

High Frequency True PWM Dimming White LED Driver MP3304 and MP3305

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As a new lighting industry revolution, the development of LED technology promoted innovative power-saving projects with worldwide attention. Compared with the traditional lighting source, White LED (WLED) solutions can provide more luminance with less power-loss and for an extended range of applications. In addition to LCD backlighting, WLEDs are also employed for low-power lighting fixture, automobile lighting, decorative illumination, and camera flashlights.

Since the WLED brightness is required to be modified according to the actual situations, the WLED driver must support an efficient solution for brightness dimming. The WLED's brightness is controlled by the forward current through the WLED devices. The voltage drop variations on WLEDs are not uniform, so the exact and flexible output current control is particularly important for brightness regulation.

The current mainstream dimming modes include analog dimming and PWM (Pulse Width Modulation) dimming:

The analog dimming control is a linear dimming mode that changes brightness by changing the WLED's forward current proportionally. It is easy to implement without potential EMC/EMI risk. But based on the WLED's characteristic, the color spectrum excursion is obvious following the change of the WLED's forward current and the human-eye is sensitive to this difference. So the WLED manufacturers recommend a given forward current range for perfect brightness and color spectrum.

To guarantee more effective dimming control, the PWM dimming control is preferred to change brightness by modulating the WLED's forward current from a 0% to 100% duty-adjustable pulse. That is the WLED brightness controlled by adjusting the relative ratios of the on time and the off time. If the dimming frequency is higher than the human-eye sensitive range (>100Hz), we can only perceive the effective brightness by averaging the on time and the off time. The average LED current corresponds to the duty cycle of the PWM signal is shown in the following equation:

$$I_{LED_AVG} = D \times I_{LED_MAX}$$

The maximum forward current is always constant at the recommended value during the on time, so WLED color spectrum doesn't vary as that in analog dimming. And it is also a pure digital dimming mode. So PWM dimming mode is more popular for the current generation of WLED applications, especially in complicated dimming control scheme.

The familiar PWM dimming frequency range is less than 1kHz. Due to the piezoelectric effect of the ceramic capacitors and the oscillation of wire winding coil, the discrete low frequency (relative to the WLED driver's switching frequency) dimming cycles can possibly cause audible noise in the system. Since the range of audio frequencies, usually from 15Hz to 20kHz, is audible to the normal human ear, higher than 20kHz dimming frequency will give the designer more selection to prevent EMI and audio problems.

MPS offers various solutions to drive WLEDs. MP3304 and MP3305 are new products whose high frequency true PWM dimming technology provides high performance to meet the broader variety dimming requirement.

This application note introduces WLED drive solutions based on MP3304 and MP3305.

MP3304 INTRODUCTION

MP3304 is an 8-pin power device integrated step-up WLED driver with fixed 2.2MHz operating frequency suitable for driving arrays of WLEDs from 5V input or a single cell Lithium Ion battery. It achieves 1.3A peak output current and incorporates both Enable and PWM dimming with a single control pin. MP3304 features up to 50kHz true PWM dimming, which allows the flexible control of the backlighting luminance under wide range of the ambient brightness, and also avoids the possibility of PWM dimming audible noise. Complete fault condition protection includes under-voltage lockout,

cycle-by-cycle peak current limiting, output over-voltage shutdown and thermal overload protection preventing damage in the event of an output overload. (Please refer to datasheet of MP3304 for details.)

The MP3304 has several selections on the over-voltage protection threshold as the **Table 1** shown below:

Table 1—MP3304 OVP Shutdown Threshold

Part Number	OVP Threshold (V_{OVP})
MP3304A	38V
MP3304B	26V
MP3304C	20V

The MP3305 has an OVP pin which can be used for programming the over voltage protection threshold externally with a resistor divider. In the following sections, the MP3304 is taken for detailed explanation.

REFERENCE DESIGN

WLED array is the common configuration for backlight applications. Conventionally, the step-up converters are used in the WLED driver application from a single cell Lithium Ion battery. Configured in boost mode, MP3304 can well regulate the WLED current to follow the variety of applications.

The step-up configuration with MP3304 for the LCD panel backlight application is shown in **Figure 1**. The backlighting source is a WLED array (3 WLEDs in series, 10 strings paralleled). It is suitable for the 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 2** and **Table 3**.

