**DESCRIPTION**

The MP3309L is a WLED step-up converter for 2.7V-to-5.5V input that uses peak-current mode to regulate the LED current sensed through an external, low-side resistor. The 200mV feedback voltage and synchronous rectification reduces power loss and reduces PCB space requirements.

The MP3309L features a programmable switching frequency to optimize efficiency. It supports both analog and PWM dimming.

In addition, the MP3309L has LED open protection, cycle-by-cycle current limit protection, thermal shutdown protection.

**FEATURES**

- 2.7V-to-5.5V Input Voltage
- Analog and PWM Dimming
- Programmable Switching Frequency
- 24V Open-Load Protection
- Low 200mV Feedback Voltage with ±1% Accuracy at Room Temperature
- UVLO, Thermal Shutdown
- Available in a 1.4×1.8mm FCQFN10 Package

**APPLICATIONS**

- Feature Phones and Smart Phones
- Tablets
- <10inch Video Displays

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## ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Part Number*</th>
<th>Package</th>
<th>Top Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP3309LGQG</td>
<td>QFN-10 (1.4mmx1.8mm)</td>
<td>See Below</td>
</tr>
</tbody>
</table>

* For Tape & Reel, add suffix –Z (e.g. MP3309LGQG–Z).

## TOP MARKING

- **CU**: product code of MP3309LGQG;
- **LL**: lot number;

## PACKAGE REFERENCE

- **TOP VIEW**

![FCQFN10 (1.4×1.8mm)](image-url)
ABSOLUTE MAXIMUM RATINGS (1)

VIN ................................................... -0.3V to +6V
VSW, VOUT .............................................. -1V to +40V
VBST ................................................ ..-0.3V to VSW +6V
All Other Pins .............................................. -0.3V to +6V
Junction Temperature ................................. 150°C
Lead Temperature ....................................... 260°C

Continuous Power Dissipation ....(TA = 25°C) (2)
QFN-10 (1.4mm×1.8mm) .................................. 0.892W

Recommended Operating Conditions (3)
Supply Voltage VIN ................................. 2.7V to 5.5V
Operating Junction Temp. (TJ) ................................. -40°C to +125°C

Thermal Resistance (4) θJA θJC
QFN-10 (1.4mm×1.8mm) .............................. 140 ...... 30 °C/W

Notes:
1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature Tj (MAX), the junction-to-ambient thermal resistance θJA, and the ambient temperature TA. The maximum allowable continuous power dissipation at any ambient temperature is calculated by PD (MAX) = (Tj (MAX) - TA) / θJA. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.
### ELECTRICAL CHARACTERISTICS

