### Description

The **XR46203** is a two-step LED current controller with line regulation compensation for operating over a wide alternative current (AC) voltage source range. It can drive an external N-channel power MOSFET to regulate the current flowing through a high voltage (HV) LED string.

The XR46203 works as a constant current sink with linear type over voltage protection (OVP), linear type over temperature protection (OTP), and line regulation compensation. It is suitable for applications with a rectified AC voltage source.

The PCB design can be very compact to meet various shape requirements. It is especially suitable for replacing incandescent light bulb and linear type fluorescent lamps.

### Typical Application

**Figure 1. Typical 2-Step Application**
Absolute Maximum Ratings

Stresses beyond the limits listed below may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Sustaining Voltage

- VIN, GATE, Source to GND: -0.3V to 85V
- GATE to Source: -0.3V to 7V
- Source to CS: -0.3V to 70V
- VL to GND: -0.3V to 7V
- CS to GND: -0.3V to 1V

VIN Input Current: 3mA

Source to CS Current: 180mA

Maximum Operating Junction Temperature, $T_J$: 150°C

Operating Temperature, $T_{opr}$: -40°C to 85°C

Storage Temperature Range: -55°C to 150°C

Lead Temperature (Soldering, 10 seconds): 260°C

NOTE:
1. All voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.
2. All parameters having Min/Max specifications are guaranteed. Typical values are for reference purposes only.
3. Unless otherwise noted, all tests are pulsed tests at the specified temperature, therefore: $T_J = T_C = T_A$.

Operating Conditions

Input Voltage, $V_{\text{IN}}$: 6 to 78V

Peak Level Current, $I_{\text{PEAK}}$: 20 to 180mA
## Electrical Characteristics

Unless otherwise noted, typical values are at $T_A = 25^\circ C$.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IN_{MIN}}$</td>
<td>Minimum $V_{IN}$ supply voltage</td>
<td>$V_{IN} = 6V$ to $73V$</td>
<td>$V_{IN} = 6V$ to $73V$</td>
<td>6</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$I_{IN}$</td>
<td>$V_{IN}$ supply current</td>
<td>$I_{IN}$ will increase to $&gt;1mA$ to clamp $V_{IN}$ at $V_{IN_{Clamp}}$</td>
<td>$I_{IN}$ will increase to $&gt;1mA$ to clamp $V_{IN}$ at $V_{IN_{Clamp}}$</td>
<td>0.3</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$V_{IN_{Clamp}}$</td>
<td>$V_{IN}$ over voltage clamp</td>
<td>When $V_{IN} &gt; V_{IN_{Clamp}}$, $I_{IN}$ will increase to $&gt;1mA$ to clamp $V_{IN}$ at $V_{IN_{Clamp}}$</td>
<td>When $V_{IN} &gt; V_{IN_{Clamp}}$, $I_{IN}$ will increase to $&gt;1mA$ to clamp $V_{IN}$ at $V_{IN_{Clamp}}$</td>
<td>74</td>
<td>76</td>
<td>80</td>
<td>V</td>
</tr>
<tr>
<td>$V_{CS}$</td>
<td>$CS$ voltage</td>
<td>$V_{VL} = 1.75V$</td>
<td>$V_{VL} = 1.75V$</td>
<td>244</td>
<td>250</td>
<td>256</td>
<td>mV</td>
</tr>
<tr>
<td>$\Delta V_{LR1}$</td>
<td>$CS$ voltage line regulation vs. $V_{VL}$</td>
<td>$V_{VL} = 1.75V$ to $1.75V$</td>
<td>$V_{VL} = 1.75V$ to $1.75V$</td>
<td>-0.28</td>
<td></td>
<td></td>
<td>mV/mV</td>
</tr>
<tr>
<td>$\Delta V_{LR2}$</td>
<td>$CS$ voltage line regulation vs. $V_{VL}$</td>
<td>$V_{VL} = 1.75V$ to $2.10V$</td>
<td>$V_{VL} = 1.75V$ to $2.10V$</td>
<td>-0.24</td>
<td></td>
<td></td>
<td>mV/mV</td>
</tr>
<tr>
<td>$\Delta V_{LR3}$</td>
<td>$CS$ voltage line regulation vs. $V_{VL}$</td>
<td>$V_{VL} = 2.10V$ to $2.28V$</td>
<td>$V_{VL} = 2.10V$ to $2.28V$</td>
<td>-0.3</td>
<td></td>
<td></td>
<td>mV/mV</td>
</tr>
<tr>
<td>$V_{REF1}/V_{REF0}$</td>
<td>Reference voltage ratio</td>
<td></td>
<td></td>
<td>86</td>
<td>90</td>
<td>94</td>
<td>%</td>
</tr>
<tr>
<td>$V_{CS_{Clamp}}$</td>
<td>Maximum $V_{CS}$ clamp</td>
<td>$VL$ under voltage protection, $V_{VL} &lt; 1.45V$</td>
<td>$VL$ under voltage protection, $V_{VL} &lt; 1.45V$</td>
<td>310</td>
<td>323</td>
<td>336</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{Gate}$</td>
<td>Gate voltage</td>
<td>Gate to Source</td>
<td>Gate to Source</td>
<td>5.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$I_{SOURCE}$</td>
<td>GATE source current$^{(2)}$</td>
<td>$V_{Gate}$ - $V_{Source} = 3V$</td>
<td>$V_{Gate}$ - $V_{Source} = 3V$</td>
<td>30</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$I_{SINK}$</td>
<td>GATE sink current$^{(2)}$</td>
<td>$V_{Gate}$ - $V_{Source} = 3V$</td>
<td>$V_{Gate}$ - $V_{Source} = 3V$</td>
<td>500</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$T_{TP}$</td>
<td>Thermal protection trip temperature$^{(2)}$</td>
<td>When $T_J$ is higher than $T_{TP}$, $V_{CS}$ decreases linearly</td>
<td>When $T_J$ is higher than $T_{TP}$, $V_{CS}$ decreases linearly</td>
<td>135</td>
<td>145</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>$\Delta V_{CS}/\Delta T_J$</td>
<td>Thermal protection mode $V_{CS}$ decreasing slope$^{(2)}$</td>
<td>$T_J &gt; T_{TP}$</td>
<td>$T_J &gt; T_{TP}$</td>
<td>-1.1</td>
<td></td>
<td></td>
<td>%/°C</td>
</tr>
</tbody>
</table>

