60V/50mA~250mA Single Channel Constant Current LED Driver

Features

- ±4.5% LED current accuracy
- Wide input voltage ranges from 7V to 40V
- 60V breakdown voltage
- Thermal protection: Current ramp down at 125°C
- RoHS Compliant and Halogen Free
- Ultra small form factor
- RoHS Compliant and Halogen Free

General Description

PS4502 is a single channel LED driver with constant current sink function. PS4502 has excellent temperature stability and output current accuracy over a wide supply voltage range from 7V to 40V. Several fixed output current versions provide a simple way to drive LEDs. A maximum voltage rating of up to 60V makes the PS4502 suitable for most DC supply voltage LED lighting applications. The PS4502 has an extremely small 426um x 745um form factor and can be assembled with LED chips in miniature devices such as COB, light strips, lamps … etc. And, it will not be damaged by high temperature with the features of a current ramp-down function from junction temperature 125°C to 145°C.

There are two ways to integrate PS4502 into an LED driving circuit. One is flip chip type and other is traditional wire bonding technology. Whether using the flip chip or wire bonding method, the PS4502 ensures excellent temperature stability and accurate current control, enhancing the overall efficiency and durability of LED products.

Applications

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

Simplified Application Circuit

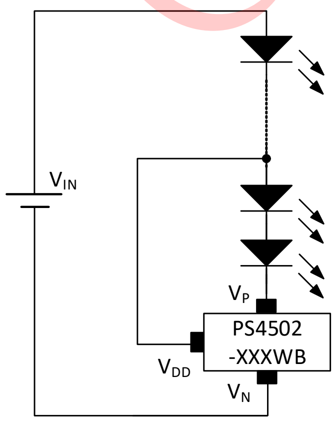
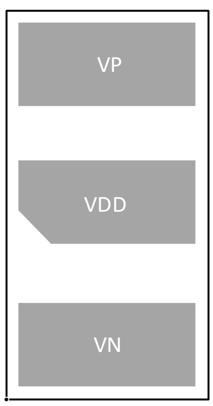


Figure 1. Single channel LED driver

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

Contents

1 Ordering Information

PS4502-□□□WB

Wafer Business

Output current

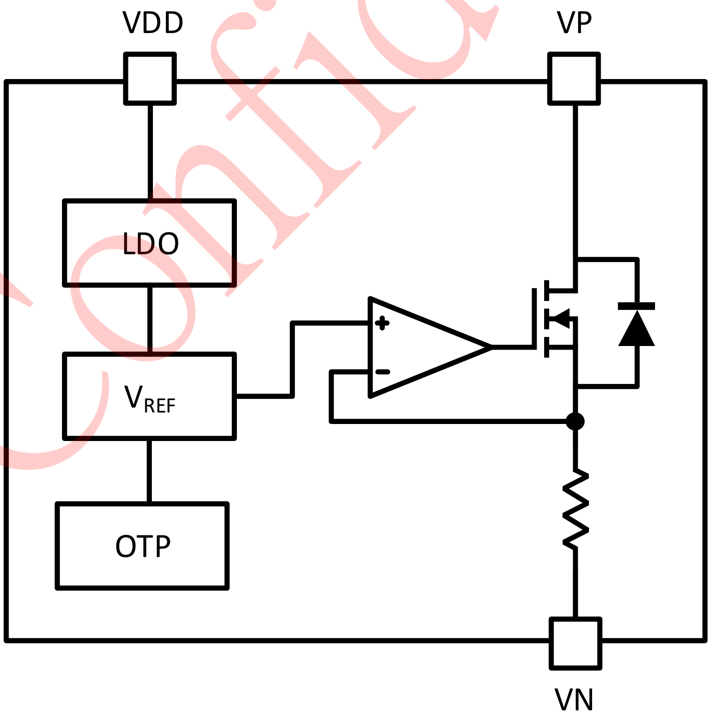
Part Number	Output Current
PS4502-050WB	50mA
PS4502-100WB	100mA
PS4502-120WB	120mA
PS4502-150WB	150mA
PS4502-200WB	200mA
PS4502-220WB	220mA
PS4502-250WB	250mA

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	7 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.

