

# High-Side Current Sensor

## FAN4010



SIP6 1.45X1.0  
CASE 127EB

### Description

The FAN4010 is a high-side current sense amplifier designed for battery-powered systems. Using the FAN4010 for high-side power-line monitoring does not interfere with the battery charger's ground path. The FAN4010 is designed for portable PCs, cellular phones, and other portable systems where battery / DC power-line monitoring is critical.

To provide a high level of flexibility, the FAN4010 functions with an external sense resistor to set the range of load current to be monitored. It has a current output that can be converted to a ground-referred voltage with a single resistor, accommodating a wide range of battery voltages and currents. The FAN4010 features allow it to be used for gas gauging as well as uni-directional or bi-directional current monitoring.

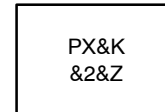
### Features at +5 V

- Low Cost, Accurate, High-Side Current Sensing
- Output Voltage Scaling
- Up to 2.5 V Sense Voltage
- 2 V to 6 V Supply Range
- 2  $\mu$ A Typical Offset Current
- 3.5  $\mu$ A Quiescent Current
- -0.2% Accuracy
- 6-Lead MicroPak™ MLP Package

### Applications Battery Chargers

- Battery Chargers
- Smart Battery Packs
- DC Motor Control
- Over-Current Monitor
- Power Management
- Programmable Current Source

### MARKING DIAGRAM



PX = Specific Device Code  
 &K = 2-Digits Lot Run Traceability Code  
 &2 = 2-Digit Date Code  
 &Z = Assembly Plant Code

### ORDERING INFORMATION

See detailed ordering and shipping information on page 7 of this data sheet.

# FAN4010

## BLOCK DIAGRAM AND TYPICAL CIRCUIT

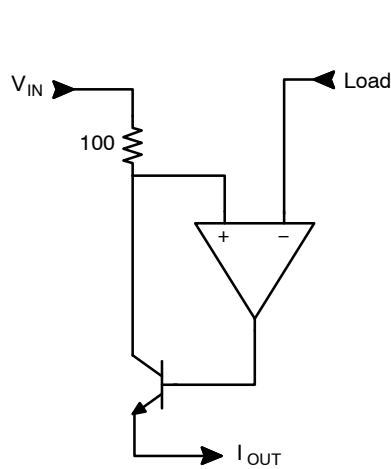


Figure 1. Functional Block Diagram

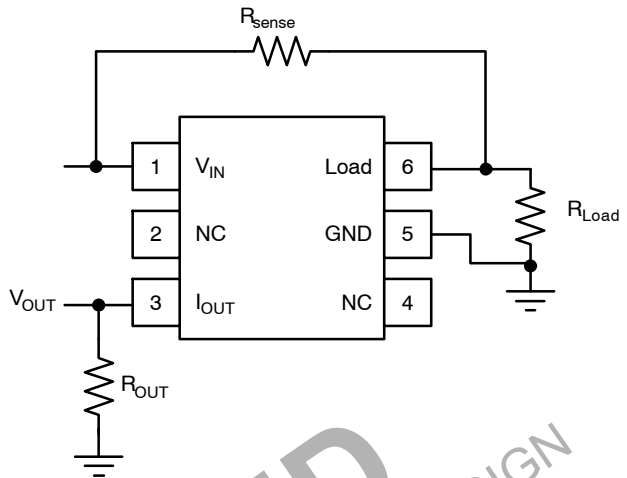


Figure 2. Typical Circuit

## PIN CONFIGURATION

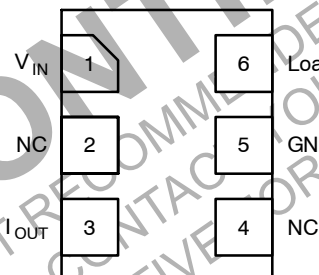


Figure 3. Pin Assignment (Top Through View)

## PIN DESCRIPTION

| Name | Type      | Description                                         |
|------|-----------|-----------------------------------------------------|
| 2, 4 | NC        | No Connect; leave pin floating                      |
| 5    | GND       | Ground                                              |
| 3    | $I_{OUT}$ | Output Current, proportional to $V_{IN} - V_{LOAD}$ |
| 1    | $V_{IN}$  | Input Voltage, Supply Voltage                       |
| 6    | Load      | Connection to load or battery                       |

