



## Table of Contents

|  |           |  |           |
|--|-----------|--|-----------|
| <b>1 Features</b> .....                        | <b>1</b>  | 7.4 Device Functional Modes.....                                 | <b>12</b> |
| <b>2 Applications</b> .....                    | <b>1</b>  | 7.5 Programming.....   | <b>12</b> |
| <b>3 Description</b> .....                     | <b>1</b>  | 7.6 Register Maps .....  | <b>18</b> |
| <b>4 Revision History</b> .....                | <b>2</b>  | <b>8 Application and Implementation</b> .....                    | <b>28</b> |
| <b>5 Pin Configuration and Functions</b> ..... | <b>3</b>  | 8.1 Application Information.....                                 | <b>28</b> |
| <b>6 Specifications</b> .....                  | <b>4</b>  | 8.2 Typical Application .....                                    | <b>28</b> |
| 6.1 Absolute Maximum Ratings .....             | <b>4</b>  | <b>9 Power Supply Recommendations</b> .....                      | <b>31</b> |
| 6.2 ESD Ratings.....                           | <b>4</b>  | <b>10 Layout</b> .....   | <b>32</b> |
| 6.3 Recommended Operating Conditions.....      | <b>4</b>  | 10.1 Layout Guidelines .....                                     | <b>32</b> |
| 6.4 Thermal Information .....                  | <b>4</b>  | 10.2 Layout Example .....  | <b>33</b> |
| 6.5 Electrical Characteristics.....            | <b>5</b>  | <b>11 Device and Documentation Support</b> .....                 | <b>34</b> |
| 6.6 Two-Wire Timing Requirements .....         | <b>6</b>  | 11.1 Receiving Notification of Documentation Updates             | <b>34</b> |
| 6.7 Typical Characteristics .....              | <b>7</b>  | 11.2 Community Resources.....                                    | <b>34</b> |
| <b>7 Detailed Description</b> .....            | <b>9</b>  | 11.3 Trademarks .....  | <b>34</b> |
| 7.1 Overview .....                             | <b>9</b>  | 11.4 Electrostatic Discharge Caution.....                        | <b>34</b> |
| 7.2 Functional Block Diagram .....             | <b>9</b>  | 11.5 Glossary .....  | <b>34</b> |
| 7.3 Feature Description.....                   | <b>10</b> | <b>12 Mechanical, Packaging, and Orderable Information</b> ..... | <b>34</b> |

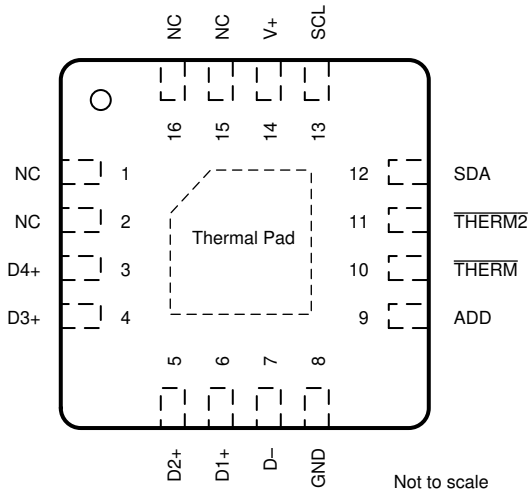
## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| <b>Changes from Revision B (August 2017) to Revision C</b>               | <b>Page</b> |
|--|-------------|
| • Changed the Device ID code from: 0x0464 to: 0x1468 .....               | <b>27</b>   |
| <b>Changes from Revision A (June 2017) to Revision B</b>                 | <b>Page</b> |
| • Changed 'QFN' to 'VQFN' in table header as per industry standard ..... | <b>4</b>    |
| <b>Changes from Original (May 2017) to Revision A</b>                    | <b>Page</b> |
| • Updated packaging information .....                                    | <b>34</b>   |

## 5 Pin Configuration and Functions

**TMP464 RGT Package  
16-Pin VQFN With Exposed Thermal Pad  
Top View**



NC - No internal connection

### Pin Functions

| PIN    |              | TYPE                               | DESCRIPTION   |
|--------|--------------|------------------------------------|---|
| NAME   | NO.          |                                    |   |
| ADD    | 9            | Digital Input                      | Address select. Connect to GND, V+, SDA, or SCL.  |
| D1+    | 6            | Analog input                       | Positive connection to remote temperature sensors. A total of 4 remote channels are supported. An unused channel must be connected to D-.   |
| D2+    | 5            | Analog input                       | Positive connection to remote temperature sensors. A total of 4 remote channels are supported. An unused channel must be connected to D-.   |
| D3+    | 4            | Analog input                       | Positive connection to remote temperature sensors. A total of 4 remote channels are supported. An unused channel must be connected to D-.   |
| D4+    | 3            | Analog input                       | Positive connection to remote temperature sensors. A total of 4 remote channels are supported. An unused channel must be connected to D-.   |
| D-     | 7            | Analog input                       | Negative connection to remote temperature sensors. Common for 4 remote channels.  |
| GND    | 8            | Ground                             | Supply ground connection  |
| NC     | 1, 2, 15, 16 | —                                  | No connection, may be left floating or connected to GND or V+   |
| SCL    | 13           | Digital input                      | Serial clock line for I <sup>2</sup> C or SMBus compatible two-wire interface. Input; requires a pullup resistor to a voltage between 1.7 V and 3.6 V (not necessarily V+) if driven by an open-drain output. |
| SDA    | 12           | Bidirectional digital input-output | Serial data line for I <sup>2</sup> C- or SMBus compatible two-wire interface. Open-drain; requires a pullup resistor to a voltage between 1.7 V and 3.6 V, not necessarily V+.                               |
| THERM  | 10           | Digital output                     | Thermal shutdown or fan-control pin. Active low; open-drain; requires a pullup resistor to a voltage between 1.7 V and 3.6 V, not necessarily V+. If this pin is not used it may be left open or grounded.    |
| THERM2 | 11           | Digital output                     | Second THERM output. Active low; open-drain; requires a pullup resistor to a voltage between 1.7 V and 3.6 V, not necessarily V+. If this pin is not used it may be left open or grounded.                    |
| V+     | 14           | Power supply                       | Positive supply voltage, 1.7 V to 3.6 V; requires 0.1-μF bypass capacitor to ground.  |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|   |   | MIN  | MAX                     | UNIT |
|---|---|------|-------------------------|------|
| Power supply                                    | V+  | −0.3 | 6                       | V    |
| Input voltage                                   | $\overline{\text{THERM}}$ , $\overline{\text{THERM2}}$ , SDA, SCL, and ADD only | −0.3 | 6                       | V    |
|   | D1+ through D4+   | −0.3 | ((V+) + 0.3)<br>and ≤ 6 |      |
|   | D− only   | −0.3 | 0.3                     |      |
| Input current                                   | SDA sink  | −25  |                         | mA   |
|   | All other pins  | −10  | 10                      |      |
| Operating temperature                           |   | −55  | 150                     | °C   |
| Junction temperature (T <sub>J</sub> , maximum) |   |      | 150                     | °C   |
| Storage temperature, T <sub>stg</sub>           |   | −60  | 150                     | °C   |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 6.2 ESD Ratings

|  |  | VALUE | UNIT |
|--|--|-------|------|
| V <sub>(ESD)</sub> Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>          | ±2000 | V    |
|  | Charged device model (CDM), JEDEC specification JESD22-C101 <sup>(2)</sup> | ±750  |      |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.  
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

|                |                                | MIN | NOM | MAX | UNIT |
|----------------|--------------------------------|-----|-----|-----|------|
| V+             | Supply voltage                 | 1.7 |     | 3.6 | V    |
| T <sub>A</sub> | Operating free-air temperature | −40 |     | 125 | °C   |
| T <sub>D</sub> | Remote junction temperature    | −55 |     | 150 | °C   |

### 6.4 Thermal Information

| THERMAL METRIC        |  | TMP464     | UNIT |
|-----------------------|--|------------|------|
|                       |  | RGT (VQFN) |      |
|                       |  | 16 PINS    |      |
| R <sub>θJA</sub>      | Junction-to-ambient thermal resistance       | 46         | °C/W |
| R <sub>θJC(top)</sub> | Junction-to-case (top) thermal resistance    | 43         | °C/W |
| R <sub>θJB</sub>      | Junction-to-board thermal resistance         | 17         | °C/W |
| ψ <sub>JT</sub>       | Junction-to-top characterization parameter   | 0.8        | °C/W |
| ψ <sub>JB</sub>       | Junction-to-board characterization parameter | 5          | °C/W |

## 6.5 Electrical Characteristics

at  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  and  $V_+ = 1.7\text{ V}$  to  $3.6\text{ V}$  (unless otherwise noted)