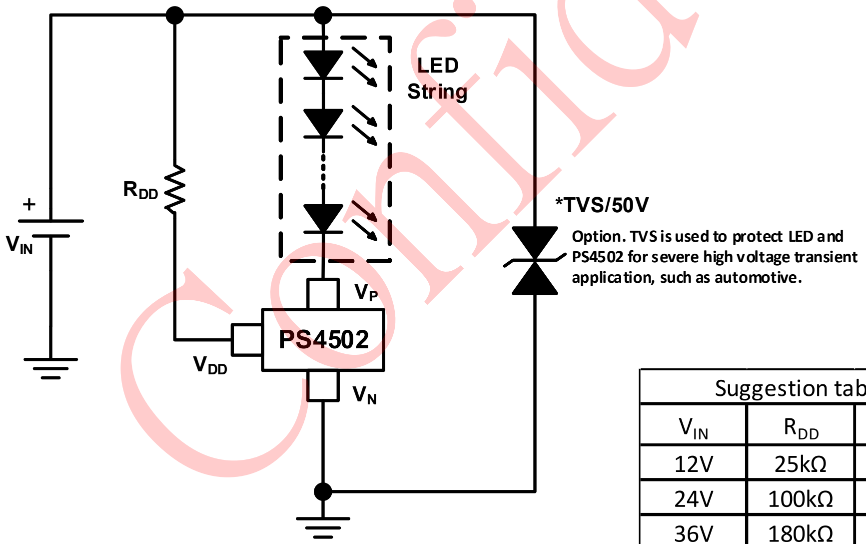
6 Electrical Characteristic

(V_{DD}= 7V, V_N= 0V, T_A= 25°C unless otherwise specified)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Supply voltage	V_{DD}	$I_{PN} \leqq I_S$	7	--	40	V
Supply current	I_{DD}	7V $\leqq V_{DD} \leqq$ 40V, I_{PN}= I_S	0.06	0.16	0.22	mA
Output current	I_S	PS4502-050WB	--	50	--	mA
		PS4502-100WB	--	100	--	
		PS4502-120WB	--	120	--	
		PS4502-150WB	--	150	--	
		PS4502-200WB	--	200	--	
		PS4502-220WB	--	220	--	
		PS4502-250WB	--	250	--	
Minimum dropout voltage	V_{PNmin}	T_J= 25°C, V_{DD} > 7V, I_{PN}= 50mA	--	0.5	--	V
		T_J= 25°C, V_{DD} > 7V, I_{PN}= 100mA	--	0.6	--	V
		T_J= 25°C, V_{DD} > 7V, I_{PN}= 120mA	--	0.7	--	V
		T_J= 25°C, V_{DD} > 7V, I_{PN}= 150mA	--	0.8	--	V
		T_J= 25°C, V_{DD} > 7V, I_{PN}= 200mA	--	0.9	--	V
		T_J= 25°C, V_{DD} > 7V, I_{PN}= 220mA	--	1	--	V
		T_J= 25°C, V_{DD} > 7V, I_{PN}= 250mA	--	1.1	1.2	V
Output current accuracy	I_{Skew}	T_J= 25°C, V_{DD}= 7V	-4.5	--	4.5	%

Output current accuracy vs temperature	$I_{Skew,T}$	T_J= -40°C~120°C	-3	--	3	%
Current ramp down temperature	T_{J_down}	$I_{PN} \leqq$ 90%I_S	--	125	--	°C
Shutdown temperature	T_{J_shtdn}	$I_{PN} \leqq$ 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 VPN	$I_{Skew,VPN}$	V_{PN}= 0.3V to 40V, V_{DD}= 7V	-1.5	--	1.5	%

7 Typical Application Circuit



Suggestion table		
V_{IN}	R_{DD}	LEDs (EA)
12V	25kΩ	3
24V	100kΩ	7
36V	180kΩ	11
48V	260kΩ	15

