

# 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.

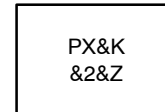
### Features at +5 V

- 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<sup>™</sup> 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

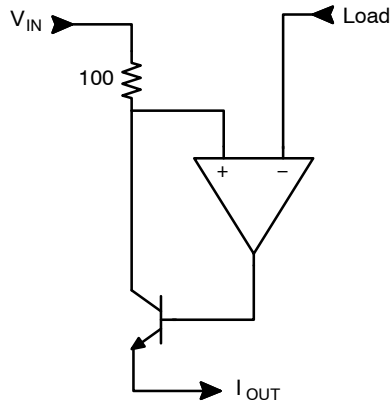


Figure 1. Functional Block Diagram

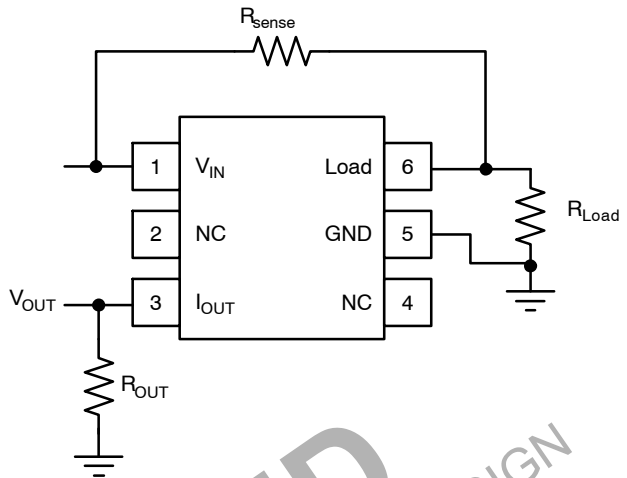


Figure 2. Typical Circuit

## PIN CONFIGURATION

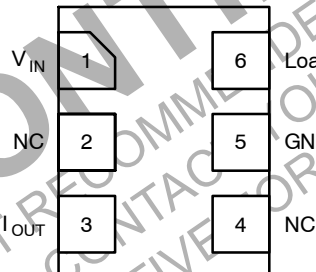


Figure 3. Pin Assignment (Top Through View)

## 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.)

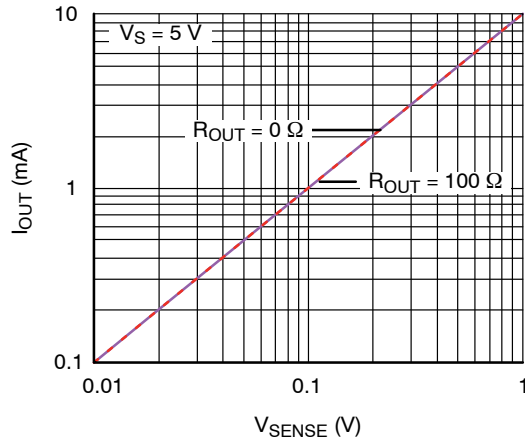
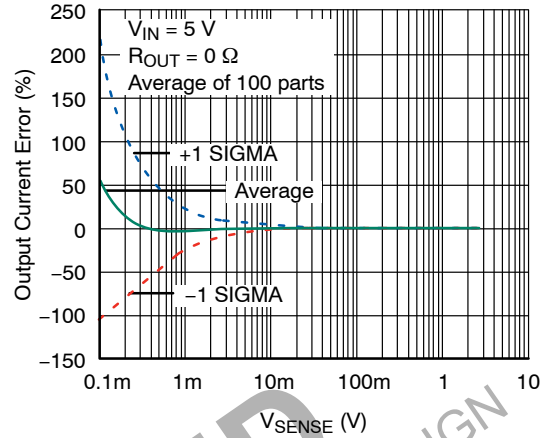
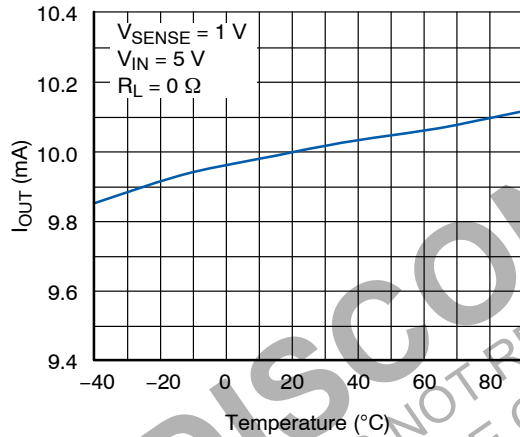
Figure 4.  $V_{SENSE}$  vs. Output CurrentFigure 5. Output Current Error vs.  $V_{SENSE}$ 