## ABSOLUTE MAXIMUM RATINGS

| Symbol        | Parameter                           | Min                               | Typ | Max  | Unit |
|---------------|-------------------------------------|-----------------------------------|-----|------|------|
| $V_S$         | Supply Voltage                      | 0                                 | –   | 6.3  | V    |
| $V_{IN}$      | Input Voltage Range                 | 0                                 | –   | 6.3  | V    |
| $T_J$         | Junction Temperature                | –                                 | –   | +150 | °C   |
| $T_{STG}$     | Storage Temperature Range           | –65                               | –   | +150 | °C   |
| $T_L$         | Reflow Temperature, Soldering       | –                                 | –   | +260 | °C   |
| $\Theta_{JA}$ | Package Thermal Resistance (Note 1) | –                                 | 456 | –    | °C/W |
| ESD           | Electrostatic Discharge Protection  | Human Body Model, JESD22–A114     |     | 5000 | V    |
|               |                                     | Charged Device Model, JESD22–C101 |     | 1000 |      |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Package thermal resistance ( $\Theta_{JA}$ ), JEDEC standard, multi-layer test boards, still air.

## RECOMMENDED OPERATING CONDITIONS

| Symbol      | Parameter                                                                    | Min | Max | Unit |
|-------------|------------------------------------------------------------------------------|-----|-----|------|
| $T_A$       | Operating Temperature Range                                                  | –40 | +85 | °C   |
| $V_S$       | Supply Voltage Range                                                         | 2   | 6   | V    |
| $V_{IN}$    | Input Voltage                                                                | 2   | 6   | V    |
| $V_{SENSE}$ | Sensor Voltage Range, $V_{SENSE} = V_{IN} - V_{LOAD}$ , $R_{OUT} = 0 \Omega$ | –   | 2.5 | V    |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

ELECTRICAL CHARACTERISTICS AT +5 V ( $T_A = 25^\circ\text{C}$ ,  $V_S = V_{IN} = 5 \text{ V}$ ,  $R_{OUT} = 100 \Omega$ ,  $R_{SENSE} = 100 \Omega$ , unless otherwise noted.)

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--------|-----------|------------|-----|-----|-----|------|
|--------|-----------|------------|-----|-----|-----|------|

## FREQUENCY DOMAIN RESPONSE

|             |                            |                                                                   |       |       |       |                 |
|-------------|----------------------------|-------------------------------------------------------------------|-------|-------|-------|-----------------|
| $B_{WSS}$   | Small Signal Bandwidth     | $P_{IN} = -40 \text{ dBm}$ (Note 2), $V_{SENSE} = 10 \text{ mV}$  | –     | 600   | –     | kHz             |
| $B_{WLS}$   | Large Signal Bandwidth     | $P_{IN} = -20 \text{ dBm}$ (Note 3), $V_{SENSE} = 100 \text{ mV}$ | –     | 2     | –     | MHz             |
| $V_{IN}$    | Input Voltage Range        | $V_{IN} = V_S$                                                    | 2     | –     | 6     | V               |
| $I_{OUT}$   | Output Current (Note 4, 5) | $V_{SENSE} = 0 \text{ mV}$                                        | 0     | 1     | 9     | $\mu\text{A}$   |
|             |                            | $V_{SENSE} = 10 \text{ mV}$                                       | 90    | 100   | 110   | mA              |
|             |                            | $V_{SENSE} = 100 \text{ mV}$                                      | 0.975 | 1.000 | 1.025 |                 |
|             |                            | $V_{SENSE} = 200 \text{ mV}$                                      | 1.95  | 2.00  | 2.05  |                 |
|             |                            | $V_{SENSE} = 1 \text{ V}$                                         | 9.7   | 10.0  | 10.3  |                 |
| $I_S$       | Supply Current (Note 4)    | $V_{SENSE} = 0 \text{ V}$ , GND Pin Current                       | –     | 3.5   | 5.0   | $\mu\text{A}$   |
| $I_{SENSE}$ | Load Pin Input Current     |                                                                   | –     | 2     | –     | nA              |
| $A_{CY}$    | Accuracy                   | $R_{SENSE} = 100 \Omega$ , $R_{SENSE} = 200 \text{ mV}$ (Note 4)  | –2.5  | –0.2  | 2.5   | %               |
| $G_m$       | Transconductance           | $I_{OUT}/V_{SENSE}$                                               | –     | 10000 | –     | $\mu\text{A/V}$ |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

2.  $-40 \text{ dBm} = 6.3 \text{ mVpp}$  into  $50 \Omega$ .

