# 60V, 20mA Single Channel Constant Current LED Driver

## General Description

XS4500 is a single channel LED driver with constant current regulator. XS4500 offers excellent temperature stability and output current accuracy (±3.5%) with a wide input voltage from 4.5V to 40V and temperature range. XS4500 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, XS4500 is featured a current ramp down function from 65$^{o}$C to 85$^{o}$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, XS4500 also supports both high-side and low-side driving for the LED strings. XS4500 is bare die and die size is 426um x 745um, which is available for COB (chip on board) LED lighting application, etc.

## 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

## Applications

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

## Ordering Information

XS4500-□□WB

WB: Wafer Business

20: IOUT= 20mA

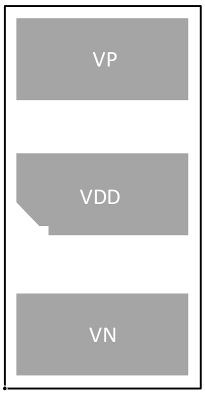
**Note:** Green Product (RoHS compliant)

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).

## Dice Information

(Top View)



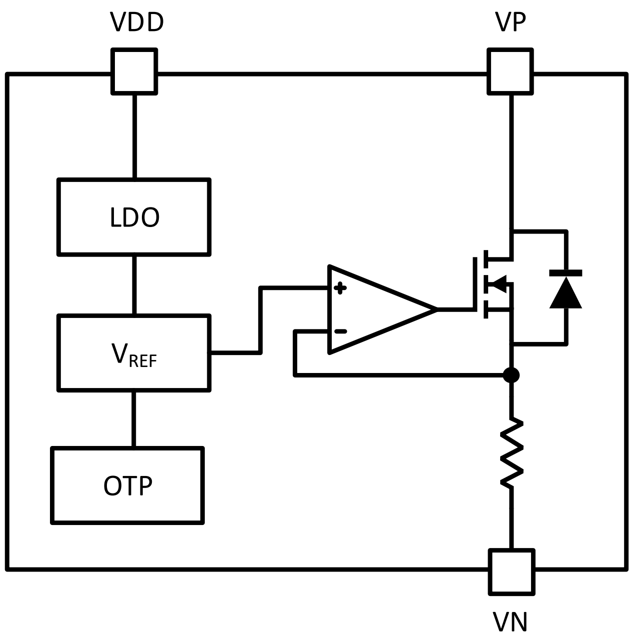

Die Size: 426um x 745um

## 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.<br>For low-side LED string application, connect the LED cathode terminal to the "VP" terminal.<br>For high-side LED string application, connect the LED anode terminal to the "VN" terminal. |
| 2 | VDD | I | Supply voltage |
| 3 | VN | -- | Power ground |

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

## Functional Block Diagram



## Absolute Maximum Ratings (Note 1)

- Supply Input Voltage: VDD, VP, VN ........................................................................-0.3V to 60V
- Junction Temperature........................................................................................................150°C

## Recommended Operating Conditions (Note 2)

- Supply Input Voltage: VDD, VP ..............................................................................4.5V to 40V
- Junction Temperature Range ..............................................................................-40°C to 65°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.

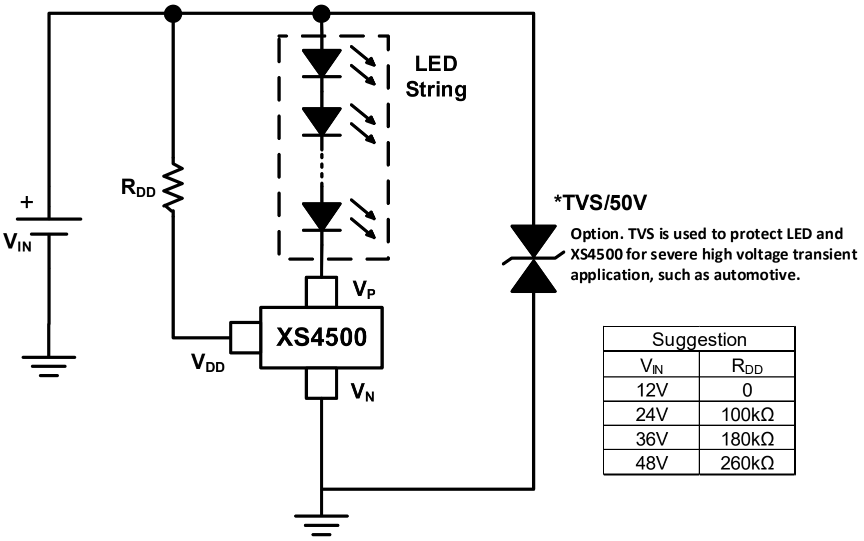
**Note 2:** Device function is not guaranteed if it is operated out of this range.

