

60V/20mA Single Channel Constant Current LED Driver

Features

- ★ 20mA constant current LED regulator
- ★ Wide input voltage range from 4.5V to 40V
- ★ 60V breakdown voltage
- ★ ±3.5% LED current accuracy
- ★ Thermal protection: Current ramp down at **125°C**

General Description

PS4501 is a single channel LED driver with constant current regulator. PS4501 offers excellent temperature stability and output current accuracy (±3.5%) with wide input voltage from 4.5V to 40V and temperature range. PS4501 implements various fixed output current versions without external current setting resistors and thus creates a simple solution for constant current LED driver. Besides, for the thermal management in LED, PS4501 is featured a current ramp down function from 125°C to 145°C of junction temperature. Moreover, taking reliability into consideration, the maximum voltage rating on VDD, VP and VN is designed as 60V ability to handle high voltage pulse suddenly. Thoughtfully, PS4501 also supports both high-side and low-side driving for the LED strings. PS4501 is bare die and die size is 426um x 745um, which is available for COB (chip on board) LED lighting application, etc.

Applications

- ★ Constant current LED (CCLED)
- ★ Constant current COB light engine

Simplified Application Circuit

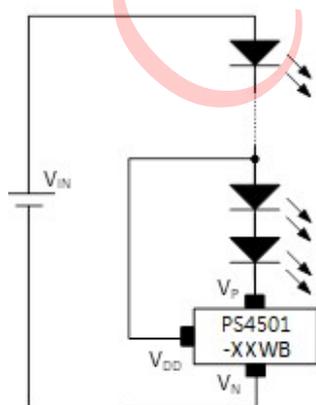
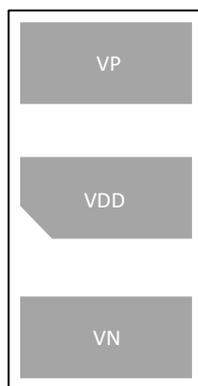


Figure 1. Single channel LED driver

Wafer and Dice Information



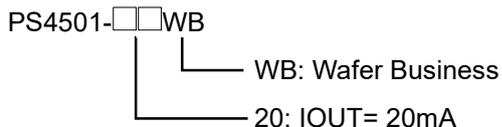
- Wafer thickness: 29mil / 6 inches
- Die size: 426um x 745um
- Scribe line: 80um
- Substrate: P-Sub
- Substrate potential: Same as VN pin or floating
- Main material of solder/bond pad: Ag
- Pad structure: Circuit under pad

Figure 2. Bare chip top view

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1 Ordering Information



Note: Green Product (RoHS compliant)

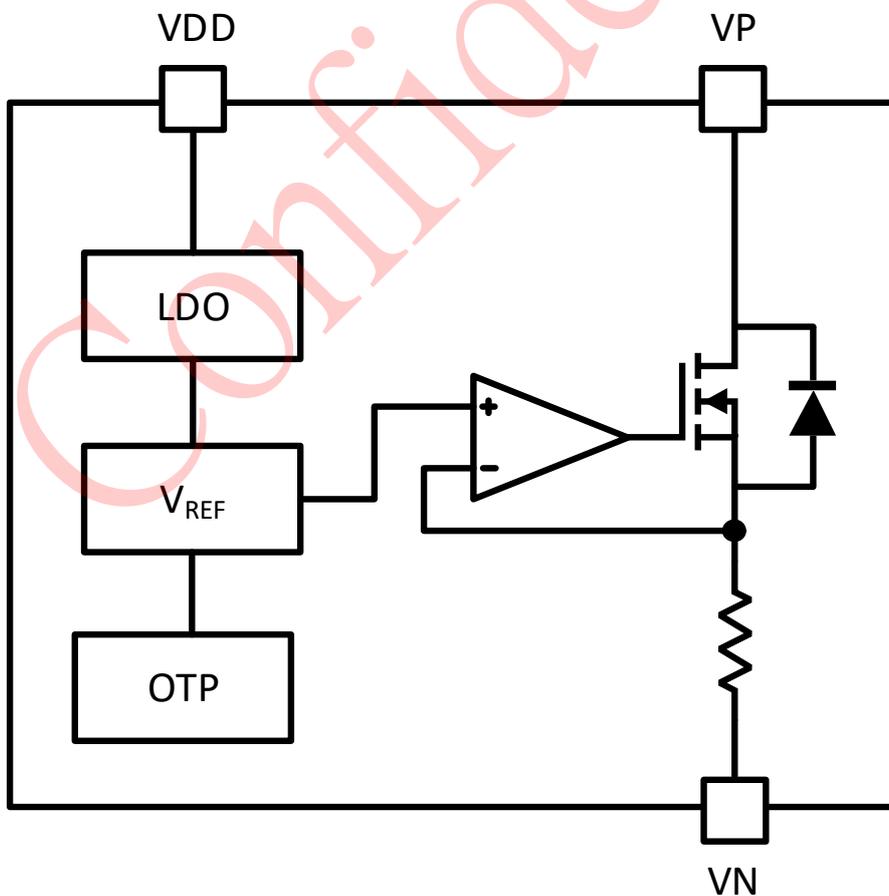
For meeting the world-wide customer requirements for environmentally friendly products and government regulations, the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020)