3.  $-20 \text{ dBm} = 63 \text{ mVpp}$  into  $50 \Omega$ .

4. 100% tested at  $25^\circ\text{C}$ .

5. Includes input offset voltage contribution.

## TYPICAL PERFORMANCE CHARACTERISTICS

( $T_A = 25^\circ\text{C}$ ,  $V_S = V_{IN} = 5\text{ V}$ ,  $R_{OUT} = 100\ \Omega$ ,  $R_{SENSE} = 100\ \Omega$ , unless otherwise noted.)

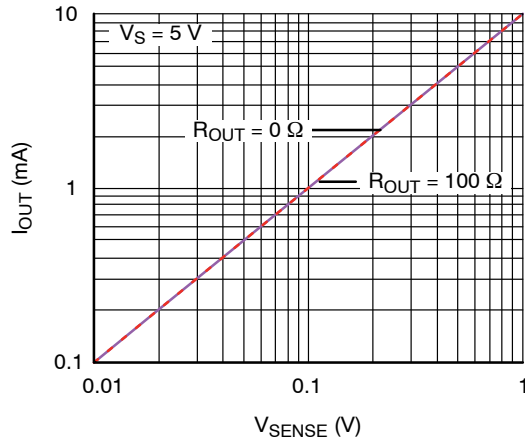
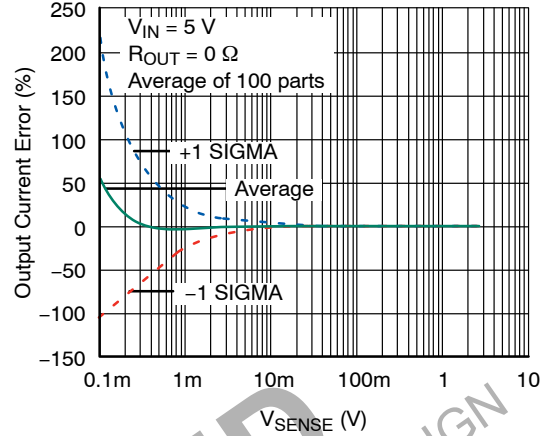
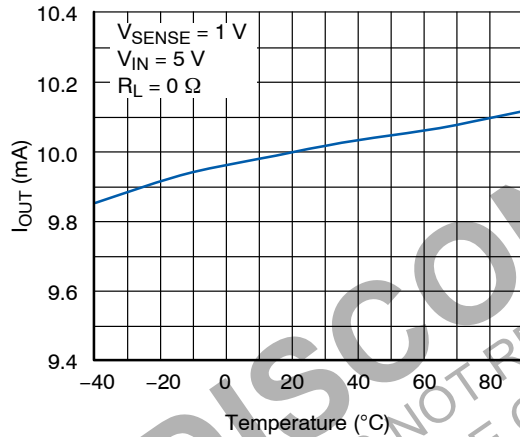
Figure 4.  $V_{SENSE}$  vs. Output CurrentFigure 5. Output Current Error vs.  $V_{SENSE}$ 

