Integrated LED Driver with Average-Mode Current Control

Features
- 3% Accurate LED Current
- 60V, 0.8Ω Integrated MOSFET
- Low Sensitivity to External Component Variation
- Single-Resistor LED Current Setting
- Fixed Off-Time Control
- PWM Dimming Input
- Output Short-Circuit Protection with Skip Mode
- Overtemperature Protection

Applications
- DC/DC or AC/DC LED Drivers
- RGB Backlighting Drivers for Flat Panel Displays
- General Purpose Constant-Current Source
- Signage and Decorative LED Lighting
- Chargers

General Description
The HV9967B is an Average-mode current control LED driver IC operating in a Constant Off-time mode.

The IC features an integrated 60V, 0.8Ω MOSFET that can be used as a stand-alone buck converter switch or connected as a source driver for driving an external high-voltage Depletion-mode MOSFET. The HV9967B is powered through its switching output when the integrated switch is off. Therefore, the same external MOSFET can be used as a high-voltage linear regulator for powering the IC.

The LED current is programmed with one external resistor. The Average-mode current control method does not produce a peak-to-average error. This greatly improves the current accuracy as well as the line and load regulations of the LED current without any need for loop compensation or direct sensing of the LED current at a high-voltage potential. The auto-zero circuit cancels the effects of the input offset voltage and of the propagation delay of the current sense comparator.

Package Types

See Table 2-1 for pin information.
Functional Block Diagram

HV9967B

- L/E Blanking
- Average Current Control Logic
- Short-Circuit Overcurrent Comparator
- SET
- T_{off} Timer
- R Q S Q
- 0.8 ms Hiccup Time
- 4.35 V
- 100 kΩ
- 0.8 ms
- PWMD
- RSENSE
- AGND
- PGND
- 1.8 V
- V_{CS}
- IN
- OUT
1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW to GND</td>
<td>–0.5V</td>
<td>0</td>
<td>+65V</td>
<td>–0.3V to +6V</td>
<td></td>
</tr>
<tr>
<td>VDD to GND</td>
<td>–0.3V</td>
<td>0</td>
<td>6V</td>
<td>–0.3V to (VDD + 0.3V)</td>
<td></td>
</tr>
<tr>
<td>Other I/O to GND</td>
<td>–0.3V</td>
<td>0</td>
<td>(VDD + 0.3V)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRT</td>
<td>2 mA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junction Temperature Range, TJ</td>
<td>–40°C</td>
<td>0</td>
<td>+150°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage Temperature Range, TS</td>
<td>–65°C</td>
<td>0</td>
<td>+150°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous Power Dissipation (TA = +25°C):</td>
<td>8-lead MSOP</td>
<td>350 mW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-lead DFN</td>
<td>1.6W</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† Notice: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only, and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