2 Pin Definitions and Functions

Pin	Name	I/O ⁽¹⁾	Description
1	VP	I	Output current regulated pin. Output current flows through this pin and regulated.
2	VDD	I	Supply voltage.
3	VN	--	Chip ground.

(1) I= Input, O= Output, --= Other

3 Functional Block Diagram



4 Absolute Maximum Ratings (Note 1)

Condition	Value	Unit
VDD	-0.3 to 60	V
VP	-0.3 to 60	V
VN	-0.3 to 60	V
Junction Temperature	150	°C

Note 1: Stresses above the ones listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

5 Recommended Operating Conditions (Note 2)

Item	Value	Unit
VDD, VP	4.5 to 40	V
Junction Temperature Range	-40 to 125	°C

Note 2: Device function is not guaranteed if it is operated out of this range.

6 Electrical Characteristic

(V_{DD}= 7V, T_A = 25°C unless otherwise specified)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Supply voltage	V _{DD}	I _{PN} ≤ 20mA	4.5	--	40	V
Supply current	I _{DD}	4.5V ≤ V _{DD} ≤ 40V I _{PN} = 20mA	0.06	0.16	0.22	mA
Minimum dropout voltage	V _{PNmin}	V _{DD} > 7V, I _{PN} = 90%I _s	0.15	--	0.3	V
Output current	I _s	V _{DD} = 7V	--	20	--	mA
Output current accuracy	I _{Skew}	T _A = 25°C, V _{DD} = 7V	-3.5	--	3.5	%
Output current accuracy vs temperature	I _{Skew,T}	T _J = -40°C~60°C	-3	--	3	%
Current ramp down temperature	T _{J_down}	I _{PN} ≤ 90%I _s	--	125	--	°C
Shutdown temperature	T _{J_shtdn}	I _{PN} ≤ 10%I _s	--	145	--	°C
Output current accuracy vs VDD	I _{Skew,VDD}	V _{DD} = 7V to 40V, V _{PN} = 1V	-1.5	--	1.5	%
Output current accuracy vs VP	I _{Skew,VP}	V _{PN} = 0.3V to 40V V _{DD} = 7V	-1	--	1	%

7 Typical Application Circuit

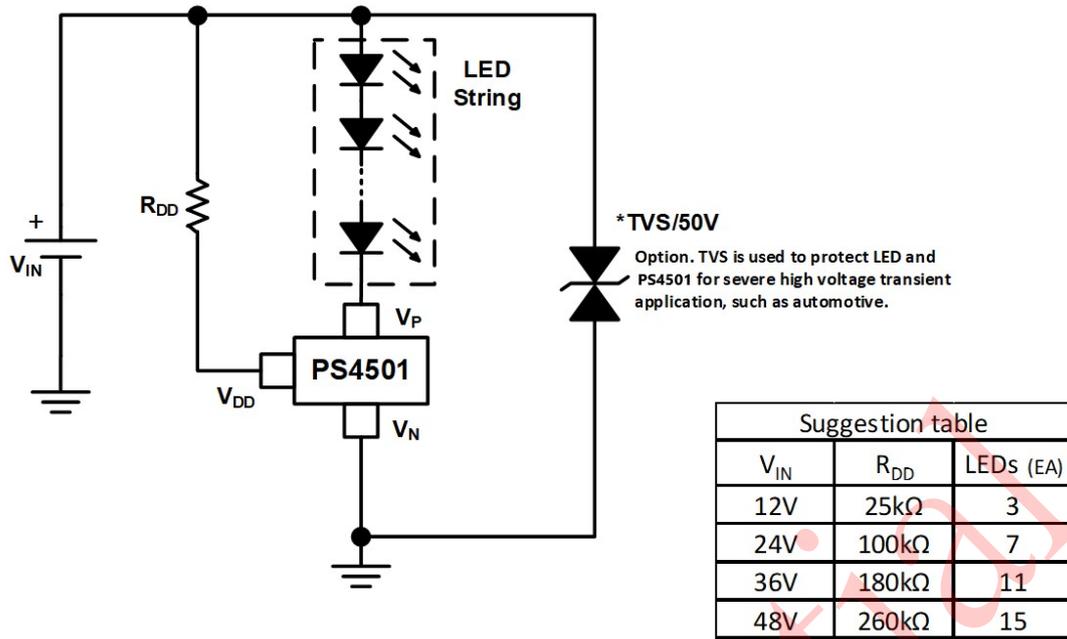


Figure 3. General DC power LED drive (Option 1).