Figure 6. Output Current vs. Temperature

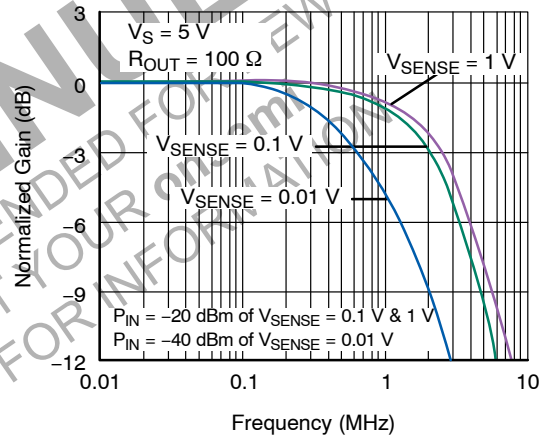


Figure 7. Frequency Response

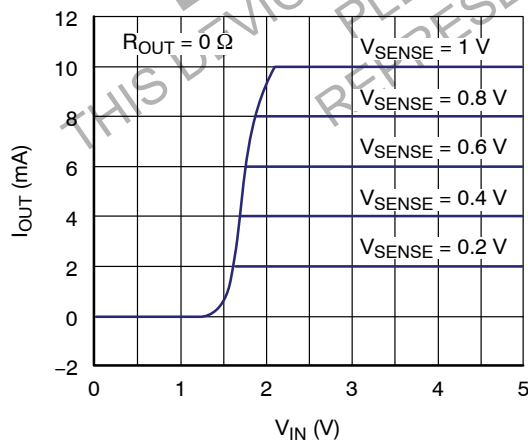


Figure 8. Transfer Characteristics

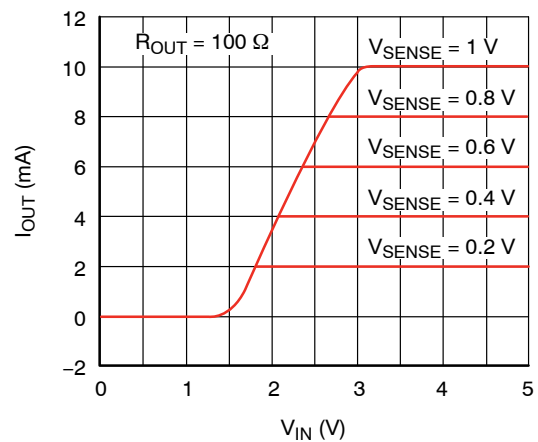
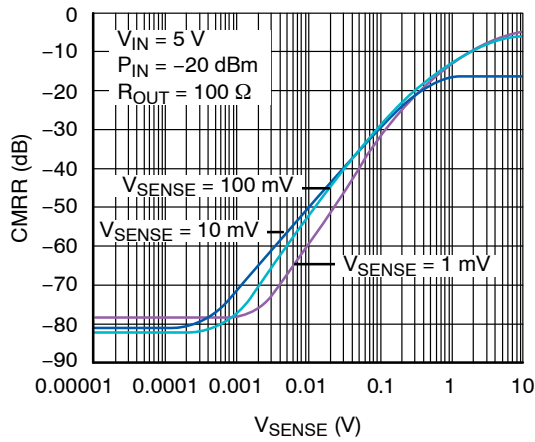


