MAX16807

Integrated 8-Channel LED Driver with Switch-Mode Boost and SEPIC Controller

General Description
The MAX16807 is an integrated, high-efficiency white or RGB LED driver. It is designed for LCD backlighting and other LED lighting applications with multiple strings of LEDs. The MAX16807 current-mode PWM controller regulates the necessary voltage to the LED array. Depending on the input voltage and LED voltage range, it can be used with boost or buck-boost (SEPIC) topologies. The MAX16807 features an 8V to 26.5V input voltage range. A wide range of adjustable frequency (20kHz to 1MHz) allows design optimization for efficiency and minimum board space.

The MAX16807 LED driver includes eight open-drain, constant-current-sinking LED driver outputs rated for 36V continuous operation. The LED current-control circuitry achieves ±3% current matching among strings and enables paralleling of outputs for LED string currents higher than 55mA. The output-enable pin is used for simultaneous PWM dimming of all output channels. Dimming frequency range is 50Hz to 30kHz and dimming ratio is up to 5000:1. The constant-current outputs are single resistor programmable and the LED current can be adjusted up to 55mA per output channel.

The MAX16807 operates either in stand-alone mode or with a microcontroller (μC) using an industry-standard, 4-wire serial interface.

The MAX16807 includes overtemperature protection, operates over the full -40°C to +125°C temperature range, and is available in a thermally enhanced, 28-pin TSSOP exposed pad package.

Features
- Eight Constant-Current Output Channels (Up to 55mA Each)
- ±3% Current Matching Among Outputs
- Paralleling Channels Allows Higher Current per LED String
- Output Rated for 36V Continuous Voltage
- Output-Enable Pin for PWM Dimming (Up to 30kHz)
- One Resistor Sets LED Current for All Channels
- Wide Dimming Ratio Up to 5000:1
- Low Current-Sense Reference (300mV) for High Efficiency
- 8V to 26.5V Input Voltage or Higher with External Biasing Devices
- 4-Wire Serial Interface to Control Individual Output Channels

Applications
- LCD White or RGB LED Backlighting:
  LCD TVs, Desktop and Notebook Panels,
  Industrial and Medical Displays
- Ambient, Mood, and Accent Lighting

Ordering Information

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<th>PART</th>
<th>TEMP RANGE</th>
<th>PIN-PACKAGE</th>
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<tr>
<td>MAX16807AU</td>
<td>-40°C to +125°C</td>
<td>28 TSSOP-EP*</td>
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</table>

*Denotes lead(Pb)-free/RoHS-compliant package.
*EP = Exposed pad.

Pin Configuration appears at end of data sheet.

Typical Operating Circuits

Typical Operating Circuits continued at end of data sheet.
**MAX16807**
Integrated 8-Channel LED Driver with Switch-Mode Boost and SEPIC Controller

**Absolute Maximum Ratings**
- VCC to AGND: -0.3V to +30V
- Current into VCC (VCC > 24V): ±30mA
- V+ to PGND: -0.3V to +6V
- OUT to AGND: -0.3V to (VCC + 0.3V)
- OUT Current (10μs duration): ±1A
- FB, COMP, CS, RTCT, REF to AGND: -0.3V to +6V
- COMP Sink Current: 10mA
- OUT0–OUT7 to PGND: -0.3V to +40V
- DIN, CLK, LE, OE, SET to PGND: -0.3V to (V+ + 0.3V)
- DOUT Current: ±10mA
- OUT0–OUT7 Sink Current: 60mA
- Total PGND Current: 480mA
- Continuous Power Dissipation (TJ = +70°C): 2162mW
- Operating 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

*Per JEDEC51 Standard (Multilayer Board).*

**Electrical Characteristics (PWM Controller)**

(VCC = +15V, V+ = +3V to +5.5V referenced to PGND, RT = 10kΩ, CT = 3.3nF, REF = open, COMP = open, CR = 0.1μF, VFB = 2V, CS = AGND, VAGND = VPV = 0V; all voltages are measured with respect to AGND, unless otherwise noted. TJ = TA = -40°C to +125°C, unless otherwise noted. Typical values are at TJ = +25°C.) (Note 1)

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<thead>
<tr>
<th>PARAMETER</th>
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<tr>
<td>Output Voltage</td>
<td>VREF</td>
<td>IREF = 1mA, TJ = +25°C</td>
<td>V</td>
</tr>
<tr>
<td>Line Regulation</td>
<td>∆VLINE</td>
<td>12V &lt; VCC &lt; 25V, IREF = 1mA</td>
<td>mV</td>
</tr>
<tr>
<td>Load Regulation</td>
<td>∆VLOAD</td>
<td>1mA &lt; IREF &lt; 20mA</td>
<td>mV</td>
</tr>
<tr>
<td>Total Output-Voltage Variation</td>
<td>VREFT</td>
<td>(Note 2)</td>
<td>V</td>
</tr>
<tr>
<td>Output Noise Voltage</td>
<td>VNOISE</td>
<td>10Hz &lt; f &lt; 10kHz</td>
<td>µV</td>
</tr>
<tr>
<td>Output Short-Circuit Current</td>
<td>ISHORT</td>
<td>VREF = 0V</td>
<td>mA</td>
</tr>
</tbody>
</table>