\( V_{IN} = 3.6V, V_{EN} = V_{IN}, T_A = 25°C, \) unless otherwise noted.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbol</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
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<tbody>
<tr>
<td><strong>STEP-UP CONVERTER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Input Voltage</td>
<td>( V_{IN} )</td>
<td>( V_{IN} = 3.6V, V_{EN} = V_{IN}, ) no load with switching</td>
<td>2.7</td>
<td>5.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Supply Current (Quiescent)</td>
<td>( I_Q )</td>
<td>( V_{EN=0V}, V_{IN}=3.6V )</td>
<td>420</td>
<td></td>
<td></td>
<td>( \mu A )</td>
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<tr>
<td>Supply Current (Shutdown)</td>
<td>( I_{ST} )</td>
<td>( EN\ Bit=0, V_{IN}=3.6V )</td>
<td>1</td>
<td></td>
<td></td>
<td>( \mu A )</td>
</tr>
<tr>
<td>Input UVLO Threshold</td>
<td>( V_{IN_UVLO} )</td>
<td>Rising Edge</td>
<td>68</td>
<td></td>
<td></td>
<td>( \mu A )</td>
</tr>
<tr>
<td>EN High Voltage</td>
<td>( V_{EN_HIGH} )</td>
<td>( V_{EN} ) Rising</td>
<td>1.2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>EN Low Voltage</td>
<td>( V_{EN_LOW} )</td>
<td>( V_{EN} ) Falling</td>
<td>0.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Switching Frequency</td>
<td>( f_{SW} )</td>
<td>( R_{OSC} = 200k\Omega )</td>
<td>540</td>
<td>640</td>
<td>740</td>
<td>kHz</td>
</tr>
<tr>
<td>Maximum Duty Cycle</td>
<td>( D_{MAX} )</td>
<td>( \text{Sync Mode, 600kHz} )</td>
<td>89</td>
<td>93</td>
<td>95</td>
<td>%</td>
</tr>
<tr>
<td>Feedback Regulation Voltage</td>
<td>( V_{REF} )</td>
<td>( \text{Sync Mode, 600kHz} )</td>
<td>198</td>
<td>200</td>
<td>202</td>
<td>mV</td>
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<tr>
<td>VREF Ramp-Up Time</td>
<td>( t_{STEP} )</td>
<td></td>
<td>320</td>
<td></td>
<td></td>
<td>( \mu s )</td>
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<tr>
<td><strong>POWER SWITCH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Switch On-Resistance</td>
<td>( R_{DSON_M} )</td>
<td>( V_{IN}=3.6V )</td>
<td>0.3</td>
<td>0.5</td>
<td></td>
<td>( \Omega )</td>
</tr>
<tr>
<td>Sync Switch On-Resistance</td>
<td>( R_{DSON_S} )</td>
<td>( V_{IN}=3.6V )</td>
<td>0.5</td>
<td>0.8</td>
<td></td>
<td>( \Omega )</td>
</tr>
<tr>
<td><strong>CURRENT DIMMING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PWMH Input Low Threshold</td>
<td>( V_{PWM_LO} )</td>
<td>( V_{PWM} ) Falling</td>
<td>0.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>PWMH Input High Threshold</td>
<td>( V_{PWM_HI} )</td>
<td>( V_{PWM} ) Rising</td>
<td>1.2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>PWML Shutdown Time</td>
<td>( t_{SD} )</td>
<td>( EN/PWML ) High to Low</td>
<td>20</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td><strong>PROTECTION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OVP Voltage</td>
<td>( V_{OVP} )</td>
<td>OVP</td>
<td>22.5</td>
<td>24</td>
<td>25.5</td>
<td>V</td>
</tr>
<tr>
<td>Cycle-Cycle Current Limit</td>
<td>( I_{LIM} )</td>
<td>Hysteresis</td>
<td>2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Startup Current Limit</td>
<td>( I_{LIM_START} )</td>
<td>Max Duty Cycle</td>
<td>0.85</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Time Step for Half Current Limit</td>
<td>( T_{LIM_HALF} )</td>
<td>Max Duty Cycle</td>
<td>5</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td>OVP UVLO Threshold</td>
<td>( V_{OVP_UV} )</td>
<td></td>
<td>1.24</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Thermal Shutdown Threshold</td>
<td>( t_{ST} )</td>
<td></td>
<td>150</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Thermal Shutdown Hysteresis</td>
<td></td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>
MP3309L—2.7V-5.5V INPUT, 24V OUTPUT, fs-PROGRAMMABLE, WHITE LED DRIVER

TYPICAL PERFORMANCE CHARACTERISTICS

Vin = 3.6V, 7 LEDs, L = 10µH, TA = 25°C, unless otherwise noted.