Electrical Specifications: TA = 25°C, VSW = 10V/10 mA, VDD = 5V unless otherwise specified.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>INPUT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input DC Supply Voltage Range</td>
<td>VSWDC</td>
<td>8</td>
<td>—</td>
<td>60</td>
<td>V</td>
<td>DC input voltage</td>
</tr>
<tr>
<td>Shutdown Mode Supply Current</td>
<td>IINS</td>
<td>—</td>
<td>0.5</td>
<td>1</td>
<td>mA</td>
<td>Pin PWMD connected to GND</td>
</tr>
<tr>
<td>INTERNAL REGULATOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internally Regulated Voltage</td>
<td>VDD</td>
<td>4.7</td>
<td>5</td>
<td>5.2</td>
<td>V</td>
<td>VPWMD = VDD, RT = 100 kΩ</td>
</tr>
<tr>
<td>VDD Undervoltage Lockout Upper Threshold</td>
<td>VUVLOR</td>
<td>4.1</td>
<td>4.35</td>
<td>4.7</td>
<td>V</td>
<td>VDD rising, as needed to ensure IC(MIN) (Note 1)</td>
</tr>
<tr>
<td>VDD Undervoltage Lockout Hysteresis</td>
<td>AVUVLO</td>
<td>—</td>
<td>150</td>
<td>—</td>
<td>mV</td>
<td>VDD falling</td>
</tr>
<tr>
<td>PMW DIMMING</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PWMD Input Low Voltage</td>
<td>VEN(LO)</td>
<td>—</td>
<td>—</td>
<td>0.8</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>PWMD Input High Voltage</td>
<td>VEN(HI)</td>
<td>2</td>
<td>—</td>
<td>—</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>PWMD Pull-Down Resistance</td>
<td>REN</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>kΩ</td>
<td></td>
</tr>
<tr>
<td>CURRENT CONTROL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RSENSE Current Threshold Voltage</td>
<td>VCS(TH)</td>
<td>243</td>
<td>250</td>
<td>257</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Threshold Voltage Temperature Coefficient</td>
<td>dVCS/dT</td>
<td>—</td>
<td>0.1</td>
<td>—</td>
<td>mV/°C</td>
<td></td>
</tr>
<tr>
<td>Current Sense Blanking Interval</td>
<td>TBLANK</td>
<td>140</td>
<td>290</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Minimum On-Time</td>
<td>TON(MIN)</td>
<td>—</td>
<td>950</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Maximum Steady-State Duty Cycle</td>
<td>DMAX</td>
<td>80</td>
<td>—</td>
<td>—</td>
<td>%</td>
<td>Reduction in output LED current may occur beyond this duty cycle. (Note 1)</td>
</tr>
<tr>
<td>SHORT-CIRCUIT PROTECTION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hiccup Threshold Voltage at RSENSE</td>
<td>VCS(SHORT)</td>
<td>355</td>
<td>400</td>
<td>440</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Current Limit Delay RSENSE to SW-OFF</td>
<td>TDELAY</td>
<td>—</td>
<td>—</td>
<td>150</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Denotes specifications which apply over the full operating ambient temperature range of –40°C < TA < +125°C

Note 2: For design guidance only
# ELECTRICAL CHARACTERISTICS (CONTINUED)

**Electrical Specifications**: \( T_A = 25^\circ C, \ V_{SW} = 10V/10 \ mA, \ V_{DD} = 5V \) unless otherwise specified.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-Circuit Hiccup Time</td>
<td>( T_{HICCUP} )</td>
<td>—</td>
<td>800</td>
<td>—</td>
<td>( \mu s )</td>
<td></td>
</tr>
<tr>
<td>Minimum On-Time (Short-Circuit)</td>
<td>( T_{ON(MIN),SC} )</td>
<td>—</td>
<td>—</td>
<td>400</td>
<td>ns</td>
<td>( V_{RSENSE} = V_{CS(SHORT)} + 50 \ mV )</td>
</tr>
<tr>
<td><strong>( T_{OFF} ) TIMER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off Time</td>
<td>( T_{OFF} )</td>
<td>28</td>
<td>40</td>
<td>48</td>
<td>( \mu s )</td>
<td>( R_T = 100 \ k\Omega ) (Note 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>10</td>
<td>12</td>
<td>( \mu s )</td>
<td>( R_T = 100 \ k\Omega ) (Note 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7</td>
<td>1</td>
<td>1.2</td>
<td>( \mu s )</td>
<td>( R_T = 10 \ k\Omega ) (Note 1)</td>
</tr>
<tr>
<td><strong>SW OUTPUT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On Resistance</td>
<td>( R_{ON} )</td>
<td>—</td>
<td>0.8</td>
<td>—</td>
<td>( \Omega )</td>
<td>( V_{DD} = 5V )</td>
</tr>
<tr>
<td>Continuous Current</td>
<td>( I_C )</td>
<td>0.75</td>
<td>—</td>
<td>—</td>
<td>A</td>
<td>( V_{DD} = 4.75V, V_{RSENSE} = 370 \ mV, V_{SW} = 10V ) (Note 1)</td>
</tr>
<tr>
<td><strong>OVERTEMPERATURE PROTECTION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Shutdown Temperature</td>
<td>( T_{SD} )</td>
<td>125</td>
<td>145</td>
<td>—</td>
<td>°C</td>
<td>Note 2</td>
</tr>
<tr>
<td>Thermal Shutdown Hysteresis</td>
<td>( \Delta T_{SD} )</td>
<td>—</td>
<td>20</td>
<td>—</td>
<td>°C</td>
<td>Note 2</td>
</tr>
</tbody>
</table>