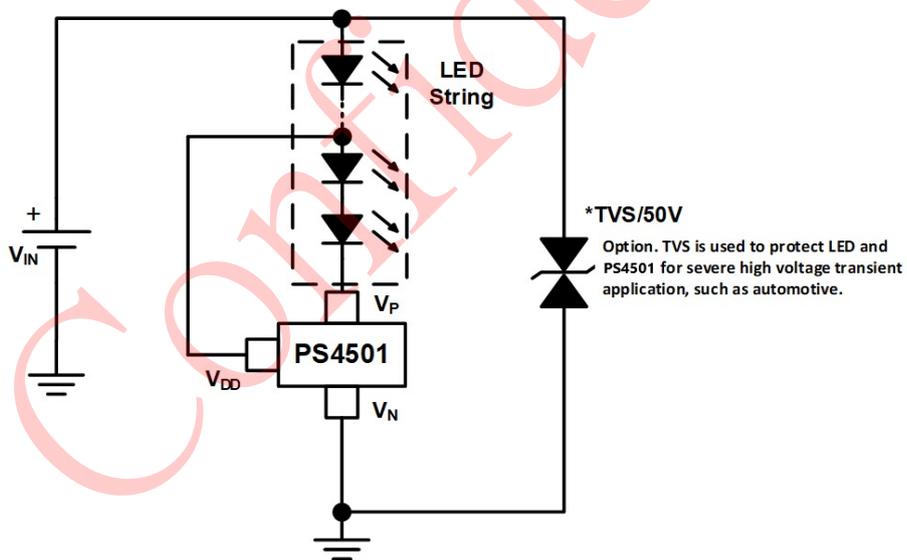


Figure 4. General DC power LED drive (Option 2).

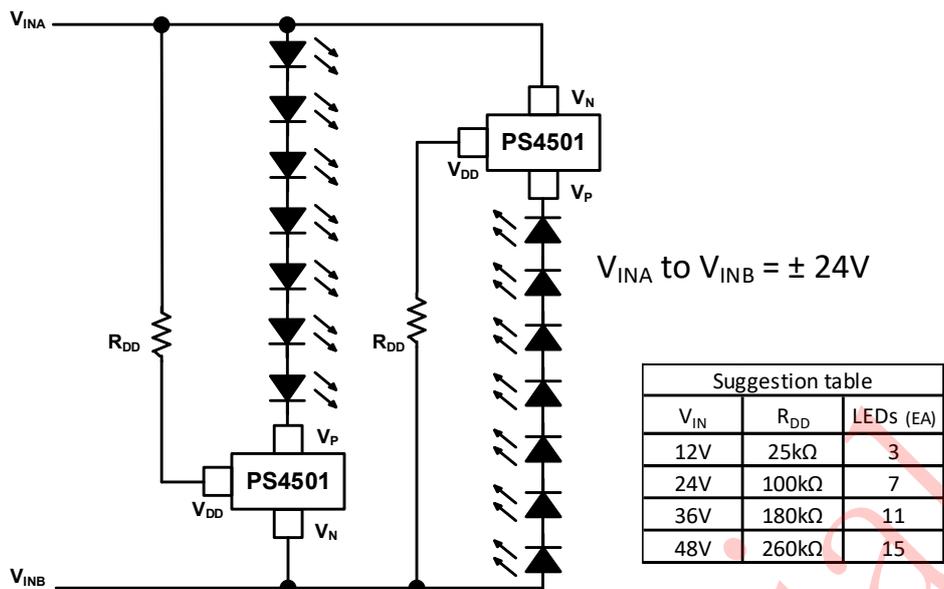


Figure 5. Dual color lighting application (Bi-direction power supply Option 1).