**OSCILLATOR**
- Initial Accuracy | TJ = +25°C | 51 | 54 | 57 | kHz |
- Voltage Stability | 12V < VCC < 25V | 0.2 | 0.5 | % |
- Temperature Stability | 1 | % |
- RTCT Ramp Peak-to-Peak | 1.7 | V |
- RTCT Ramp Valley | 1.1 | V |
- Discharge Current | IDIS | VRTCT = 2V, TJ = +25°C | mA |
- | | VRTCT = 2V, -40°C ≤ TJ ≤ +125°C | mA |
- Frequency Range | fOSC | 20 | 1000 | kHz |

**ERROR AMPLIFIER**
- FB Input Voltage | VFB | FB shorted to COMP | V |
- Input Bias Current | IB(FB) | -0.01 | -0.1 | µA |
- Open-Loop Gain | AVOL | 2V ≤ VCOMP ≤ 4V | 100 | dB |
- Unity-Gain Bandwidth | fGBW | 1 | MHz |
- Power-Supply Rejection Ratio | PSRR | 12V ≤ VCC ≤ 25V | 60 | 80 | dB |
- COMP Sink Current | ISINK | VFB = 2.7V, VCOMP = 1.1V | 2 | 6 | mA |
- COMP Source Current | ISOURCE | VFB = 2.3V, VCOMP = 5V | 0.5 | 1.2 | 1.8 | mA |
- COMP Output-Voltage High | VOH | VFB = 2.3V, RCOMP = 15kΩ to AGND | 5 | 5.8 | V |
- COMP Output-Voltage Low | VOL | VFB = 2.7V, RCOMP = 15kΩ to VREF | 0.1 | 1.1 | V |

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.
### Electrical Characteristics (PWM Controller) (continued)

\( V_{CC} = +15\, \text{V}, \ V^+ = +3\, \text{V} \) to \(+5.5\, \text{V} \) referenced to PGND, \( R_T = 10\, \text{k} \Omega, \ C_T = 3.3\, \text{nF}, \ \text{REF} = \text{open}, \ \text{COMP} = \text{open}, \ C_{\text{REF}} = 0.1\, \mu\text{F}, \ V_{\text{FB}} = 2\, \text{V}, \ CS = \text{AGND}, \ V_{\text{AGND}} = V_{\text{PGND}} = 0\, \text{V}; \) all voltages are measured with respect to AGND, unless otherwise noted. \( T_J = T_A = -40^\circ\text{C} \) to \(+125^\circ\text{C} \), unless otherwise noted. Typical values are at \( T_A = +25^\circ\text{C} \). (Note 1)