**Note 1**: Denotes specifications which apply over the full operating ambient temperature range of \( -40^\circ C < T_A < +125^\circ C \)

**Note 2**: For design guidance only

## TEMPERATURE SPECIFICATIONS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TEMPERATURE RANGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Ambient Temperature</td>
<td>( T_A )</td>
<td>–40</td>
<td>—</td>
<td>+125</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>( T_{J(ABSMAx)} )</td>
<td>—</td>
<td>—</td>
<td>+150</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>( T_s )</td>
<td>–65</td>
<td>—</td>
<td>+150</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td><strong>PACKAGE THERMAL RESISTANCE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-lead MSOP</td>
<td>( \theta_{JA} )</td>
<td>—</td>
<td>216</td>
<td>—</td>
<td>°C/W</td>
<td></td>
</tr>
<tr>
<td>8-lead DFN</td>
<td>( \theta_{JA} )</td>
<td>—</td>
<td>60</td>
<td>—</td>
<td>°C/W</td>
<td></td>
</tr>
</tbody>
</table>
2.0 PIN DESCRIPTION

Table 2-1 shows the pin description details of HV9967B. Refer to Package Types for the location of pins.

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Pin Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SW</td>
<td>Drain of 60V 0.8Ω NDMOS switch and input of H/V regulator</td>
</tr>
<tr>
<td>2</td>
<td>RSENSE</td>
<td>Source of NDMOS switch and current sense input. Connect a resistor between RSENSE and GND to program the output current and short-circuit protection tripping current.</td>
</tr>
<tr>
<td>3</td>
<td>PGND</td>
<td>Power ground. Must be wired to AGND on PCB.</td>
</tr>
<tr>
<td>4</td>
<td>PWMD</td>
<td>PWM dimming input. This TTL input enables switching of SW when in High state.</td>
</tr>
<tr>
<td>5</td>
<td>NC</td>
<td>No connection</td>
</tr>
<tr>
<td>6</td>
<td>RT</td>
<td>Resistor connected between RT and VDD. This programs the off time of SW.</td>
</tr>
<tr>
<td>7</td>
<td>AGND</td>
<td>Analog ground (0V)</td>
</tr>
<tr>
<td>8</td>
<td>VDD</td>
<td>Power supply for all internal circuits. Bypass with a low ESR capacitor to PGND (&gt;0.5 μF). Connect gate of external Depletion-mode NFET for high-voltage operation.</td>
</tr>
</tbody>
</table>
3.0 APPLICATION INFORMATION

3.1 General Description
The HV9967B employs a control scheme that achieves fast and extremely accurate control of the average current in the buck inductor by sensing only the switch current. No compensation of the current control loop is required. The LED current response to PWMD input is similar to that of the peak-current control ICs, such as the HV9910B. The inductor current ripple amplitude does not affect this control scheme significantly. Therefore, the LED current is independent of the variation in inductance, switching frequency and output voltage. Constant off-time control of the buck converter is used for stability and to reduce input voltage regulation of the LED current.

3.2 Off Timer
The timing resistor connected to RT pin determines the off time of the gate driver and SW. The timing resistor must be wired across RT pin and VDD pin. Refer to Equation 3-1 for the computation of the SW off time.

