AN009

Wide Input Voltage Range White LED Driver Solutions with MP2481

At the turn of the 21st century, the development of LED technology promoted innovative power-saving projects. White LED (WLED) solutions can be applied for an extended range of application target. In addition to LCD backlighting, WLEDs are also employed for low-power lighting fixture, automobile lighting, decorative illumination, and camera flashlights.

The primary generation of WLED applications requires higher forward voltages and larger currents to meet the illumination requirement. Supply sources are typically the batteries whose supply voltages are sometimes lower than the WLEDs forward voltage drop and the driving capacity is limited. So driver ICs which can boost the supply voltage and improve efficiency are necessary to meet the illumination requirement, reduce power consumption and increase battery life. Most of the available WLED driver solutions focus on voltage boost scheme, including the inductive boost converter and charge pump configuration.

But the batteries are not fixed supplies for all actual situations. Sometimes the driver ICs have to permit operation at input voltages above, below or equal to the output voltages. Especially in the condition that the input voltages are very close to the output voltages, regular buck or boost schemes will not be suitable and the buck-boost scheme will be the ideal solution. The main challenge is coming from the requirements of more flexible configuration, wider supply voltage range and more convenient employment for WLED driver ICs to accord with a broader variety of WLED applications.

MPS offers various solutions to drive WLEDs. And MP2481 is a new product whose unique technology provides high performance under the condition as stated above.

This application note introduces WLED drive solutions based on MP2481.

MP2481 INTRODUCTION

MP2481 is an 8-pin power device integrated WLED driver with fixed 1.4MHz operating frequency suitable for either buck or inverting buck-boost applications. It achieves 1.2A peak output current over a wide 4.5V to 36V input supply range (for buck configuration) and incorporates both DC and PWM dimming with a single control pin. The unique feature is that the IC employs separate input reference ground pin which allows direct enabling and/or dimming control for a positive to negative buck-boost power conversion, which can dramatically simplify the design and the external circuit. The buck boost configuration provides the user great flexibility to utilize the input voltage to power up WLED (arrays) that have a voltage drop equal, below, or above the input voltage. Complete fault condition protection includes thermal shutdown, cycle-by-cycle peak current limiting, input over voltage protection, open LED protection and output short circuit protection, which improves the reliability of the whole solution. (Please refer to datasheet of MP2481 for details.)

BUCK-BOOST CONFIGURATION REFERENCE DESIGN

WLED array is the common configuration for backlight applications. Conventionally, step-up or step-down converters are used in the WLED driver application. However, when meeting the application that requires the input voltage to overlap the output voltage, the buck-boost topology is a simple and proper choice. Configured in buck-boost mode, MP2481 can well regulate the WLED current to follow the variety of application case under wide supply voltage range.

The buck-boost configuration with MP2481 for LCD panel backlight application is shown in **Figure 1**. The backlighting source is a WLED array (3 WLEDs in series, 13 strings paralleled). It is suitable for the

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portable system that the input voltage could be both the batteries and the adapter input. The detailed design specifications and BOM list are shown in **Table 1** and **Table 2**.

