Description

The AL5809 is a constant current linear LED driver and it provides a cost-effective two pin solution. It has an excellent temperature stability of 20ppm/°C and the current accuracy ±5% regulated over a wide voltage and temperature range. The AL5809 comes in various fixed output current versions removing the need for external current setting resistors creating a simple solution for the linear driving of LEDs. It supports both the high-side and low-side driving of LED chains.

The AL5809 turns on when the voltage between IN and OUT swings from 2.5V up to 60V enabling it drive long LED chains. The floating ground, 60V Voltage rating between Input and Output pins designed to withstand the high peak voltage incurred in offline applications.

The AL5809 is available in either thermally robust package PowerDI123 or SOD-123 package.

Features

- 2.5V to 60V Operating Voltage Between Two Terminals
- Robust Power Package Up to 1.2W for PowerDI®-123
- -40°C to +125°C Temperature Range
- ±5% LED Current Tolerance Over-Temperature
- 15mA, 20mA, 25mA, 30mA, 40mA, 50mA, 60mA, 90mA, 100mA, 120mA, and 150mA Available in PowerDI123 Package
- 15mA, 20mA, 25mA, 30mA, 40mA and 50mA available in SOD-123 Package, Other Current Options Available by Request
- Constant Current with Low Temperature Drift and High Power Supply Rejection Ratio
- Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)
- Halogen and Antimony Free. “Green” Device (Note 3)

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
2. See http://www.diodes.com/quality/lead_free.html for more information about Diodes Incorporated’s definitions of Halogen- and Antimony-free, “Green” and Lead-free.
3. Halogen- and Antimony-free “Green” products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

Pin Assignments

Applications

- Offline LED Lamps
- LED Power Supplies
- White Goods
- LED Signs
- Instrumentation Illumination
Typical Applications Circuit

![Typical Applications Circuit Diagram](image)

Pin Descriptions

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number (PowerDI123)</th>
<th>Function</th>
</tr>
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<tbody>
<tr>
<td>In</td>
<td>1</td>
<td>LED Current Input Terminal. For low side LED string application, connect the LED cathode terminal to the “In” terminal. For high side LED string application, connect the LED anode terminal to the “Out” terminal.</td>
</tr>
<tr>
<td>Out</td>
<td>2</td>
<td>LED Current Output Terminal. For low side LED string application, connect the LED anode terminal to the “Out” terminal. For high side LED string application, connect the LED cathode terminal to the “Out” terminal.</td>
</tr>
</tbody>
</table>

Functional Block Diagram

![Functional Block Diagram](image)
## Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameters</th>
<th>Ratings</th>
<th>Unit</th>
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<tbody>
<tr>
<td>V_{InOut}</td>
<td>“In” Voltage Relative to “Out” Pin</td>
<td>-0.3 to +80</td>
<td>V</td>
</tr>
<tr>
<td>I_{InOut}</td>
<td>LED Current from “In” to “Out”</td>
<td>180</td>
<td>mA</td>
</tr>
<tr>
<td>ESD HBM</td>
<td>Human Body Model ESD Protection</td>
<td>4</td>
<td>kV</td>
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<tr>
<td>ESD MM</td>
<td>Machine Model ESD Protection</td>
<td>400</td>
<td>V</td>
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<td>T_J</td>
<td>Operating Junction Temperature</td>
<td>-40 to +175</td>
<td>°C</td>
</tr>
<tr>
<td>T_{ST}</td>
<td>Storage Temperature</td>
<td>-55 to +150</td>
<td>°C</td>
</tr>
</tbody>
</table>

**Caution:** Stresses greater than the ‘Absolute Maximum Ratings’ specified above, may cause permanent damage to the device. These are stress ratings only; functional operation of the device at these or any other conditions exceeding those indicated in this specification is not implied. Device reliability may be affected by exposure to absolute maximum rating conditions for extended periods of time. Semiconductor devices are ESD sensitive and may be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting these devices.
## Package Thermal Data

<table>
<thead>
<tr>
<th>Package</th>
<th>$\theta_{JC}$ Thermal Resistance Junction-to-Case</th>
<th>$\theta_{JA}$ Thermal Resistance Junction-to-Ambient</th>
<th>$P_{DIS}$ $T_A = +25^\circC$, $T_J = +125^\circC$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PowerDI123</td>
<td>27.15°C/W</td>
<td>148.61°C/W (Note 4)</td>
<td>0.68W</td>
</tr>
<tr>
<td>PowerDI123</td>
<td>17.81°C/W</td>
<td>81.39°C/W (Note 5)</td>
<td>1.24W</td>
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<tr>
<td>SOD-123</td>
<td>69.56°C/W</td>
<td>278.42°C/W (Note 6)</td>
<td>0.36W</td>
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## Recommended Operating Conditions