## Electrical Characteristic

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

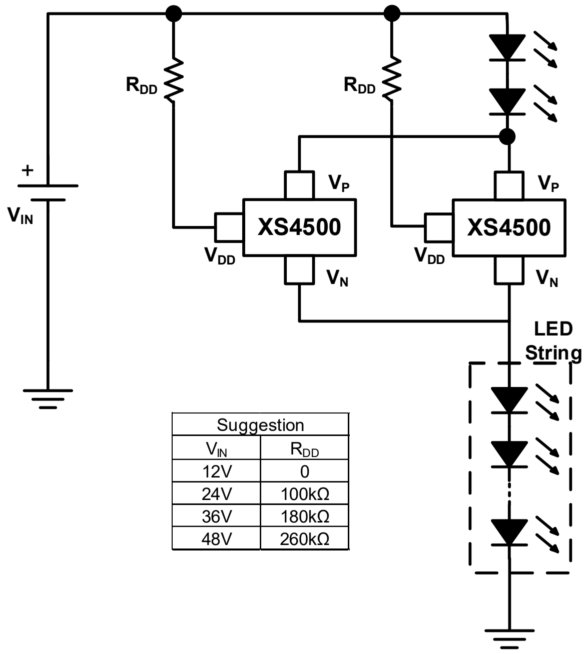
| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Supply voltage | $V_{DD}$ | $I_{PN} \leqq$ 20mA | 4.5 | | 40 | V |
| Supply current | $I_{DD}$ | 4.5V $\leqq V_{DD} \leqq$ 40V<br>$I_{PN}$= 20mA | 0.06 | 0.16 | 0.22 | mA |
| Minimum dropout voltage | $V_{PN}$ | $V_{DD}$ > 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 | $T_{J\_down}$ | $I_{PN} \leqq$ 90%$I_S$ | | 65 | | °C |
| Shutdown temperature | $T_{J\_shtdn}$ | $I_{PN} \leqq$ 10%$I_S$ | | 85 | | °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<br>$V_{DD}$= 7V | -1 | | 1 | % |

## Typical Application Circuit




| Suggestion | |
|---|---|
| $V_{IN}$ | $R_{DD}$ |
| 12V | 0 |
| 24V | 100kΩ |
| 36V | 180kΩ |
| 48V | 260kΩ |

Figure 1. General DC power LED drive.




| Suggestion | |
|---|---|
| $V_{IN}$ | $R_{DD}$ |
| 12V | 0 |
| 24V | 100kΩ |
| 36V | 180kΩ |
| 48V | 260kΩ |

Figure 2. Parallel configuration for higher LED current requirement.