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

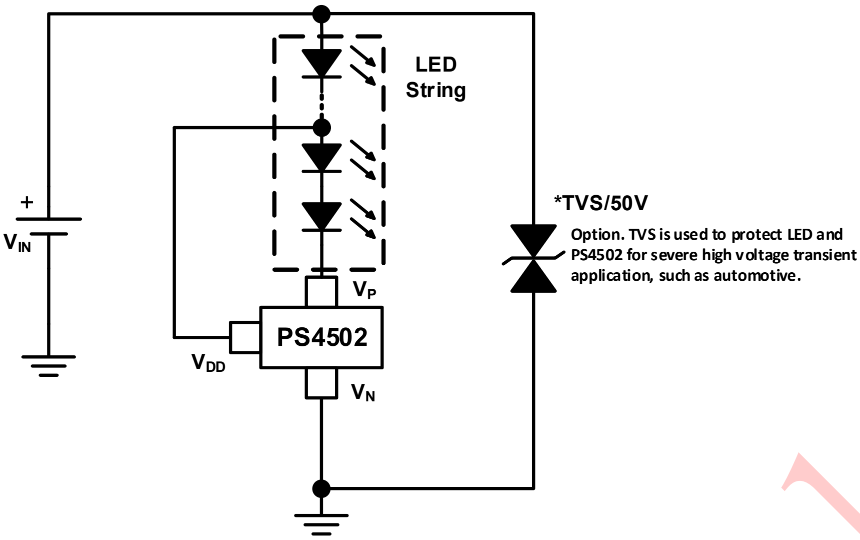


Figure 4. General DC power LED drive (Option 2).

8 Typical Operating Characteristics

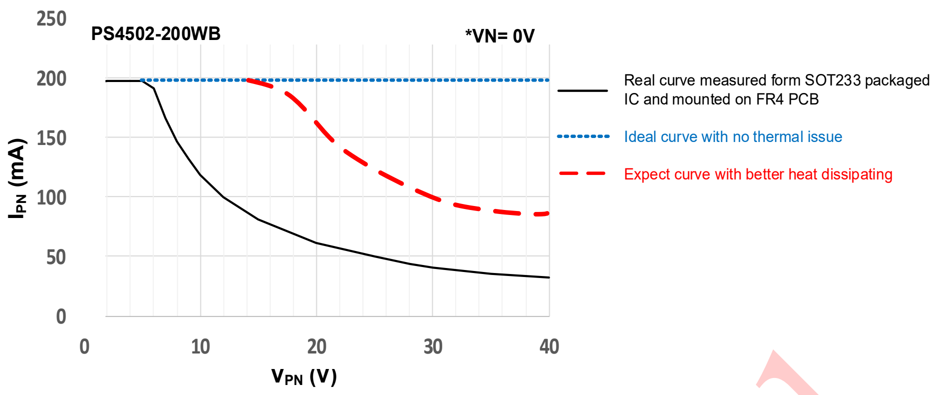


Figure 5. Load regulation, I_{PN} vs V_{PN}

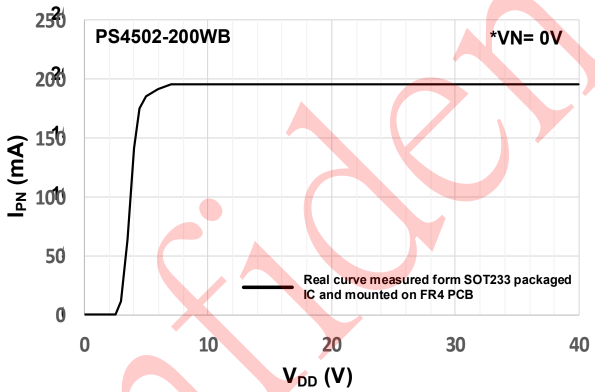


Figure 6. Line regulation, I_{PN} vs V_{DD}

9 Application Information

The PS4502 is a Constant Current Regulator (CCR) for LED driver. CCR is achieved by adjusting the internal self-biased transistor to regulate the current through PS4502 and any devices in series with it. Besides, as operating temperature rising, PS4502 features a thermal protection function to protect LEDs through reducing operating current if junction temperature of PS4502 is above 125°C.

9.1 Single LED String

PS4502 can be placed in a series of LEDs string, as shown in Figure 7. The number of the LEDs is limited by the voltage across the V_{PN} of PS4502 and V_{IN} supply voltage. Hence, the design must estimate the voltage across the LEDs and PS4502 by taking the minimum input voltage greater than the sum of maximum voltage across the LED string and minimum V_{PN} drop out.