### Notes:
1. The $CS$ voltage line regulation is defined as:

\[
\Delta V_{LR1} = \frac{\Delta V_{CS}}{\Delta V_{VL}} = \frac{V_{CS}(V_{VL} = 1.75V) - V_{CS}(V_{VL} = 1.57V)}{1.75V - 1.57V}
\]
\[
\Delta V_{LR2} = \frac{\Delta V_{CS}}{\Delta V_{VL}} = \frac{V_{CS}(V_{VL} = 2.10V) - V_{CS}(V_{VL} = 1.75V)}{2.10V - 1.75V}
\]
\[
\Delta V_{LR3} = \frac{\Delta V_{CS}}{\Delta V_{VL}} = \frac{V_{CS}(V_{VL} = 2.28V) - V_{CS}(V_{VL} = 2.10V)}{2.28V - 2.10V}
\]

2. Guarantee by design, not by production test.
Pin Configuration

3mm x 3mm TDFN-8, Top View

Pin Functions

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Pin Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VIN</td>
<td>Power supply pin.</td>
</tr>
<tr>
<td>2</td>
<td>NC</td>
<td>No connection.</td>
</tr>
<tr>
<td>3</td>
<td>VL</td>
<td>Line regulation sense pin. The reference voltage is adjusted according to VL to provide the line regulation compensation and to provide over voltage protection.</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>Ground pin.</td>
</tr>
<tr>
<td>5</td>
<td>CS</td>
<td>Current sense pin. Connect a sense resistor, $R_{CS}$, between this pin and the GND pin. The peak current is set by: $I_{OUT} = \frac{V_{CS}}{R_{CS}}$.</td>
</tr>
<tr>
<td>6</td>
<td>NC</td>
<td>No connection.</td>
</tr>
<tr>
<td>7</td>
<td>Source</td>
<td>External HV NMOS source pin. The $V_F$ of the LED segment connected between the source pin and the CS pin should not be higher than 70V.</td>
</tr>
<tr>
<td>8</td>
<td>GATE</td>
<td>External HV NMOS gate driving pin. Limited to 5.5V maximum.</td>
</tr>
<tr>
<td></td>
<td>Exposed Thermal Pad (EP)</td>
<td>Exposed thermal pad of the chip. Use this pad to enhance the power dissipation capability. The thermal conductivity will be improved if a copper foil on PCB is soldered with the thermal pad. It is recommended to connect the exposed thermal pad to the GND pin.</td>
</tr>
</tbody>
</table>
Functional Block Diagram

Figure 2. Functional Block Diagram
Applications Information

Typical Application

For a typical 2-step driving scheme using a single XR46203, the electrical performance is good enough to meet applications where the Power Factor (PF) is higher than 0.92 and the Total Harmonic Distortion (THD) is around 30%. If higher PF or lower THD is required, one more XR46083 or XR46084 can be added to the circuit to make a 3-step driving scheme, as shown in below. The 3-step system can provide better electrical performance with PF greater than 0.96 and THD approximately 20%. Line regulation, THD and PF performance are illustrated in Figures 5 and 6.

