General Description

The MAX16835 current regulator operates from a 6.5V to 40V input voltage range and delivers up to a total of 350mA to one or more strings of high-brightness LEDs (HB LEDs). The output current of the MAX16835 is adjusted by using an external current-sense resistor in series with the LEDs. An enable input allows wide-range “pulsed” dimming. Wave-shaping circuitry reduces EMI. The differential current-sense input increases noise immunity. The MAX16835 is well suited for applications requiring high-voltage input and is able to withstand automotive load-dump events up to 40V. An on-board pass element minimizes external components while providing ±3.5% output current accuracy. Additional features include a 5V regulated output and short-circuit and thermal protection.

The MAX16835 is available in a thermally enhanced, 5mm x 5mm, 16-pin TQFN package and is specified over the automotive -40°C to +125°C temperature range.

Applications

- Automotive Interior: Map, Courtesy, and Cluster Lighting
- Automotive Exterior: Tail Lights and CHMSL Warning Lights for Emergency Vehicles
- Navigation and Marine Indicators
- General Illumination
- Signage, Gasoline Canopies, Beacons

Features

- +6.5V to +40V Operating Range
- Adjustable LED Current (35mA to 350mA)
- ±3.5% Output Current Accuracy
- Integrated Pass Element with Low-Dropout Voltage (0.55V typ)
- Output Short-Circuit Protection
- +5V Regulated Output with 4mA Source Capability
- Thermal Shutdown
- Differential LED Current Sense
- High-Voltage Enable Pin for Dimming Interface
- Low Shutdown Supply Current (35µA typ)
- Low 200mV Current-Sense Reference Reduces Power Losses
- Wave-Shaped Edges Reduce Radiated EMI During PWM Dimming
- Available in Small, Thermally Enhanced, 5mm x 5mm, 16-Pin TQFN Package
- -40°C to +125°C Operating Temperature Range

Ordering Information

<table>
<thead>
<tr>
<th>PART</th>
<th>TEMP RANGE</th>
<th>PIN-PACKAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX16835ATE+</td>
<td>-40°C to +125°C</td>
<td>16 TQFN-EP*</td>
</tr>
<tr>
<td>MAX16835ATE/V+</td>
<td>-40°C to +125°C</td>
<td>16 TQFN-EP*</td>
</tr>
</tbody>
</table>

+Denotes a lead(Pb)-free/RoHS-compliant package.
*EP = Exposed pad.
/V denotes an automotive qualified part.

Pin Configuration

<table>
<thead>
<tr>
<th>TOP VIEW</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>N.C.</td>
</tr>
</tbody>
</table>

Simplified Diagram

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim’s website at www.maximintegrated.com.
MAX16835

High-Voltage, 350mA, Adjustable Linear High-Brightness LED Driver

ABSOLUTE MAXIMUM RATINGS

IN to GND ..............................................................-0.3V to +45V

OUT, EN to GND .......................................................-0.3V to (VIN + 0.3V)

CS+, CS-, and V5 to GND ............................................-0.3V to +6V

OUT Short Circuited to GND Duration
(at VIN = +16V) .......................................................60 minutes

Maximum Current into Any Pin (except IN and OUT) ..........±20mA

Continuous Power Dissipation (TA = +70°C)
16-Pin TQFN 5mm x 5mm (derate 33.3mW/°C above +70°C) ...........2666.7mW

Operating Junction Temperature Range ...............-40°C to +125°C

Junction Temperature ..................................................+150°C

Storage Temperature Range ......................................-65°C to +150°C

Lead Temperature (soldering, 10s) .........................+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

PACKAGE THERMAL CHARACTERISTICS (Note 1)

Junction-to-Ambient Thermal Resistance (θJA) ..............30°C/W

Junction-to-Case Thermal Resistance (θJC) .......................2°C/W

Note 1: Package thermal resistances obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, see www.maximintegrated.com/thermal-tutorial.