| PARAMETER                       |   | TEST CONDITIONS   | MIN                              | TYP                     | MAX  | UNIT |
|---------------------------------|---|---|----------------------------------|-------------------------|------|------|
| TEMPERATURE MEASUREMENT         |   |   |                                  |                         |      |      |
| T <sub>LOCAL</sub>              | Local temperature sensor accuracy           | T <sub>A</sub> = −40°C to 100°C, V <sub>+</sub> = 1.7 V to 3.6 V                                    | −0.75                            | ±0.125                  | 0.75 | °C   |
|                                 |   | T <sub>A</sub> = −40°C to 125°C, V <sub>+</sub> = 1.7 V to 3.6 V                                    | −1                               | ±0.5                    | 1    | °C   |
| T <sub>REMOTE</sub>             | Remote temperature sensor accuracy          | T <sub>A</sub> = −10°C to 85°C, T <sub>D</sub> = −55°C to 150°C<br>V <sub>+</sub> = 1.7 V to 3.6 V  | −0.75                            | ±0.125                  | 0.75 |      |
|                                 |   | T <sub>A</sub> = −40°C to 125°C, T <sub>D</sub> = −55°C to 150°C<br>V <sub>+</sub> = 1.7 V to 3.6 V | −1                               | ±0.5                    | 1    | °C   |
|                                 | Local temperature error supply sensitivity  | V <sub>+</sub> = 1.7 V to 3.6 V   | −0.15                            | ±0.05                   | 0.15 | °C/V |
|                                 | Remote temperature error supply sensitivity | V <sub>+</sub> = 1.7 V to 3.6 V   | −0.25                            | ±0.1                    | 0.25 | °C/V |
|                                 | Temperature resolution (local and remote)   |   |                                  | 0.0625                  |      | °C   |
|                                 | ADC conversion time                         | One-shot mode, per channel (local or remote)  |                                  | 16                      | 17   | ms   |
|                                 | ADC resolution                              |   |                                  | 13                      |      | Bits |
|                                 | Remote sensor source current                | High  | Series resistance 1 kΩ (maximum) | 120                     |      | μA   |
|                                 |   | Medium  |                                  | 45                      |      |      |
|                                 |   | Low   |                                  | 7.5                     |      |      |
| η                               | Remote transistor ideality factor           |   |                                  | 1.008                   |      |      |
| SERIAL INTERFACE (SCL, SDA)     |   |   |                                  |                         |      |      |
| V <sub>IH</sub>                 | High-level input voltage                    |   | 0.7 × (V <sub>+</sub> )          |                         |      | V    |
| V <sub>IL</sub>                 | Low-level input voltage                     |   | 0.3 × (V <sub>+</sub> )          |                         |      | V    |
|                                 | Hysteresis                                  |   | 200                              |                         |      | mV   |
|                                 | SDA output-low sink current                 |   | 20                               |                         |      | mA   |
| V <sub>OL</sub>                 | Low-level output voltage                    | I <sub>O</sub> = −20 mA, V <sub>+</sub> ≥ 2 V   | 0.15                             |                         | 0.4  | V    |
|                                 |   | I <sub>O</sub> = −15 mA, V <sub>+</sub> < 2 V   | 0.2 × V <sub>+</sub>             |                         | V    |      |
|                                 | Serial bus input leakage current            | 0 V ≤ V <sub>IN</sub> ≤ 3.6 V   | −1                               |                         | 1    | μA   |
|                                 | Serial bus input capacitance                |   | 4                                |                         |      | pF   |
| DIGITAL INPUTS (ADD)            |   |   |                                  |                         |      |      |
| V <sub>IH</sub>                 | High-level input voltage                    |   | 0.7 × (V <sub>+</sub> )          |                         |      | V    |
| V <sub>IL</sub>                 | Low-level input voltage                     |   | −0.3                             | 0.3 × (V <sub>+</sub> ) |      | V    |
|                                 | Input leakage current                       | 0 V ≤ V <sub>IN</sub> ≤ 3.6 V   | −1                               |                         | 1    | μA   |
|                                 | Input capacitance                           |   | 4                                |                         |      | pF   |
| DIGITAL OUTPUTS (THERM, THERM2) |   |   |                                  |                         |      |      |
|                                 | Output-low sink current                     | V <sub>OL</sub> = 0.4 V   | 6                                |                         |      | mA   |
| V <sub>OL</sub>                 | Low-level output voltage                    | I <sub>O</sub> = −6 mA  | 0.15                             |                         | 0.4  | V    |
| I <sub>OH</sub>                 | High-level output leakage current           | V <sub>O</sub> = V <sub>+</sub>   |                                  |                         | 1    | μA   |
| POWER SUPPLY                    |   |   |                                  |                         |      |      |
| V <sub>+</sub>                  | Specified supply voltage range              |   | 1.7                              |                         | 3.6  | V    |
| I <sub>Q</sub>                  | Quiescent current                           | Active conversion, local sensor   | 240                              |                         | 375  | μA   |
|                                 |   | Active conversion, remote sensors   | 400                              |                         | 600  |      |
|                                 |   | Standby mode (between conversions)  | 15                               |                         | 21   |      |
|                                 |   | Shutdown mode, serial bus inactive  | 0.3                              |                         | 4    |      |
|                                 |   | Shutdown mode, serial bus active, f <sub>S</sub> = 400 kHz  | 120                              |                         |      | μA   |
|                                 |   | Shutdown mode, serial bus active, f <sub>S</sub> = 2.56 MHz   | 300                              |                         |      | μA   |
| POR                             | Power-on-reset threshold                    | Rising edge   | 1.5                              |                         | 1.65 | V    |
|                                 |   | Falling edge  | 1                                |                         | 1.2  |      |
| POH                             | Power-on-reset hysteresis                   |   | 0.2                              |                         |      | V    |

## 6.6 Two-Wire Timing Requirements

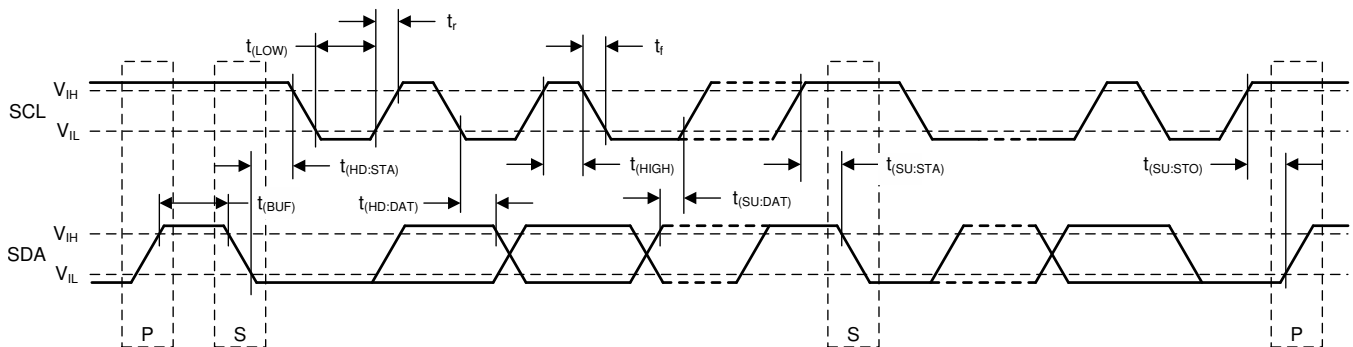
at  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  and  $V_+ = 1.7\text{ V}$  to  $3.6\text{ V}$  (unless otherwise noted)

The master and the slave have the same  $V_+$  value. Values are based on statistical analysis of samples tested during initial release.

|                         |  |                 | MIN                     | MAX  | UNIT              |
|-------------------------|--|-----------------|-------------------------|------|-------------------|
| $f_{\text{SCL}}$        | SCL operating frequency  | Fast mode       | 0.001                   | 0.4  | MHz               |
|                         |  | High-speed mode | 0.001                   | 2.56 |                   |
| $t_{\text{BUF}}$        | Bus free time between stop and start condition   | Fast mode       | 1300                    |      | ns                |
|                         |  | High-speed mode | 160                     |      |                   |
| $t_{\text{HD;STA}}$     | Hold time after repeated start condition. After this period, the first clock is generated. | Fast mode       | 600                     |      | ns                |
|                         |  | High-speed mode | 160                     |      |                   |
| $t_{\text{SU;STA}}$     | Repeated start condition setup time  | Fast mode       | 600                     |      | ns                |
|                         |  | High-speed mode | 160                     |      |                   |
| $t_{\text{SU;STO}}$     | Stop condition setup time  | Fast mode       | 600                     |      | ns                |
|                         |  | High-speed mode | 160                     |      |                   |
| $t_{\text{HD;DAT}}$     | Data hold time   | Fast mode       | 0                       |      | <sup>(1)</sup> ns |
|                         |  | High-speed mode | 0                       | 130  |                   |
| $t_{\text{VD;DAT}}$     | Data valid time <sup>(2)</sup>   | Fast mode       | 0                       | 900  | ns                |
|                         |  | High-speed mode | —                       | —    |                   |
| $t_{\text{SU;DAT}}$     | Data setup time  | Fast mode       | 100                     |      | ns                |
|                         |  | High-speed mode | 20                      |      |                   |
| $t_{\text{LOW}}$        | SCL clock low period   | Fast mode       | 1300                    |      | ns                |
|                         |  | High-speed mode | 250                     |      |                   |
| $t_{\text{HIGH}}$       | SCL clock high period  | Fast mode       | 600                     |      | ns                |
|                         |  | High-speed mode | 60                      |      |                   |
| $t_F - \text{SDA}$      | Data fall time   | Fast mode       | $20 \times (V_+ / 5.5)$ | 300  | ns                |
|                         |  | High-speed mode |                         | 100  |                   |
| $t_F, t_R - \text{SCL}$ | Clock fall and rise time   | Fast mode       |                         | 300  | ns                |
|                         |  | High-speed mode |                         | 40   |                   |
| $t_R$                   | Rise time for $\text{SCL} \leq 100\text{ kHz}$   | Fast mode       |                         | 1000 | ns                |
|                         |  | High-speed mode |                         |      |                   |
|                         | Serial bus timeout   | Fast mode       | 15                      | 20   | ms                |
|                         |  | High-speed mode | 15                      | 20   |                   |

(1) The maximum  $t_{\text{HD;DAT}}$  can be  $0.9\text{ }\mu\text{s}$  for fast mode, and is less than the maximum  $t_{\text{VD;DAT}}$  by a transition time.

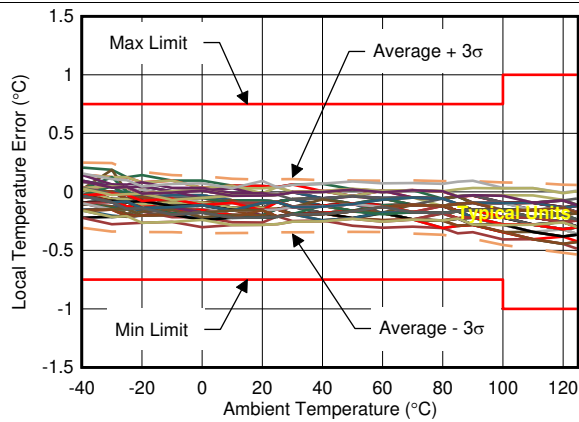
(2)  $t_{\text{VD;DAT}}$  = time for data signal from SCL LOW to SDA output (HIGH to LOW, depending on which is worse).



**Figure 1. Two-Wire Timing Diagram**

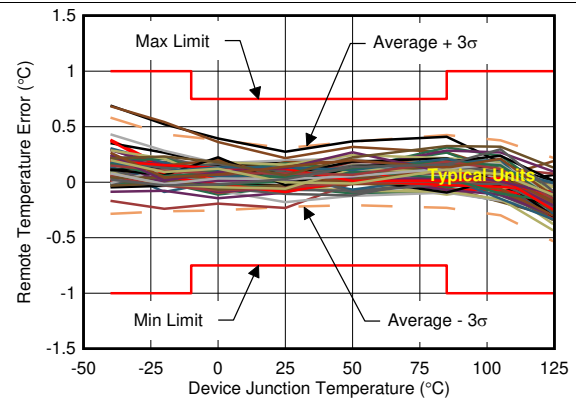
## 6.7 Typical Characteristics

at  $T_A = 25^\circ\text{C}$  and  $V_+ = 3.6\text{ V}$  (unless otherwise noted)



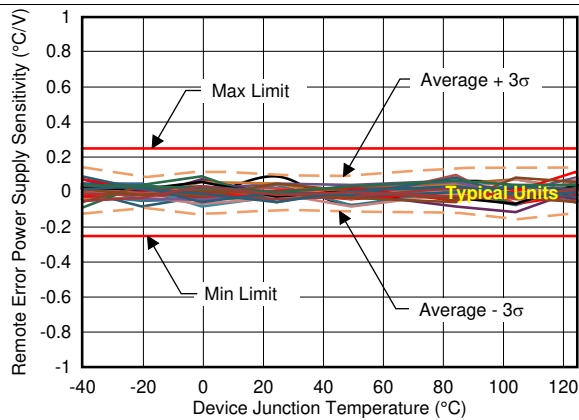
Typical behavior of 75 devices over temperature at  $V_+ = 1.8\text{ V}$

**Figure 2. Local Temperature Error vs Ambient Temperature**



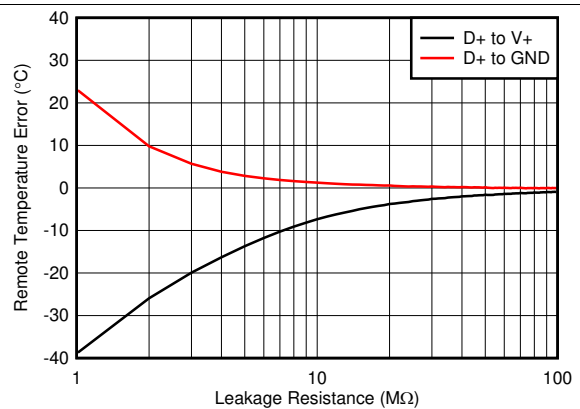
Typical behavior of 75 devices over temperature at  $V_+ = 1.8\text{ V}$  with the remote diode junction at  $150^\circ\text{C}$ .

