum LED output current	3.0<V <sub>IN</sub> <5.5, V <sub>LED</sub> =3.5V, R <sub>set</sub> =24KΩ, V <sub>EN</sub> =V <sub>IN</sub> , and unmeasured LEDs are all open.	18	20	22	mA
I <sub>Match</sub> <sup>(note7)</sup>	Current match between D1, D2, D3 and D4	3.0<V <sub>IN</sub> <5.5, 0.5mA≤I <sub>LED</sub> ≤30mA			3	%
V <sub>ovp</sub>	Over output voltage protection	V <sub>IN</sub> =4, Open all LED		5.5		V
I <sub>OLP</sub>	Over Load Protection	Short V <sub>OUT</sub> to GND		200		mA

## 1x/1.5x Auto-Adjust Charge Pump 4-Channel White LED Driver with Two Dimming Modes

### ELECTRICAL CHARACTERISTICS (Continued) (Note 4, 5)

SYMBOL	ITEMS	CONDITIONS	MIN.	TYP.	MAX.	UNIT
<b>Chip Enable</b>						
V <sub>IL</sub>	EN, CTRL0, CTRL1 Maximum Low Level Threshold				0.4	V
V <sub>IH</sub>	EN, CTRL0, CTRL1, Minimum high level threshold		1.8			V
T <sub>CTRL</sub>	CTRL0, CTRL1 minimum pulse width when dimming with PWM signal			100		us
<b>Thermal</b>						
T <sub>SD</sub>	Thermal Shutdown Threshold	Temperature rise		160		°C
T <sub>HY</sub>	Thermal Shutdown Hysteresis			10		°C

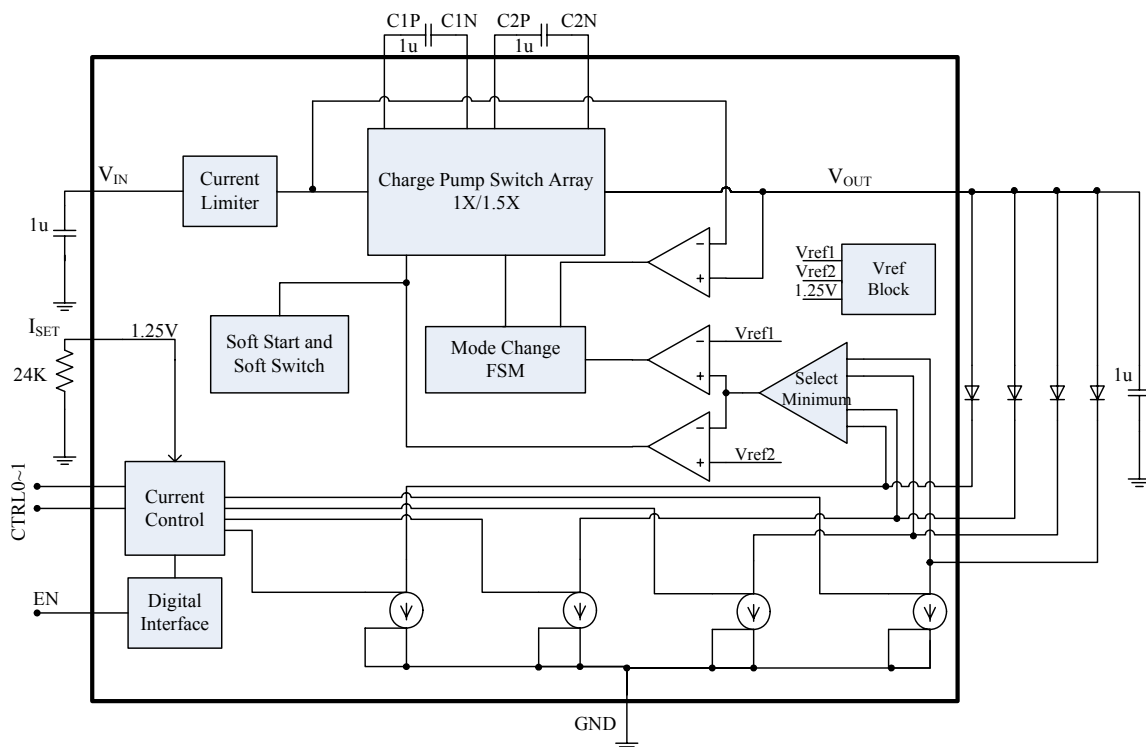
**Note 4:** Typicals are measured at 25°C and represent the parametric norm.