ELECTRICAL CHARACTERISTICS

(VIN = VEN = +12V, CV5 = 0.1µF to GND, IV5 = 0, CS- = GND, connect RSENSE = 0.58Ω between CS+ and CS-. TA = -40°C to +125°C, unless otherwise noted. Typical values are at TA = +25°C.) (Notes 2 and 3)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage Range</td>
<td>VIN</td>
<td>(Note 2)</td>
<td>6.5</td>
<td>40.0</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Ground Current</td>
<td>IG</td>
<td>ILOAD = 350mA</td>
<td>1.28</td>
<td>3</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Shutdown Supply Current</td>
<td>ISHDN</td>
<td>VEN ≤ 0.6V</td>
<td>35</td>
<td>70</td>
<td>µA</td>
<td></td>
</tr>
<tr>
<td>Guaranteed Output Current</td>
<td>IOUT</td>
<td>RSENSE = 0.55Ω</td>
<td>350</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Current Accuracy</td>
<td></td>
<td>35mA &lt; IOUT &lt; 350mA</td>
<td>±3.5</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dropout Voltage (Note 4)</td>
<td>∆VDO</td>
<td>IOUT = 350mA (current pulsed), 12V &lt; VIN &lt; 40V</td>
<td>0.55</td>
<td>1.2</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>IOUT = 350mA (current pulsed), 6.5V &lt; VIN &lt; 40V</td>
<td>0.55</td>
<td>1.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Output Current Slew Rate</td>
<td></td>
<td>Current rising</td>
<td>7.8</td>
<td>mA/µs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Current falling</td>
<td>7.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-Circuit Current</td>
<td></td>
<td>VIN = 12V, VCS+ = 0V</td>
<td>400</td>
<td>500</td>
<td>650</td>
<td>mA</td>
</tr>
</tbody>
</table>

LOGIC INPUT

EN Input Current | IEN | -2.5 | -1.0 | -0.2 | µA |

EN Input Voltage High | VIH | 2.8 | V |

EN Input Voltage Low | VIL | 0.6 | V |

Turn-On Time | tON | VEN rising edge to 90% of OUT | 110 | 350 | µs |

CURRENT SENSE

Regulated RSENSE Voltage | VSENSE | VSENSE = VCS+ - VCS- | 193 | 200 | 207 | mV |

Input Current (CS+) | VCS+ | 220mA | 2.7 | 7.0 | µA |

Input Current (CS-) | VCS- | 220mV | -50 | -17.2 | µA |
**MAX16835**

**High-Voltage, 350mA, Adjustable Linear High-Brightness LED Driver**

**ELECTRICAL CHARACTERISTICS (continued)**

(V\textsubscript{IN} = V\textsubscript{EN} = +12V, C\textsubscript{V5} = 0.1\mu F to GND, I\textsubscript{V5} = 0, CS- = GND, connect R\textsubscript{SENSE} = 0.58\Omega between CS+ and CS-. TA = -40°C to +125°C, unless otherwise noted. Typical values are at TA = +25°C.) (Notes 2 and 3)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>THERMAL OVERLOAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal-Shutdown Temperature</td>
<td>V\textsubscript{VS}</td>
<td></td>
<td></td>
<td></td>
<td>+159</td>
<td>°C</td>
</tr>
<tr>
<td>Thermal-Shutdown Hysteresis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24</td>
<td>°C</td>
</tr>
<tr>
<td>+5V REGULATOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage</td>
<td>V\textsubscript{V5}</td>
<td></td>
<td>4.85</td>
<td>5.00</td>
<td>5.20</td>
<td>V</td>
</tr>
<tr>
<td>Output Voltage Load Regulation</td>
<td>\Delta V5</td>
<td>0 &lt; I\textsubscript{LOAD} &lt; 4mA (Note 5)</td>
<td>12</td>
<td>20</td>
<td>mV/mA</td>
<td></td>
</tr>
<tr>
<td>V5 Short-Circuit Current</td>
<td>V\textsubscript{V5} = 0V (Note 6)</td>
<td>15</td>
<td>mA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 2: Resistors were added from OUT to CS+ to aid with the power dissipation during testing.

Note 3: All devices 100% production tested at TA = +25°C. Limits over the operating temperature range are guaranteed by design.