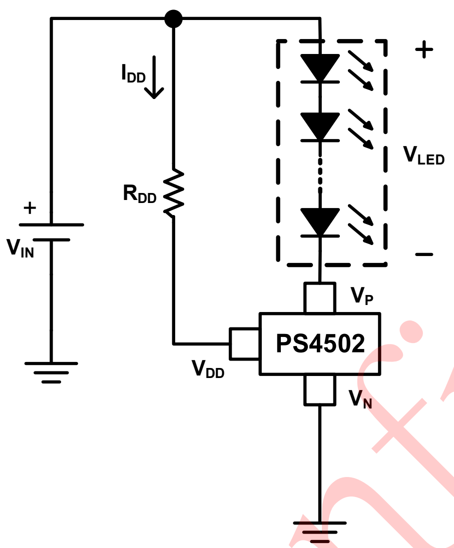


Figure 7. General LED driving application

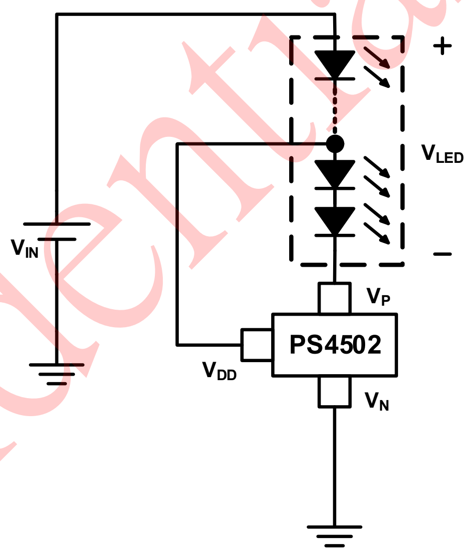


Figure 8. Self-bias LED driving application

Figure 7 is a general LED driving method. the minimum input voltage $V_{IN(min)}$ has to be higher than V_{LED}+V_{PN} or I_{DD} · R_{DD}+7V. Resistor R_{DD} is used to protect the V_{DD} pin from damage due to fast V_{IN} transitions, such as hot plug of V_{IN} power or unexpected high spikes from power line. The equation is as follows:

$$V_{IN(min)} = V_{LED(max)} + V_{PN(min)} \quad (1)$$

$$R_{DD} \leq \frac{V_{IN}-7V}{I_{DD(max)}} \quad (2)$$

Figure 8 shows another way to driving LEDs. In this way, the self-bias V_{DD} voltage of PS4502 is equal to the total V_F voltage of LEDs between V_{DD} and V_P pin plus $V_{PN(min)}$ voltage. This V_{DD} voltage should be approximately above 7V. Generally, 2 white LEDs or 3 red LEDs between V_{DD} and V_P pin are sufficient for this application.

9.2 Higher Current LED Strings

For higher LED current demand, two or more PS4502 can be connected in parallel to increase the LED current as shown in Figure 9.

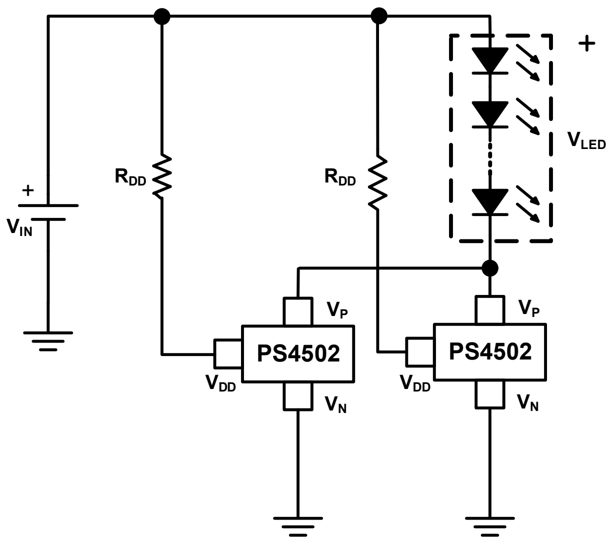


Figure 9. High current application.