Figure 6. Output Current vs. Temperature

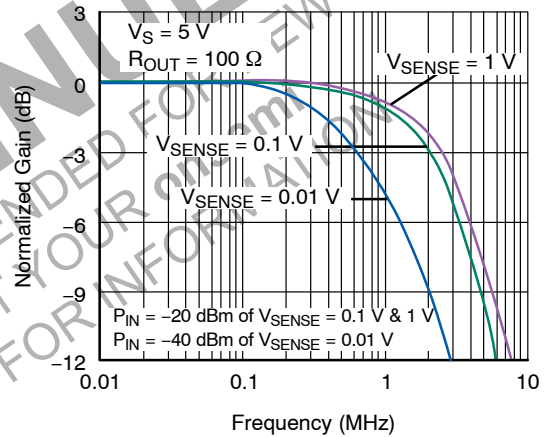


Figure 7. Frequency Response

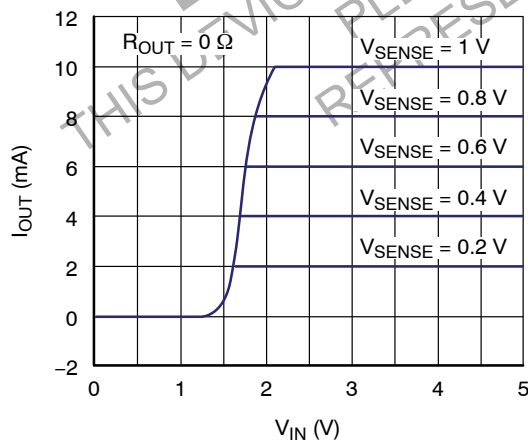


Figure 8. Transfer Characteristics

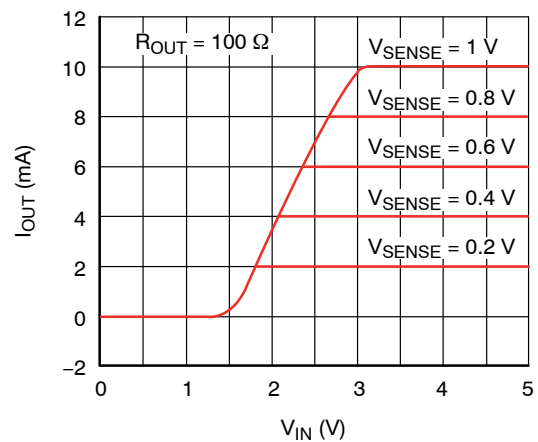
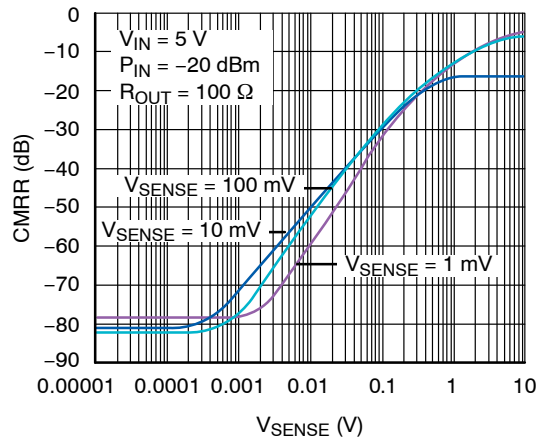


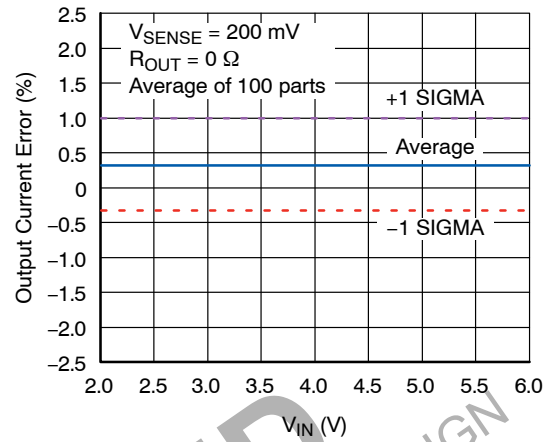
Figure 9. Transfer Characteristics

**TYPICAL PERFORMANCE CHARACTERISTICS** (Continued)

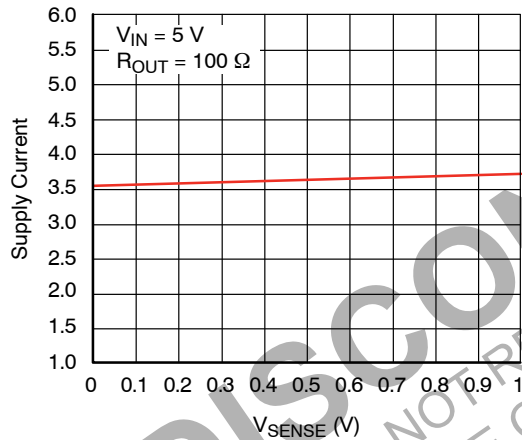
( $T_A = 25^\circ\text{C}$ ,  $V_S = V_{IN} = 5\text{ V}$ ,  $R_{OUT} = 100\ \Omega$ ,  $R_{SENSE} = 100\ \Omega$ , unless otherwise noted.)