**Note 5:** Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

**Note 6:** The soft start time would change with the input voltage.

**Note 7:**  $I_{Match} = |(I_{LED(MAX)} - I_{LED(MIN)}) / (I_{LED(MAX)} + I_{LED(MIN)})| \times 100\%$

### SIMPLIFIED BLOCK DIAGRAM



**Figure 4. Simplified Block Diagram of the PT4303**

## 1x/1.5x Auto-Adjust Charge Pump 4-Channel White LED Driver with Two Dimming Modes

### OPERATION DESCRIPTION

The PT4303 uses a 1.5x/1x charge pump and current sink to drive the 4 channels white LED. 1x charge pump can achieve high efficiency for high input voltage, 1.5x charge pump guarantees the enough current through the LED for low level input voltage. The current through the LED can be pre-set by an external resistor. The four LEDs can be turned on and off individually or in a group of two to four through the two control terminals, which can also be used to dim the LEDs by applying PWM control signals.

- **Mode Decision**

The PT4303 uses a 1.5x/1x charge pump. The switching between the two modes is through a “smart” control. The PT4303 constantly senses the voltage at D1 to D4 ( the one with the lowest voltage will be selected), the input and output voltage. Based on this information, the PT4303 determines which charge pump mode to be selected in order to achieve the maximum efficiency. User intervention isn’t needed to complete this process.

- **Fault LED Detection**

The PT4303 goes through an LED current detection sequence, when the chip is powered on or when OVP is triggered. If a channel is unused and floating, or if a channel has a failed LED to become open circuit, the PT4303 automatically changes the sense point to a channel that has normal operation to maintain the maximum efficiency.

- **Soft Start**

A soft start circuit is turned on at power on or mode switching process in order to reject the inrush current from VIN. The circuit sets the current limit low initially and increases the input current gradually in discrete steps. The soft start time is dependent on the input level, the output current and the LED forward voltage.

- **Over Load Protection**

The PT4303 employs the over-load protection to avoid the high current from VIN. Whenever the input current rises above the threshold, the PT4303 decreases the input current to protect the chip and battery.

- **Over Voltage Protection**

The PT4303 employs an over voltage protection circuit to detect the output voltage in 1.5x mode. Whenever the output voltage level rises above the threshold of 1.5x mode, the PT4303 shuts down the charge pump until the output voltage falls below the threshold.

- **Thermal Shutdown**

When the chip temperature rises above the 160 °C, the PT4303 shuts down the charge pump and the current sink to protect the chip from thermal damage.

- **LED Current On/Off Setting**

Each LED to be turned on or off can be set by 2 control bits. The control scheme is shown in the following table.

Control Bits		Output Status			
CTRL0	CTRL1	LED1	LED2	LED3	LED4
0	0	ON	ON	OFF	OFF
0	1	ON	ON	ON	ON
1	0	ON	ON	ON	OFF
1	1	OFF	OFF	OFF	OFF