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
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<tbody>
<tr>
<td>$V_{IN\text{Out}}$</td>
<td>“In” Voltage Range Relative to “Out” Pin</td>
<td>2.5</td>
<td>60</td>
<td>V</td>
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<tr>
<td>$I_{IN\text{Out}}$</td>
<td>LED Current (Note 7)</td>
<td>15</td>
<td>150</td>
<td>mA</td>
</tr>
<tr>
<td>$T_A$</td>
<td>Operating Ambient Temperature Range (Note 8)</td>
<td>-40</td>
<td>+125</td>
<td>°C</td>
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## Electrical Characteristics ($V_{IN\text{Out}} = 3.5V$) (Note 9)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
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<tbody>
<tr>
<td>$V_{IN\text{Out}}$</td>
<td>In-Out Supply Voltage</td>
<td>$T_A = -40^\circC$ to +125°C</td>
<td>2.5</td>
<td>-</td>
<td>60</td>
<td>V</td>
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<tr>
<td>$I_{LINE}$</td>
<td>$I_{IN\text{Out}}$ Current Line Regulation</td>
<td>$V_{IN\text{Out}} = 2.5V$ to 60V (Note 10)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>%</td>
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<tr>
<td>$V_{MIN}$</td>
<td>Minimum Power Up Voltage</td>
<td>$T_A = +25^\circC$</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>%</td>
</tr>
<tr>
<td>$I_{ON_MIN}$</td>
<td>Minimum On pulse width</td>
<td>Increase $V_{IN\text{Out}}$ (Note 11)</td>
<td>-</td>
<td>500</td>
<td>-</td>
<td>µS</td>
</tr>
<tr>
<td>$I_{OFF_MIN}$</td>
<td>Minimum Off pulse width</td>
<td>(Note 12, 13)</td>
<td>-</td>
<td>500</td>
<td>-</td>
<td>µS</td>
</tr>
<tr>
<td>$T_{SHDN}$</td>
<td>Thermal Shutdown Junction Temperature</td>
<td>(Note 14)</td>
<td>-</td>
<td>+165</td>
<td>-</td>
<td>°C</td>
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<tr>
<td>$T_{THYS}$</td>
<td>Thermal Shutdown Hysteresis</td>
<td>-</td>
<td>-</td>
<td>+30</td>
<td>-</td>
<td>°C</td>
</tr>
</tbody>
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Notes:
1. Test condition for PowerDI-123: Device mounted on 25.4mm x 25.4mm FR-4 PCB (10mm x 10mm 1oz copper, minimum recommended pad layout on top layer and thermal via to bottom layer ground plane). For better thermal performance, larger copper pad for heat-sink is needed.
2. When mounted on 50.8mm x 50.8mm GETEK PCB with 25.4mm x 25.4mm copper pads.
3. Test condition for SOD-123: Device mounted on FR-4 PCB with 50.8mm x 50.8mm 2oz copper, minimum recommended pad layout on top layer and thermal via to bottom layer with maximum area ground plane. For better thermal performance, larger copper pad for heat-sink is needed.
4. The LED operating current is determined by the AL5809 current option index XXX, AL5809-XXXS/P1-7.
5. The Maximum LED current is also limited by ambient temperature and power dissipation such that junction temperature should be kept less than or equal to +125°C.
6. All voltages unless otherwise stated are measured with respect to OUT pin.
7. Measured by the percentage degree of LED current variation when $V_{IN\text{Out}}$ varies from 2.5V to 60V each current option.
8. Apply the power linearly to the chip until the device starts to turn on.
9. $I_{ON\_MIN}$ time includes the delay and the rise time needed for $I_{OUT}$ to reach 90% of its final value. $I_{OFF\_MIN}$ time is the time needed for $I_{OUT}$ to drop below 10% of its final value.
10. This parameter only guaranteed by design, not tested in production.
11. Ambient temperature at which OTP is triggered may vary depending on application, PCB layout and material used.

www.diodes.com
Application Information

Description
The AL5809 is a constant current Linear LED driver and can be placed in series with LEDs as a High Side or a Low Side constant current regulator. The AL5809 offers various current settings from 15mA up to 150mA and different current settings available upon request (contact Diodes local sales office at http://www.diodes.com).