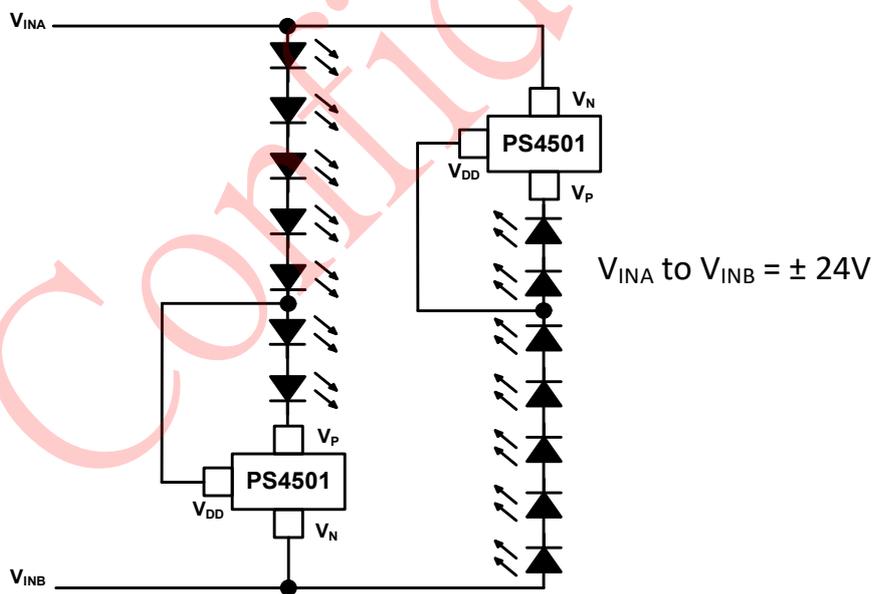


Figure 6. Dual color lighting application (Bi-direction power supply Option 2).

8 Typical Operating Characteristics

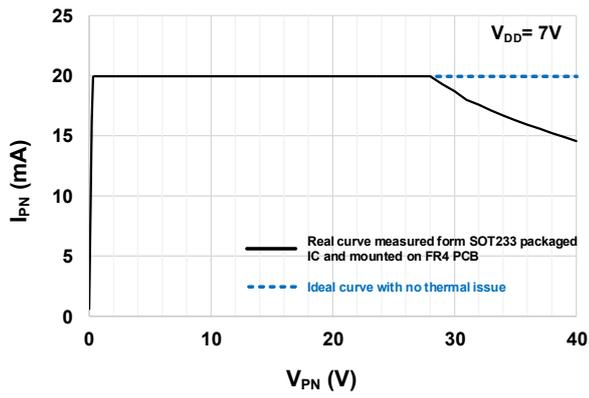


Figure 7. Load regulation, I_{PN} VS V_{PN}

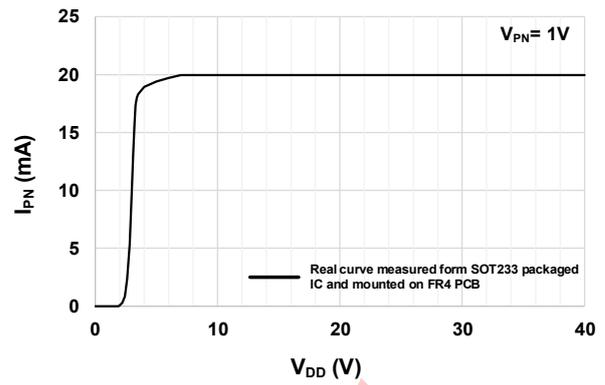


Figure 8. Line regulation, I_{PN} VS V_{DD}

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9 Application Information

The PS4501 is a Constant Current Regulator (CCR) for LED driver and provides two kinds of driving method for LED, high-side driver and low-side driver. CCR is achieved by adjusting the internal self-biased transistor to regulate the current through PS4501 or any devices in series with it. Besides, as operating temperature rising, PS4501 features a thermal protection function to protect LEDs through reducing operating current if junction temperature of PS4501 is above 125°C.

9.1 Single LED String

PS4501 can be placed for high-side or low-side driver for LED as shown in Figure 9. The number of the LEDs is limited by the voltage across the V_{PN} of PS4501. Hence, the designed must estimate the maximum and minimum voltage across the V_{PN} by taking the maximum input voltage less the voltage across the LED string.