**Table.1 LED’s On/Off and the Control Bits**

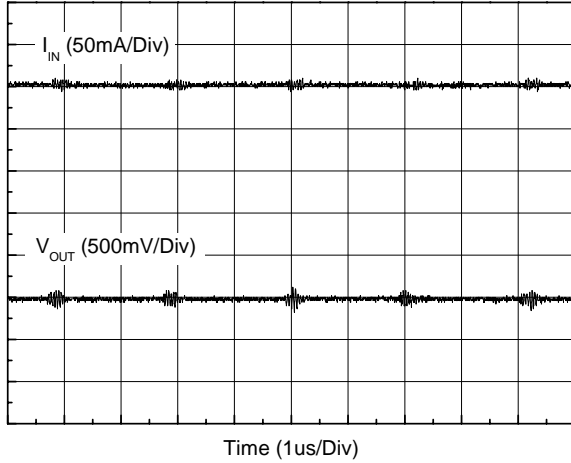
## 1x/1.5x Auto-Adjust Charge Pump 4-Channel White LED Driver with Two Dimming Modes

### TYPICAL PERFORMANCE CHARACTERISTICS

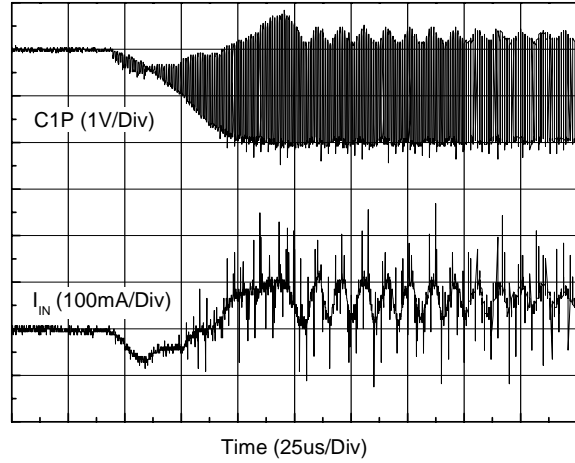
Note: Typical characteristics are obtained in the following condition:

$V_{LED} = 3.3V$ ,  $C1 = C2 = C_{IN} = C_{OUT} = 1\mu F$  (Ceramic, ESR=0.03 $\Omega$ ),  $T_A=25^\circ C$ , unless specified otherwise.

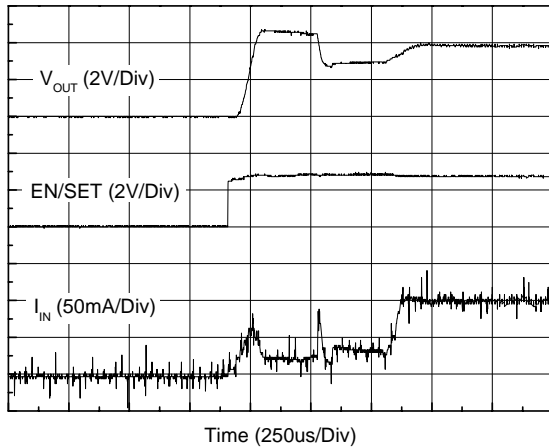
1x Mode Operation (AC coupling)



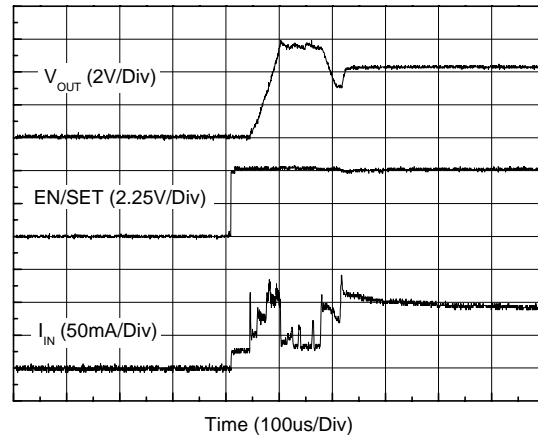
Mode Change Inrush Current (1x to 1.5x)