The AL5809 contains a Low-Dropout regulator which provides power to the internal Current regulation control block. A fixed preset LED current setting resistor sets the reference current of the Current regulation block. The LED current setting resistor varies with each variant of the AL5809. An accurate current mirror within the Current regulation control block increases the reference current to the preset LED current of the AL5809.

Simple LED String
The AL5809 can be placed in series with LEDs as a Low Side/High Side constant current regulator. The number of the LEDs can vary from one to as many as can be supported by the input supply voltage. The designer needs to calculate the maximum voltage between In and Out by taking the maximum input voltage minus the voltage across the LED string (Figures 1 & 2).

![Figure 1 Low Side LED String Tapping](image1)

![Figure 2 High Side LED String Tapping](image2)

The AL5809 can also be used on the high side of the LEDs, see Figure 2. The minimum system input voltage can be calculated by:

\[ V_{\text{IN(min)}} = V_{\text{LED_CHAIN}} + 2.5V \]

Where \( V_{\text{LED_CHAIN}} \) is the LED chain voltage.

The LED current can be increased by connecting two or more AL5809 in parallel in Figure 3.

![Figure 3 Higher LED Current by Parallel Configuration of AL5809](image3)
PWM Dimming

The AL5809 can be used to provide LED current dimming driving the Out pin via the MOSFET switch to ground (Figure 4a) applying a PWM signal with a frequency range between 100Hz and 200Hz. The Out pin current is then effectively switched on and off to modulate the output LED current. The dimming effect can be achieved by varying the PWM signal duty cycle.

![PWM Dimming Circuit Diagram]

Recommended PWM Frequency and Dimming Range

<table>
<thead>
<tr>
<th>PWM Frequency (Hz)</th>
<th>Duty Cycle (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>100</td>
<td>5</td>
<td>95</td>
</tr>
<tr>
<td>200</td>
<td>10</td>
<td>90</td>
</tr>
</tbody>
</table>

Test conditions (Figure 4a): PWM frequency 100Hz–200Hz Square wave, 0-4V gate voltage, VIN = 6V, 1 LED, AL5809-30mA

Use the following formula to calculate the Min and Max duty cycle:

Min. Duty cycle (%) = \( \frac{t_{ON,\text{MIN}}}{\text{time period of the PWM signal}} \)

Max. Duty cycle (%) = 100% - \( \frac{t_{OFF,\text{MIN}}}{\text{time period of the PWM signal}} \)

Notes: \( t_{ON,\text{MIN}} = 0.5\text{mS (Min. value)} \), and \( t_{OFF,\text{MIN}} = 0.5\text{mS (Min. value)} \) are listed in the Electrical Characteristics table on page 4.
Application Information (continued)

Dimming Curves

Figure 5 PWM Dimming 30mA vs. Duty Cycle

Figure 6 Area Zoom In within Duty Cycle 30% of Figure 5

Recommended Minimum On/Off Pulse Width

Figure 7 Minimum On Pulse Width (t_{ON\_MIN})

Figure 8 Minimum Off Pulse Width (t_{OFF\_MIN})
Power Dissipation

The maximum ambient temperature range of the AL5809 is determined by its power dissipation and thermal impedance of the PCB onto which it is mounted. Its junction temperature must be kept equal to or less than +125°C.

The power dissipated is determined by the LED current version that has been selected (15, 20, 25, 30, 40, 50, 60, 90, 100, 120 or 150mA) and the difference between the input voltage and LED chain voltage.

\[ V_{\text{INOUT}} \times I_{\text{LED}} \]

In a typical 12V system, the input voltage can vary between 11.4V and 12.6V. The recommended minimum \( V_{\text{INOUT}} \) voltage of 2.5V enables the AL5809 to drive 2 LED in series from the 12V rail (assuming \( V_{\text{LED}} < 3.25V \)).