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<th>MAX</th>
<th>UNITS</th>
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<tbody>
<tr>
<td><strong>CURRENT-SENSE AMPLIFIER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current-Sense Gain</td>
<td>( A_{CS} )</td>
<td>(Notes 3, 4)</td>
<td>2.85</td>
<td>3.00</td>
<td>3.40</td>
<td>V/V</td>
</tr>
<tr>
<td>Maximum Current-Sense Signal</td>
<td>( V_{CS_\text{MAX}} )</td>
<td>(Note 3)</td>
<td>0.275</td>
<td>0.300</td>
<td>0.325</td>
<td>V</td>
</tr>
<tr>
<td>Power-Supply Rejection Ratio</td>
<td>PSRR</td>
<td>( 12, \text{V} \leq V_{CC} \leq 25, \text{V} )</td>
<td>70</td>
<td></td>
<td></td>
<td>dB</td>
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<tr>
<td>Current-Sense Input Bias Current</td>
<td>( I_{CS} )</td>
<td>( V_{\text{COMP}} = 0, \text{V} )</td>
<td>-1</td>
<td>-2.5</td>
<td></td>
<td>( \mu\text{A} )</td>
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<tr>
<td>Current Sense to OUT Delay</td>
<td>( t_{\text{PWM}} )</td>
<td>50mV overdrive</td>
<td>60</td>
<td></td>
<td></td>
<td>( \text{ns} )</td>
</tr>
<tr>
<td><strong>MOSFET DRIVER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OUT Low-Side On-Resistance</td>
<td>( V_{RDS_\text{ONL}} )</td>
<td>( I_{\text{SINK}} = 200, \text{mA} )</td>
<td>4.5</td>
<td>10</td>
<td></td>
<td>( \Omega )</td>
</tr>
<tr>
<td>( T_J = -40^\circ\text{C} ) to (+85^\circ\text{C} ) (Note 2)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>OUT High-Side On-Resistance</td>
<td>( V_{RDS_\text{ONH}} )</td>
<td>( I_{\text{SOURCE}} = 100, \text{mA} )</td>
<td>4.5</td>
<td>12</td>
<td></td>
<td>( \Omega )</td>
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<tr>
<td>( T_J = -40^\circ\text{C} ) to (+125^\circ\text{C} )</td>
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<td></td>
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<td></td>
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<tr>
<td>Source Current (Peak)</td>
<td>( I_{\text{SOURCE}} )</td>
<td>( C_{\text{LOAD}} = 10, \text{nF} )</td>
<td>2</td>
<td></td>
<td></td>
<td>A</td>
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<tr>
<td>Sink Current (Peak)</td>
<td>( I_{\text{SINK}} )</td>
<td>( C_{\text{LOAD}} = 10, \text{nF} )</td>
<td>1</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Rise Time</td>
<td>( t_r )</td>
<td>( C_{\text{LOAD}} = 1, \text{nF} )</td>
<td>15</td>
<td></td>
<td></td>
<td>( \text{ns} )</td>
</tr>
<tr>
<td>Fall Time</td>
<td>( t_f )</td>
<td>( C_{\text{LOAD}} = 1, \text{nF} )</td>
<td>22</td>
<td></td>
<td></td>
<td>( \text{ns} )</td>
</tr>
<tr>
<td><strong>UNDERVOLTAGE LOCKOUT/STARTUP</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Startup Voltage Threshold</td>
<td>( V_{CC_\text{START}} )</td>
<td></td>
<td>7.98</td>
<td>8.4</td>
<td>8.82</td>
<td>V</td>
</tr>
<tr>
<td>Minimum Operating Voltage After Turn-On</td>
<td>( V_{CC_\text{MIN}} )</td>
<td></td>
<td>7.1</td>
<td>7.6</td>
<td>8.0</td>
<td>V</td>
</tr>
<tr>
<td>Undervoltage-Lockout Hysteresis</td>
<td>( U\text{VLO_HYST} )</td>
<td></td>
<td>0.8</td>
<td></td>
<td></td>
<td>V</td>
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<tr>
<td><strong>PULSE-WIDTH MODULATION (PWM)</strong></td>
<td></td>
<td></td>
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<tr>
<td>Maximum Duty Cycle</td>
<td>( D_{\text{MAX}} )</td>
<td></td>
<td>94.5</td>
<td>96</td>
<td>97.5</td>
<td>%</td>
</tr>
<tr>
<td>Minimum Duty Cycle</td>
<td>( D_{\text{MIN}} )</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td><strong>SUPPLY CURRENT</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Startup Supply Current</td>
<td>( I_{\text{START}} )</td>
<td>( V_{CC} = 7.5, \text{V} )</td>
<td>32</td>
<td>65</td>
<td></td>
<td>( \mu\text{A} )</td>
</tr>
<tr>
<td>Operating Supply Current</td>
<td>( I_{\text{CC}} )</td>
<td>( V_{\text{FB}} = V_{\text{CS}} = 0, \text{V} )</td>
<td>3</td>
<td>5</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>( V_{CC} ) Zener Voltage</td>
<td>( V_{Z} )</td>
<td>( I_{\text{CC}} = 25, \text{mA} )</td>
<td>24</td>
<td>26.5</td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>
## Electrical Characteristics (LED Driver)

\( V^+ = +3\text{V} \) to +5.5\text{V}, \( V_{\text{AGND}} = V_{\text{PGND}} = 0\text{V} \); all voltages are measured with respect to PGND, unless otherwise noted. \( T_A = T_J = -40^\circ\text{C} \) to +125\(^\circ\text{C} \), unless otherwise noted. Typical values are at \( T_A = +25^\circ\text{C} \). (Note 1)

### OPERATING CONDITIONS

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<th>MAX</th>
<th>UNITS</th>
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<tbody>
<tr>
<td>Operating Supply Voltage</td>
<td>( V^+ )</td>
<td></td>
<td>3.0</td>
<td>5.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>( V_{\text{OUT}} )</td>
<td></td>
<td>36</td>
<td></td>
<td></td>
<td>V</td>
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</tbody>
</table>

### STANDBY CURRENT

#### (Interface Idle, All Output Ports High Impedance)

\( R_{\text{SET}} = 360\Omega, \, \text{DIN, LE, CLK} = \text{PGND or V}^+, \, \text{OE} = V^+, \, \text{DOUT} \) unconnected

\[ 3.6 \text{ mA} \leq I_{\text{STBY_IDLE}} \leq 4.5 \text{ mA} \]