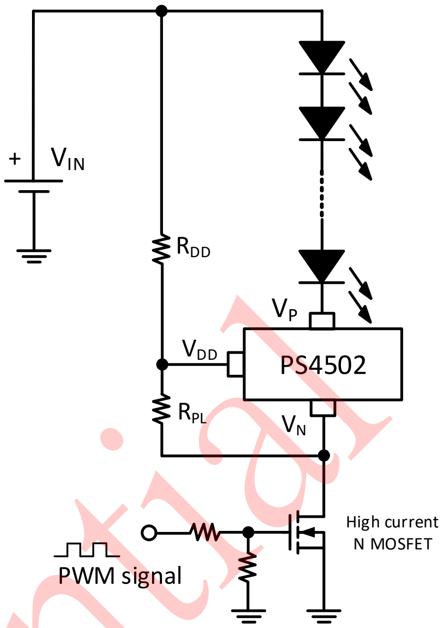


Figure 10. PWM dimming by external MOSFET

9.3 PWM Dimming

Figure 10 is the best PWM dimming application circuit. To achieve LED dimming in an LED driving circuit with the PS4502, you can use a MOSFET to switch the power supply. The brightness is controlled by the duty cycle of a PWM (Pulse Width Modulation) signal. Resistor R_{DD} and R_{PL} act as a voltage divider to generate the proper V_{DD} voltage for PS4502 and discharge the residual charge on power line while the switch MOSFET is off. To discharge the residual charge is important because it will cause instability in dimming control, resulting in flickering or inconsistent brightness. The duty cycle of the PWM signal is defined as the ratio of the LED on time (T_{ON}) to the entire cycle time (T). The duty cycle of the PWM signal is shown in Figure 11. Figure 12 shows the current accuracy with different duty cycle.

$$Duty = \frac{T_{ON}}{T_{ON}+T_{OFF}} = \frac{T_{ON}}{T} \quad \text{.......... (3)}$$

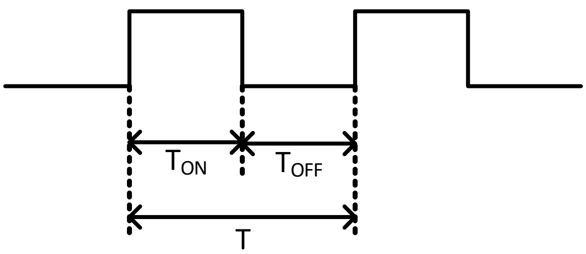


Figure 11. PWM dimming signal

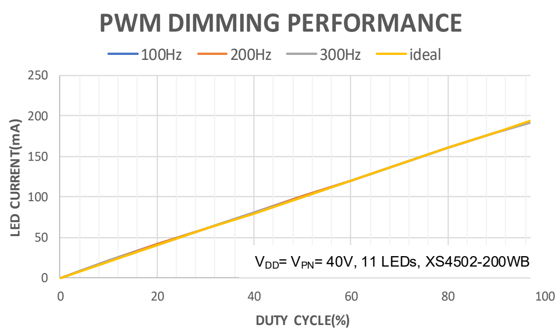


Figure 12. Current accuracy vs PWM dimming

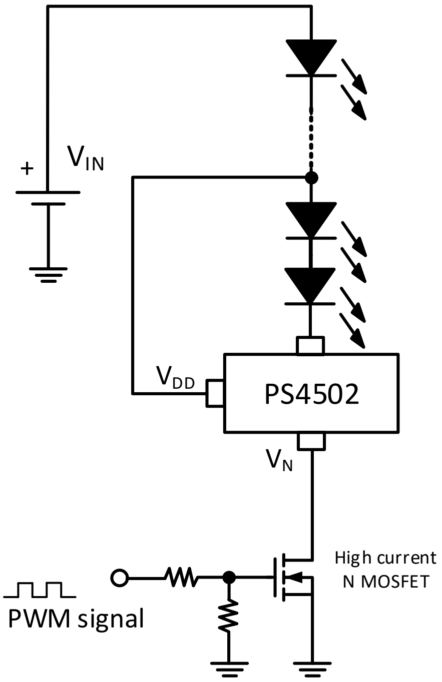


Figure 13. Simplified dimming circuit.