**Figure 3. Remote Temperature Error vs Device Junction Temperature**

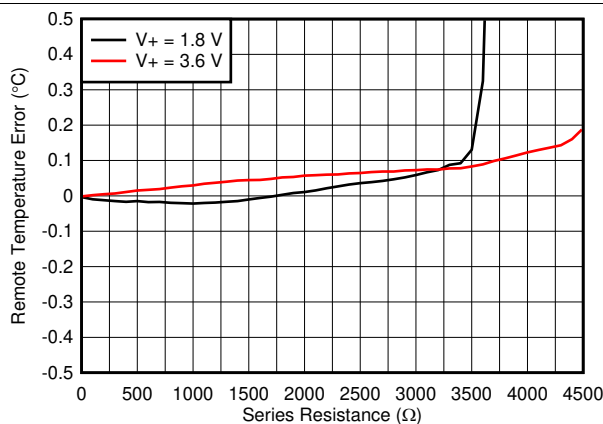


Typical behavior of 30 devices over temperature with  $V_+$  from  $1.8\text{ V}$  to  $3.6\text{ V}$

**Figure 4. Remote Temperature Error Power Supply Sensitivity vs Device Junction Temperature**

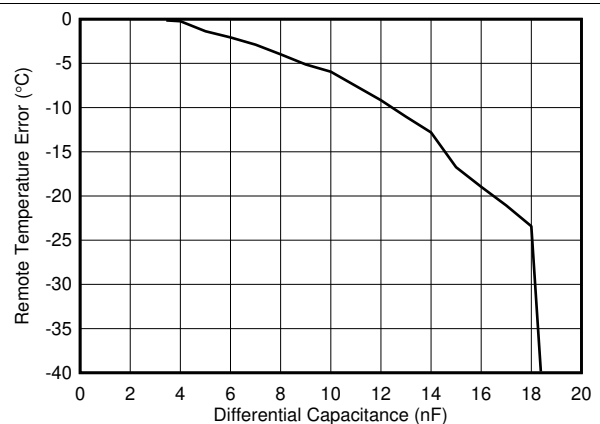


**Figure 5. Remote Temperature Error vs Leakage Resistance**



No physical capacitance during measurement

**Figure 6. Remote Temperature Error vs Series Resistance**



No physical series resistance on  $D_+$ ,  $D_-$  pins during measurement

**Figure 7. Remote Temperature Error vs Differential Capacitance**

## Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$  and  $V_+ = 3.6\text{ V}$  (unless otherwise noted)

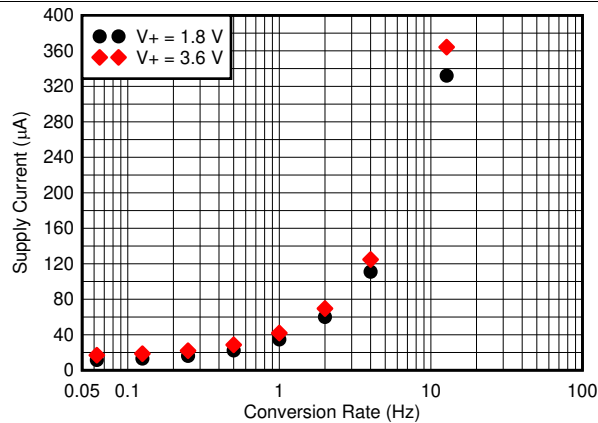


Figure 8. Quiescent Current vs Conversion Rate °

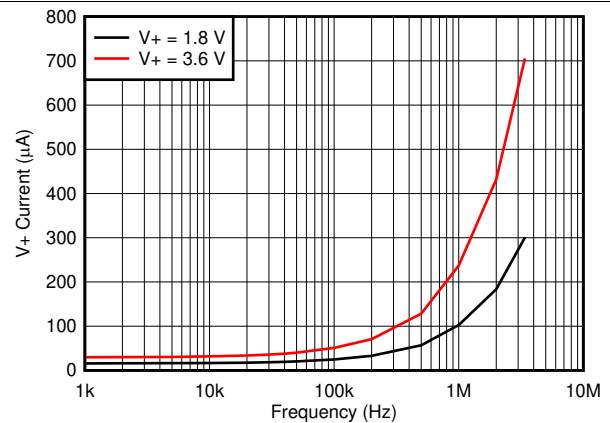


Figure 9. Shutdown Quiescent Current vs SCL Clock Frequency

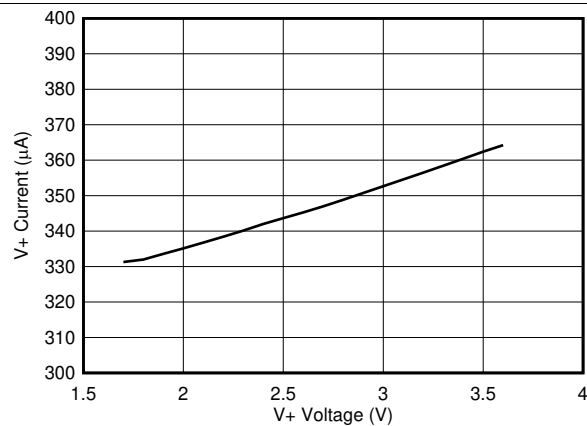


Figure 10. Quiescent Current vs Supply Voltage (at Default Conversion Rate of 16 Conversions Per Second)

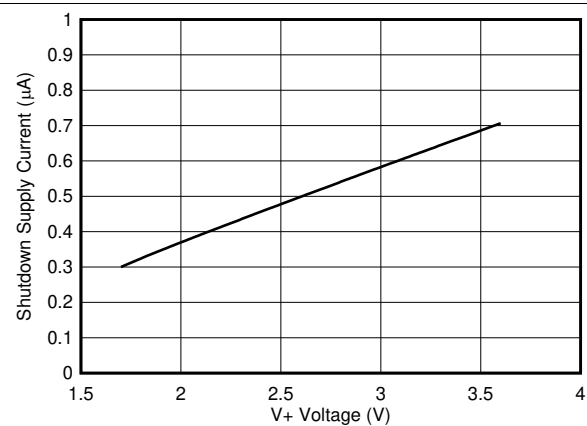


Figure 11. Shutdown Quiescent Current vs Supply Voltage

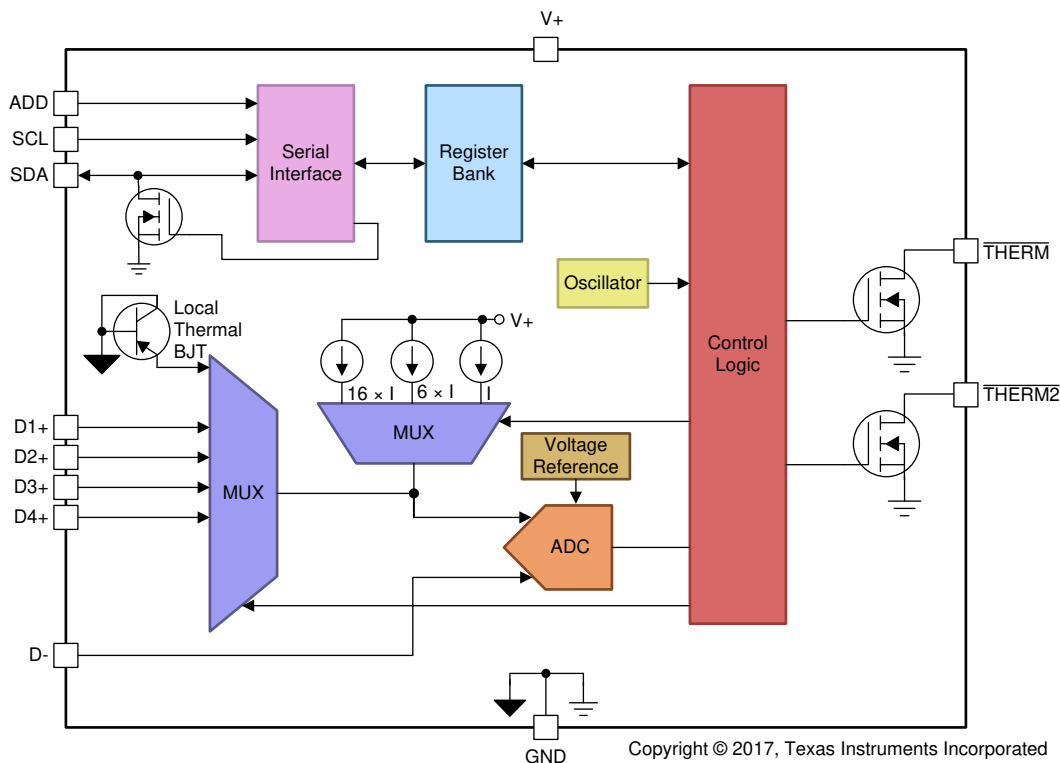


## 7 Detailed Description

### 7.1 Overview

The TMP464 device is a digital temperature sensor that combines a local temperature measurement channel and four remote-junction temperature measurement channels in a VQFN-16 package. The device has a two-wire-interface that is compatible with I<sup>2</sup>C or SMBus interfaces and includes four pin-programmable bus address options. The TMP464 is specified over a local device temperature range from –40°C to +125°C. The TMP464 device also contains multiple registers for programming and holding configuration settings, temperature limits, and temperature measurement results. The TMP464 pinout includes THERM and THERM2 outputs that signal overtemperature events based on the settings of temperature limit registers.

### 7.2 Functional Block Diagram



## 7.3 Feature Description

### 7.3.1 Temperature Measurement Data

The local and remote temperature sensors have a resolution of 13 bits (0.0625°C). Temperature data that result from conversions within the default measurement range are represented in binary form, as shown in the *Standard Binary* column of [Table 1](#). Negative numbers are represented in two's-complement format. The resolution of the temperature registers extends to 255.9375°C and down to –256°C, but the actual device is limited to ranges as specified in the [Electrical Characteristics](#) table to meet the accuracy specifications. The TMP464 device is specified for ambient temperatures ranging from –40°C to +125°C; parameters in the [Absolute Maximum Ratings](#) table must be observed to prevent damage to the device.