**Figure 10. CMRR vs. Frequency**



**Figure 11. Output Current Error**



**Figure 12. Supply Current vs.  $V_{SENSE}$**

## APPLICATION INFORMATION

## Detailed Description

The FAN4010 measures the voltage drop ( $V_{SENSE}$ ) across an external sense resistor in the high-voltage side of the circuit.  $V_{SENSE}$  is converted to a linear current via an internal operational amplifier and precision  $100\ \Omega$  resistor. The value of this current is  $V_{SENSE}/100\ \Omega$  (internal). Output current flows from the  $I_{OUT}$  pin to an external resistor  $R_{OUT}$  to generate an output voltage proportional to the current flowing to the load.

Use the following equations to scale a load current to an output voltage:

$$V_{SENSE} = I_{LOAD} \cdot R_{SENSE} \quad (\text{eq. 1})$$

$$V_{OUT} = 0.01 \times V_{SENSE} \times R_{OUT} \quad (\text{eq. 2})$$

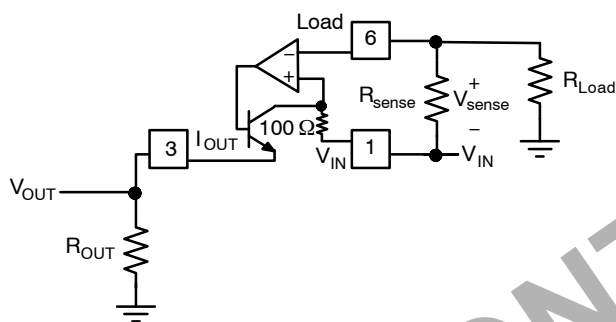


Figure 13. Functional Circuit

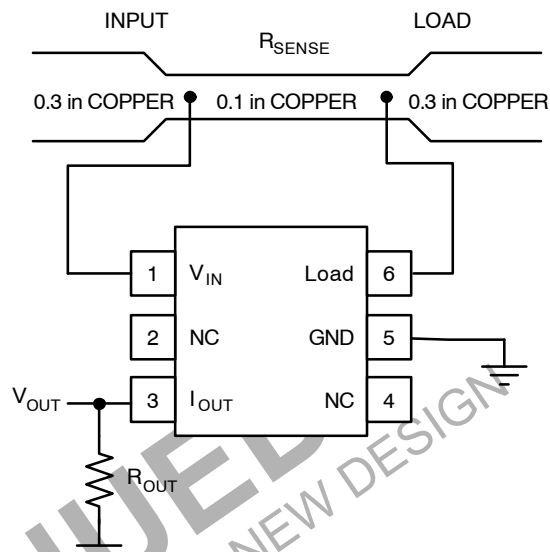
Selecting  $R_{SENSE}$ 

Selection of  $R_{SENSE}$  is a balance between desired accuracy and allowable voltage loss. Although the FAN4010 is optimized for high accuracy with low  $V_{SENSE}$  values, a larger  $R_{SENSE}$  value provides additional accuracy. However, larger values of  $R_{SENSE}$  create a larger voltage drop, reducing the effective voltage available to the load. This can be troublesome in low-voltage applications. Because of this, the maximum expected load current and allowable load voltage should be well understood. Although higher values of  $V_{SENSE}$  can be used,  $R_{SENSE}$  should be chosen to satisfy the following condition:

$$10\text{ mV} < V_{SENSE} < 200\text{ mV} \quad (\text{eq. 3})$$

For low-cost applications where accuracy is not as important, a portion of the printed circuit board (PCB) trace can be used as an  $R_{SENSE}$  resistor. Figure 14 shows an example of this configuration. The resistivity of a 0.1-inch wide trace of two-ounce copper is about  $30\text{ m}\Omega/\text{ft}$ . Unfortunately, the resistance temperature coefficient is relatively large (approximately  $0.4\%/^{\circ}\text{C}$ ), so systems with a wide temperature range may need to compensate for this effect. Additionally, self heating due to load currents

introduces a nonlinearity error. Care must be taken not to exceed the maximum power dissipation of the copper trace.