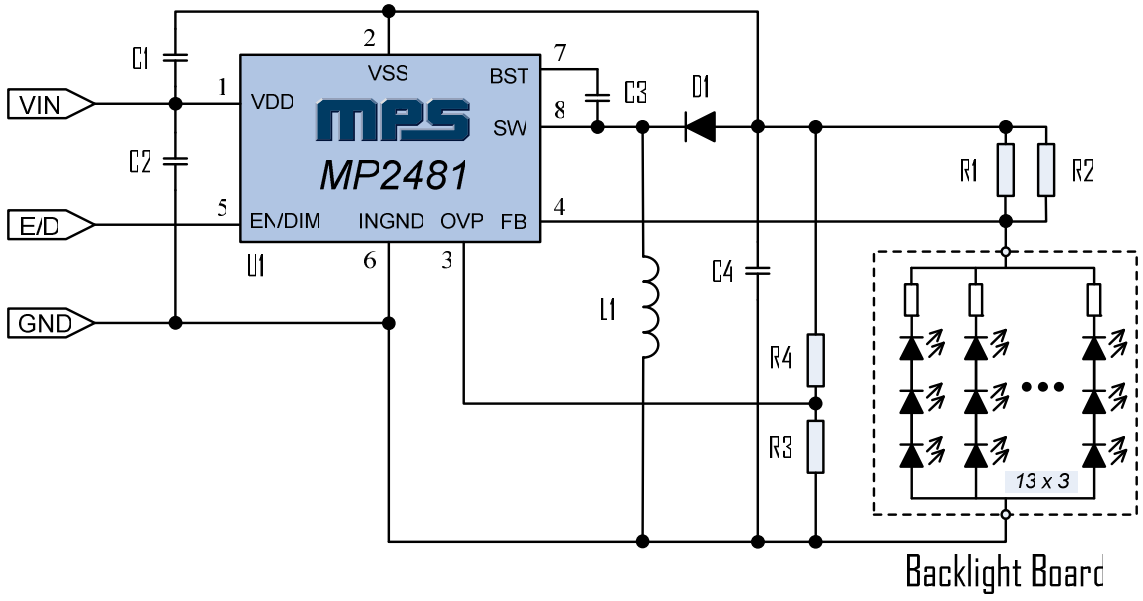

Figure 1—Application for Driving WLED Array

Table 1—Specifications for Driving WLED Array

Input Voltage	**4.5V~25V** (compatible for 2 cell batteries input and adaptor)
LED Forward Voltage	**9V ~ 11V**
LED Current	250mA ± 3%
Open LED Protection	Yes
Short Circuit Protection	Yes

Table 2—BOM List for Driving WLED Array

Qty	Ref	Value	Description	Package	Manufacturer	Manufacturer P/N
1	C1	1μF	Ceramic Capacitor,50V,X7R	1206	TDK	C3216X7R1H105K
1	C2	4.7μF	Ceramic Capacitor,50V,X7R	1210	Murata	GRM32ER71H475KA88L
1	C3	10n	Ceramic Capacitor,16V,X7R	0603	TDK	C1608X7R1H103K
1	C4	4.7μF	Ceramic Capacitor,25V,X7R	1206	Murata	GRM31CR71E475KA88L
1	D1	B140	Diode Schottky	SMA	Diodes Inc.	B140-13-F
1	L1	4.7μH	Inductor 1.66A	D63LCB	TOKO	D63LCB-#A921CY-4R7M
2	R1, R2	1.62	1%	0805	Yageo	RC0805FR-071R62L
1	R3	100k	5%	0603	Any	
1	R4	10k	5%	0603	Any	
1	U1	MP2481DH	MPS WLED Driver	MSOP8EP	MPS	MP2481DH-LF-Z

For MP2481, the reference of regulated output current, over voltage protection (OVP) and feed-back signal is VSS while the reference of supply voltage and enable/dimming control signal is INGND. Therefore, in buck-boost applications, though the output polarity is inverted, the enable, dimming control signal and the feedback signal from the output side can feed to the IC directly regardless of its different polarity and reference point, which dramatically simplify the whole circuit.

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With the integrated power device and internal compensation, the external component count required by MP2481 is minimized.

Ceramic capacitors with X5R or X7R dielectrics are recommended for the input filter capacitors (C1 and C2) and bootstrap capacitor (C3) for low ESR and small temperature coefficients. The voltage stress applied on the rectifier diode (D1) is $V_{IN}+V_O$, and considering some derating of the diode in practical application, a 1A/40V Schottky diode could be used for most application.

The buck-boost recommended inductance value can be derived from the following equation:

$$L = -\frac{V_{IN} \times V_{OUT}}{(V_{IN} - V_{OUT}) \times \Delta I_L \times f_{sw}} \qquad \textbf{Eq. 1}$$

Where V_{IN} is the lowest input voltage, V_{OUT} is the output voltage (negative), ΔI_L is the inductor ripple current, For MP2481 in buck-boost mode, designing ΔI_L approximately equal to 0.6A is a good choice.

In this application, V_{IN-MIN}=4.5V, V_{OUT}=-11V, f_{SW}=1.4MHz, the calculated L=3.9μH. So a 4.7μH inductor could be selected.

For most application, a **3.3μH to 10μH** with suitable DC current rating is recommended. If the calculation of above equations results in an inductance greater than 10μH, a 10uH inductor is still preferred.

The output capacitor keeps the output voltage ripple small and ensures feedback loop stability. A 1μF to 10μF ceramic capacitor with adequate rating will be sufficient.

To make sure the MP2481 functions properly, the Over Voltage Protection (OVP) resistor divider must be set with proper value, the recommended OVP point is about approximately 1.3~1.5 times higher than the output voltage for normal operation and over voltage protection. For this example, since the output voltage is about 10V, the OVP point can be set to about 13.2V.