**Table 1. Temperature Data Format (Local and Remote Temperature)**

| TEMPERATURE<br>(°C) | LOCAL OR REMOTE TEMPERATURE REGISTER VALUE<br>(0.0625°C RESOLUTION) |       |
|---------------------|---|-------|
|                     | STANDARD BINARY <sup>(1)</sup>                                      |       |
|                     | BINARY  | HEX   |
| –64                 | 1110 0000 0000 0000   | E0 00 |
| –50                 | 1110 0111 0000 0000   | E7 00 |
| –25                 | 1111 0011 1000 0000   | F3 80 |
| –0.1250             | 1111 1111 1111 0000   | FF F0 |
| –0.0625             | 1111 1111 1111 1000   | FF F8 |
| 0                   | 0000 0000 0000 0000   | 00 00 |
| 0.0625              | 0000 0000 0000 1000   | 00 08 |
| 0.1250              | 0000 0000 0001 0000   | 00 10 |
| 0.1875              | 0000 0000 0001 1000   | 00 18 |
| 0.2500              | 0000 0000 0010 0000   | 00 20 |
| 0.3125              | 0000 0000 0010 1000   | 00 28 |
| 0.3750              | 0000 0000 0011 0000   | 00 30 |
| 0.4375              | 0000 0000 0011 1000   | 00 38 |
| 0.5000              | 0000 0000 0100 0000   | 00 40 |
| 0.5625              | 0000 0000 0100 1000   | 00 48 |
| 0.6250              | 0000 0000 0101 0000   | 00 50 |
| 0.6875              | 0000 0000 0101 1000   | 00 58 |
| 0.7500              | 0000 0000 0110 0000   | 00 60 |
| 0.8125              | 0000 0000 0110 1000   | 00 68 |
| 0.8750              | 0000 0000 0111 0000   | 00 70 |
| 0.9375              | 0000 0000 0111 1000   | 00 78 |
| 1                   | 0000 0000 1000 0000   | 00 80 |
| 5                   | 0000 0010 1000 0000   | 02 80 |
| 10                  | 0000 0101 0000 0000   | 05 00 |
| 25                  | 0000 1100 1000 0000   | 0C 80 |
| 50                  | 0001 1001 0000 0000   | 19 00 |
| 75                  | 0010 0101 1000 0000   | 25 80 |
| 100                 | 0011 0010 0000 0000   | 32 00 |
| 125                 | 0011 1110 1000 0000   | 3E 80 |
| 127                 | 0011 1111 1000 0000   | 3F 80 |
| 150                 | 0100 1011 0000 0000   | 4B 00 |
| 175                 | 0101 0111 1000 0000   | 57 80 |
| 191                 | 0101 1111 1000 0000   | 5F 80 |

(1) Resolution is 0.0625°C per count. Negative numbers are represented in two's-complement format.

Both local and remote temperature data use two bytes for data storage with a two's-complement format for negative numbers. The high byte stores the temperature with 2°C resolution. The second or low byte stores the decimal fraction value of the temperature and allows a higher measurement resolution, as shown in Table 1. The measurement resolution for both the local and the remote channels is 0.0625°C.

### 7.3.2 Series Resistance Cancellation

Series resistance cancellation automatically eliminates the temperature error caused by the resistance of the routing to the remote transistor or by the resistors of the optional external low-pass filter. A total up to 1-kΩ series resistance can be cancelled by the TMP464 device, which eliminates the need for additional characterization and temperature offset correction. See Figure 6 for details on the effects of series resistance on sensed remote temperature error.

### 7.3.3 Differential Input Capacitance

The TMP464 device tolerates differential input capacitance of up to 1000 pF with minimal change in temperature error. The effect of capacitance on the sensed remote temperature error is illustrated in Figure 7.

### 7.3.4 Sensor Fault

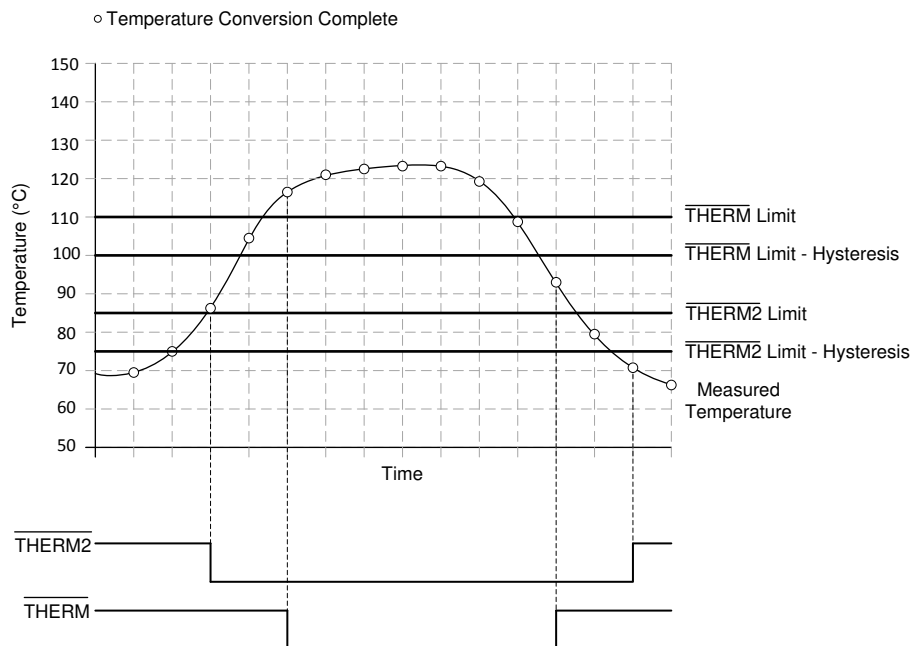
The TMP464 device can sense a fault at the D+ resulting from an incorrect diode connection. The TMP464 device can also sense an open circuit. Short-circuit conditions return a value of –256°C. The detection circuitry consists of a voltage comparator that trips when the voltage at D+ exceeds (V+) – 0.3 V (typical). The comparator output is continuously checked during a conversion. If a fault is detected, then the RxOP bit in the Remote Channel Status register is set to 1.

When not using the remote sensor with the TMP464 device, the corresponding D+ and D– inputs must be connected together to prevent meaningless fault warnings.

### 7.3.5 THERM Functions

Operation of the  $\overline{\text{THERM}}$  (pin 10) and  $\overline{\text{THERM2}}$  (pin 11) interrupt pins are shown in Figure 12.

The hysteresis value is stored in the  $\overline{\text{THERM}}$  Hysteresis register and applies to both the  $\overline{\text{THERM}}$  and  $\overline{\text{THERM2}}$  interrupts.



**Figure 12.  $\overline{\text{THERM}}$  and  $\overline{\text{THERM2}}$  Interrupt Operation**

## 7.4 Device Functional Modes

### 7.4.1 Shutdown Mode (SD)

The TMP464 shutdown mode enables the user to save maximum power by shutting down all device circuitry other than the serial interface, and reducing current consumption to typically less than 0.3  $\mu$ A; see [Figure 11](#). Shutdown mode is enabled when the shutdown bit (SD, bit 5) of the Configuration Register is HIGH; the device shuts down immediately. When the SD bit is LOW, the device maintains a continuous-conversion state.

## 7.5 Programming

### 7.5.1 Serial Interface

The TMP464 device operates only as a slave device on the two-wire bus (I<sup>2</sup>C or SMBus). Connections to either bus are made using the open-drain I/O lines, SDA, and SCL. The SDA and SCL pins feature integrated spike suppression filters and Schmitt triggers to minimize the effects of input spikes and bus noise. The TMP464 device supports the transmission protocol for fast (1 kHz to 400 kHz) and high-speed (1 kHz to 2.56 MHz) modes. All data bytes are transmitted MSB first.

While the TMP464 device is unpowered bus traffic on SDA and SCL may continue without any adverse effects to the communication or to the TMP464 device itself. As the TMP464 device is powering up, the device does not load the bus, and as a result the bus traffic may continue undisturbed.

#### 7.5.1.1 Bus Overview

The TMP464 device is compatible with the I<sup>2</sup>C or SMBus interface. In I<sup>2</sup>C or SMBus protocol, the device that initiates the transfer is called a *master*, and the devices controlled by the master are *slaves*. The bus must be controlled by a master device that generates the serial clock (SCL), controls the bus access, and generates the start and stop conditions.

To address a specific device, a start condition is initiated. A start condition is indicated by pulling the data line (SDA) from a high-to-low logic level when SCL is high. All slaves on the bus shift in the slave address byte, with the last bit indicating whether a read or write operation is intended. During the ninth clock pulse, the addressed slave responds to the master by generating an *acknowledge* (ACK) bit and pulling SDA low.

Data transfer is then initiated and sent over eight clock pulses followed by an acknowledge bit (ACK). During data transfer, SDA must remain stable when SCL is high. A change in SDA when SCL is high is interpreted as a control signal. The TMP464 device has a word register structure (16-bit wide), with data writes always requiring two bytes. Data transfer occurs during the ACK at the end of the second byte.

After all data are transferred, the master generates a stop condition. A stop condition is indicated by pulling SDA from low to high when SCL is high.

## Programming (continued)

### 7.5.1.2 Bus Definitions

The TMP464 device has a two-wire interface that is compatible with the I<sup>2</sup>C or SMBus interface. Figure 13 through Figure 18 illustrate the timing for various operations on the TMP464 device. The bus definitions are as follows:

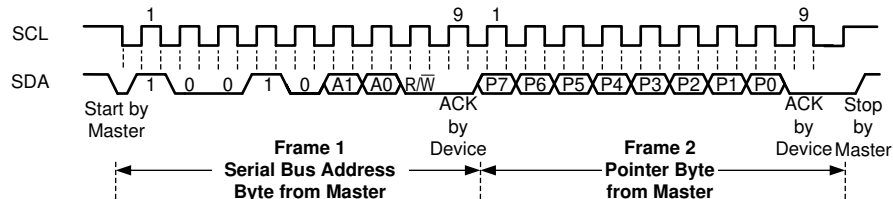
**Bus Idle:** Both SDA and SCL lines remain high.

**Start Data Transfer:** A change in the state of the SDA line (from high to low) when the SCL line is high defines a start condition. Each data transfer initiates with a start condition.