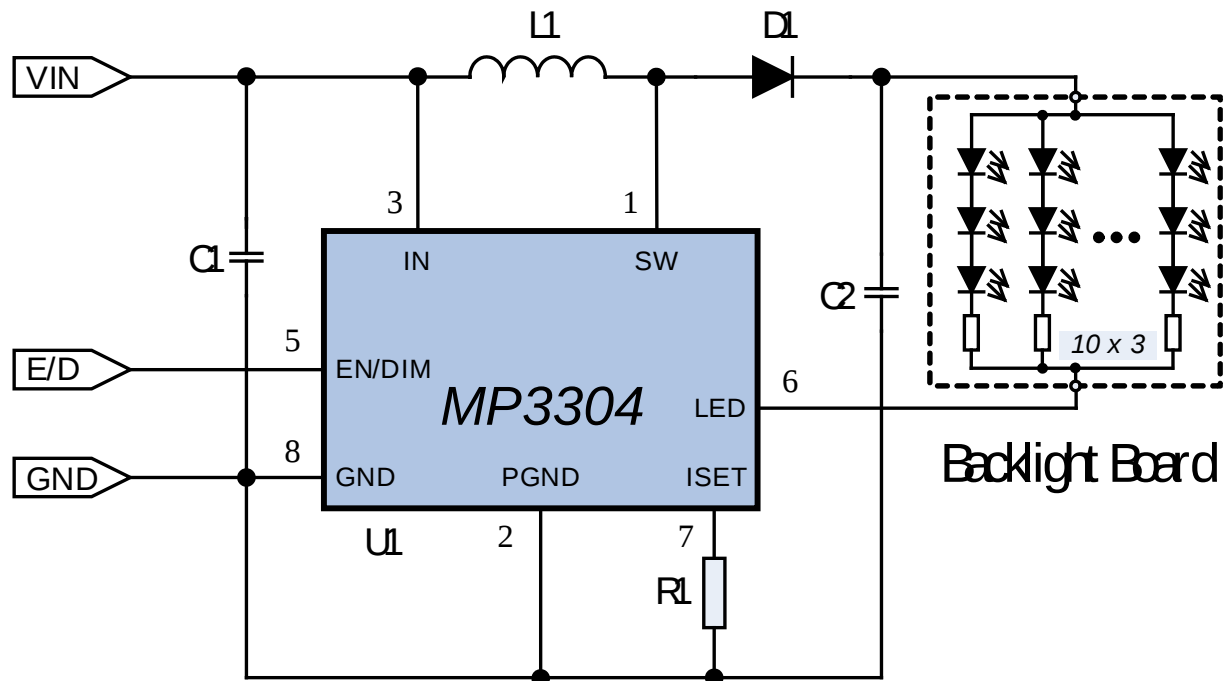


Figure 1—Application for Driving WLED Array

Table 2—Specifications for Driving WLED Array

Input Voltage	5V±10%
LED Forward Voltage	9V ~ 11V
LED Current	200mA
Open LED Protection	Yes

Table 3—BOM List for Driving WLED Array

Qty	Ref	Value	Description	Package	Manufacturer	Manufacturer P/N
1	C1	4.7uF	Ceramic Capacitor,16V,X5R	0805	muRata	GRM21BR61C475KA88
1	C2	2.2uF	Ceramic Capacitor,25V,X7R	0805	muRata	GRM21BR71E225KA73L
1	D1	B0530	Diode Schottky	SOD-123	Diodes Inc.	B0530W
1	L1	2uH	Inductor 2.8A	D53LC	TOKO	D53LC-#A915AY-2R0M
1	R1	1Ω	1%	0805	Yageo	RC0805FR-071RL
1	U1	MP3304CDD	MPS WLED Driver	QFN8(2x3mm)	MPS	MP3304CDD-LF-Z

With the integrated power device, internal compensation and protection mechanism, the external component count required by MP3304 is minimized.

The input filter capacitors (C1) are recommended with X5R or X7R dielectrics ceramic capacitor for low ESR and small temperature coefficients. The voltage stress applied on the rectifier diode (D1) is V_O , considering some derating of the diode in practical applications, a 500mA/30V Schottky diode can be used for most applications.

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

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

Where V_{IN} is the lowest input voltage, V_{OUT} is the output voltage, ΔI_L is the inductor ripple current,

For MP3304 in boost mode, designing ΔI_L approximately equal to 0.6A is a good choice.

In this application, $V_{IN-MIN}=4.5V$, $V_{OUT}=11V$, $f_{SW}=2.2MHz$, the calculated $L=2\mu H$. So a $2\mu H$ inductor could be selected.