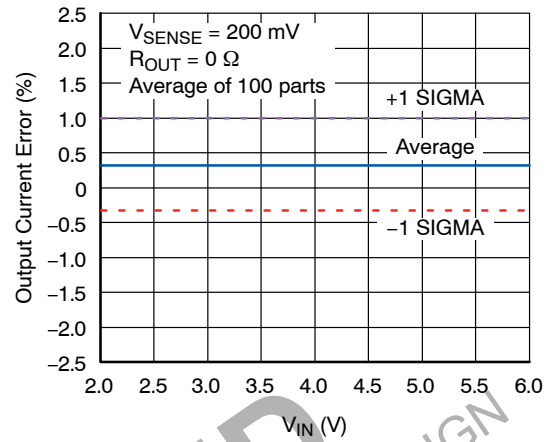
Figure 9. Transfer Characteristics

**TYPICAL PERFORMANCE CHARACTERISTICS** (Continued)

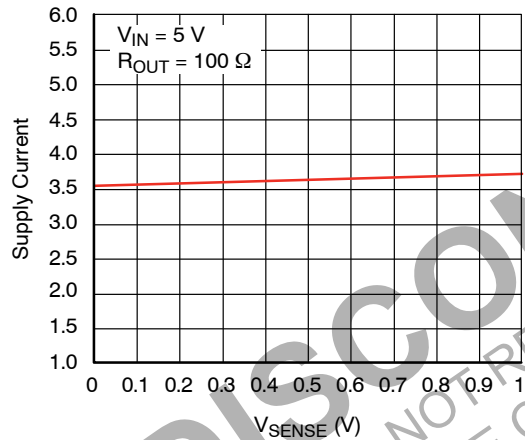
( $T_A = 25^\circ\text{C}$ ,  $V_S = V_{IN} = 5\text{ V}$ ,  $R_{OUT} = 100\ \Omega$ ,  $R_{SENSE} = 100\ \Omega$ , unless otherwise noted.)



**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:

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

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

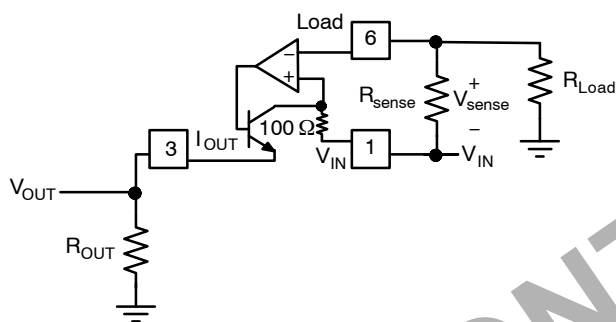


Figure 13. Functional Circuit

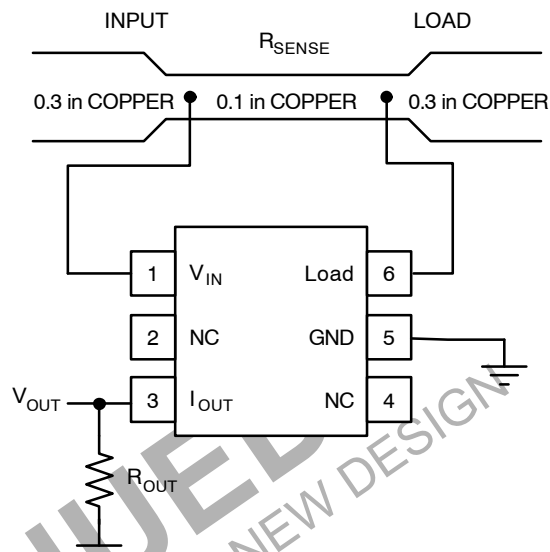
Selecting  $R_{SENSE}$ 

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.