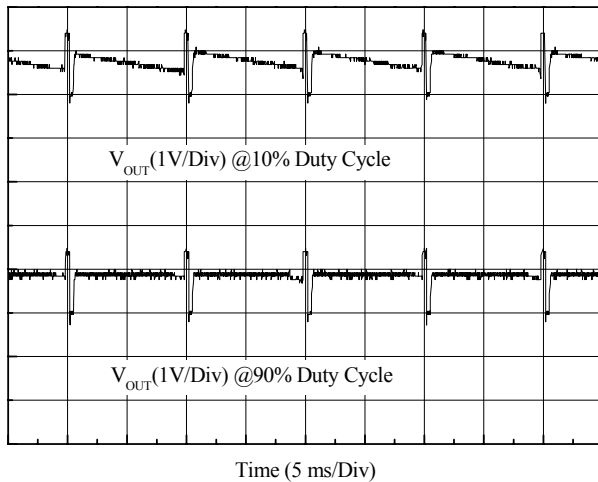
Startup Response ( $V_{IN}=3V$ )



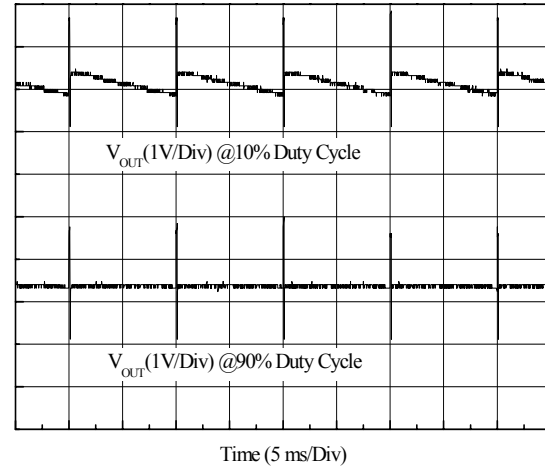
Startup Response ( $V_{IN}=4.5V$ )



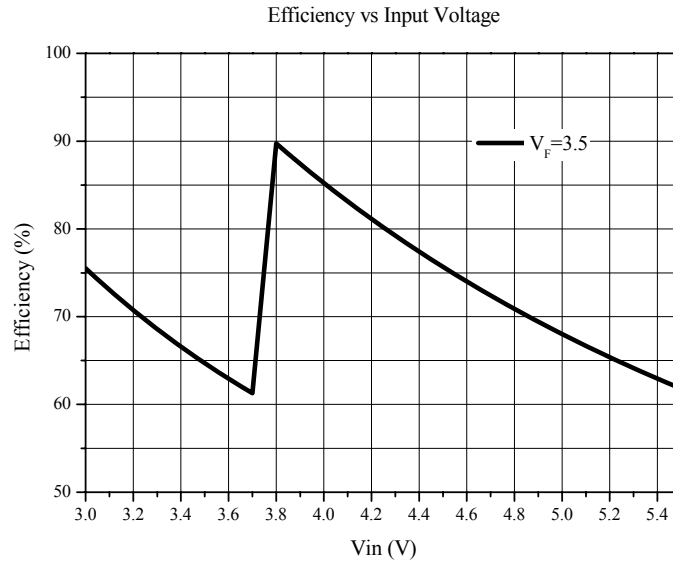
Dimming by EN @  $f=100Hz$ ,  $V_{IN}=3V$