#### (Interface Active, All Output Ports High Impedance)

\( R_{\text{SET}} = 360\Omega, \, f_{\text{CLK}} = 5\text{MHz}, \, \text{OE} = V^+, \, \text{DIN, LE} = \text{PGND or V}^+, \, \text{DOUT} \) unconnected

\[ 3.8 \text{ mA} \leq I_{\text{STBY_ACTIVE}} \leq 4.8 \text{ mA} \]

### SUPPLY CURRENT

#### (Interface Idle, All Output Ports Active Low)

\( I^+ \) \( R_{\text{SET}} = 360\Omega, \, \text{OE} = \text{PGND, DIN, LE} = V^+, \, \text{DOUT} \) unconnected

\[ 17 \text{ mA} \leq I_{\text{SUPPLY_IDLE}} \leq 30 \text{ mA} \]

### INTERFACE (DIN, CLK, DOUT, LE, OE)

#### Input-Voltage High

(DIN, CLK, LE, OE)

\( V_{\text{IH}} \) \( 0.7 \times V^+ \)

#### Input-Voltage Low

(DIN, CLK, LE, OE)

\( V_{\text{IL}} \) \( 0.3 \times V^+ \)

#### Hysteresis Voltage

(DIN, CLK, LE, OE)

\( V_{\text{HYST}} \) \( 0.8 \times V^+ \)

#### Input Leakage Current

(DIN, CLK)

\( I_{\text{LEAK}} \) \(-1 \mu\text{A}\) \( +1 \mu\text{A}\)

#### OE Pullup Current to V+

\( I_{\text{OE}} \) \( V^+ = 5.5\text{V}, \, \text{OE} = \text{PGND} \)

\[ 0.25 \mu\text{A} \leq I_{\text{OE}} \leq 1.5 \mu\text{A} \]

#### LE Pulldown Current to PGND

\( I_{\text{LE}} \) \( V^+ = 5.5\text{V}, \, \text{LE} = V^+ \)

\[ 0.25 \mu\text{A} \leq I_{\text{LE}} \leq 1.5 \mu\text{A} \]

#### Output-Voltage High (DOUT)

\( V_{\text{OH}} \) \( I_{\text{SOURCE}} = 4\text{mA} \)

\[ V^+ - 0.5\text{V} \]

#### Output-Voltage Low (DOUT)

\( V_{\text{OL}} \) \( I_{\text{SINK}} = 4\text{mA} \)

\[ 0.5\text{V} \]

#### OUT＿ Output Current

\( 0^\circ\text{C} \leq T_A \leq +125^\circ\text{C}, \, V_{\text{OUT}} = 1\text{V} \) to 2.5\text{V}, \( R_{\text{SET}} = 360\Omega \)

\[ 46.5 \text{ mA} \leq I_{\text{OUT}} \leq 50 \text{ mA} \]

#### OUT＿ Leakage Current

\( \text{OE} = V^+ \)

\[ 1 \mu\text{A} \]

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## 5V Timing Characteristics

(V+ = +4.5V to +5.5V, VAGND = VP GND = 0V; all voltages are measured with respect to PGND, unless otherwise noted. TA = TJ = -40°C to +125°C, unless otherwise noted. Typical values are at TA = +25°C.) (Notes 1, 5)

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<td>INTERFACE TIMING CHARACTERISTICS</td>
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<tr>
<td>CLK Clock Period</td>
<td>tCP</td>
<td></td>
<td>40</td>
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<td>ns</td>
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<tr>
<td>CLK Pulse-Width High</td>
<td>tCH</td>
<td></td>
<td>19</td>
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<td>ns</td>
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<tr>
<td>CLK Pulse-Width Low</td>
<td>tCL</td>
<td></td>
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<tr>
<td>DIN Setup Time</td>
<td>tDS</td>
<td></td>
<td>4</td>
<td></td>
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</tr>
<tr>
<td>DIN Hold Time</td>
<td>tDH</td>
<td></td>
<td>8</td>
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<td>ns</td>
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<tr>
<td>DOUT Propagation Delay</td>
<td>tDO</td>
<td></td>
<td>12</td>
<td>50</td>
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<tr>
<td>DOUT Rise Time</td>
<td>tDR</td>
<td>CDOUT = 10pF, 20% to 80%</td>
<td>10</td>
<td></td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>DOUT Fall Time</td>
<td>tDF</td>
<td>CDOUT = 10pF, 80% to 20%</td>
<td>10</td>
<td></td>
<td>ns</td>
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<tr>
<td>LE Pulse-Width High</td>
<td>tLW</td>
<td></td>
<td>20</td>
<td></td>
<td>ns</td>
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<tr>
<td>LE Setup Time</td>
<td>tLS</td>
<td></td>
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<tr>
<td>LE Rising to OUT_ Rising Delay</td>
<td>tLRR</td>
<td>(Note 6)</td>
<td>110</td>
<td></td>
<td>ns</td>
<td></td>
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<tr>
<td>LE Rising to OUT_ Falling Delay</td>
<td>tLRF</td>
<td>(Note 6)</td>
<td>325</td>
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<tr>
<td>CLK Rising to OUT_ Rising Delay</td>
<td>tCRR</td>
<td>(Note 6)</td>
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<td>ns</td>
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<tr>
<td>CLK Rising to OUT_ Falling Delay</td>
<td>tCRF</td>
<td>(Note 6)</td>
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<td>OE Rising to OUT_ Rising Delay</td>
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<td>(Note 6)</td>
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<tr>
<td>OE Falling to OUT_ Falling Delay</td>
<td>tOEF</td>
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<tr>
<td>OUT_ Turn-On Fall Time</td>
<td>tF</td>
<td>80% to 20% (Note 6)</td>
<td>210</td>
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<tr>
<td>OUT_ Turn-Off Rise Time</td>
<td>tR</td>
<td>20% to 80% (Note 6)</td>
<td>130</td>
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3.3V Timing Characteristics