The internal reference for the output current is 0.2V. With a given output current I_{LED}, the current sense resistor can be calculated by **Eq. 2**

$$R_{SENSE} = \frac{0.200}{I_{LED}} \qquad \textbf{Eq. 2}$$

Where R_{sence} is the resistance that R1 paralleling with R2 in Figure1.

For 250mA output LED current in the application shown in Figure 1, an 800mΩ current sense resistor is required.

MP2481 allows both DC and PWM dimming. When $V_{EN/DIM} - V_{INGND}$ is less than 0.6V, the chip is turned off. When $V_{EN/DIM} - V_{INGND}$ rises from 0.7V to 1.4V, the LED current will linearly change from 0% to 100% of the maximum LED current in analog dimming manner. If $V_{EN/DIM} - V_{INGND}$ is higher than 1.4V, maximum LED current will be generated. If a PWM dimming signal is applied, its high level must be greater than 1.4V and low level must be lower than 0.6V. The PWM frequency can be set up to 1 kHz.

Figure 2 shows the bench-test waveform for this design. The input voltage is 10V that is very close to output voltage, the output LED current is regulated to 250mA. The system works steadily at 1kHz PWM dimming. **Figure 3** shows the dimming-test curve. The WLED current changes linearly with both PWM dimming duty and analog dimming voltage (0.7V~1.4V).

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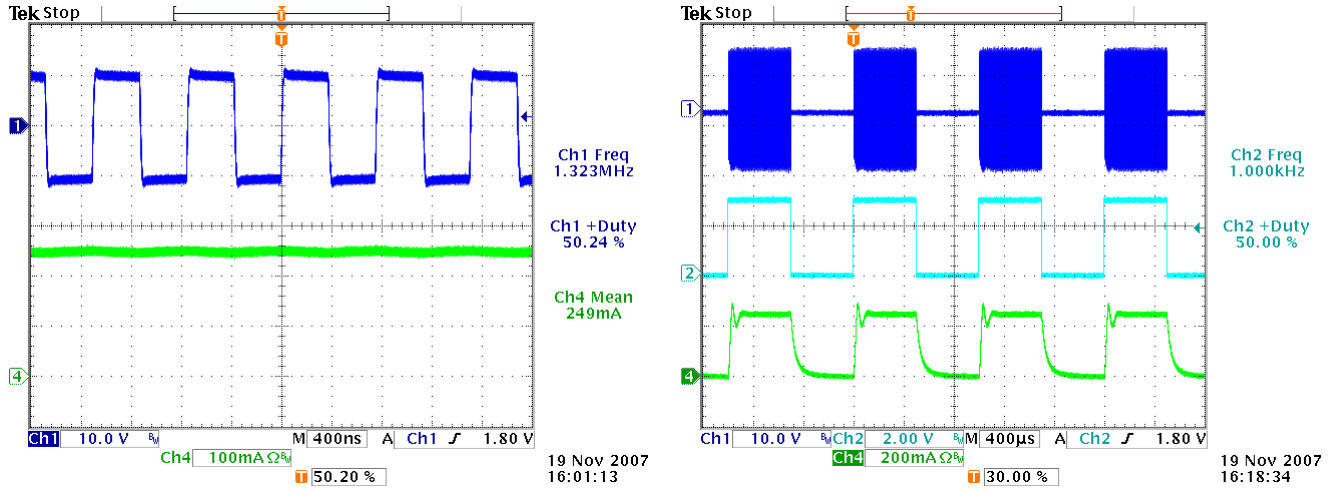

(a) Steady State (Vin=10V, close to output voltage) **(b) PWM dimming (Vin=12V)**

Figure 2—The Bench-test Waveform for Buck-boost Configuration Design (CH1: SW voltage, CH2: PWM dimming signal, CH4: I_{LAMP})