Note 4: Dropout is measured as follows:

Connect RO = 27\Omega from OUT to CS+. Connect R\textsubscript{SENSE} = 0.58\Omega from CS+ to CS-. Set V\textsubscript{IN} = +12V (record V\textsubscript{OUT} as V\textsubscript{OUT1}).

Reduce V\textsubscript{IN} until V\textsubscript{OUT} = 0.97 x V\textsubscript{OUT1} (record as V\textsubscript{IN2} and V\textsubscript{OUT2}). \Delta V\textsubscript{DO} = V\textsubscript{IN2} - V\textsubscript{OUT2}.

Note 5: Current regulation varies with V5 load (see the Typical Operating Characteristics).

Note 6: Thermal shutdown does not function if the output of the 5V reference is shorted to ground.

---

**Typical Operating Characteristics**

(V\textsubscript{IN} = V\textsubscript{EN} = +12V, TA = +25°C, unless otherwise noted.)

[Images of graphs showing output current vs. temperature, output current vs. output current, and output current vs. input voltage]
MAX16835
High-Voltage, 350mA, Adjustable Linear
High-Brightness LED Driver

Typical Operating Characteristics (continued)
(V_IN = V_EN = +12V, T_A = +25°C, unless otherwise noted.)

 dropout voltage vs. temperature

 shutdown current vs. temperature

 +5V regulator output vs. temperature

 (V_{CS+} - V_{CS-}) vs. I_{VS}

 +5V regulator output vs. V_IN

 200Hz dimmed operation

 200Hz dimmed operation expanded

 200Hz dimmed operation expanded

 200Hz dimmed operation

 Maxim Integrated
**Pin Description**

<table>
<thead>
<tr>
<th>PIN</th>
<th>NAME</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 16</td>
<td>OUT</td>
<td>Current-Regulated Output. Connect pin 1 to pin 16.</td>
</tr>
<tr>
<td>2, 3</td>
<td>IN</td>
<td>Positive Input Supply. Bypass IN with a 0.1µF (min) capacitor to GND. Connect pin 2 to pin 3.</td>
</tr>
<tr>
<td>4–8, 13, 14</td>
<td>N.C.</td>
<td>No Connection. Not internally connected.</td>
</tr>
<tr>
<td>9</td>
<td>CS+</td>
<td>Positive Input of the Internal Differential Amplifier. Connect the current-sense resistor between CS+ and CS- to program the output current level.</td>
</tr>
<tr>
<td>10</td>
<td>CS-</td>
<td>Negative Input of the Internal Differential Amplifier. Connect the current-sense resistor between CS- and CS+ to program the output current level.</td>
</tr>
<tr>
<td>11</td>
<td>V5</td>
<td>+5V Regulated Output. Connect a 0.1µF capacitor from V5 to GND.</td>
</tr>
<tr>
<td>12</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>15</td>
<td>EN</td>
<td>Enable Input. Drive EN high to enable the output.</td>
</tr>
<tr>
<td>—</td>
<td>EP</td>
<td>Exposed Pad. Connect to the ground plane for effective power dissipation. Do not use as the only ground connection.</td>
</tr>
</tbody>
</table>

**Detailed Description**

The MAX16835 is a high-current regulator capable of providing up to a total of 350mA of current to one or more strings of high-brightness LEDs. A wide operating input voltage range of +6.5V to +40V makes the MAX16835 ideal for automotive applications. A +5V regulated output provides up to 4mA of current to power external circuitry. In addition, the MAX16835 features thermal and output short-circuit protection. The wide operating voltage range helps protect the MAX16835 against large transients such as those found in load-dump situations up to 40V.

The MAX16835 uses a feedback loop to control the output current. The differential voltage across the sense resistor is compared to a fixed reference voltage, and the error is amplified to serve as the drive to the internal controller. This ensures precise current regulation and provides overcurrent protection. The enable input (EN) allows the user to control the output, enabling or disabling it as needed. The exposed pad (EP) is designed for connection to the ground plane to maximize power dissipation, ensuring reliable operation under all conditions.
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High-Voltage, 350mA, Adjustable Linear High-Brightness LED Driver

power series pass device (see the Functional Diagram). The regulation point is factory set at (VCS+ - VCS-) = 200mV ±3.5%. The regulated current is user defined by the value of RSENSE. The MAX16835 is a current controller internally optimized for driving the impedance range expected from one or more HB LEDs.