EQUATION 3-1:
\[ T_{OFF} = R_T \times 100 \mu F \]
Within the range of 10 kΩ ≤ R_T ≤ 400 kΩ

3.3 Average Current Control Feedback and Output Short-Circuit Protection
The constant-current control feedback derives the average-current signal from the source current of the switching MOSFET. This current is detected with a sense resistor at the RSENSE pin. The feedback operates in a fast Open-loop mode. No compensation is required. Output current is programmed as seen in Equation 3-2:

EQUATION 3-2:
\[ I_{LED} = \frac{0.25V}{R_{CS}} \]
The above equation is only valid for continuous conduction of the output inductor. It is a good practice to design the inductor such that the peak-to-peak switching inductor ripple current in it is 30% to 40% of its average full DC current load. Hence, the recommended inductance can be computed as specified in Equation 3-3:

EQUATION 3-3:
\[ L_o = \frac{V_{O(MAX)} \times T_{OFF}}{0.4 \times I_o} \]
The duty cycle range of the current control feedback is limited to D ≤ 0.8. A reduction in the LED current may occur when the LED string voltage V_o is greater than 80% of the input voltage V_IN of the HV9967B LED driver.

Reducing the output LED voltage V_o below \( V_{O(MIN)} = V_{IN} \times D_{MIN} \), where \( D_{MIN} = 0.8 \mu s/(T_{OFF} + 8 \mu s) \), may also result in loss of LED current regulation. This condition, however, causes an increase in the LED current and can potentially trip the short-circuit protection comparator threshold.

The short-circuit protection comparator trips when the voltage at RSENSE exceeds 0.4V. When this occurs, the SW off time \( T_{HICCUP} = 800 \mu s \) is generated to prevent the staircasing of the inductor current and, potentially, its saturation due to insufficient output voltage. The typical short-circuit inductor current is shown in the waveform in Figure 3-1.

FIGURE 3-1: Short-Circuit Inductor Current.

A leading-edge blanking delay is provided at RSENSE pin to prevent false triggering of the short-circuit hiccup threshold voltage and the short-circuit protection.

3.4 SW Input and Linear Regulator
The HV9967B includes an integrated 60V, 0.8Ω switching MOSFET at the SW input. The power for the IC is supplied from a built-in linear 5V regulator that is also derived from the SW input.

3.5 PWM Dimming
The HV9967B features a TTL-compatible dimming input PWMD. Applying a square-wave voltage to PWMD will modulate the duty ratio of the LED current accordingly. The rising and falling edges are limited by the current slew rate in the inductor. The first switching cycle is terminated upon reaching the 250 mV level at RSENSE pin. The circuit will reach the Steady state within three to four switching cycles regardless of the switching frequency.

3.6 Overtemperature Protection
The HV9967B includes overtemperature protection. Typically, when the junction temperature exceeds 145°C, switching of the SW input is disabled. The switching resumes when the temperature falls by approximately 20°C from the trip point.
4.0 PACKAGING INFORMATION

4.1 Package Marking Information

Legend:

XX...X  Product Code or Customer-specific information
Y       Year code (last digit of calendar year)
YY      Year code (last 2 digits of calendar year)
WW      Week code (week of January 1 is week '01')
NNN     Alphanumeric traceability code
③ Pb-free JEDEC® designator for Matte Tin (Sn)
* This package is Pb-free. The Pb-free JEDEC designator (③) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for product code or customer-specific information. Package may or not include the corporate logo.
8-Lead MSOP Package Outline (MG)
3.00x3.00mm body, 1.10mm height (max), 0.65mm pitch

Note: For the most current package drawings, see the Microchip Packaging Specification at www.microchip.com/packaging.