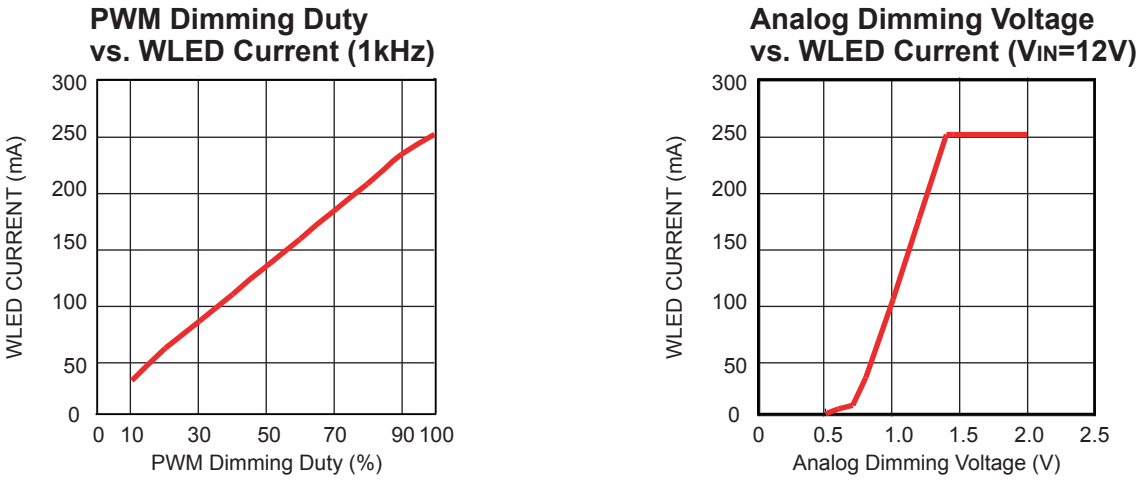

Figure 3—The Dimming-test Curve for Buck-boost Configuration Design

BUCK CONFIGURATION REFERENCE DESIGN

In low output voltage WLED driving application, like driving LEDs in parallel or one high power LED, the output voltage can be as low as 4V, MP2481 can be configured as a step down converter for even better efficiency and simple circuit, i.e. Buck configuration.

For buck configuration, MP2481 can operate over 4.5V to 36V input voltage range for a broad range of LED current-driving applications. Such as 12VAC~24VAC input decorative illumination, battery based LED Miner's Lamp, WLED flash light, and general purpose illumination. **Figure 4** shows a general buck based application of driving high-power LEDs with up to 1A capability. The specifications and BOM list are detailed in **Table 3** and **Table 4**.

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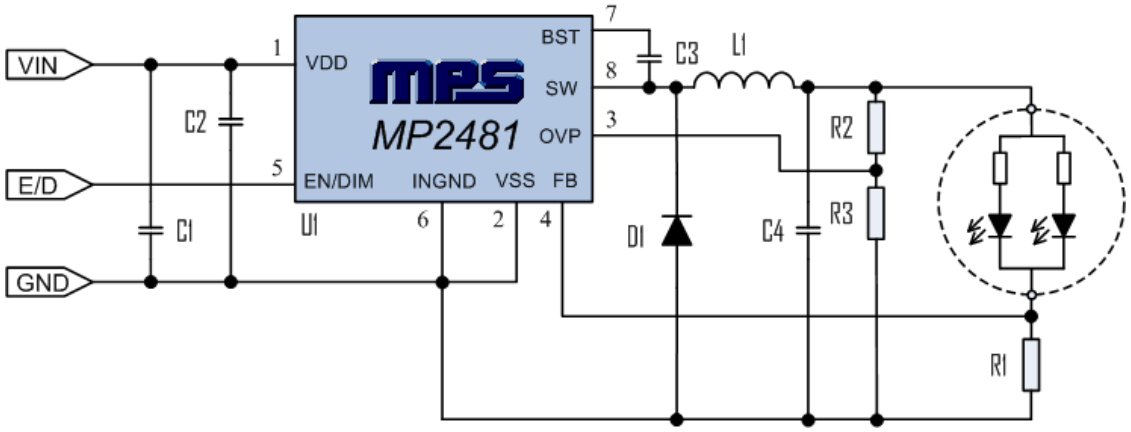

Figure 4—Application for Driving High-power LEDs

Table3—Specifications for Driving High-power LEDs

Input Voltage	**5V~36V**
LED Forward Voltage	**3.5V ~ 4V**
LED Current	1A ± 3%
Open LED Protection	Yes
Short Circuit Protection	Yes