For most application, a $2\mu H$ to $10\mu H$ with suitable DC current rating is recommended. If the calculation of above equations results in an inductance greater than $10\mu H$, a $10\mu H$ inductor is still preferred.

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

MP3304 is turned off if an over-voltage condition is present due to an open circuit condition. The Over Voltage Protection (OVP) function is triggered by SW pin. If the SW voltage goes too high, the Open Load protection will shut off MP3304. In some cases an LED may fail, this will result in the feedback voltage always being zero. The part will run at maximum duty cycle boosting the output voltage higher and higher. If the output voltage ever exceeds the open load protection threshold voltage, MP3304 will shut down. The part will not switch again until the power is recycled.

To make sure the MP3304 functions properly and to avoid the OVP detection mistriggering, careful attention must be paid to the PCB board layout and component placement to reduce the noise on SW pin. Proper layout of the high frequency switching path is critical to prevent noise and electromagnetic

interference problems. The loop of MP3304 SW to GND pin, output diode, and output capacitor is flowing with high frequency ripple current, it must be as short as possible. And the proper output cap value is also helpful.

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**:

$$R_{SENSE} = \frac{0.200}{I_{LED}} \quad \text{Eq. 2}$$

Where R_{SENSE} is the resistor $R1$ in **Figure 1**.

For 200mA output LED current in the application shown in **Figure 1**, a 1Ω current sense resistor is required.

Figure 2 shows the bench-test waveform for this design. The input voltage is 5V and the output LED current is regulated to 200mA. The OVP threshold of MP3304C is about 20V.

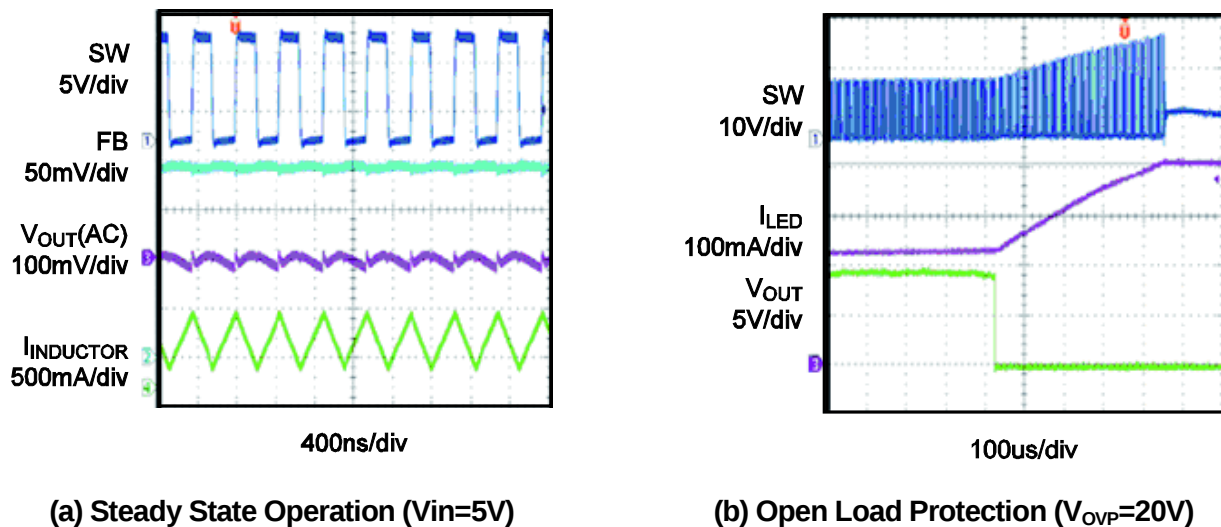


Figure 2—The Bench-test Waveform for Reference Design

HIGH FREQUENCY TRUE PWM DIMMING

MP3304 accepts PWM dimming and Enable signals with a single control pin. When $V_{EN/DIM} - V_{GND}$ is less than 0.4V, the chip is turned off. If $V_{EN/DIM} - V_{GND}$ is higher than 1.8V, maximum WLED current will be generated. If a PWM dimming signal is applied, its high level must be greater than 2V and low level must be lower than 0.4V. The PWM square waveform frequency can be set from 250Hz to up to 50kHz, which is beyond audible spectrum.