Dimming by EN @  $f=100Hz$ ,  $V_{IN}=4.5V$



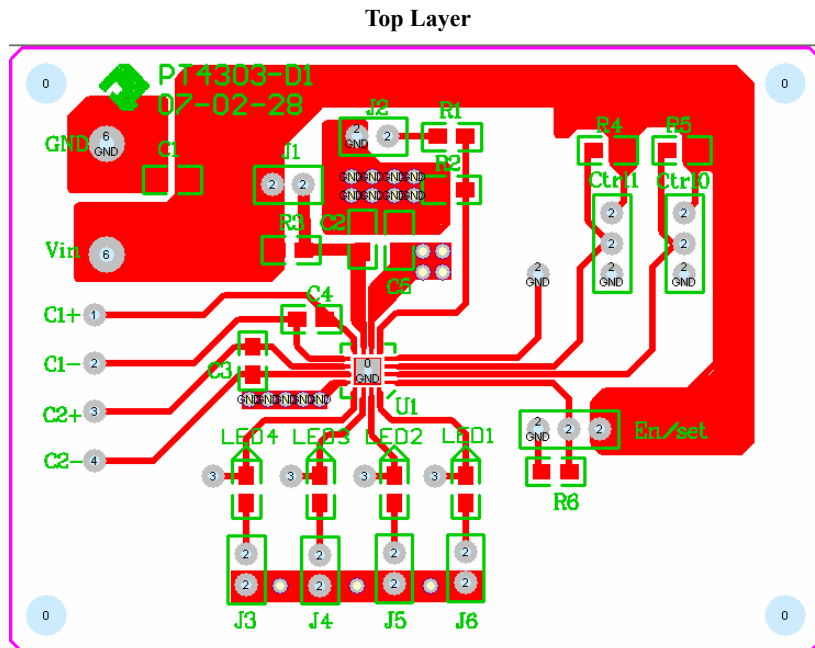
### TYPICAL PERFORMANCE CHARACTERISTICS (Continued)



### APPLICATION INFORMATION

#### ● PCB Board Layout

The PT4303 is a high-frequency switched-capacitor converter. For the best performance, all the external components should be placed as close to the IC as possible. Besides a solid ground plane is recommended on the bottom layer of the PCB. The ground should be connected C<sub>IN</sub> and C<sub>OUT</sub> together and as close to the IC as possible. Figure 5 shows the recommended layout of the PT4303's EVB board.



### APPLICATION INFORMATION (Continued)

Bottom Layer

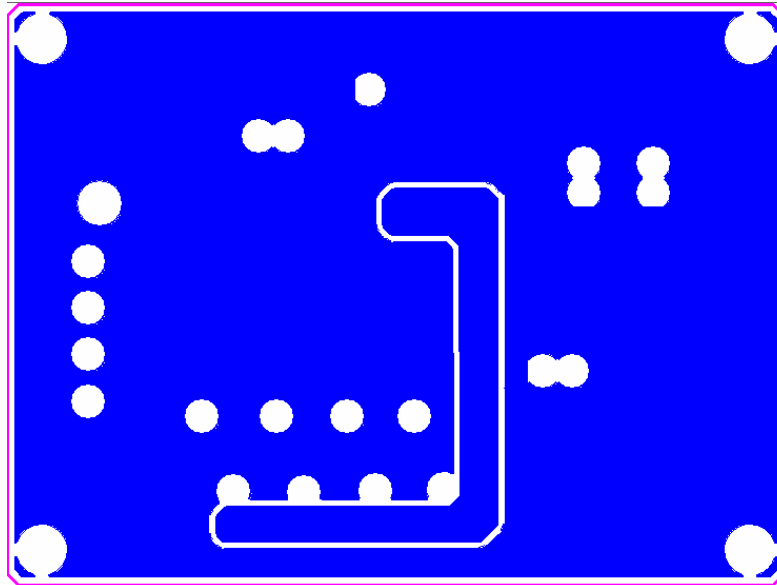


Figure 5. PT4303 EVB Board

#### ● Component Selection

The PT4303 can drive four white LEDs up to 20mA with the LED forward voltage of ranging from 3.0V to 4V. If one LED channel is disabled by setting CTRL0~1, this LED pin can be float or connected to  $V_{IN}$ ,  $V_{OUT}$  or GND. If all channels are enabled by setting CTRL0~1, the unused LED pin can be float or connected to GND. The LED current does not change with the variation of the LED forward voltage because current sink is internally regulated. The selection of the four external capacitors  $C_{IN}$ , C1, C2 and  $C_{OUT}$  is critical because they will affect turn-on time, output ripple, and stability. Low ESR capacitors are recommended for low ripples.