Note:
1. A Pin 1 identifier must be located in the index area indicated. The Pin 1 identifier can be: a molded mark/identifier, an embedded metal marker, or a printed indicator.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>A</th>
<th>A1</th>
<th>A2</th>
<th>b</th>
<th>D</th>
<th>E</th>
<th>E1</th>
<th>e</th>
<th>L</th>
<th>L1</th>
<th>L2</th>
<th>θ</th>
<th>θ1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension (mm)</td>
<td>MIN</td>
<td>0.75*</td>
<td>0.00</td>
<td>0.75</td>
<td>0.22</td>
<td>2.80*</td>
<td>4.65*</td>
<td>2.80*</td>
<td>0.65 BSC</td>
<td>0.40</td>
<td>0.95 REF</td>
<td>0.25 BSC</td>
<td>0°</td>
</tr>
<tr>
<td>NOM</td>
<td>-</td>
<td>-</td>
<td>0.85</td>
<td>-</td>
<td>3.00</td>
<td>4.90</td>
<td>3.00</td>
<td>-</td>
<td>0.60</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MAX</td>
<td>1.10</td>
<td>0.15</td>
<td>0.95</td>
<td>0.38</td>
<td>3.20*</td>
<td>5.15*</td>
<td>3.20*</td>
<td>-</td>
<td>0.80</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8°</td>
</tr>
</tbody>
</table>

* This dimension is not specified in the JEDEC drawing.
Drawings are not to scale.
8-Lead DFN Package Outline (K7)
3.00x3.00mm body, 0.80mm height (max), 0.65mm pitch

Note: For the most current package drawings, see the Microchip Packaging Specification at www.microchip.com/packaging.

Notes:
1. A Pin 1 identifier must be located in the index area indicated. The Pin 1 identifier can be a molded mark/identifier, an embedded metal marker, or a printed indicator.

2. Depending on the method of manufacturing, a maximum of 0.15mm pullback (L1) may be present.

3. The inner tip of the lead may be either rounded or square.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>A</th>
<th>A1</th>
<th>A3</th>
<th>b</th>
<th>D</th>
<th>D2</th>
<th>E</th>
<th>E2</th>
<th>e</th>
<th>L</th>
<th>L1</th>
<th>θ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension (mm)</td>
<td>MIN</td>
<td>0.70</td>
<td>0.00</td>
<td>0.20</td>
<td>2.85*</td>
<td>1.60</td>
<td>2.85*</td>
<td>1.35</td>
<td>0.65</td>
<td>0.30</td>
<td>0.00*</td>
<td>0°</td>
</tr>
<tr>
<td></td>
<td>NOM</td>
<td>0.75</td>
<td>0.02</td>
<td>0.30</td>
<td>3.00</td>
<td>-</td>
<td>3.00</td>
<td>-</td>
<td>0.65</td>
<td>0.40</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>MAX</td>
<td>0.80</td>
<td>0.05</td>
<td>0.35</td>
<td>3.15*</td>
<td>2.50</td>
<td>3.15*</td>
<td>1.75</td>
<td>0.50</td>
<td>0.15</td>
<td>14°</td>
<td></td>
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</tbody>
</table>

* This dimension is not specified in the JEDEC drawing.

Drawings not to scale.
APPENDIX A: REVISION HISTORY

Revision A (February 2020)

• Converted Supertex Doc# DSFP-HV9967B to Microchip DS20005734A
• Updated the package marking format
• Updated the packaging quantity of the 8-lead DFN K7 package from 3000/Reel to 3300/Reel to align it with the actual BQM
• Made minor text changes throughout the document
**PRODUCT IDENTIFICATION SYSTEM**

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

<table>
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<tr>
<th>PART NO.</th>
<th>XX</th>
<th>Package Options</th>
<th>Environmental</th>
<th>Media Type</th>
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<tr>
<td>HV9967B</td>
<td>G</td>
<td>MG = 8-lead MSOP</td>
<td>G = Lead (Pb)-free/RoHS-compliant Package</td>
<td></td>
</tr>
<tr>
<td>Packages</td>
<td>K7</td>
<td></td>
<td></td>
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<tr>
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<tr>
<td>Media Type</td>
<td>(blank)</td>
<td>2500/Reel for an MG Package, 3300/Reel for a K7 Package</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Examples:**

a) HV9967BMG-G: Integrated LED Driver with Average-Mode Current Control, 8-lead MSOP, 2500/Reel

b) HV9967BK7-G: Integrated LED Driver with Average-Mode Current Control, 8-lead WDFN, 3300/Reel
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