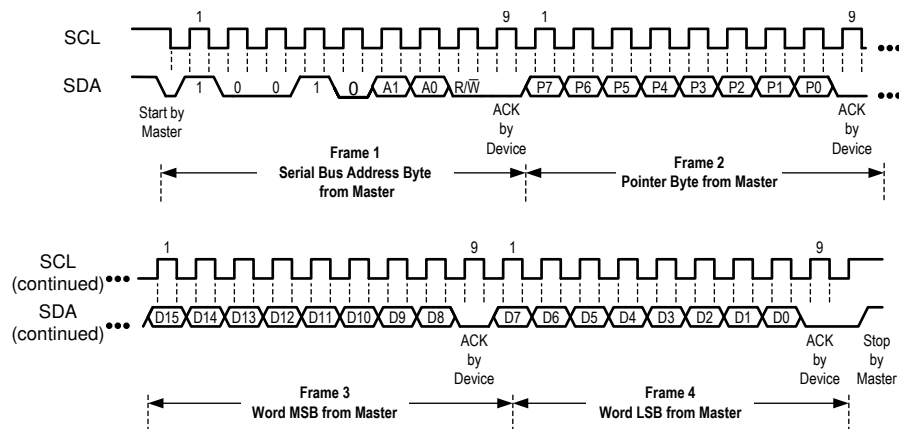
**Stop Data Transfer:** A change in the state of the SDA line (from low to high) when the SCL line is high defines a stop condition. Each data transfer terminates with a repeated start or stop condition.

**Data Transfer:** The number of data bytes transferred between a start and stop condition is not limited and is determined by the master device. The receiver acknowledges the data transfer.

**Acknowledge:** Each receiving device, when addressed, is obliged to generate an acknowledge bit. A device that acknowledges must pull down the SDA line during the acknowledge clock pulse in such a way that the SDA line is stable low during the high period of the acknowledge clock pulse. Take setup and hold times into account. On a master receive, data transfer termination can be signaled by the master generating a not-acknowledge on the last byte that is transmitted by the slave.

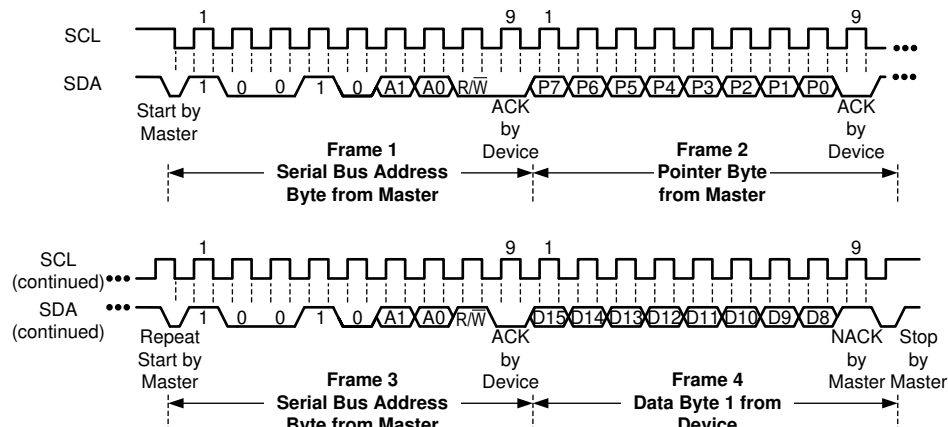


**Figure 13. Two-Wire Timing Diagram for Write Pointer Byte**



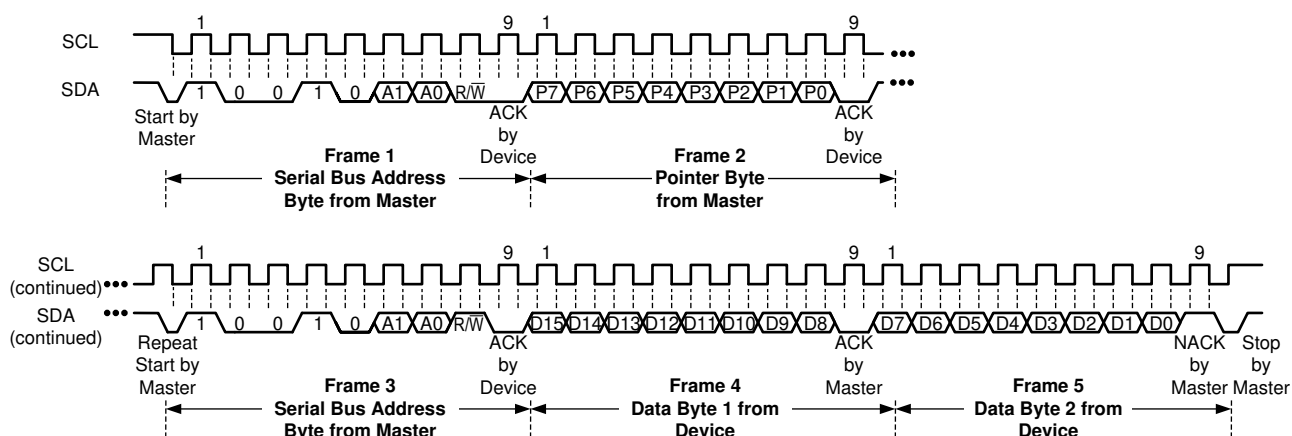
**Figure 14. Two-Wire Timing Diagram for Write Pointer Byte and Value Word**

## Programming (continued)

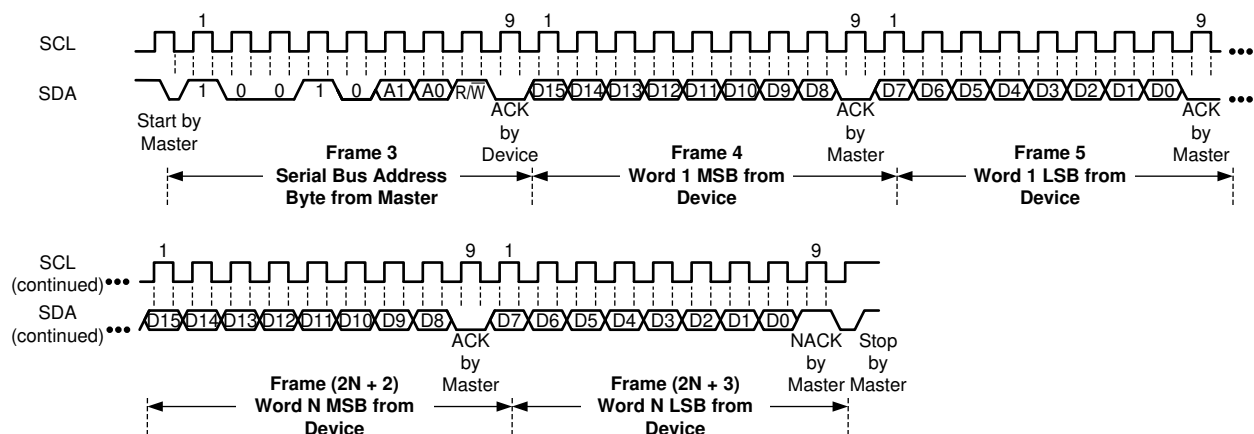
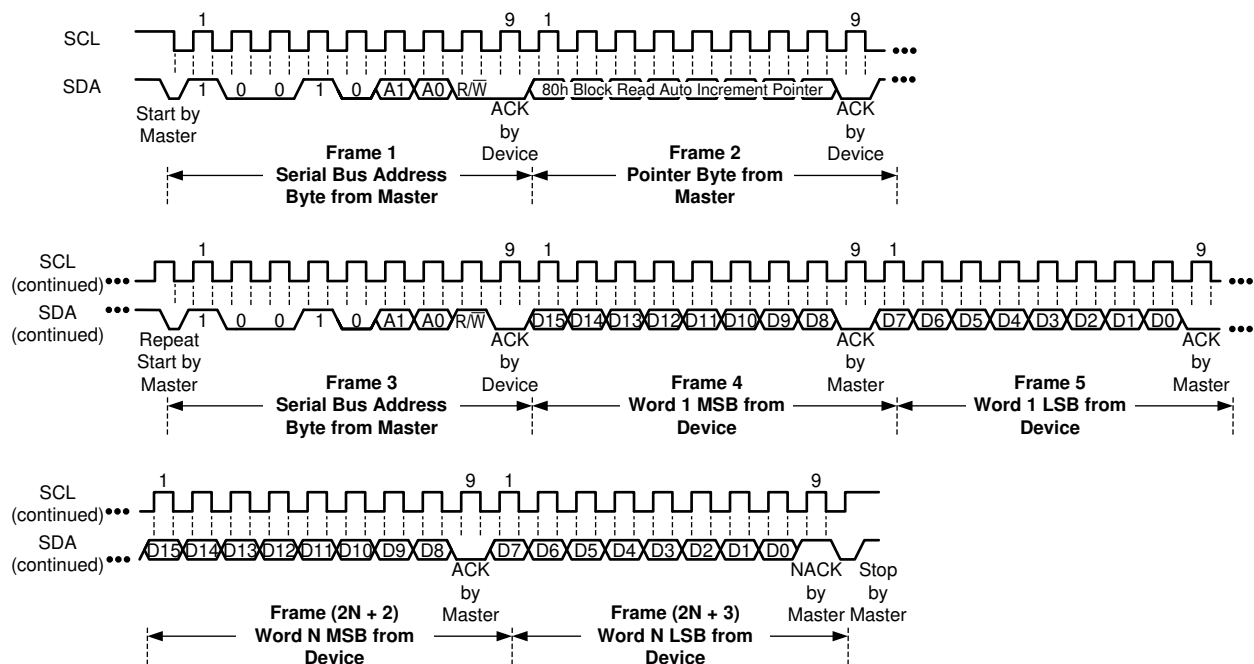


(1) The master must leave SDA high to terminate a single-byte read operation.

**Figure 15. Two-Wire Timing Diagram for Pointer Set Followed by a Repeat Start and Single-Byte Read Format**



**Figure 16. Two-Wire Timing Diagram for Pointer Byte Set Followed by a Repeat Start and Word (Two-Byte) Read**



## Programming (continued)

### 7.5.1.3 Serial Bus Address

To communicate with the TMP464 device, the master must first address slave devices using a slave address byte. The slave address byte consists of seven address bits and a direction bit indicating the intent of executing a read or write operation. The TMP464 device allows up to four devices to be addressed on a single bus. The assigned device address depends on the ADD pin connection as described in [Table 2](#).

**Table 2. TMP464 Slave Address Options**

| ADD PIN CONNECTION | SLAVE ADDRESS |     |
|--------------------|---------------|-----|
|                    | BINARY        | HEX |
| GND                | 1001000       | 48  |
| V+                 | 1001001       | 49  |
| SDA                | 1001010       | 4A  |
| SCL                | 1001011       | 4B  |

### 7.5.1.4 Read and Write Operations

Accessing a particular register on the TMP464 device is accomplished by writing the appropriate value to the pointer register. The value for the pointer register is the first byte transferred after the slave address byte with the R/W bit low. Every write operation to the TMP464 device requires a value for the pointer register (see [Figure 14](#)).

The TMP464 registers can be accessed with block or single register reads. Block reads are only supported for pointer values 80h to 84h. Registers at 80h through 84h mirror the Remote and Local Temperature registers (00h to 04h). Pointer values 00h to 04h are for single register reads.

#### 7.5.1.4.1 Single Register Reads

When reading from the TMP464 device, the last value stored in the pointer register by a write operation is used to determine which register is read by a read operation. To change which register is read for a read operation, a new value must be written to the pointer register. This transaction is accomplished by issuing a slave address byte with the R/W bit low, followed by the pointer register byte; no additional data are required. The master can then generate a start condition and send the slave address byte with the R/W bit high to initiate the read command; see [Figure 15](#) through [Figure 17](#) for details of this sequence.