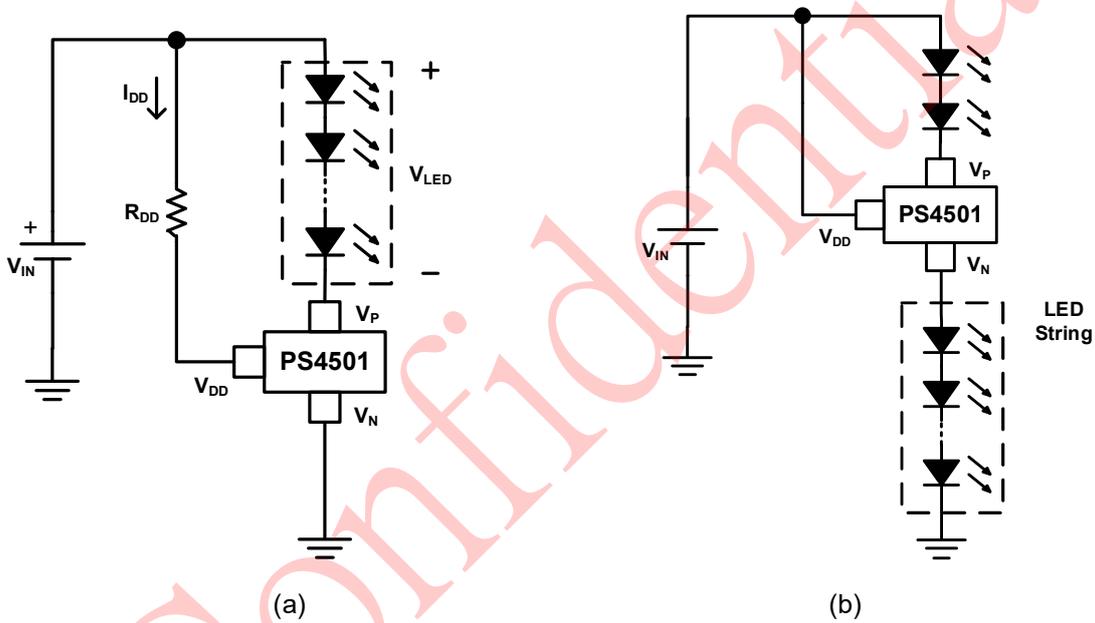


Figure 9. (a) Low-side LED Driver (b) High-side LED Driver

As PS4501 used for low-side LED driver referred to Figure 9 (a), the minimum input voltage $V_{IN(min)}$ has to be larger than $V_{LED}+V_{PN}$ or $I_{DD} \cdot R_{DD}+4.5V$ which depends on the LED string voltage. The equation is as follows:

If $V_{LED} > I_{DD} \cdot R_{DD} + 4.5 - V_{PNmin}$
 $V_{IN(min)} = V_{LED} + V_{PNmin}$ (1)

If $V_{LED} < I_{DD} \cdot R_{DD} + 4.5 - V_{PNmin}$
 $V_{IN(min)} = I_{DD} \cdot R_{DD} + 4.5$ (2)

For high-side LED driver referred to Figure 9 (b), the minimum input voltage $V_{IN(min)}$ is as follows:

$V_{IN(min)} = V_{PNmin} + V_{LED}$ (3)

9.2 Higher Current LED Strings

For higher LED current demand, two or more PS4501 can be connected in parallel to increase the LED current as shown in Figure 10.

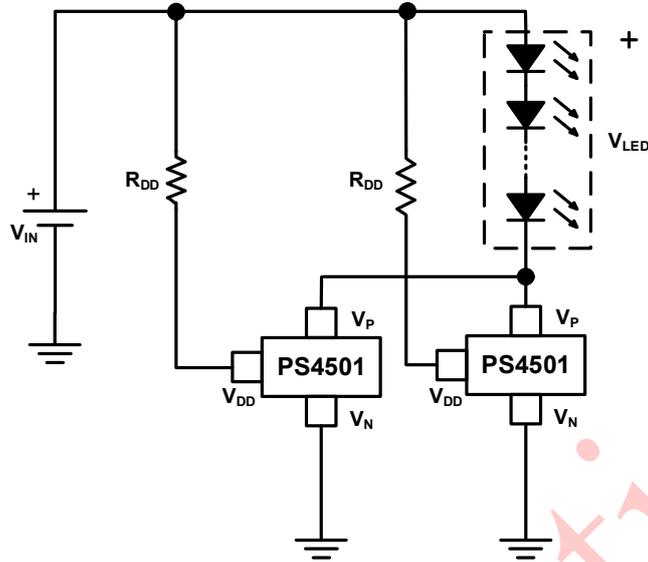


Figure 10. High current application.

9.3 Thermal Protection: LED Current Ramp Down

For protecting LED under high temperature application, LED current is decreased automatically while PS4501’s junction temperature is over 125°C. Besides, if PS4501’s junction temperature approaches 145°C, LED current remains around 10%. Along with temperature reducing, the LED current is recovery when junction temperature is below 125°C.