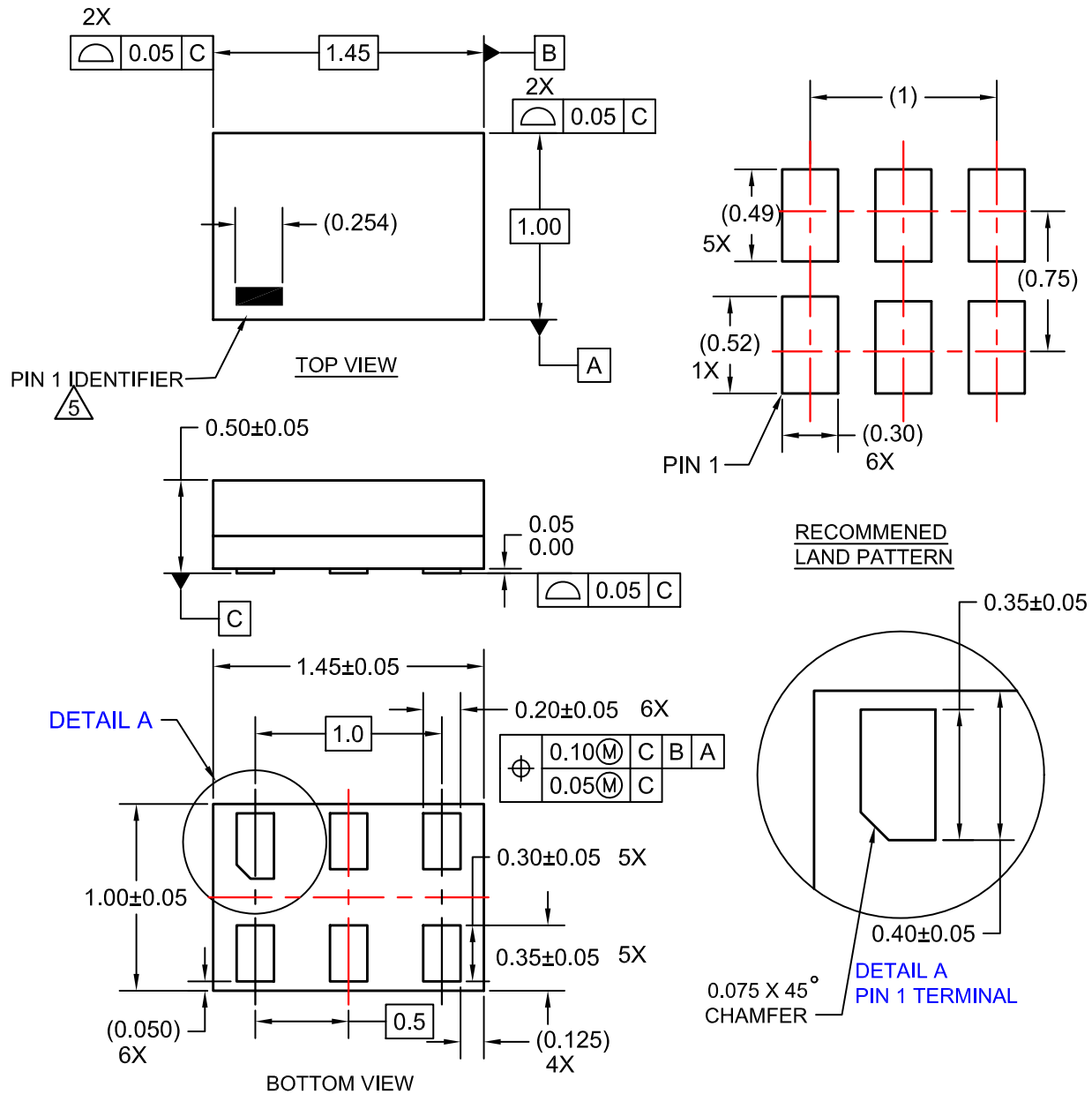
- 6. Legacy product number; please order FAN4010IL6X for new designs.
- 7. All packages are lead free per JEDEC: J-STD-020B standard.
- 8. Moisture sensitivity level for all parts is MSL-1.

**DISCONTINUED**  
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**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.

|                         |                      |                                                                                                                                                                                     |
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