Component	Value	Description	Manufacturer	Part Number
$C_{IN}$ , C1,C2, $C_{OUT}$	1uF	1uF±10%, Ceramic Capacitors	Taiyo Yuden	JMK107BJ105KA
D1, D2, D3, D4	-	White LEDs	Nichia	NSCW215T

#### ● Setting the LED Current by RSET

The PT4303 can be set to a fixed LED current by a resistor  $R_{SET}$  connected from  $I_{SET}$  to GND, and the current is mirrored into LED1, LED2, LED3 and LED4. The current into LED can be calculated by the formula as below:

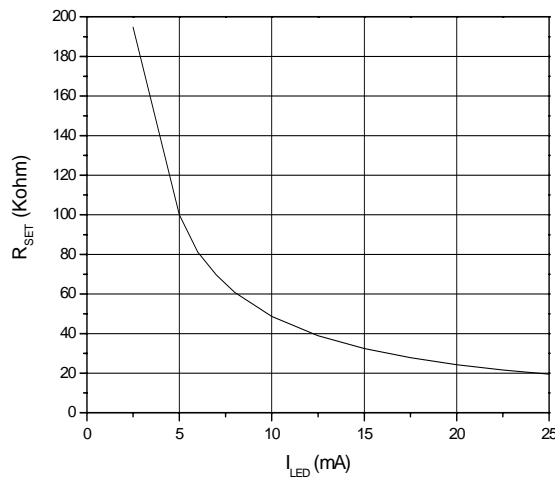
$$I_{LED}=487(V)/R_{SET}(\Omega)$$

Figure 6 shows the typical value of  $R_{SET}$  versus average LED current and table 2 shows the value of  $R_{SET}$  for a fixed LED current.

$I_{LED}(mA)$	$R_{SET}(K\Omega)$	Nearest Standard Values for $R_{SET}(K\Omega)$
5	100	100
10	49.2	48.7
15	32.7	32.4
20	24	24.0
25	19	19.1

Table 2.  $R_{SET}$  Value Selection

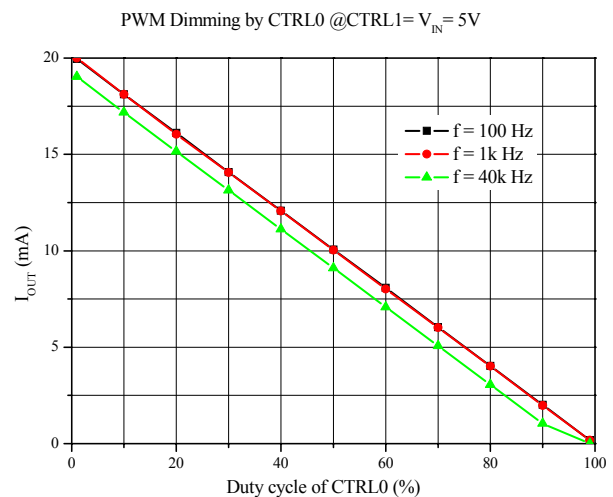




**Figure 6. R<sub>SET</sub> vs Average LED Current**

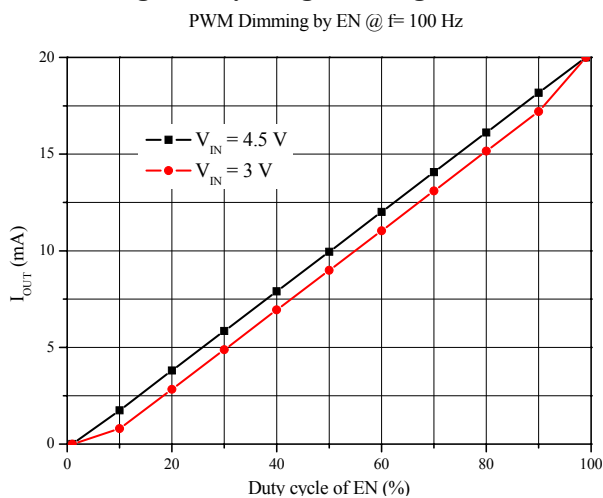
- **Dimming LED by using PWM signal into CTRL0~1**