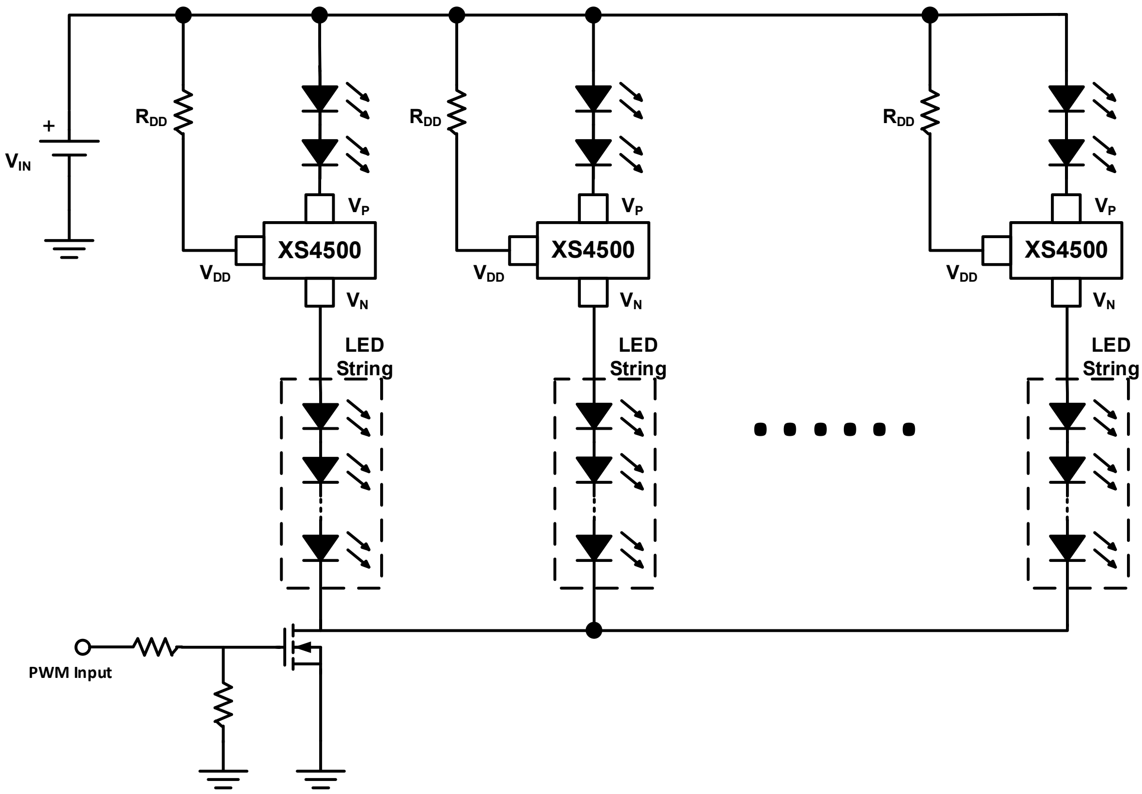



Figure 3. LED strings PWM dimming by external MOSFET

## Typical Operating Characteristics

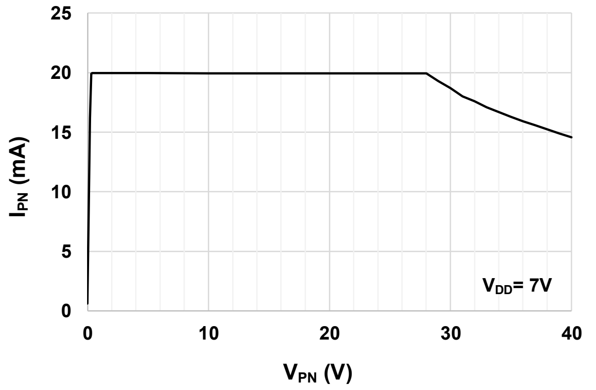



Figure 4. Line regulation, $I_{PN}$ vs $V_{PN}$

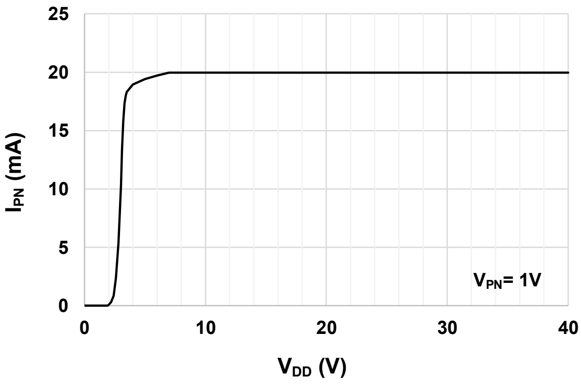



Figure 5. Line regulation, $I_{PN}$ vs $V_{DD}$

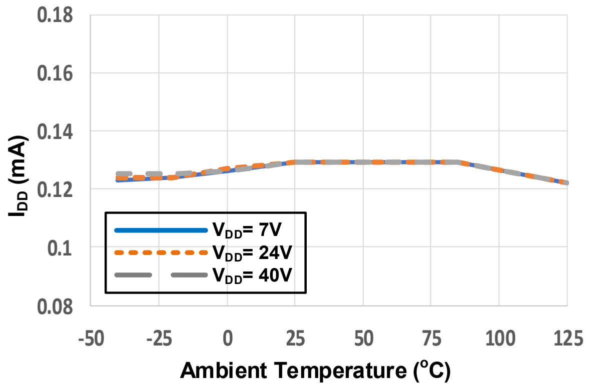



Figure 6. Supply current $I_{DD}$ vs $T_a$

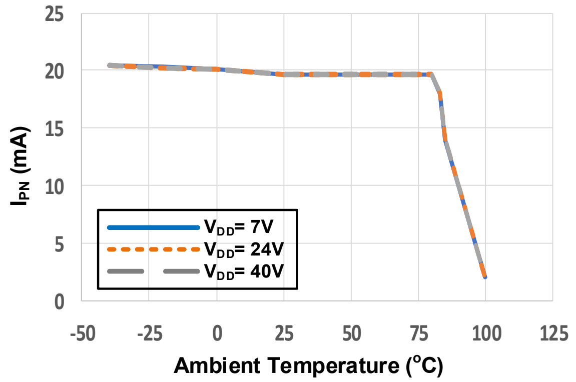



Figure 7. Regulated current $I_{PN}$ vs $T_a$

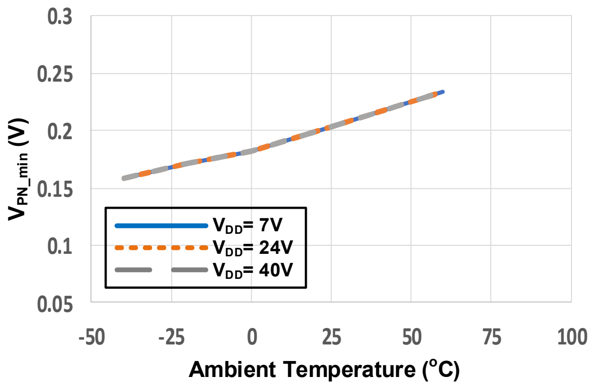


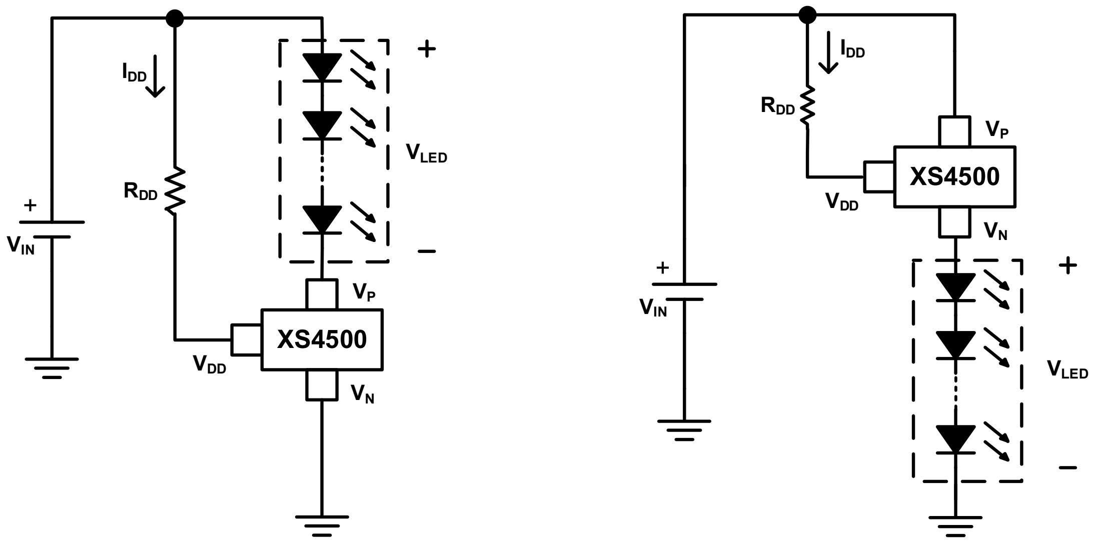

Figure 8. Minimum drop voltage $V_{PN\_min}$ vs $T_a$

## Application Information

The XS4500 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 XS4500 or any devices in series with it. Besides, as operating temperature rising, XS4500 features a thermal protection function to protect LEDs through reducing operating current if junction temperature of XS4500 is above 65°C.

### Single LED String

XS4500 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 XS4500. 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.




(a) (b)

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

As XS4500 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 $V_{LED} > I_{DD} \cdot R_{DD} + 4.5 - V_{PN}$,

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

If $V_{LED} < I_{DD} \cdot R_{DD} + 4.5 - V_{PN}$,

$V_{IN(\min)} = I_{DD} \cdot R_{DD} + 4.5$ ........................................ (2)

For high-side LED driver referred to figure 9 (b), the minimum input voltage $V_{IN(min)}$ is as follows $V_{IN(\min)} = I_{DD} \cdot R_{DD} + 4.5 + V_{LED}$ ........................................ (3)

### Higher Current LED Strings

For higher LED current demand, two or more XS4500 can be connected in parallel to increase the LED current as shown in figure 10.