(V+ = +3V to < +4.5V, VAGND = VP-GND = 0V; all voltages are measured with respect to PGND, unless otherwise noted. TA = TJ = -40°C to +125°C, unless otherwise noted. Typical values are at TA = +25°C.) (Notes 1, 5)

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<tbody>
<tr>
<td>INTERFACE TIMING CHARACTERISTICS</td>
<td></td>
<td></td>
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<td>CLK Clock Period</td>
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<td>CLK Pulse-Width High</td>
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<td>DIN Hold Time</td>
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<td>DOUT Rise Time</td>
<td>tDR</td>
<td>CDOUT = 10pF, 20% to 80%</td>
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<td>DOUT Fall Time</td>
<td>tDF</td>
<td>CDOUT = 10pF, 80% to 20%</td>
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<td>ns</td>
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<tr>
<td>LE Rising to OUT_ Rising Delay</td>
<td>tLRR</td>
<td>(Note 6)</td>
<td></td>
<td>140</td>
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<td>ns</td>
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<td>LE Rising to OUT_ Falling Delay</td>
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<td>(Note 6)</td>
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<td>(Note 6)</td>
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<td>tORE</td>
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<td>tR</td>
<td>20% to 80% (Note 6)</td>
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Note 1: All devices are 100% production tested at TJ = +25°C and TA = +125°C. Limits to TA = -40°C are guaranteed by design.

Note 2: Guaranteed by design, not production tested.

Note 3: Parameter is measured at trip point of latch with VFB = 0V.

Note 4: Gain is defined as A = ΔVCOMP/ΔVCS, 0.05V ≤ VCS ≤ 0.25V.

Note 5: See Figures 3 and 4.

Note 6: A 65Ω pullup resistor is connected from OUT_ to 5.5V. Rising refers to VOUT_ when current through OUT_ is turned off and falling refers to VOUT_ when current through OUT_ is turned on.
Typical Operating Characteristics

\( V_{CC} = +15\text{V}, \ V^+ = 3\text{V to 5.5V}, \ R_T = 10k\Omega, \ C_T = 3.3\text{nF}, \ V_{REF} = \text{COMP} = \text{open}, \ C_{REF} = 0.1\mu\text{F}, \ V_{FB} = 2\text{V}, \ V_{CS} = V_{AGND} = V_{PGND} = 0\text{V}. \)

Typical values are at \( T_A = +25°C, \) unless otherwise noted.)
Typical Operating Characteristics (continued)

\(V_{CC} = +15V, V^+ = 3V\) to 5.5V, \(R_T = 10k\Omega, C_T = 3.3nF, V_{REF} = \text{COMP} = \text{open}, C_{REF} = 0.1\mu F, V_{FB} = 2V, V_{CS} = V_{AGND} = V_{PGND} = 0V.\) Typical values are at \(T_A = +25^\circ C, \) unless otherwise noted.)
**Typical Operating Characteristics (continued)**

\(V_{CC} = +15V, V^+ = 3V \text{ to } 5.5V, R_T = 10k\Omega, C_T = 3.3nF, V_{REF} = \text{COMP} = \text{open}, C_{REF} = 0.1\mu F, V_{FB} = 2V, V_{CS} = V_{AGND} = V_{PGND} = 0V.\)

Typical values are at \(T_A = +25^\circ C, \) unless otherwise noted.)
Typical Operating Characteristics (continued)

(V_{CC} = +15V, V_+ = 3V to 5.5V, R_T = 10kΩ, C_T = 3.3nF, V_{REF} = COMP = open, C_{REF} = 0.1μF, V_FB = 2V, V_CS = V_{AGND} = V_{PGND} = 0V. Typical values are at T_A = +25°C, unless otherwise noted.)