If repeated reads from the same register are desired, continually sending the pointer register bytes is not necessary because the TMP464 device retains the pointer register value until the value is changed by the next write operation. The register bytes are sent by the MSB first, followed by the LSB. If only one byte is read (MSB), a consecutive read of TMP464 device results in the MSB being transmitted first. The LSB can only be accessed through two-byte reads.

The master terminates a read operation by issuing a *not-acknowledge* (NACK) command at the end of the last byte to be read or transmitting a stop condition. For a single-byte operation, the master must leave the SDA line high during the acknowledge time of the first byte that is read from the slave.

The TMP464 register structure has a word (two-byte) length, so every write transaction must have an even number of bytes (MSB and LSB) following the pointer register value (see [Figure 14](#)). Data transfers occur during the ACK at the end of the second byte or LSB. If the transaction does not finish, signaled by the ACK at the end of the second byte, then the data is ignored and not loaded into the TMP464 register. Read transactions do not have the same restrictions and may be terminated at the end of the last MSB.

#### 7.5.1.4.2 Block Register Reads

The TMP464 supports block mode reads at address 80h through 84h for temperature results alone. Setting the pointer register to 80h signals to the TMP464 device that a block of more than two bytes must be transmitted before a stop is issued. In this mode, the TMP464 device auto increments the internal pointer. If the transmission is terminated before register 84h is read, the pointer increments so a consecutive read (without a pointer set) can access the next register.



### 7.5.1.5 Timeout Function

The TMP464 device resets the serial interface if either SCL or SDA are held low for 17.5 ms (typical) between a start and stop condition. If the TMP464 device is holding the bus low, the device releases the bus and waits for a start condition. To avoid activating the timeout function, maintain a communication speed of at least 1 kHz for the SCL operating frequency.

### 7.5.1.6 High-Speed Mode

For the two-wire bus to operate at frequencies above 1 MHz, the master device must issue a high-speed mode (HS-mode) master code (0000 1xxx) as the first byte after a start condition to switch the bus to high-speed operation. The TMP464 device does not acknowledge the master code byte, but switches the input filters on SDA and SCL and the output filter on SDA to operate in HS-mode, allowing transfers up to 2.56 MHz. After the HS-mode master code is issued, the master transmits a two-wire slave address to initiate a data transfer operation. The bus continues to operate in HS-mode until a stop condition occurs on the bus. Upon receiving the stop condition, the TMP464 device switches the input and output filters back to fast mode.

## 7.5.2 TMP464 Register Reset

The TMP464 registers can be software reset by setting bit 15 of the Software Reset register (20h) to 1. This software reset restores the power-on-reset state to all TMP464 registers and aborts any conversion in progress.

## 7.5.3 Lock Register

All of the configuration and limit registers may be locked for writes (making the registers write-protected), which decreases the chance of software runaway from issuing false changes to these registers. The *Lock* column in [Table 3](#) identifies which registers may be locked. Lock mode does not effect read operations. To activate the lock mode, Lock Register C4h must be set to 0x5CA6. The lock only remains active while the TMP464 device is powered up. Because the TMP464 device does not contain nonvolatile memory, the settings of the configuration and limit registers are lost once a power cycle occurs regardless if the registers are locked or unlocked.

In lock mode, the TMP464 device ignores a write operation to configuration and limit registers except for Lock Register C4h. The TMP464 device does not acknowledge the data bytes during a write operation to a locked register. To unlock the TMP464 registers, write 0xEB19 to register C4h. The TMP464 device powers up in locked mode, so the registers must be unlocked before the registers accept writes of new data.

## 7.6 Register Maps

**Table 3. Register Map**

| PTR   | POR               | Lock  | TMP464 Functional Registers - BIT DESCRIPTION |                      |        |        |        |        |        |        |        |        |      |      |      |                  |      | REGISTER DESCRIPTION |   |
|-------|-------------------|-------|---|----------------------|--------|--------|--------|--------|--------|--------|--------|--------|------|------|------|------------------|------|----------------------|---|
| (HEX) | (HEX)             | (Y/N) | 15  | 14                   | 13     | 12     | 11     | 10     | 9      | 8      | 7      | 6      | 5    | 4    | 3    | 2                | 1    |                      | 0   |
| 00    | 0000              | N/A   | LT12  | LT11                 | LT10   | LT9    | LT8    | LT7    | LT6    | LT5    | LT4    | LT3    | LT2  | LT1  | LT0  | 0 <sup>(1)</sup> | 0    | 0                    | Local temperature   |
| 01    | 0000              | N/A   | RT12  | RT11                 | RT10   | RT9    | RT8    | RT7    | RT6    | RT5    | RT4    | RT3    | RT2  | RT1  | RT0  | 0                | 0    | 0                    | Remote temperature 1  |
| 02    | 0000              | N/A   | RT12  | RT11                 | RT10   | RT9    | RT8    | RT7    | RT6    | RT5    | RT4    | RT3    | RT2  | RT1  | RT0  | 0                | 0    | 0                    | Remote temperature 2  |
| 03    | 0000              | N/A   | RT12  | RT11                 | RT10   | RT9    | RT8    | RT7    | RT6    | RT5    | RT4    | RT3    | RT2  | RT1  | RT0  | 0                | 0    | 0                    | Remote temperature 3  |
| 04    | 0000              | N/A   | RT12  | RT11                 | RT10   | RT9    | RT8    | RT7    | RT6    | RT5    | RT4    | RT3    | RT2  | RT1  | RT0  | 0                | 0    | 0                    | Remote temperature 4  |
| 20    | 0000              | N/A   | RST   | 0                    | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0    | 0    | 0    | 0                | 0    | 0                    | Software Reset Register   |
| 21    | N/A               | N/A   | 0   | 0                    | 0      | 0      | R4TH   | R3TH   | R2TH   | R1TH   | LTH    | 0      | 0    | 0    | 0    | 0                | 0    | 0                    | THERM Status  |
| 22    | N/A               | N/A   | 0   | 0                    | 0      | 0      | R4TH2  | R3TH2  | R2TH2  | R1TH2  | LTH2   | 0      | 0    | 0    | 0    | 0                | 0    | 0                    | THERM2 Status   |
| 23    | N/A               | N/A   | 0   | 0                    | 0      | 0      | R4OPN  | R3OPN  | R2OPN  | R1OPN  | 0      | 0      | 0    | 0    | 0    | 0                | 0    | 0                    | Remote channel OPEN Status  |
| 30    | 0F9C              | Y     | 0   | 0                    | 0      | 0      | REN4   | REN3   | REN2   | REN1   | LEN    | OS     | SD   | CR2  | CR1  | CR0              | BUSY | 0                    | Configuration Register (Enables, OneShot, ShutDown, ConvRate, BUSY) |
| 38    | 0080              | Y     | 0   | HYS11                | HYS10  | HYS9   | HYS8   | HYS7   | HYS6   | HYS5   | HYS4   | 0      | 0    | 0    | 0    | 0                | 0    | 0                    | THERM hysteresis  |
| 39    | 3E80<br>(125°C)   | Y     | LTH112  | LTH111               | LTH110 | LTH109 | LTH108 | LTH107 | LTH106 | LTH105 | LTH104 | LTH103 | 0    | 0    | 0    | 0                | 0    | 0                    | Local temp THERM limit  |
| 3A    | 7FC0<br>(225.5°C) | Y     | LTH212  | LTH211               | LTH210 | LTH209 | LTH208 | LTH207 | LTH206 | LTH205 | LTH204 | LTH203 | 0    | 0    | 0    | 0                | 0    | 0                    | Local temp THERM2 limit   |
| 40    | 0000              | Y     | ROS12   | ROS12 <sup>(2)</sup> | ROS10  | ROS9   | ROS8   | ROS7   | ROS6   | ROS5   | ROS4   | ROS3   | ROS2 | ROS1 | ROS0 | 0                | 0    | 0                    | Remote temp 1 offset  |
| 41    | 0000              | Y     | RNC7  | RNC6                 | RNC5   | RNC4   | RNC3   | RNC2   | RNC1   | RNC0   | 0      | 0      | 0    | 0    | 0    | 0                | 0    | 0                    | Remote temp 1 $\eta$ -factor correction                             |

(1) Register bits highlighted in purple are reserved for future use and always reports 0; writes to these bits are ignored.

(2) Register bits highlighted in green show sign extended values.

## Register Maps (continued)

**Table 3. Register Map (continued)**

| PTR<br>(HEX) | POR<br>(HEX) | Lock<br>(Y/N) | TMP464 Functional Registers - BIT DESCRIPTION |         |          |         |         |         |          |          |         |         |      |      |      |   |   |   | REGISTER DESCRIPTION   |
|--------------|--------------|---------------|---|---------|----------|---------|---------|---------|----------|----------|---------|---------|------|------|------|---|---|---|--|
|              |              |               | 15  | 14      | 13       | 12      | 11      | 10      | 9        | 8        | 7       | 6       | 5    | 4    | 3    | 2 | 1 | 0 |  |
| 42           | 3E80         | Y             | RTH1_12                                       | RTH1_11 | RT H1_10 | RTH1_09 | RTH1_08 | RTH1_07 | RT H1_06 | RT H1_05 | RTH1_04 | RTH1_03 | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 1 THERM limit  |
| 43           | 7FC0         | Y             | RTH2_12                                       | RTH2_11 | RT H2_10 | RTH2_09 | RTH2_08 | RTH2_07 | RT H2_06 | RT H2_05 | RTH2_04 | RTH2_03 | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 1 THERM2 limit   |
| 48           | 0000         | Y             | ROS12   | ROS12   | ROS10    | ROS9    | ROS8    | ROS7    | ROS6     | ROS5     | ROS4    | ROS3    | ROS2 | ROS1 | ROS0 | 0 | 0 | 0 | Remote temp 2 offset   |
| 49           | 0000         | Y             | RNC7  | RNC6    | RNC5     | RNC4    | RNC3    | RNC2    | RNC1     | RNC0     | 0       | 0       | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 2 $\eta$ -factor correction                                |
| 4A           | 3E80         | Y             | RTH1_12                                       | RTH1_11 | RT H1_10 | RTH1_09 | RTH1_08 | RTH1_07 | RT H1_06 | RT H1_05 | RTH1_04 | RTH1_03 | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 2 THERM limit  |
| 4B           | 7FC0         | Y             | RTH2_12                                       | RTH2_11 | RT H2_10 | RTH2_09 | RTH2_08 | RTH2_07 | RT H2_06 | RT H2_05 | RTH2_04 | RTH2_03 | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 2 THERM2 limit   |
| 50           | 0000         | Y             | ROS12   | ROS12   | ROS10    | ROS9    | ROS8    | ROS7    | ROS6     | ROS5     | ROS4    | ROS3    | ROS2 | ROS1 | ROS0 | 0 | 0 | 0 | Remote temp 3 offset   |
| 51           | 0000         | Y             | RNC7  | RNC6    | RNC5     | RNC4    | RNC3    | RNC2    | RNC1     | RNC0     | 0       | 0       | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 3 $\eta$ -factor correction                                |
| 52           | 3E80         | Y             | RTH1_12                                       | RTH1_11 | RT H1_10 | RTH1_09 | RTH1_08 | RTH1_07 | RT H1_06 | RT H1_05 | RTH1_04 | RTH1_03 | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 3 THERM limit  |
| 53           | 7FC0         | Y             | RTH2_12                                       | RTH2_11 | RT H2_10 | RTH2_09 | RTH2_08 | RTH2_07 | RT H2_06 | RT H2_05 | RTH2_04 | RTH2_03 | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 3 THERM2 limit   |
| 58           | 0000         | Y             | ROS12   | ROS12   | ROS10    | ROS9    | ROS8    | ROS7    | ROS6     | ROS5     | ROS4    | ROS3    | ROS2 | ROS1 | ROS0 | 0 | 0 | 0 | Remote temperature 4 offset  |
| 59           | 0000         | Y             | RNC7  | RNC6    | RNC5     | RNC4    | RNC3    | RNC2    | RNC1     | RNC0     | 0       | 0       | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 4 $\eta$ -factor correction                                |
| 5A           | 3E80         | Y             | RTH1_12                                       | RTH1_11 | RT H1_10 | RTH1_09 | RTH1_08 | RTH1_07 | RT H1_06 | RT H1_05 | RTH1_04 | RTH1_03 | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 4 THERM limit  |
| 5B           | 7FC0         | Y             | RTH2_12                                       | RTH2_11 | RT H2_10 | RTH2_09 | RTH2_08 | RTH2_07 | RT H2_06 | RT H2_05 | RTH2_04 | RTH2_03 | 0    | 0    | 0    | 0 | 0 | 0 | Remote temp 4 THERM2 limit   |
| 80           | 0000         | N/A           | LT12  | LT11    | LT10     | LT9     | LT8     | LT7     | LT6      | LT5      | LT4     | LT3     | LT2  | LT1  | LT0  | 0 | 0 | 0 | Local temperature (Block read range - auto increment pointer register) |