MP3304 uses the integrated dimming control switch to modulate the output WLED current. (MP3304 dimming configuration is shown in **Figure 3**) During dimming on time, the dimming switch is turned on to conduct the WLED current. The LED current flows into LED pin and out from ISET pin, LED current is hence sensed at the ISET pin for step-up converter feedback regulation. When the PWM signal is off, the dimming switch cuts off the WLED current conduction loop to turn off the WLED. So the WLED current vanishes very quickly. Once the dimming switch is disconnected, the chip stops boost switching simultaneously and the output voltage remains almost unchanged. The boost switching resumes to normal operation at the beginning of the next PWM period. As the output voltage keeps at a DC voltage without dimming frequency ripple. The audible noise can be prevented.

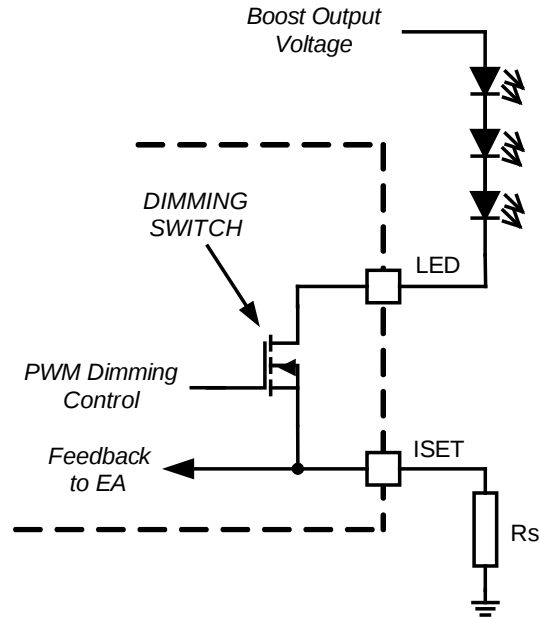
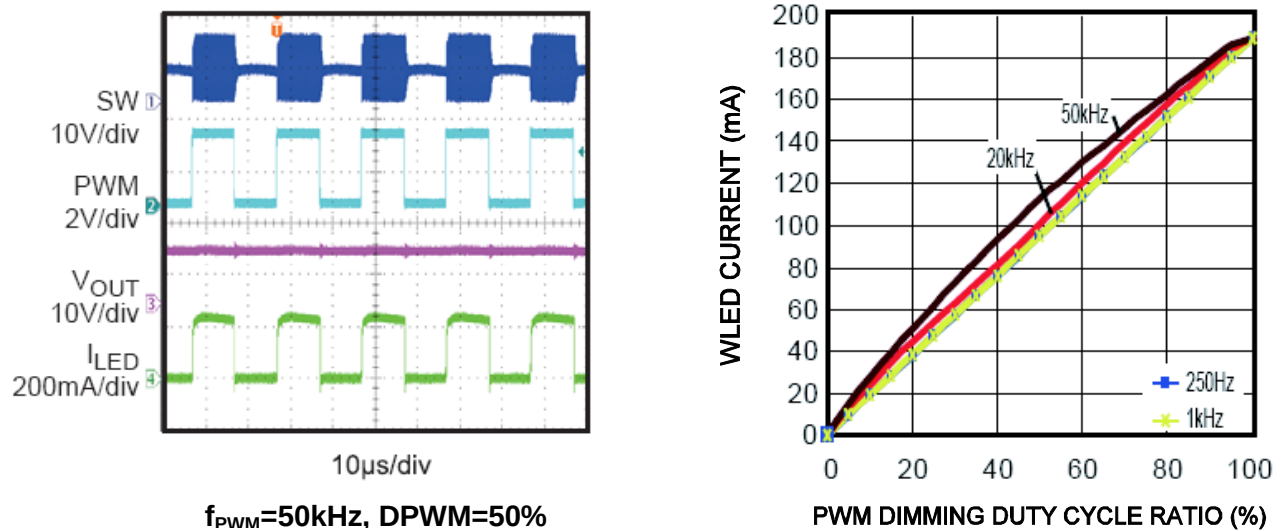


Figure 3—Internal Dimming Configuration

Figure 4 shows the dimming-test waveform and curve. Due to the dimming control switch, the output WLED current is modulated by PWM dimming signal. The average WLED current changes linearly with the wide frequency range of the PWM dimming duty cycle ratio.



CONCLUSION

Compared to other white LED driver, MP3304 is an excellent high frequency dimming solution for WLED driver with the following advantages:

- **Low cost off-the-shelf components**
- **Internal 40V power switch**
- **Wide PWM dimming frequency range (250Hz to 50kHz)**
- **High Frequency true PWM dimming with audible noise prevention**

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