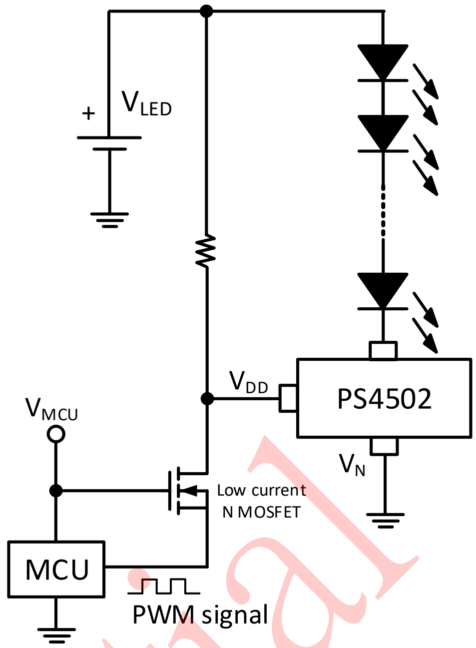


Figure 14. PWM dimming by external MOSFET

Figure 13 shows the self-bias dimming circuit. The advantage is no need of resister for PS4502 biasing. In many compact LED applications this will mostly reduce the procedure of production. The disadvantage is the PWM dimming frequency should be lower. It is suggested the frequency should be lower than 1KHz to get better dimming control. Both switch N MOSFETs in Figure 10 and Figure 13 are to switch the total power of LED loads, so it should have lower R_{DS} resistance and lager power dissipation capability to minimize the power lost and heat generation. In contrast to those two circuits, Figure 14 provides alternative way to control the V_{DD} of PS4502 by using a small, low power N MOSFET. This MOS can resist the higher PS4502 V_{DD} voltage from V_{LED} or cut off this voltage while MCU outputs a low voltage.

9.4 Thermal Protection: LED Current Ramp Down

For protecting LED under high temperature application, LED current is decreased automatically while PS4502's junction temperature is over 125°C. If PS4502's junction temperature approaches 145°C, LED current remains below 10%. As the temperature decreases, the LED current will recover when the junction temperature is below 125°C.

9.5 Power Dissipation

The power consumption of PS4502 can be calculated by multiplying the regulated current I_{PN} by the V_{PN} voltage that is the system supply voltage substrate the voltage across the LED string V_{LED}.

$$V_{PN} = V_{IN} - V_{LED} \quad (4)$$

$$P_D = I_{PN} \times V_{PN} \quad (5)$$

When using the PS4502 as a flip chip application, soldering the 3 pads directly onto a copper path on the PCB can be a suitable approach for electrical and thermal connection. This method ensures efficient heat dissipation and reliable electrical contact between the LED driver and the PCB. Absolutely, ensuring adequate heat dissipation capability in the PCB design is crucial when using the PS4502 as a flip chip application, especially considering the potential heat generated by the driver. A well-designed PCB with robust heat dissipation capabilities ensures that the PS4502 operates within its specified temperature range, contributing to the reliability and longevity of the LED lighting system.

Another method to integrate PS4502 into an LED driving circuit is by using traditional wire bonding techniques, typically employing 0.8mil to 1mil gold wire for interconnection and conductive silver glue for die bond. The back of the PS4502 die, which is bonded to the PCB using conductive silver glue, must be held at the same potential as the V_N pin of the PS4502 or left in a voltage floating state. This is crucial to prevent any potential differences that could lead to malfunction or damage.

9.6 PCB design considerations for flip chip application

When integrating the PS4502 as a flip chip application, the major ingredient of the three pads on the PS4502 surface is silver. These silver pads can be soldered to the copper paths on the PCB using tin (solder). Figure 15 shows the cross-section of how the PS4502 is soldered to the PCB.

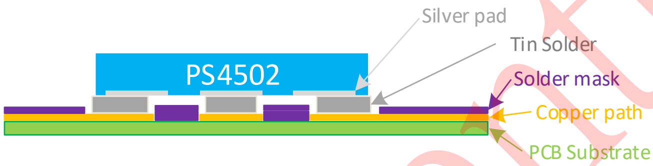


Figure 15. Cross section of PS4502 on PCB.

Figure 16 (a) shows the recommend foot print design of PS4502. Figure 16(c) shows the flipped PS4502 dice. Figure 16 (b) shows the flipped PS4502 which is placed on PCB. For good thermal management, the larger VP and VN copper path area, the better heat dissipation capability.