## Register Maps (continued)

**Table 3. Register Map (continued)**

| PTR   | POR   | Lock  | TMP464 Functional Registers - BIT DESCRIPTION                 |      |      |     |     |     |     |     |     |     |     |     |     |   |   |   | REGISTER DESCRIPTION  |
|-------|-------|-------|---|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|---|---|
| (HEX) | (HEX) | (Y/N) | 15  | 14   | 13   | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2 | 1 | 0 |   |
| 81    | 0000  | N/A   | RT12  | RT11 | RT10 | RT9 | RT8 | RT7 | RT6 | RT5 | RT4 | RT3 | RT2 | RT1 | RT0 | 0 | 0 | 0 | Remote temperature 1 (Block read range - auto increment pointer register) |
| 82    | 0000  | N/A   | RT12  | RT11 | RT10 | RT9 | RT8 | RT7 | RT6 | RT5 | RT4 | RT3 | RT2 | RT1 | RT0 | 0 | 0 | 0 | Remote temperature 2 (Block read range - auto increment pointer register) |
| 83    | 0000  | N/A   | RT12  | RT11 | RT10 | RT9 | RT8 | RT7 | RT6 | RT5 | RT4 | RT3 | RT2 | RT1 | RT0 | 0 | 0 | 0 | Remote temperature 3 (Block read range - auto increment pointer register) |
| 84    | 0000  | N/A   | RT12  | RT11 | RT10 | RT9 | RT8 | RT7 | RT6 | RT5 | RT4 | RT3 | RT2 | RT1 | RT0 | 0 | 0 | 0 | Remote temperature 4 (Block read range - auto increment pointer register) |
| C4    | 8000  | N/A   | Write 0x5CA6 to lock registers and 0xEB19 to unlock registers |      |      |     |     |     |     |     |     |     |     |     |     |   |   |   | Lock Registers after initialization                                       |
|       |       |       | Read back: locked 0x8000; unlocked 0x0000                     |      |      |     |     |     |     |     |     |     |     |     |     |   |   |   |   |
| FE    | 5449  | N/A   | 0   | 1    | 0    | 1   | 0   | 1   | 0   | 0   | 0   | 1   | 0   | 0   | 1   | 0 | 0 | 1 | Manufacturers Identification Register                                     |
| FF    | 1468  | N/A   | 0   | 0    | 0    | 1   | 0   | 1   | 0   | 0   | 0   | 1   | 1   | 0   | 1   | 0 | 0 | 0 | Device Identification/Revision Register                                   |

## 7.6.1 Register Information

The TMP464 device contains multiple registers for holding configuration information, temperature measurement results, and status information. These registers are described in [Figure 19](#) and [Table 3](#).

### 7.6.1.1 Pointer Register

[Figure 19](#) shows the internal register structure of the TMP464 device. The 8-bit pointer register addresses a given data register. The pointer register identifies which of the data registers must respond to a read or write command on the two-wire bus. This register is set with every write command. A write command must be issued to set the proper value in the pointer register before executing a read command. [Table 3](#) describes the pointer register and the internal structure of the TMP464 registers. The power-on-reset (POR) value of the pointer register is 00h (0000 0000b). [Table 3](#) lists a summary of the pointer values for the different registers. Writing data to unassigned pointer values are ignored and does not **affect** the operation of the device. Reading an unassigned register returns undefined data and is ACKed.

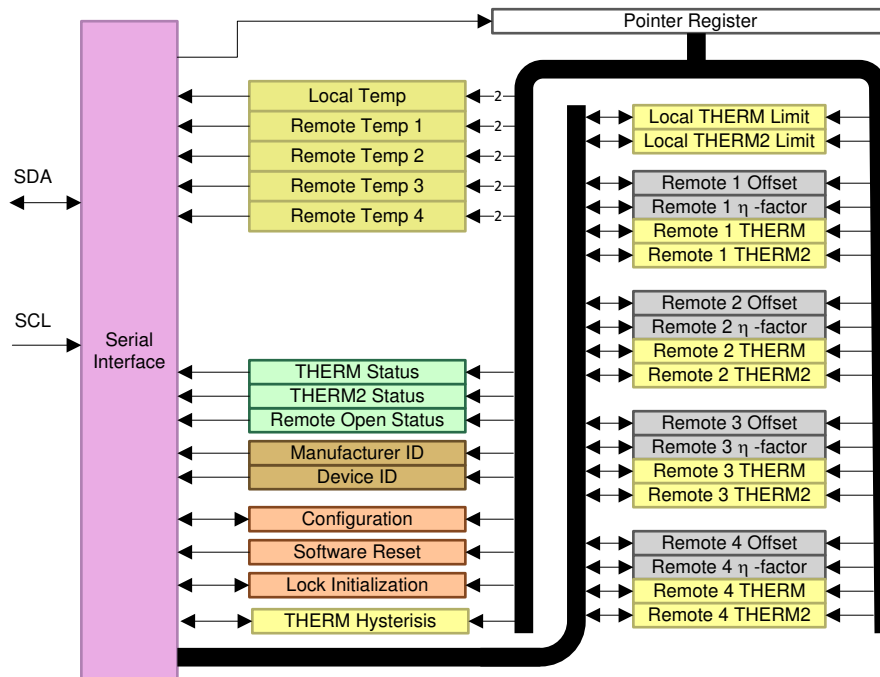


Figure 19. TMP464 Internal Register Structure

### 7.6.1.2 Local and Remote Temperature Value Registers

The TMP464 device has multiple 16-bit registers that hold 13-bit temperature measurement results. The 13 bits of the local temperature sensor result are stored in register 00h. The 13 bits of the four remote temperature sensor results are stored in registers 01h through 04h. The four assigned LSBs of both the local (LT3:LT0) and remote (RT3:RT0) sensors indicate the temperature value after the decimal point (for example, if the temperature result is 10.0625°C, then the high byte is 0000 0101 and the low byte is 0000 1000). These registers are read-only and are updated by the ADC each time a temperature measurement is complete. Asynchronous reads are supported, so a read operation can occur at any time and results in valid conversion results being transmitted once the first conversion is complete after power up for the channel being accessed. If after power up a read is initiated before a conversion is complete, the read operation results in all zeros (0x0000).

### 7.6.1.3 Software Reset Register

The Software Reset Register allows the user to reset the TMP464 registers through software by setting the reset bit (RST, bit 15) to 1. The power-on-reset value for this register is 0x0000. Resets are ignored when the device is in lock mode, so writing a 1 to the RST bit does not reset any registers.

**Table 4. Software Reset Register Format**

| STATUS REGISTER (READ = 20h, WRITE = 20h, POR = 0x0000) |          |  |
|---|----------|--|
| BIT NUMBER  | BIT NAME | FUNCTION   |
| 15  | RST      | 1 software reset device; writing a value of 0 is ignored |
| 14:0  | 0        | Reserved for future use; always reports 0                |

#### 7.6.1.4 THERM Status Register

The THERM Status register reports the state of the THERM limit comparators for local and four remote temperatures. [Table 5](#) lists the status register bits. The THERM Status register is read-only and is read by accessing pointer address 21h.

**Table 5. THERM Status Register Format**

| <u>THERM</u> STATUS REGISTER (READ = 21h, WRITE = N/A) |          |  |
|--|----------|--|
| BIT NUMBER   | BIT NAME | FUNCTION   |
| 15:12  | 0        | Reserved for future use; always reports 0.         |
| 11   | R4TH     | 1 when Remote 4 exceeds the <u>THERM</u> limit     |
| 10   | R3TH     | 1 when Remote 3 exceeds the <u>THERM</u> limit     |
| 9  | R2TH     | 1 when Remote 2 exceeds the <u>THERM</u> limit     |
| 8  | R1TH     | 1 when Remote 1 exceeds the <u>THERM</u> limit     |
| 7  | LTH      | 1 when Local sensor exceeds the <u>THERM</u> limit |
| 6:0  | 0        | Reserved for future use; always reports 0.         |

The R4TH:R1TH and LTH flags are set when the corresponding temperature exceeds the respective programmed THERM limit (39h, 42h, 4Ah, 52h, and 5Ah). These flags are reset automatically when the temperature returns below the THERM limit minus the value set in the THERM Hysteresis register (38h). The THERM output goes low in the case of overtemperature on either the local or remote channels, and goes high as soon as the measurements are less than the THERM limit minus the value set in the THERM Hysteresis register. The THERM Hysteresis register (38h) allows hysteresis to be added so that the flag resets and the output goes high when the temperature returns to or goes below the limit value minus the hysteresis value.

### 7.6.1.5 **THERM2 Status Register**

The **THERM2** Status register reports the state of the **THERM2** limit comparators for local and remote 1-4 temperatures. [Table 6](#) lists the status register bits. The **THERM2** Status register is read-only and is read by accessing pointer address 22h.