Table4—BOM List for Driving High-power LEDs

Qty	Ref	Value	Description	Package	Manufacturer	Manufacturer P/N
1	C1	1uF	Ceramic Capacitor,50V,X7R	1206	TDK	C3216X7R1H105K
1	C2	4.7uF	Ceramic Capacitor,50V,X7R	1210	Murata	GRM32ER71H475KA88L
1	C3	10n	Ceramic Capacitor,16V,X7R	0603	TDK	C1608X7R1H103K
1	C4	4.7uF	Ceramic Capacitor,25V,X7R	1206	Murata	GRM31CR71E475KA88L
1	D1	B140	Diode Schottky	SMA	Diodes Inc.	B140-13-F
1	L1	4.7uH	Inductor 1.66A	D63LCB	TOKO	D63LCB-#A921CY-4R7M
1	R1	0.2	1%	1206	CYNTEC	RL1632H-R200-FN
1	R2	39k	5%	0603	Any	
1	R3	10k	5%	0603	Any	
1	U1	MP2481DH	MPS WLED Driver	MSOP8EP	MPS	MP2481DH-LF-Z

Similar with the buck-boost application, the only alteration is INGND is shorted to VSS instead of being connected to the anode of the LED. So power reference and input ground reference are same.

The recommended inductance value can be derived from the following equation:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{sw}} \qquad \textbf{Eq. 3}$$

Where V_{IN} is the lowest input voltage, V_{OUT} is the output voltage, ΔI_L is the inductor ripple current, For MP2481 in buck mode, designing ΔI_L approximately equal to 0.3A is a good choice.

In this application, V_{IN-MIN}=5V, V_{OUT}=4V, f_{SW}=1.4MHz, the calculated L=2μH. A 4.7μH inductor is selected because the input spec range is very wide.

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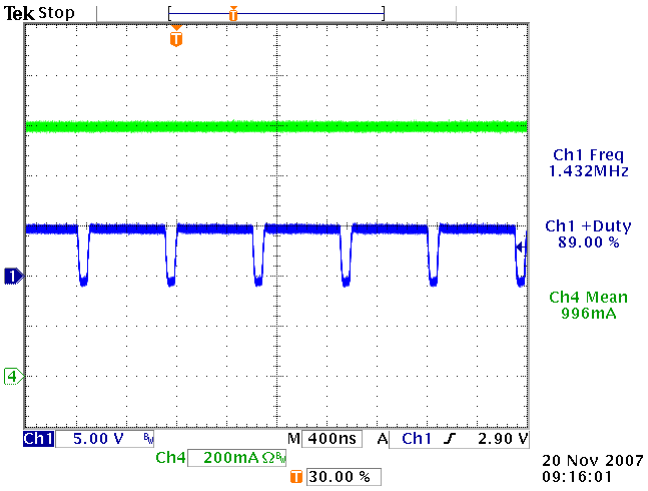
For most buck application, a **3.3μH to 10μH** with suitable DC current rating is recommended. If the calculation of above equations results in an inductance greater than 10uH, a 10uH inductor is still preferred.

The output capacitor keeps the output voltage ripple small and ensures feedback loop stability. A 1μF to 10μF ceramic capacitor with adequate rating will be sufficient.

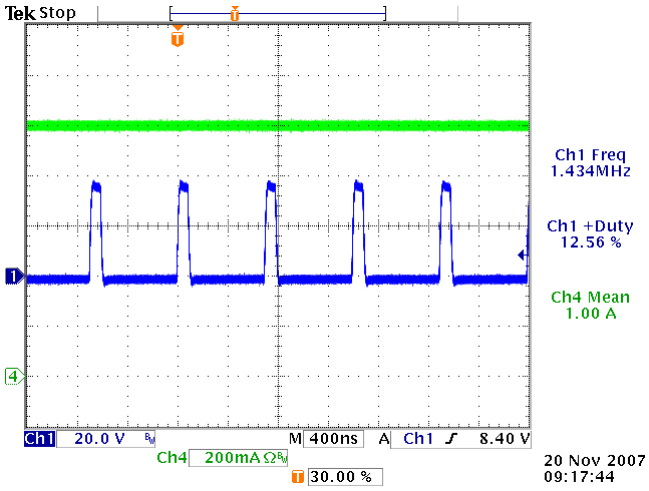
To make sure the MP2481 functions properly, the Over Voltage Protection (OVP) resistor divider must be set with proper value, the recommended OVP point is about approximately 1.3~1.5 times higher than the output voltage for normal operation and over voltage protection. For this example, since the output voltage is about 4V, the OVP point can be set to about 6V.

200mΩ is the proper value of the sense resistor for 1A output LED current (derived from **Eq. 2**). The values of other components are the same with those in buck-boost configuration design.