OUT_CURRENT vs. OUT_VOLTAGE
(RSET = 360Ω, V_+ = 5.0V)

OUT_CURRENT vs. SUPPLY_VOLTAGE V+
(RSET = 720Ω, V_OUT = 2V)

OUT_CURRENT vs. SUPPLY_VOLTAGE V+
(RSET = 360Ω, V_OUT = 2V)

OUT_CURRENT vs. SET RESISTANCE
(V_+ = 5.0V)
**Detailed Description**

The MAX16807 LED driver includes an internal switch-mode controller that can be used as boost or buck-boost (SEPIC) converters to generate the voltage necessary to drive the multiple strings of LEDs. This device incorporates an integrated low-side driver, programmable oscillator (20kHz to 1MHz), error amplifier, low-voltage (300mV) current sense for higher efficiency, and a 5V reference to power up external circuitry (see Figures 1a and 1b).

The MAX16807 LED driver includes a 4-wire serial interface and a current-mode PWM controller to generate the necessary voltage for driving eight open-drain, constant-current-sinking output ports. The driver uses current-sensing feedback circuitry (not simple current mirrors) to ensure very small current variations over the full allowed range of output voltage (see the Typical Operating Characteristics). The 4-wire serial interface comprises an 8-bit shift register and an 8-bit transparent latch. The shift register is written through a clock input (CLK) and a data input (DIN), and the data propagates to a data output (DOUT). The data output allows multiple drivers to be cascaded and operated together. The contents of the 8-bit shift register are loaded into the transparent latch through a latch-enable input (LE). The latch is transparent to the shift-register outputs while LE is high. Data is latched into the output latch(es) on LE’s falling edge, and retained while LE is low.

The MAX16807 LED driver outputs OUT0–OUT7 are open-drain, constant-current-sinking outputs rated for 36V. The driver uses current-sensing feedback circuitry (not simple current mirrors) to ensure very small current variations over the full allowed range of output voltage (see the Typical Operating Characteristics). The 4-wire serial interface comprises an 8-bit shift register and an 8-bit transparent latch. The shift register is written through a clock input (CLK) and a data input (DIN), and the data propagates to a data output (DOUT). The data output allows multiple drivers to be cascaded and operated together. The contents of the 8-bit shift register are loaded into the transparent latch through a latch-enable input (LE). The latch is transparent to the shift-register outputs when high and latches the current state on the falling edge of LE. Each driver output is an open-drain, constant-current sink that should be connected to the cathode of a string of LEDs con-
nected in series. The constant-current capability is up to 55mA per output, set for all eight outputs by an external resistor (RSET). The device can operate in stand-alone mode (see the Typical Operating Circuits.)

The number of channels can be expanded by using the MAX6970 and MAX6971 family in conjunction with the MAX16807.

Figure 1a. Internal Block Diagram (MAX16807)
Switch-Mode Controller

Current-Mode Control Loop

The advantages of current-mode control over voltage-mode control are twofold. First, there is the feed-forward characteristic brought on by the controller’s ability to adjust for variations in the input voltage on a cycle-by-cycle basis. Second, the stability requirements of the current-mode controller are reduced to that of a single-pole system, unlike the double pole in the voltage-mode control scheme. The MAX16807 uses a current-mode control loop where the output of the error amplifier is compared to the current-sense voltage (V\textsubscript{CS}). When the current-sense signal is lower than the inverting input of the CPWM comparator, the output of the comparator is low and the switch is turned on at each clock pulse. When the current-sense signal is higher than the inverting input of the CPWM comparator, the output is high and the switch is turned off.

Undervoltage Lockout (UVLO)

The turn-on supply voltage for the MAX16807 is 8.4V (typ). Once V\textsubscript{CC} reaches 8.4V, the reference powers up. There is 0.8V of hysteresis from the turn-on voltage to the UVLO threshold. Once V\textsubscript{CC} reaches 8.4V, the MAX16807 operates with V\textsubscript{CC} down to 7.6V (typ). Once V\textsubscript{CC} goes below 7.6V, the device is in UVLO. When in UVLO, the quiescent supply current into V\textsubscript{CC} falls back to 32μA (typ), and OUT and REF are pulled low.

MOSFET Driver

OUT drives an external n-channel MOSFET and swings from AGND to V\textsubscript{CC}. Ensure that V\textsubscript{CC} remains below the absolute maximum V\textsubscript{GS} rating of the external MOSFET. OUT is a push-pull output with the on-resistance of the pMOS (typically 3.5Ω) and the on-resistance of the nMOS (typically 4.5Ω). The driver can source 2A and sink 1A (typ). This allows for the MAX16807 to quickly turn on and off high gate-charge MOSFETs. Bypass V\textsubscript{CC} with one or more 0.1μF ceramic capacitors to AGND, placed close to the V\textsubscript{CC} pin. The average current sourced to drive the external MOSFET depends on the total gate charge (Q\textsubscript{G}) and operating frequency of the converter. The power dissipation in the device is a function of the average output drive current (I\textsubscript{DRIVE}). Use the following equation to calculate the power dissipation in the device due to I\textsubscript{DRIVE}:

\[
I\textsubscript{DRIVE} = (Q\textsubscript{G} \times f\textsubscript{SW})
\]

\[
PD = (I\textsubscript{DRIVE} + I\textsubscript{CC}) \times V\textsubscript{CC}
\]

where I\textsubscript{CC} is the operating supply current. See the Typical Operating Characteristics for the operating supply current at a given frequency.