For a discussion regarding the basic circuit operation of MaxLinear’s AC step drivers, see XR46083 Application Note.

![Figure 3. 2-Step (PF > 0.92, THD = ~30%)](image3.png)

![Figure 4. 3-Step (PF > 0.96, THD = ~20%)](image4.png)

![Figure 5. THD and PF vs. $V_{AC}$ for 3-Step Solution](image5.png)

![Figure 6. Line Regulation vs. $V_{AC}$ for 3-Step Solution](image6.png)
Applications Information (Continued)

Linear Type Thermal Protection
When the junction temperature $T_J$ rises to the Thermal Protection Trip Temperature $T_{TP}$ (typically 145°C), the current sense voltage $V_{CS}$ starts to decrease linearly at a slope of -1.1%/°C. The LED driving current decreases proportionally with the $V_{CS}$ voltage. The system will function normally during the thermal protection mode with the lower driving current, but the power dissipation of the XR46203 chip will decrease until thermal equilibrium is reached.

![Figure 7. $V_{CS}$ vs. $T_J$](image)

Line Regulation Compensation
When there is variation in line voltage ($V_{AC}$), the power of the lamp will also change if the LED driving current is kept unchanged. In order to provide good line regulation when $V_{AC}$ varies within a ±20% range, the average of the rectified $V_{AC}$ is sensed by the $V_L$ pin to provide compensation in order to attempt to keep the power of the lamp at the same level.

The LED driving current is adjusted as the voltage level $V_{VL}$ at the $V_L$ pin is changed. Based on the design, the LED driving current will be lower when $V_{AC}$ is higher than the nominal value, and the LED driving current will be higher when $V_{AC}$ is lower than the nominal value. The system power can then be maintained at approximately the same level. During power on, the driving current may be slightly higher for a few cycles until steady state is reached.

With the compensation function, the XR46203 provides excellent power line regulation over a ±20% $V_{AC}$ variation range, as shown in Figures 8 and 9.

![Figure 8. 120V$_{AC}$ Power Line Regulation (120V$_{AC}$ ±15%)](image)

![Figure 9. 230V$_{AC}$ Power Line Regulation (230V$_{AC}$ ±20%)](image)
Applications Information (Continued)

Layout Suggestion
The exposed thermal pad under the chip is used to enhance the power dissipation capability of the DFN package. The thermal conductivity will be improved if a copper foil on the PCB that is soldered to the thermal pad can be as large as possible. It is strongly recommended to connect the GND pin to the exposed thermal pad.

The external HV NMOS is also recommended to be placed close to the XR46203. In addition, the current sense resistor connected between the CS pin and GND pin should be placed as close as possible to the CS pin and GND pin, as the example in below.

Figure 10. Recommended Layout
Mechanical Dimensions

TOP VIEW

BOTTOM VIEW

SIDE VIEW

TERMINAL DETAILS

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS, ANGLES ARE IN DEGREES.
Recommended Land Pattern and Stencil

TYPICAL RECOMMENDED LAND PATTERN

TYPICAL RECOMMENDED STENCIL

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS, ANGLES ARE IN DEGREES.

Drawing No.: P0D-00000088
Revision: D
Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Operating Temperature Range</th>
<th>Lead-Free</th>
<th>Package</th>
<th>Packaging Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR46203IHBTR</td>
<td>-40°C to 85°C</td>
<td>Yes(2)</td>
<td>TDFN8 3x3</td>
<td>Tape and Reel</td>
</tr>
</tbody>
</table>

NOTE:
1. Refer to www.exar.com/XR46203 for most up-to-date Ordering Information.

Revision History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>June 2015</td>
<td>Initial Release.</td>
</tr>
<tr>
<td>1A</td>
<td>Oct 2016</td>
<td>New datasheet format, update Typical Application and update Package Description.</td>
</tr>
<tr>
<td>1B</td>
<td>Aug 2018</td>
<td>Update to MaxLinear logo. Update format.</td>
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