9.4 Power Dissipation

The power dissipation can be determined from the regulated current I_S multiplying the voltage across the V_{PN} that is the supply voltage on V_P to substrate the voltage across the LED string V_{LED} .

$$V_{PN} = V_{IN} - V_{LED} \dots\dots\dots (3)$$

$$P_D = I_S \times V_{PN} \dots\dots\dots (4)$$

As the power requirement of LED is increased, the power dissipation should be considered for thermal relief. The maximum power dissipation supported by the device is dependent on PCB layout design, PCB material and operating ambient temperature. Further, the maximum power dissipation before current ramp down function triggering is given by:

$$P_{D(max)} = \frac{125 - T_A}{R_{\theta JA}} \text{ , where } R_{\theta JA} = 245^\circ\text{C/W} \dots\dots\dots (5)$$

9.5 PWM Dimming

The LED dimming can be easily achieved by placing an external MOSFET in series with PS4501 and the dimming effect can be achieved by adjusting the PWM duty cycle, as shown in Figure 11. Besides, duty cycle is expressed as below and that is a ration of LED turn-on time (T_{ON}) dividing the total time of an on/off cycle (T) which is shown in Figure 12, and Figure 13 shows the current accuracy with different duty cycle.

$$D = \frac{T_{ON}}{T_{ON}+T_{OFF}} = \frac{T_{ON}}{T} \dots\dots\dots (6)$$

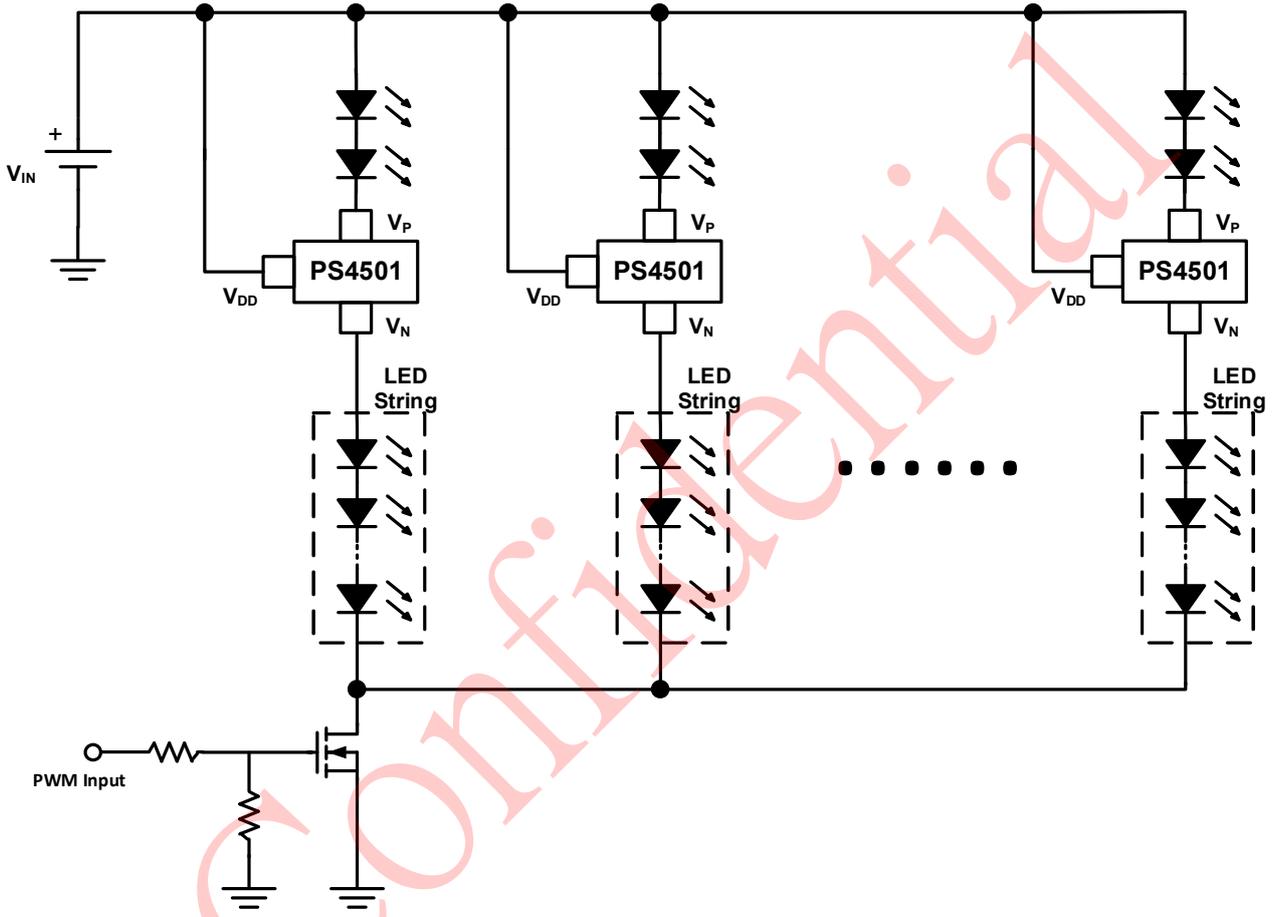


Figure 11. LED strings PWM dimming by external MOSFET

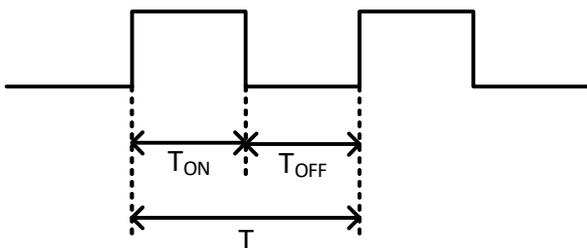


Figure 12. PWM dimming signal

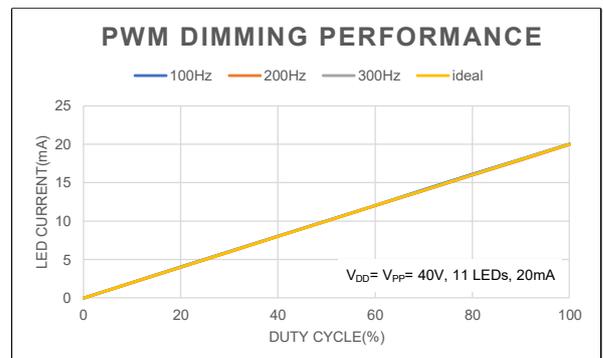


Figure 13. Current accuracy vs PWM dimming

9.6 PCB design considerations for flip chip application

When integrating the PS4501 as a flip chip application, the major ingredient of the three pads on the PS4501 surface is silver. These silver pads can be soldered to the copper paths on the PCB using tin (solder). Figure 14 shows the cross-section of how the PS4501 is soldered to the PCB.

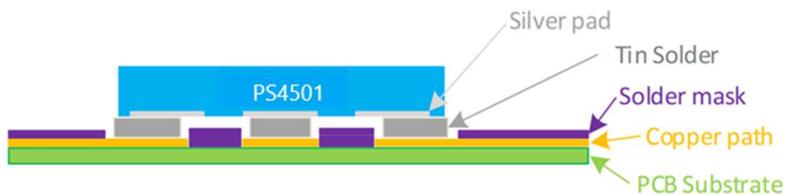


Figure 14. Cross section of PS4501 on PCB.

Figure 15 (a) shows the recommend foot print design of PS4501. Figure 15 (c) shows the flipped PS4501 dice. Figure 15 (b) shows the flipped PS4501 which is placed on PCB. For good thermal management, the larger VP and VN copper path area, the better heat dissipation capability.