The LED current can be controlled by applying a PWM signal to CTRL0~1, and the relationship is shown in table1. For example, if CTRL1 = "1", and applying a PWM signal to CTRL0, then the four LEDs are dimmed synchronously. The recommended operating frequency range is from 100Hz to 40k Hz, and figure7 shows the average I<sub>OUT</sub> versus duty cycle of CTRL0 at different operating frequency. The dimming of the LEDs can also be controlled individually. For example, if CTRL1 is set to "0", and applying a PWM signal to CTRL0, then the LED3 is being dimmed, and the current through LED1, LED2 will be unchanged.



**Figure 7. PWM Dimming by CTRL0**

- **Dimming LED by using PWM signal into EN**

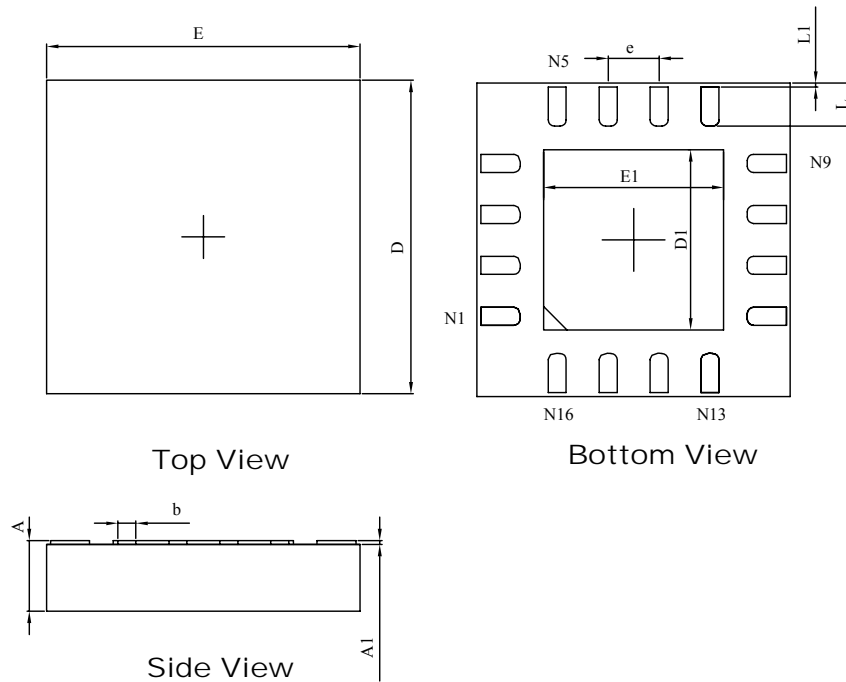


**Figure 8. PWM Dimming by EN**

The LED current can be adjusted by applying a PWM signal to EN. The frequency range is 50Hz to 200Hz, and the minimum pulse width of high or low level should be more than 1ms to ensure the chip is started or shutdown completely. For instance, when the frequency of PWM signal is 200Hz, the duty cycle can range from 20% to 80%. Figure8 shows the average I<sub>OUT</sub> versus duty cycle of EN at operating frequency of 100Hz.

### PACKAGE INFORMATION

#### QFN16 (3X3):



SYMBOL	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	0.000	0.900	0.000	0.035
A1	0.010	0.090	0.000	0.004
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
D1	1.700 REF.		0.067 REF.	
E1	1.700 REF.		0.067 REF.	
b	0.150	0.250	0.006	0.010
e	0.500 BSC.		0.020 BSC.	
L	0.350	0.450	0.014	0.018
L1	0.000	0.050	0.000	0.002