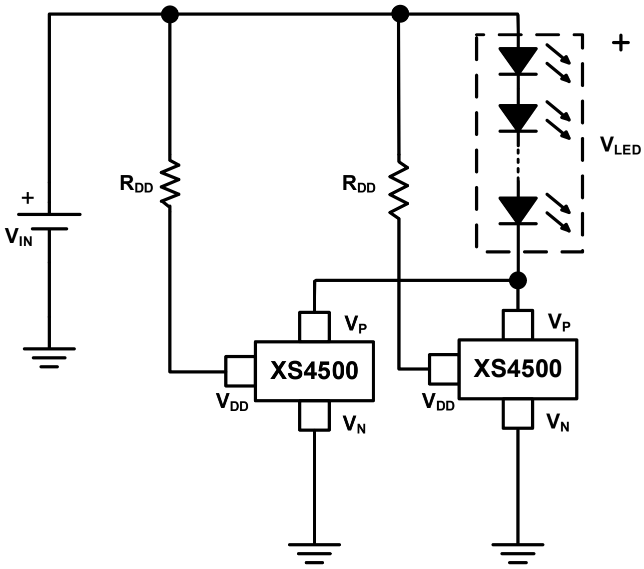



Figure 10. High current application.

### Thermal Protection: LED Current Ramp Down

For protecting LED under high temperature application, LED current is decreased automatically while XS4500's junction temperature is over 65°C. Besides, if XS4500's junction temperature approaches 85°C, LED current remains around 10%. Along with temperature reducing, the LED current is recovery when junction temperature is below 65°C.

### 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 $V_{LED}$.

$V_{PN} = V_P - V_{LED}$ ........................................................................ (4)

$P_D = I_S \times V_{PN}$ ........................................................................ (5)

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:

$P_{D(max)} = \frac{60-T_A}{R_{\theta JA}}$ , where $R_{\theta JA} = 245°C/W$ ........................................................ (6)

**PWM Dimming**

The LED dimming can be easily achieved by placing an external MOSFET in series with XS4500 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.