Figure 14. Using PCB Trace for  $R_{SENSE}$ Selecting  $R_{OUT}$ 

$R_{OUT}$  can be chosen to obtain the output voltage range required for the particular downstream application. For example, if the output of the FAN4010 is intended to drive an analog-to-digital convertor (ADC),  $R_{OUT}$  should be chosen such that the expected full-scale output current produces an input voltage that matches the input range of the ADC. For instance, if expected loading current ranges from 0 to 1 A, an  $R_{SENSE}$  resistor of  $1\ \Omega$  produces an output current that ranges from 0 to 10 mA. If the input voltage range of the ADC is 0 to 2 V, an  $R_{OUT}$  value of  $200\ \Omega$  should be used. The input voltage and full-scale output current ( $I_{OUT\_FS}$ ) needs to be taken into account when setting up the output range. To ensure sufficient operating headroom, choose:

$$(R_{OUT} \cdot I_{OUT\_FS}) \text{ such that } V_{IN} - V_{SENSE} - (R_{OUT} \cdot I_{OUT\_FS}) > 1.6\text{ V} \quad (\text{eq. 4})$$

Output current accuracy for the recommended  $V_{SENSE}$  between 10 mV and 200 mV are typically better than 1%. As a result, the absolute output voltage accuracy is dependent on the precision of the output resistor.

Make sure the input impedance of the circuit connected to  $V_{OUT}$  is much higher than  $R_{OUT}$  to ensure accurate  $V_{OUT}$  values.

Since the FAN4010 provides a trans-impedance function, it is suitable for applications involving current rather than voltage sensing.

## FAN4010

### ORDERING INFORMATION

| Device                       | Operating Temperature Range | Top Mark | Package                                            | Shipping <sup>†</sup> |
|------------------------------|-----------------------------|----------|----------------------------------------------------|-----------------------|
| FAN4010IL6X                  | -40°C to +85°C              | PX       | 6-Lead, Molded Leadless Package (MLP)<br>(Pb-Free) | 5000 / Tape & Reel    |
| FAN4010IL6X-F113<br>(Note 6) |                             |          |                                                    |                       |

<sup>†</sup>For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

- 6. Legacy product number; please order FAN4010IL6X for new designs.
- 7. All packages are lead free per JEDEC: J-STD-020B standard.
- 8. Moisture sensitivity level for all parts is MSL-1.

**DISCONTINUED**  
THIS DEVICE IS NOT RECOMMENDED FOR NEW DESIGN  
PLEASE CONTACT YOUR onsemi  
REPRESENTATIVE FOR INFORMATION

MicroPak is trademark of Semiconductor Components Industries, LLC (SCILLC) or its subsidiaries in the United States and/or other countries.

**SIP6 1.45X1.0**  
CASE 127EB  
ISSUE O

DATE 31 AUG 2016



## NOTES:

1. CONFORMS TO JEDEC STANDARD MO-252 VARIATION UAAD
2. DIMENSIONS ARE IN MILLIMETERS
3. DRAWING CONFORMS TO ASME Y14.5M-2009
4. PIN ONE IDENTIFIER IS 2X LENGTH OF ANY OTHER LINE IN THE MARK CODE LAYOUT.

|                         |                      |                                                                                                                                                                                     |
|-------------------------|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DOCUMENT NUMBER:</b> | <b>98AON13590G</b>   | Electronic versions are uncontrolled except when accessed directly from the Document Repository.<br>Printed versions are uncontrolled except when stamped "CONTROLLED COPY" in red. |
| <b>DESCRIPTION:</b>     | <b>SIP6 1.45X1.0</b> | <b>PAGE 1 OF 1</b>                                                                                                                                                                  |

onsemi and onsemi are trademarks of Semiconductor Components Industries, LLC dba onsemi or its subsidiaries in the United States and/or other countries. onsemi reserves the right to make changes without further notice to any products herein. onsemi makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does onsemi assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. onsemi does not convey any license under its patent rights nor the rights of others.

**onsemi**, **Onsemi**, and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi**'s product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

## ADDITIONAL INFORMATION

### TECHNICAL PUBLICATIONS:

Technical Library: [www.onsemi.com/design/resources/technical-documentation](http://www.onsemi.com/design/resources/technical-documentation)  
onsemi Website: [www.onsemi.com](http://www.onsemi.com)

### ONLINE SUPPORT: [www.onsemi.com/support](http://www.onsemi.com/support)

For additional information, please contact your local Sales Representative at  
[www.onsemi.com/support/sales](http://www.onsemi.com/support/sales)