Efficiency vs. Vin

Steady State

VIN Power On

EN Power On

PWM Dimming

fDIM = 200Hz, DDIM = 50%

Analog Dimming

fDIM = 20kHz, DDIM = 90%

Open LED Protection
## PIN FUNCTIONS

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 10</td>
<td>PWMH</td>
<td>Analog Dimming Input. &gt;20kHz PWM signal is recommended if using a PWM signal input for analog dimming.</td>
</tr>
<tr>
<td>2</td>
<td>VIN</td>
<td>Input Supply Pin. Provides power for internal power and logic circuits. Must be locally bypassed.</td>
</tr>
<tr>
<td>3</td>
<td>EN/PWML</td>
<td>PWM Brightness Control/Enable. Apply a PWM signal for PWM dimming. The LED current dimming ratio is proportional to the PWM frequency—a lower dimming frequency results in a smaller dimming current. For most applications, use a frequency range of 200Hz to 2kHz. A low-level signal longer than 20ms will shutdown the IC.</td>
</tr>
<tr>
<td>4</td>
<td>RFEQ</td>
<td>Switching Frequency Set. Connect a resistor between this pin and GND to program the converter switching frequency. Do not leave this pin floating.</td>
</tr>
<tr>
<td>5</td>
<td>FB</td>
<td>LED Current Feedback. Regulates the voltage across the current sense resistor between FB and GND to 200mV.</td>
</tr>
<tr>
<td>6</td>
<td>GND</td>
<td>Ground.</td>
</tr>
<tr>
<td>7</td>
<td>SW</td>
<td>Power Switch Node. Drain of the internal low-side MOSFET. Connect the power inductor between SW and VIN pin.</td>
</tr>
<tr>
<td>8</td>
<td>VOUT</td>
<td>Output Voltage. Internally connected to the source of the synchronous MOSFET.</td>
</tr>
<tr>
<td>9</td>
<td>BST</td>
<td>Booststrap. Connect a capacitor between SW and BST pin to provide the synchronous MOSFET gate driver.</td>
</tr>
</tbody>
</table>
Figure 1: Functional Block Diagram
OPERATION

The MP3309L uses peak-current-mode control to regulate the current through the WLED string. At the start of each oscillator cycle, the control circuit turns on the low-side MOSFET (LS-FET, M1). A stabilizing ramp added to the output of the current-sense amplifier, which then feeds into the positive input of the PWM comparator, prevents sub-harmonic oscillations at duty cycles greater than 50%. When the input to the PWM comparator equals the output voltage of the error amplifier, M1 turns off. Then the inductor current flows through the synchronous power MOSFET, which forces the inductor current to decrease.

The voltage at the output of the error amplifier is the amplified difference between the 200mV reference voltage and the feedback voltage. If the feedback voltage starts to drop, the output of the error amplifier increases, increasing the current flowing through the M1, thus increasing the power to the inductor and output power. This method accurately regulates the LED current.

System Startup

When enabled, the MP3309L checks safety limits, including UVLO and over-temperature protection (OTP), over-current protection. If all the protection tests pass, the chip then starts boosting the step-up converter with an internal soft-start. During the soft-start, the current limit drops to 0.85A during startup to prevent a large inrush current. This low-current-limit time lasts for 5ms after the IC is enabled.

Dimming Control

The MP3309L provides two dimming methods: PWM and analog dimming mode.

For PWM dimming, apply a PWM signal to the EN/PWML pin. The LED current is then segmented as per the PWM signal and the average LED current equals:

\[ I_{\text{set}} \times D_{\text{dim}} \]

Where \( D_{\text{dim}} \) is the PWM duty cycle, and \( I_{\text{set}} \) is the LED current amplitude. When PWM signal is high, the converter operates in normal mode. Conversely, when the PWM amplitude is low, the converter stops switching. Make sure that the PWM-signal low-level time is less than 20ms or the IC will shut down. Use a 100Hz-to-2kHz PWM-dimming frequency for most dimming ratio requests.

For analog dimming, connect the PWM dimming signal on PWMH pin, an internal RC filter filters the PWM signal. The LED current amplitude equals \( I_{\text{set}} \times D_{\text{dim}} \), where \( D_{\text{dim}} \) is the PWM duty cycle and \( I_{\text{set}} \) is the LED current amplitude. Use a >20kHz PWM signal to improve filtering performance.

Open-String Protection

The MP3309L monitors the VOUT pin for open-string protection. If the LED string is open, the feedback voltage is lower than the reference voltage. The COMP then rises and charges the output capacitor until the VOUT voltage reaches the protection point, \( V_{\text{OVP}} \).

The IC stops switching when \( V_{\text{OUT}} \) reaches the OVP threshold, the IC resumes function when \( V_{\text{OUT}} \) drops below the threshold.

Input Under-Voltage Protection

When VIN exceeds 2.5V, the converter starts to charge the internal reference and provides power to the internal control circuitry. There is UVLO hysteresis, approximately 200mV, as VIN falls. The IC shuts down when the input voltage drops below 2.3V.