$$D = \frac{T_{ON}}{T_{ON}+T_{OFF}} = \frac{T_{ON}}{T} \quad (7)$$

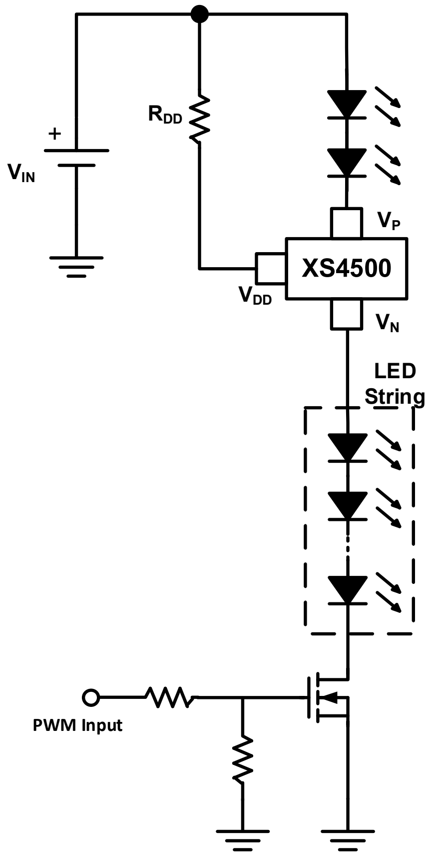



Figure 11. PWM dimming by external MOSFET

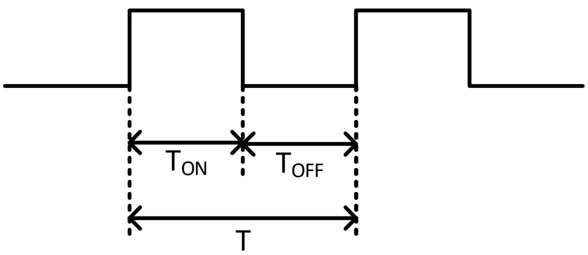



Figure 12. PWM dimming signal

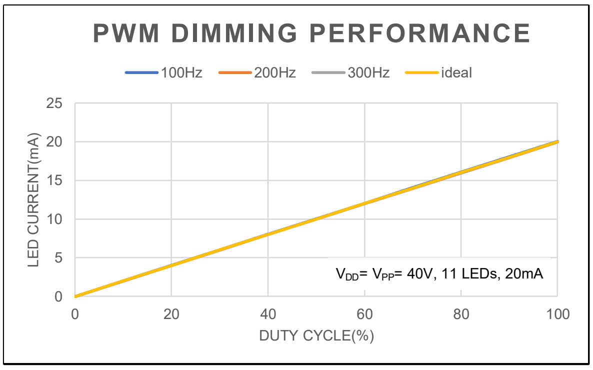
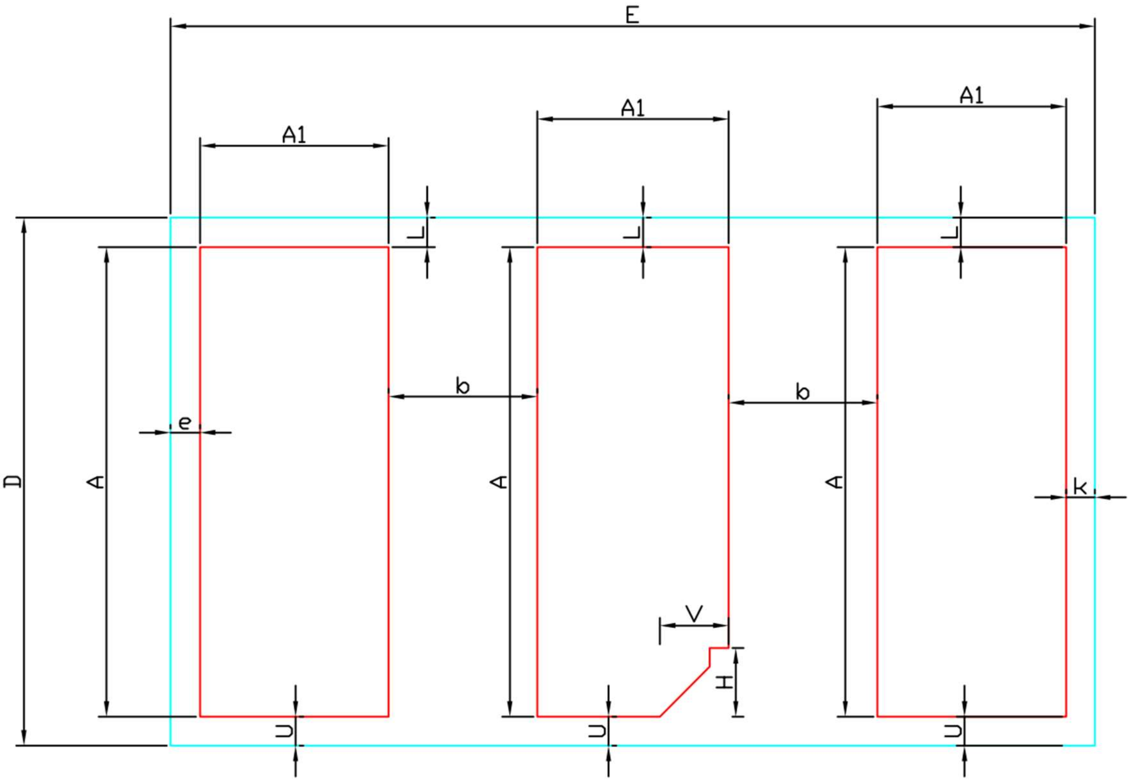



Figure 13. Current accuracy vs PWM dimming

## Outline Dimension




| Symbol | Dimensions In Millimeters | Dimensions In Inches |
|---|---|---|
| A | 0.380 | 0.015 |
| A1 | 0.150 | 0.006 |
| H | 0.055 | 0.002 |
| b | 0.120 | 0.005 |
| D | 0.426 | 0.017 |
| e | 0.0236 | 0.001 |
| E | 0.745 | 0.029 |
| k | 0.0233 | 0.001 |
| L | 0.0238 | 0.001 |
| U | 0.0233 | 0.001 |
| V | 0.055 | 0.002 |

## Revision History

| Revised on | Version | Description |
|---|---|---|
| 2022.7.8 | 00 | Release |
| 2022.10.25 | 01 | Modify accuracy SPEC |