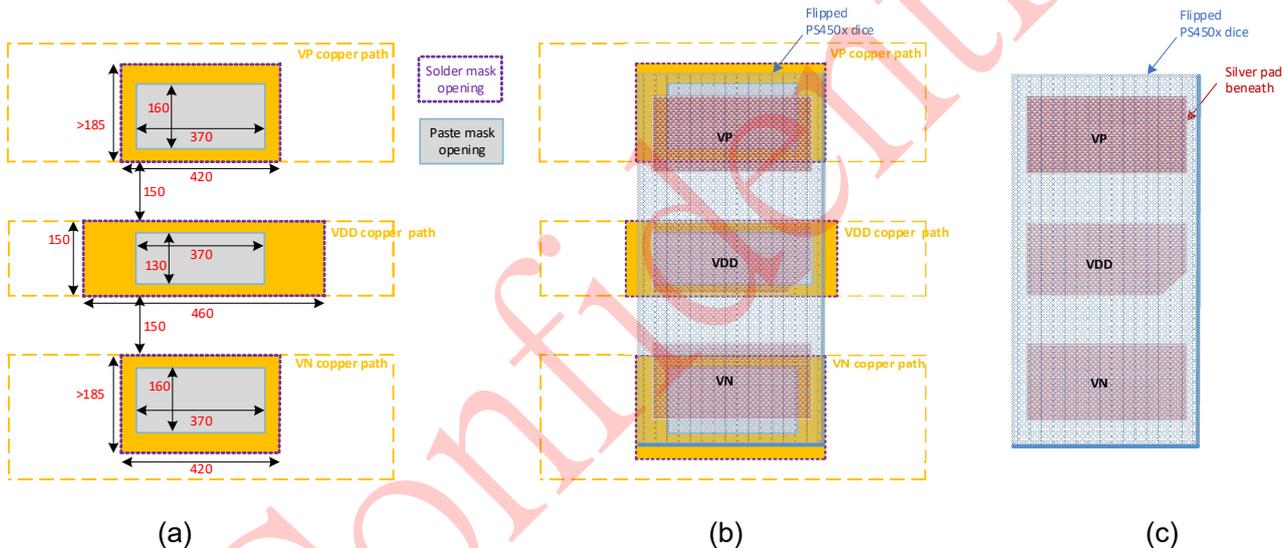
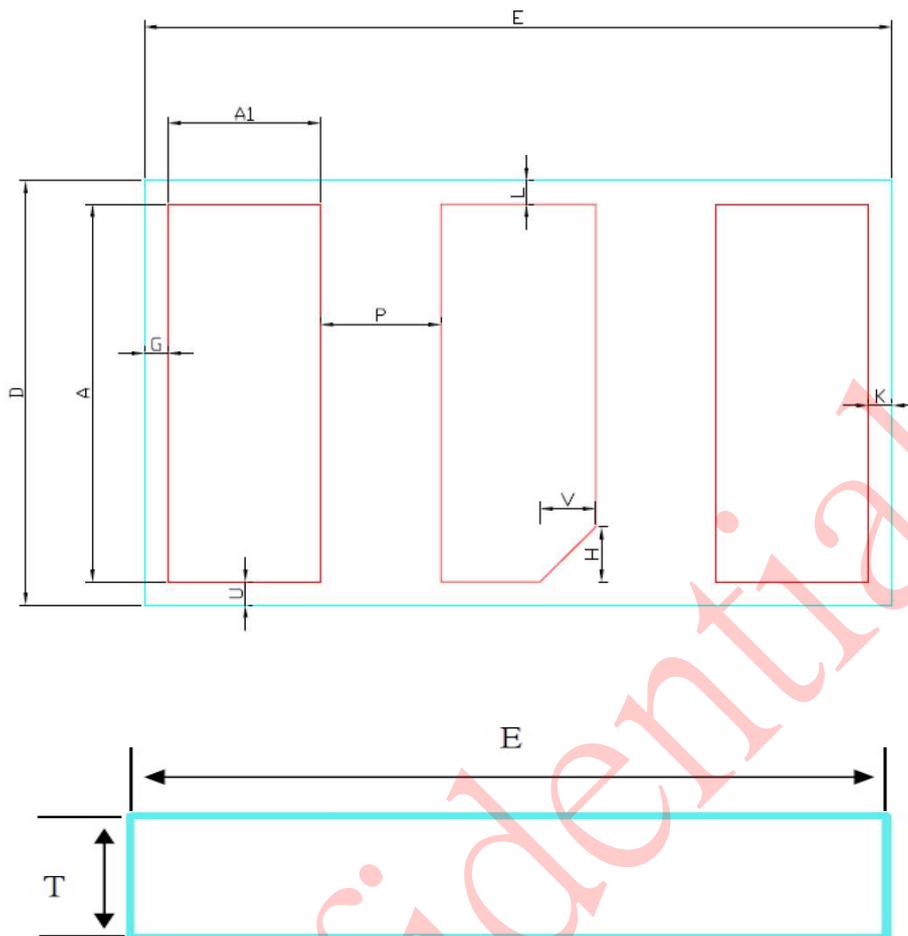


Figure 15. PS4501 foot print for flip chip applications

10 Outline Dimension



Note3: Die thickness(T)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.389	0.409	0.0153	0.0161
A1	0.157	0.177	0.0062	0.0070
D	0.456	0.476	0.0180	0.0187
E	0.775	0.795	0.0305	0.0313
P	0.102	0.122	0.0040	0.0048
G	0.0235	0.0435	0.0009	0.0017
U	0.0235	0.0435	0.0009	0.0017
K	0.0235	0.0435	0.0009	0.0017
L	0.0235	0.0435	0.0009	0.0017
H	0.06	0.08	0.0024	0.0031
V	0.06	0.08	0.0024	0.0031
T	0.19	0.21	0.0075	0.0083

11 Flip chip application notice

1. The recommended dice thickness is 200um. (Wafer back side grinding thickness: 200um)
2. Step cut in wafer dicing process. It is recommended that the width of the first saw blade is 40um, sawing depth is about 1/2 wafer thickness and sawing speed is about 10 to 15 mm/sec. The second saw blade is 30um wide, and saw it off.
3. The recommended solder thickness is about 50um to 60um and the solder mask opening area is about 70% of the pad area.
4. When the PS4501 bare die is exposed to bright light, the driving current may drift. It works better if the bare die is covered with an opaque material or mechanical structure to keep light out.

12 Restrictions on product use

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