Error Amplifier

The MAX16807 includes an internal error amplifier. The inverting input is at FB and the noninverting input is internally connected to a 2.5V reference. Set the output voltage using a resistive divider between the output of the converter (V\textsubscript{OUT}, FB, and AGND). Use the following formula to set the output voltage:

\[
V\textsubscript{OUT} = \left(1 + \frac{R1}{R2}\right) \times V\textsubscript{FB}
\]

where V\textsubscript{FB} = 2.5V.

Oscillator

The oscillator frequency is programmable using an external capacitor and a resistor at RTCT (see R\textsubscript{T} and C\textsubscript{T} in the Typical Operating Circuits). R\textsubscript{T} is connected from RTCT to the 5V reference (REF), and C\textsubscript{T} is connected from RTCT to AGND. REF charges C\textsubscript{T} through R\textsubscript{T} until its voltage reaches 2.8V. C\textsubscript{T} then discharges through an 8.3mA internal current sink until C\textsubscript{T}’s voltage reaches 1.1V, at which time C\textsubscript{T} is allowed to charge through R\textsubscript{T} again. The oscillator’s period is the sum of the charge and discharge times of C\textsubscript{T}. Calculate the charge time as follows:

\[
t\textsubscript{C} = 0.57 \times R\textsubscript{T} \times C\textsubscript{T}
\]

where t\textsubscript{C} is in seconds, RT in ohms (Ω), and C\textsubscript{T} in Farads (F). The discharge time is then:

\[
t\textsubscript{D} = (R\textsubscript{T} \times C\textsubscript{T} \times 1000) / [(4.88 \times R\textsubscript{T}) - (1.8 \times 1000)]
\]

where t\textsubscript{D} is in seconds, R\textsubscript{T} in ohms (Ω), and C\textsubscript{T} in Farads (F).
The oscillator frequency is then:

\[ \text{OSC} = \frac{t_c}{t_D} \]

**Reference Output (REF)**

REF is a 5V reference output that can source 20mA. Bypass REF to AGND with a 0.1\(\mu\)F capacitor.

**Current Limit**

The MAX16807 includes a fast current-limit comparator to terminate the on-cycle during an overload or a fault condition. The current-sense resistor \((R_{CS})\) connected between the source of the external MOSFET and AGND, sets the current limit. The CS input has a voltage trip level \((V_{CS})\) of 0.3V. Use the following equation to calculate \(R_{CS}\):

\[ R_{CS} = \frac{V_{CS}}{I_{P-P}} \]

\(I_{P-P}\) is the peak current that flows through the MOSFET. When the voltage produced by this current (through the current-sense resistor) exceeds the current-limit comparator threshold, the MOSFET driver (OUT) turns the switch off within 60ns. In most cases, a small RC filter is required to filter out the leading-edge spike on the sense waveform. Set the time constant of the RC filter at 50ns.

**Buck-Boost (SEPIC) Operation**

Figure 2 shows a buck-boost application circuit using the MAX16807 in stand-alone mode of operation. SEPIC topology is necessary when the total forward voltage of the LEDs in a string is such that \(V_{OUT}\) can be below or above \(V_{IN}\).

![Figure 2. Buck-Boost (SEPIC) Configuration](image-url)
LED Driver

4-Wire Interface

The MAX16807 also operates in stand-alone mode (see the Typical Operating Circuits). For use with a microcontroller, the MAX16807 features a 4-wire serial interface using DIN, CLK, LE, OE inputs and DOUT as a data output. This interface is used to write the LED channels’ data to the MAX16807. The serial-interface data word length is 8 bits (D0–D7). See Figure 3.

The functions of the five interface pins are as follows:

- DIN is the serial-data input, and must be stable when it is sampled on the rising edge of CLK. Data is shifted in MSB first. This means that data bit D7 is clocked in first, followed by seven more data bits, finishing with the LSB (D0).
- CLK is the serial-clock input that shifts data at DIN into the MAX16807’s 8-bit shift register on its rising edge.
- LE is the latch-enable input of the MAX16807 that transfers data from the 8-bit shift register to its 8-bit output latch (transparent latch). The data is latched on the falling edge of LE (Figure 4). The fourth input (OE) provides output-enable control of the output drivers. When OE is driven high, the outputs (OUT0–OUT7) are forced to high impedance without altering the contents of the output latches. Driving OE low enables the outputs to follow the state of the output latches. OE is independent of the operation of the serial interface operation. Data can be shifted into the serial-interface shift register and latched, regardless of the state of OE. DOUT is the serial-data output that shifts data out from the MAX16807’s 8-bit shift register on the rising edge of CLK. Data at DIN propagates through the shift register and appears at DOUT eight clock cycles later. Table 1 shows the 4-wire serial-interface truth table.