Thermal-Shutdown Protection

Thermal shutdown prevents the IC from operating at exceedingly high temperatures. When the die temperature exceeds the upper threshold (\( T_{\text{ST}} \), the IC shuts down and resumes normal operation when the die temperature drops below lower threshold. Typically, the hysteresis is 25°C.
APPLICATION INFORMATION

Selecting the Switching Frequency
The switching frequency of the step-up converter can be programmed from 300kHz to 1.2MHz. A resistor on the OSC pin sets the internal oscillator frequency for the step-up converter as per the equation below:

\[ f_{SW}(kHz) = \frac{120000}{R_{OSC}(k\Omega)} \]

For instance, if \( R_{OSC}=200k\Omega \), the switching frequency is to 600kHz.

Setting the LED Current
Set the LED current through the current-setting resistor on the FB pin.

\[ I_{LED}(mA) = \frac{V_{REF}(V)}{R_{FB}(\Omega)} \times 1000 \]

For instance, if \( V_{REF}=200mV \), and \( R_{FB}=10\Omega \), the LED current is 20mA. Do not leave the FB pin floating.

Selecting the Input Capacitor
The input capacitor reduces the surge current drawn from the input supply and the switching noise from the device. The input capacitor impedance at the switching frequency should be less than the input source impedance to prevent the high-frequency switching current from passing through to the input. Use ceramic capacitors with X5R or X7R dielectrics for their low ESR and small temperature coefficients. For most applications, use a 2.2µF-to-10µF ceramic capacitor.

Selecting the Inductor
The MP3309L requires an inductor to boost its output voltage. A larger value inductor results in less ripple current, lowering both the peak-inductor current and the stress on the internal N-channel MOSFET. However, the larger inductor is physically larger, has a higher series resistance, and a lower saturation current.

Choose an inductor that does not saturate under the worst-case load conditions. Select the minimum inductor value to ensure that the boost converter works in continuous-conduction mode with high efficiency and good EMI performance. Calculate the required inductance value using the equation:

\[ L \geq \frac{\eta \times V_{OUT} \times D \times (1-D)^2}{2 \times f_{SW} \times I_{LOAD} \times V_{IN} \times V_{OUT}} \]

Where \( V_{IN} \) and \( V_{OUT} \) are the input and output voltages, \( f_{SW} \) is the switching frequency, \( I_{LOAD} \) is the LED load current, and \( \eta \) is the efficiency.

The switching current for peak-current mode. To avoid hitting the current limit, the worst-case inductor peak current should be less than 80% of the current limit, \( I_{LIM} \).

Selecting the Output Capacitor
The output capacitor keeps the output voltage ripple small and ensures feedback loop stability. The output capacitor impedance must be low at the switching frequency. Ceramic capacitors with X7R dielectrics are recommended for their low ESR characteristics. Selection must also account for the capacitance’s dependence on the voltage rating; with a DC bias voltage, the capacitor can lose as much as 50% of its capacitance at its rated voltage rating. Leave a sufficient voltage rating margin when select the component.

Too-low or too-high capacitance will cause loop instability. For most applications, select a capacitor in the range of 0.1µF to 1µF.

Layout Considerations
Careful attention must be paid to the PCB board layout and components placement. Proper layout of the high frequency switching path is critical to prevent noise and limit electromagnetic interference. The loop consisting of MP3309L’s internal low-side MOSFET, synchronous MOSFET, and output capacitor contains a high-frequency ripple current—minimize this loop. Place the input and output capacitor should as to the IC as possible.
TYPICAL APPLICATION CIRCUITS

Figure 2: Typical Application for Single String 7LEDs

Figure 3: Typical Application for 3X3 LED Array
Figure 4: Typical Application for More Noise Robust Test
PACKAGE INFORMATION

QFN-10 (1.4mmX1.8mm)

**TOP VIEW**

**BOTTOM VIEW**

**SIDE VIEW**

**RECOMMENDED LAND PATTERN**

**NOTE:**
1) ALL DIMENSIONS ARE IN MILLIMETERS
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH
3) LEAD COPLANARITY SHALL BE 10 MILLIMETER MAX
4) JEDEC REFERENCE IS MO-220.
5) DRAWING IS NOT TO SCALE

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