+5V Regulator

The MAX16835 includes a fixed +5V output regulator that delivers up to 4mA of load current for low-power applications throughout the +6.5V to +40V input voltage range. Connect a 0.1µF compensation capacitor from V5 to ground. Shorting V5 to ground disables the thermal shutdown. When EN is low, V5 is off.

Thermal Protection

The MAX16835 enters a thermal-shutdown mode in the event of overheating. This typically occurs in overload or output short-circuit conditions. When the junction temperature exceeds TJ = +159°C (typ), the internal thermal-protection circuitry turns off the series pass device. The MAX16835 recovers from thermal-shutdown mode once the junction temperature drops by 24°C (typ). The part therefore protects itself by thermally cycling in the event of a short-circuit or overload condition. Shorting V5 to ground disables the thermal shutdown.

Applications Information

Programming the LED Current

The MAX16835 uses a sense resistor across CS+ and CS- to set the LED current. The differential sense amplifier connected across RSENSE provides ground-loop immunity and low-frequency noise rejection. The LED current is given by the equation below:

\[ I_{LED} = \frac{V_{SENSE}}{R_{SENSE}} \]

Input Voltage Considerations

For proper operation, the minimum input voltage must always be:

\[ V_{IN(MIN)} \geq V_{SENSE(MAX)} + V_{FT(MAX)} + \Delta V_{DO(MAX)} \]

where VFT(MAX) is the total forward voltage of all series-connected LEDs. The minimum operating voltage of the device is +6.5V. The device operates below +6.5V; however, the output current may not meet the full regulation specification.

Low-Frequency PWM at the Output

The MAX16835 provides pulsed or chopped current dimming. Generally, HB LEDs are binned to match at their full-rated current; however, LEDs from the same bin exhibit poor matching at currents other than full-rated current. To achieve uniformity, HB LED manufacturers recommend PWM pulsing of the LED current at their full-rated value. There are two methods for producing a PWM output. One method is by pulsing the enable input (EN) while having a constant voltage at IN. The other method is to connect EN to IN and pulse both EN and IN. Both methods generate a regulated-amplitude PWM current (variable duty cycle) that can provide control over the LED brightness (see Figures 1 and 2).

Figure 1. Pulse Application with VIN at a Constant Voltage

Figure 2. Pulse Application with EN Connected to VIN
**MAX16835**

**High-Voltage, 350mA, Adjustable Linear High-Brightness LED Driver**

**Typical Operating Circuit**

**Chip Information**

PROCESS: BiCMOS

**Package Information**

For the latest package outline information and land patterns (footprints), go to www.maximintegrated.com/packages. Note that a "+", ",", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

<table>
<thead>
<tr>
<th>PACKAGE TYPE</th>
<th>PACKAGE CODE</th>
<th>OUTLINE NO.</th>
<th>LAND PATTERN NO.</th>
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<tr>
<td>16 TQFN</td>
<td>T1655+3</td>
<td>21-0140</td>
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# MAX16835

**High-Voltage, 350mA, Adjustable Linear High-Brightness LED Driver**

## Revision History

<table>
<thead>
<tr>
<th>REVISION NUMBER</th>
<th>REVISION DATE</th>
<th>DESCRIPTION</th>
<th>PAGES CHANGED</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2/08</td>
<td>Initial release</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>5/08</td>
<td>Updated <em>Ordering Information, Electrical Characteristics, and Package Information</em></td>
<td>1, 2, 8, 9</td>
</tr>
<tr>
<td>2</td>
<td>10/12</td>
<td>Added automotive qualified part to <em>Ordering Information</em></td>
<td>1</td>
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</table>

Maxim Integrated cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim Integrated product. No circuit patent licenses are implied. Maxim Integrated reserves the right to change the circuitry and specifications without notice at any time. The parametric values (min and max limits) shown in the Electrical Characteristics table are guaranteed. Other parametric values quoted in this data sheet are provided for guidance.