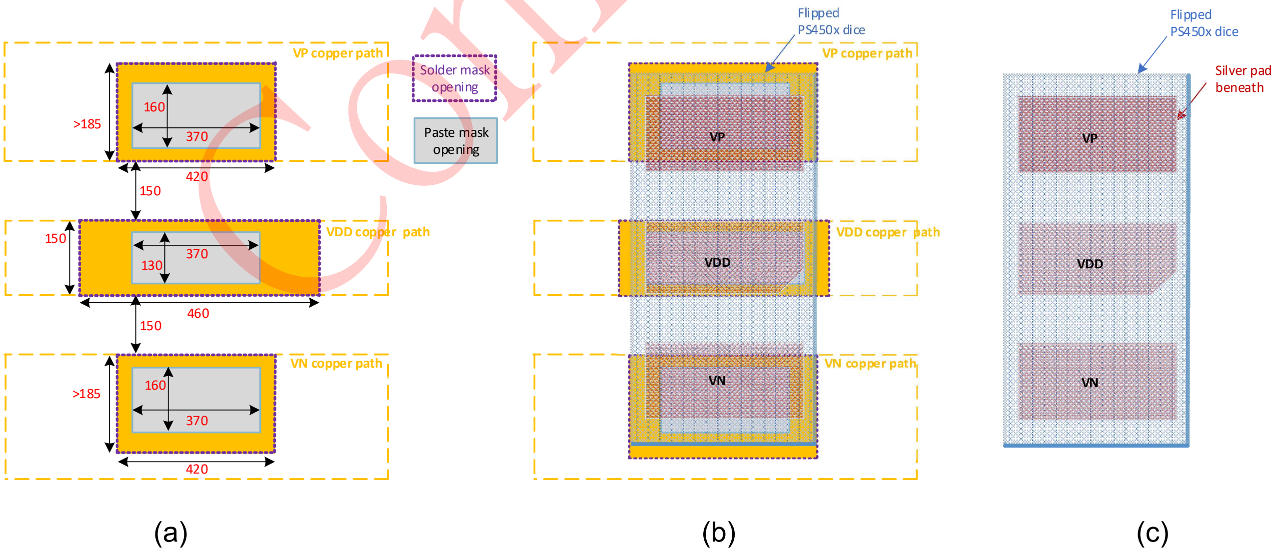
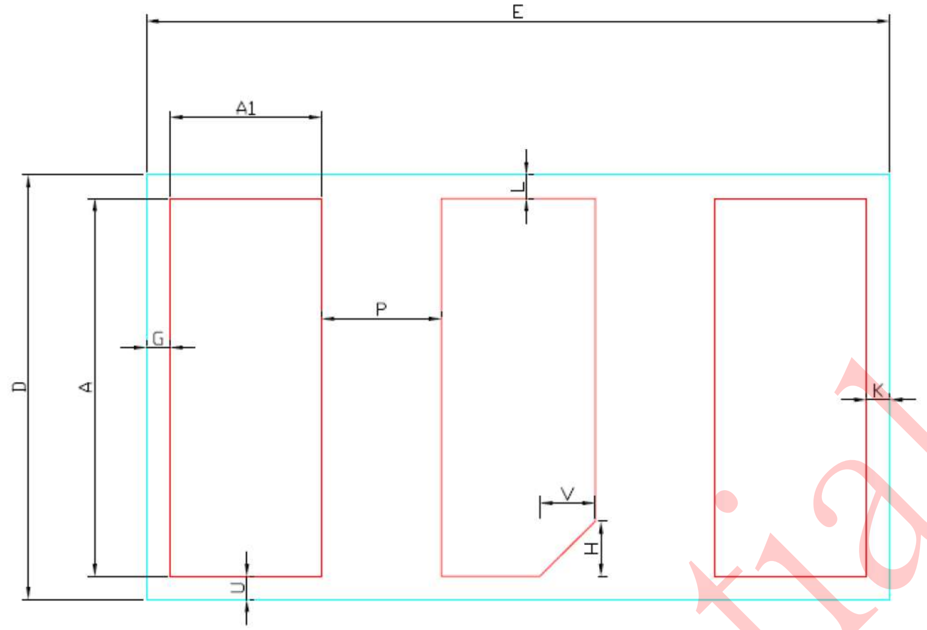
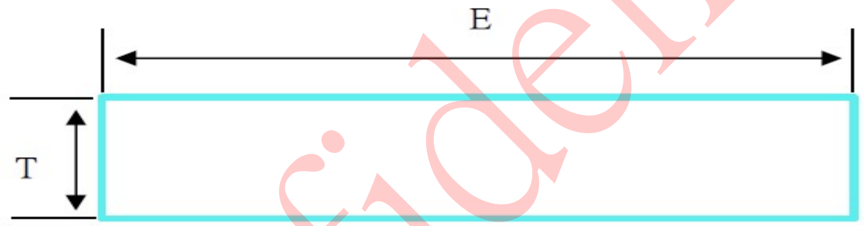


Figure 16. PS4502 foot print for flip chip applications

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 PS4502 bare die is exposed to 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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