The AL5809’s power dissipation under minimum input voltage conditions will be:

\[ V_{\text{INOUT}} \times I_{\text{LED}} = (11.4 - 6.5) \times I_{\text{LED}} = 4.9V \times 20mA = 98mW \]

Under maximum input conditions (12.6V) the AL5809’s power dissipation will be:

\[ V_{\text{INOUT}} \times I_{\text{LED}} = (12.6 - 6.5) \times I_{\text{LED}} = 6.1V \times 20mA = 122mW \]

So there is a large difference in power dissipation of the Linear LED driver between minimum and maximum battery voltages. And care must be taken to calculate expected power dissipations and then determine the suitable PCB material and layout. See Figures 9, 10 and 11 for graphs showing power dissipation and maximum \( V_{\text{INOUT}} \), for different currents and PCB material. Maximizing the area and mass of the ground plane and additional vias between the pad of the OUT pin will improve the thermal impedance (\( \theta_{JA} \)) of the AL5809.

Figure 9 Power Dissipation vs. Ambient Temperature @\( T_J = +145°C \)

Figure 10 Maximum \( V_{\text{INOUT}} \) vs. Temperature

Figure 11 Maximum \( V_{\text{INOUT}} \) vs. Temperature
Application Information (cont.)

Figure 12 Power Dissipation vs. Ambient Temperature

Figure 13 Power Dissipation vs. Junction Temperature
Typical Performance Characteristics (15mA, 20mA, 25mA, 30mA, 40mA, 50mA PowerDI options)

Figure 14 LED Current vs. VinOut

Figure 15 Startup Minimum Operating Voltage

Figure 16 LED Current vs. Ambient Temperature

Figure 17 LED Current Accuracy (%) vs. VinOut across Temperature

Figure 18 THSD of 20mA Current Option

Figure 19 THSD of 40mA Current Option
Figure 20 LED Current vs. VInOut

Figure 21 Startup Minimum Operating Voltage

Figure 22 LED Current across Temperature

Figure 23 LED Current Accuracy (%) vs. VInOut across Temperature

Figure 24 THSD of 60mA Current Option

Figure 25 THSD of 150mA Current Option
# Ordering Information

## AL5809 - XXX X1-XX

<table>
<thead>
<tr>
<th>Current Option</th>
<th>Package Code</th>
<th>Packing</th>
<th>7” Tape and Reel</th>
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<tbody>
<tr>
<td>15 : 15mA</td>
<td>P1 : PowerDI123</td>
<td>7 : 7” Tape &amp; Reel</td>
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<td>20 : 20mA</td>
<td>S1 : SOD123</td>
<td>3,000/ Tape &amp; Reel</td>
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<td>25 : 25mA</td>
<td>P1 : PowerDI123</td>
<td>3,000/ Tape &amp; Reel</td>
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<tr>
<td>30 : 30mA</td>
<td>S1 : SOD123</td>
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<td>40 : 40mA</td>
<td>P1 : PowerDI123</td>
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<td>50 : 50mA</td>
<td>S1 : SOD123</td>
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<table>
<thead>
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## Marking Information

![Top View](image)

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</table>

## Package Outline Dimensions

Please see [http://www.diodes.com/package-outlines.html](http://www.diodes.com/package-outlines.html) for the latest version.

**PowerDI123 (Type B)**

### PowerDI123 Type B

<table>
<thead>
<tr>
<th>Dim</th>
<th>Min</th>
<th>Max</th>
<th>Typ</th>
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<td>B</td>
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<td>3.00</td>
<td>2.80</td>
</tr>
<tr>
<td>C</td>
<td>1.63</td>
<td>1.93</td>
<td>1.78</td>
</tr>
<tr>
<td>D</td>
<td>0.93</td>
<td>1.00</td>
<td>0.98</td>
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<tr>
<td>E</td>
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<td>1.25</td>
<td>1.00</td>
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<tr>
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<td>0.20</td>
</tr>
<tr>
<td>L</td>
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<td>0.65</td>
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</table>

All Dimensions in mm
Package Outline Dimensions (continued)
Please see http://www.diodes.com/package-outlines.html for the latest version.

SOD123

Suggested Pad Layout
Please see http://www.diodes.com/package-outlines.html for the latest version.

PowerDI123 (Type B)

<table>
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<tr>
<th>Dimensions</th>
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</thead>
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<tr>
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</table>

SOD123

<table>
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<th>Dimensions</th>
<th>Value (in mm)</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
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<tr>
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</tbody>
</table>
Taping Orientation

The taping orientation of the other package type can be found on our website at http://www.diodes.com/datasheets/ap02007.pdf.

PowerDI123 (Type B)

SOD123
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