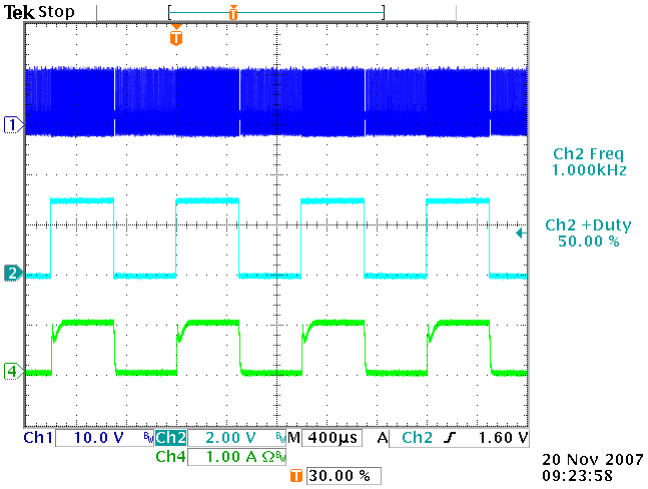
The function of dimming control please refers to the buck-boost configuration design.



(a) Steady State (V_{IN}=5V)



(b) Steady State (V_{IN}=36V)



(c) PWM dimming (Vin=12V)

Figure 4—The Bench-test Waveforms for Buck Configuration Design

(CH1: SW pin voltage, CH2: PWM dimming signal, CH4: I_{LAMP})

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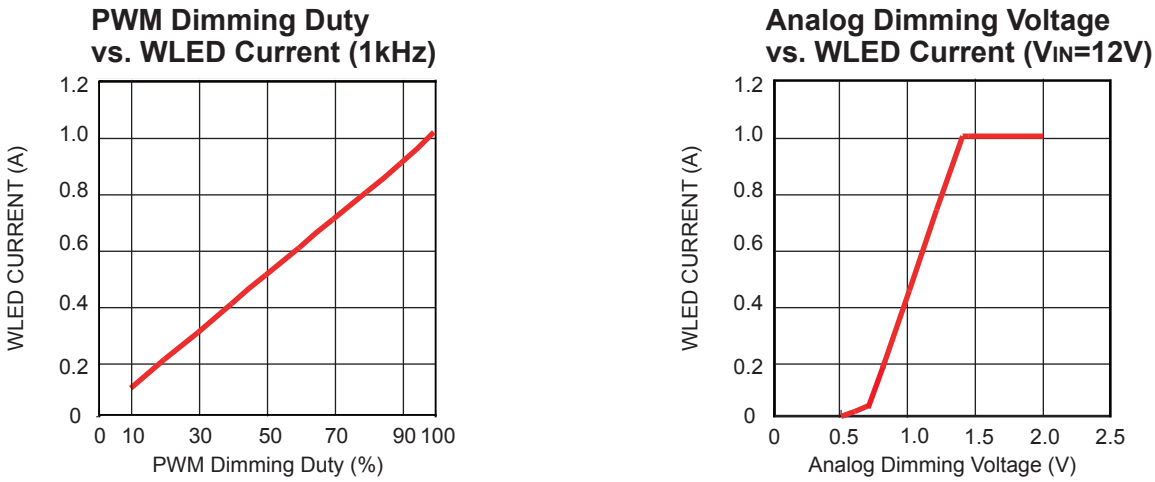

Figure 5—The Dimming-test Curve for Buck-boost Configuration Design

Figure 4 shows the bench-test waveforms for buck configuration design. The input voltage range is very broad for normal operation, and the output LED current is well regulated to a constant 1A current. **Figure 5** shows the dimming-test curve, the WLED current changes with both PWM dimming duty and analog dimming voltage (0.7V~1.4V) linearly. For most applications, the only change needed is to adjust the OVP point and the value of sensing resistor according to the actual LED voltage drop and current requirement to meet the required target.

CONCLUSION

Compared to other white LED driver, MP2481 is a unique and excellent solution for WLED driver with the following advantage:

- **Flexible configuration (either buck or inverting buck-boost applications)**
- **Internal 36V power switch**
- **Wide supply voltage range (4.5V~36V)**
- **Single Pin to realize Analog Dimming and PWM Dimming**

Therefore, MP2481 offers a high performance, high-powered, greatly flexible design solution for constant-current WLED driving.

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