Selecting External Component RSET to Set LED Output Current

The MAX16807 uses an external resistor (RSET) to set the LED current for outputs OUT0–OUT7. The minimum allowed value of RSET is 330Ω, which sets the output currents to 55mA. The maximum allowed value of RSET is 5kΩ (IOUT = 3.6mA) and the maximum allowed capacitance at SET is 100pF.

Use the following formula to set the output current:

\[ R_{SET} = \frac{18,000}{I_{OUT}} \]

where IOUT is the desired output current in milliamps and the value for RSET is in ohms.

Overtemperature Cutoff

The MAX16807 contains an internal temperature sensor that turns off all outputs when the die temperature exceeds +165°C. The outputs are enabled again when the die temperature drops below +140°C. Register contents are not affected, so when a driver is overdissipating, the external symptom is the load LEDs cycling on and off as the driver repeatedly overheats and cools, alternately turning itself off and then back on again.

Table 1. 4-Wire Serial-Interface Truth Table

<table>
<thead>
<tr>
<th>SERIAL DATA INPUT DIN</th>
<th>CLOCK INPUT</th>
<th>SHIFT REGISTER CONTENTS</th>
<th>LOAD INPUT</th>
<th>LATCH CONTENTS</th>
<th>BLANKING INPUT</th>
<th>OUTPUT CONTENTS CURRENT AT OUT_</th>
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<td>CL</td>
<td>D0</td>
<td>D1</td>
<td>D2</td>
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<td>Dn</td>
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<tr>
<td>H</td>
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<td>R0</td>
<td>R1</td>
<td>...</td>
<td>Rn-2</td>
<td>Rn-1</td>
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<tr>
<td>L</td>
<td>L</td>
<td>R0</td>
<td>R1</td>
<td>...</td>
<td>Rn-2</td>
<td>Rn-1</td>
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<td>X</td>
<td>X</td>
<td>...</td>
<td>X</td>
<td>X</td>
<td>L</td>
</tr>
</tbody>
</table>

L = Low Logic Level
H = High Logic Level
X = Don’t Care
P = Present State (Shift Register)
R = Previous State (Latched)
Stand-Alone Operation

In stand-alone operation, the MAX16807 does not use the 4-wire interface (see the Typical Operating Circuits). Connecting DIN and LE to V+ provides at least eight external clock pulses to CLK to enable the $R_{SET}$ outputs. This startup pulse sequence can be provided either using an external clock or the PWM signal. The external clock can also be generated using the signal at RTCT and an external comparator.

**LED Dimming**

**PWM Dimming**

All the output channels can be dimmed simultaneously by applying a PWM signal (50Hz to 30kHz) to OE. This allows for a wide range of dimming up to a 5000:1 ratio. Each channel can be independently turned on and off using a 4-wire serial interface. The dimming is proportional to the PWM duty cycle.

**LED Current-Amplitude Adjustment**

Using an analog or digital potentiometer as $R_{SET}$ allows for LED current-amplitude adjustment and linear dimming.
Computing Power Dissipation

Use the following equation to estimate the upper-limit power dissipation (PD) for the MAX16807:

\[
PD = DUTY \times \left( V_+ \times I_+ + \sum_{i=0}^{i=7} V_{\text{OUTi}} \times I_{\text{OUTi}} \right) + \left( V_{\text{CC}} \times I_{\text{CC}} \right)
\]

where:

- \(V_+\) = Supply voltage
- \(I_+\) = Operating supply current
- \(DUTY\) = PWM duty cycle applied to \(\bar{OE}\)
- \(V_{\text{OUTi}}\) = MAX16807 port output voltage when driving load LED(s)
- \(I_{\text{OUTi}}\) = LED drive current programmed by \(R_{\text{SET}}\)
- \(PD\) = Power dissipation

PCB Layout Guidelines

Careful PCB layout is critical to achieve low switching losses and clean, stable operation. Use a multilayer board whenever possible for better noise immunity. Protect sensitive analog grounds by using a star ground configuration. Minimize ground noise by connecting AGND, PGND, the input bypass-capacitor ground lead, and the output-filter ground lead to a single point (star ground configuration). Also, minimize trace lengths to reduce stray capacitance, trace resistance, and radiated noise. The trace between the output voltage-divider and the FB pin must be kept short, as well as the trace between AGND and PGND.

Chip Information

PROCESS: BiCMOS
MAX16807 Integrated 8-Channel LED Driver with Switch-Mode Boost and SEPIC Controller

Typical Operating Circuits (continued)

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.

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Revision History

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