**Table 6. **THERM2** Status Register Format**

| <b>THERM2 STATUS REGISTER (READ = 22h, WRITE = N/A)</b> |                 |   |
|---|-----------------|---|
| <b>BIT NUMBER</b>                                       | <b>BIT NAME</b> | <b>FUNCTION</b>                                     |
| 15:12   | 0               | Reserved for future use; always reports 0.          |
| 11  | R4TH2           | 1 when Remote 4 exceeds the <b>THERM2</b> limit     |
| 10  | R3TH2           | 1 when Remote 3 exceeds the <b>THERM2</b> limit     |
| 9   | R2TH2           | 1 when Remote 2 exceeds the <b>THERM2</b> limit     |
| 8   | R1TH2           | 1 when Remote 1 exceeds the <b>THERM2</b> limit     |
| 7   | LTH2            | 1 when Local Sensor exceeds the <b>THERM2</b> limit |
| 6:0   | 0               | Reserved for future use; always reports 0.          |

The R4TH2:R1TH2 and LTH2 flags are set when the corresponding temperature exceeds the respective programmed **THERM2** limit (3Ah, 43h, 4Bh, 53h, 5Bh, 63h, 6Bh, 73h, 7Bh). These flags are reset automatically when the temperature returns below the **THERM2** limit minus the value set in the **THERM** Hysteresis register (38h). The **THERM2** output goes low in the case of overtemperature on either the local or remote channels, and goes high as soon as the measurements are less than the **THERM2** limit minus the value set in the **THERM** Hysteresis register. The **THERM** Hysteresis register (38h) allows hysteresis to be added so that the flag resets and the output goes high when the temperature returns to or goes below the limit value minus the hysteresis value.

### 7.6.1.6 **Remote Channel Open Status Register**

The Remote Channel Open Status register reports the state of the connection of remote channels one through four. [Table 7](#) lists the status register bits. The Remote Channel Open Status register is read-only and is read by accessing pointer address 23h.

**Table 7. Remote Channel Open Status Register Format**

| <b>REMOTE CHANNEL OPEN STATUS REGISTER (READ = 23h, WRITE = N/A)</b> |                 |  |
|--|-----------------|--|
| <b>BIT NUMBER</b>  | <b>BIT NAME</b> | <b>FUNCTION</b>                            |
| 15:12  | 0               | Reserved for future use; always reports 0. |
| 11   | R4OPEN          | 1 when Remote 4 channel is an open circuit |
| 10   | R3OPEN          | 1 when Remote 3 channel is an open circuit |
| 9  | R2OPEN          | 1 when Remote 2 channel is an open circuit |
| 8  | R1OPEN          | 1 when Remote 1 channel is an open circuit |
| 7:0  | 0               | Reserved for future use; always reports 0. |

The R4OPEN:R1OPEN bits indicate an open-circuit condition on remote sensors four through one, respectively. The setting of these flags does not directly affect the state of the **THERM** or **THERM2** output pins. Indirectly, the temperature reading(s) may be erroneous and exceed the respective **THERM** and **THERM2** limits, activating the **THERM** or **THERM2** output pins.

### 7.6.1.7 Configuration Register

The Configuration Register sets the conversion rate, starts one-shot conversion of all enabled channels, enables conversion the temperature channels, controls the shutdown mode and reports when a conversion is in process. The Configuration Register is set by writing to pointer address 30h, and is read from pointer address 30h. [Table 8](#) summarizes the bits of the Configuration Register.

**Table 8. Configuration Register Bit Descriptions**

| CONFIGURATION REGISTER (READ = 30h, WRITE = 30h, POR = 0x0F9C) |           |  |                      |
|--|-----------|--|----------------------|
| BIT NUMBER   | NAME      | FUNCTION   | POWER-ON-RESET VALUE |
| 15:12  | 0         | Reserved for future use; always reports 0  | 0000                 |
| 11:8   | REN4:REN1 | 1 = enable respective remote channel 4 through 1 conversions   | 1111                 |
| 7  | LEN       | 1 = enable local channel conversion  | 1                    |
| 6  | OS        | 1 = start one-shot conversion on enabled channels  | 0                    |
| 5  | SD        | 1 = enables device shutdown  | 0                    |
| 4:2  | CR2:CR0   | Conversion rate control bits; control conversion rates for all enabled channels from 16 seconds to continuous conversion | 111                  |
| 1  | BUSY      | 1 when the ADC is converting (read-only bit ignores writes)  | 0                    |
| 0  | Reserved  | —  | 0                    |

The Remote Enable four through one (REN4:REN1, bits 11:8) bits enable conversions on the respective remote channels. The Local Enable (LEN, bit 7) bit enables conversions of the local temperature channel. If all LEN and REN are set to 1 (default), this enables the ADC to convert the local and all remote temperatures. If the LEN is set to 0, the local temperature conversion is skipped. Similarly if a REN is set to 0, that remote temperature conversion channel is skipped. The TMP464 device steps through each enabled channel in a round-robin fashion in the following order: LOC, REM1, REM2, REM4, LOC, REM1, and so on. All local and remote temperatures are converted by the internal ADC by default after power up. The configuration register LEN and REN bits can be configured to save power by reducing the total ADC conversion time for applications that do not require all of the four remote and local temperature information. Note writing all zeros to REN4:REN1 and LEN has the same effect as SD = 1 and OS = 0.

The shutdown bit (SD, bit 5) enables or disables the temperature-measurement circuitry. If SD = 0 (default), the TMP464 device converts continuously at the rate set in the conversion rate register. When SD is set to 1, the TMP464 device immediately stops the conversion in progress and instantly enters shutdown mode. When SD is set to 0 again, the TMP464 device resumes continuous conversions starting with the local temperature.

The BUSY bit = 1 if the ADC is making a conversion. This bit is set to 0 if the ADC is not converting.

After the TMP464 device is in shutdown mode, writing a 1 to the one-shot (OS, bit 6) bit starts a single ADC conversion of all the enabled temperature channels. This write operation starts one conversion and comparison cycle on either the four remote and one local sensor or any combination of sensors, depending on the LEN and REN values in the Configuration Register (read address 30h). The TMP464 device returns to shutdown mode when the cycle is complete. [Table 9](#) details the interaction of the SD, OS, LEN, and REN bits.

**Table 9. Conversion Modes**

| WRITE              |    |    | READ          |    |    | FUNCTION              |
|--------------------|----|----|---------------|----|----|-----------------------|
| REN[8:1], LEN      | OS | SD | REN[8:1], LEN | OS | SD |                       |
| All 0              | —  | —  | All 0         | 0  | 1  | Shutdown              |
| At least 1 enabled | —  | 0  | Written value | 0  | 0  | Continuous conversion |
| At least 1 enabled | 0  | 1  | Written value | 0  | 1  | Shutdown              |
| At least 1 enabled | 1  | 1  | Written value | 1  | 1  | One-shot conversion   |



The conversion rate bits control the rate that the conversions occur (CR2:CR0, bits 4:2). The value of CR2:CR0 bits controls the idle time between conversions but not the conversion time itself, which allows the TMP464 device power dissipation to be balanced with the update rate of the temperature register. [Table 10](#) describes the mapping for CR2:CR0 to the conversion rate or temperature register update rate.

**Table 10. Conversion Rate**

| CR2:CR0 | DECIMAL VALUE | FREQUENCY (Hz)  | TIME (s) |
|---------|---------------|---|----------|
| 000     | 0             | 0.0625  | 16       |
| 001     | 1             | 0.125   | 8        |
| 010     | 2             | 0.25  | 4        |
| 011     | 3             | 0.5   | 2        |
| 100     | 4             | 1   | 1        |
| 101     | 5             | 2   | 0.5      |
| 110     | 6             | 4   | 0.25     |
| 111     | 7             | Continuous conversion; depends on number of enabled channels; see <a href="#">Table 11</a> (default). |          |

**Table 11. Continuous Conversion Times**

| NUMBER OF REMOTE CHANNELS ENABLED | CONVERSION TIME (ms) |               |
|-----------------------------------|----------------------|---------------|
|                                   | LOCAL DISABLED       | LOCAL ENABLED |
| 0                                 | 0                    | 15.5          |
| 1                                 | 15.8                 | 31.3          |
| 2                                 | 31.6                 | 47.1          |
| 3                                 | 47.4                 | 62.9          |
| 4                                 | 63.2                 | 78.7          |

The remaining bits of the configuration register are reserved and must always be set to 0. The POR value for this register is 0x0F9C.

### 7.6.1.8 $\eta$ -Factor Correction Register

The TMP464 device allows for a different  $\eta$ -factor value to be used for converting remote channel measurements to temperature for each temperature channel. There are four  $\eta$ -Factor Correction registers assigned: one to each of the remote input channels (addresses 41h, 49h, 51h, and 59h). Each remote channel uses sequential current excitation to extract a differential  $V_{BE}$  voltage measurement to determine the temperature of the remote transistor. [Equation 1](#) shows this voltage and temperature.

$$V_{BE2} - V_{BE1} = \frac{\eta k T}{q} \ln \left( \frac{I_2}{I_1} \right) \quad (1)$$

The value  $\eta$  in [Equation 1](#) is a characteristic of the particular transistor used for the remote channel. The POR value for the TMP464 device is  $\eta = 1.008$ . The value in the  $\eta$ -Factor Correction register can be used to adjust the effective  $\eta$ -factor, according to [Equation 2](#) and [Equation 3](#).

$$\eta_{\text{eff}} = \left( \frac{1.008 \times 2088}{2088 + N_{\text{ADJUST}}} \right) \quad (2)$$

$$N_{\text{ADJUST}} = \left( \frac{1.008 \times 2088}{\eta_{\text{eff}}} \right) - 2088 \quad (3)$$

The  $\eta$ -factor correction value must be stored in a two's-complement format, which yields an effective data range from –128 to +127. The POR value for each register is 0000h, which does not affect register values unless a different value is written to the register. The resolution of the  $\eta$ -factor register changes linearly as the code changes and has a range from 0.0004292 to 0.0005476, with an average of 0.0004848.

**Table 12.  $\eta$ -Factor Range**

| N <sub>ADJUST</sub> ONLY BITS 15 TO 8 IN THE REGISTER ARE SHOWN |     |         | $\eta$   |
|---|-----|---------|----------|
| BINARY  | HEX | DECIMAL |          |
| 0111 1111   | 7F  | 127     | 0.950205 |
| 0000 1010   | 0A  | 10      | 1.003195 |
| 0000 1000   | 08  | 8       | 1.004153 |
| 0000 0110   | 06  | 6       | 1.005112 |
| 0000 0100   | 04  | 4       | 1.006073 |
| 0000 0010   | 02  | 2       | 1.007035 |
| 0000 0001   | 01  | 1       | 1.007517 |
| 0000 0000   | 00  | 0       | 1.008    |
| 1111 1111   | FF  | –1      | 1.008483 |
| 1111 1110   | FE  | –2      | 1.008966 |
| 1111 1100   | FC  | –4      | 1.009935 |
| 1111 1010   | FA  | –6      | 1.010905 |
| 1111 1000   | F8  | –8      | 1.011877 |
| 1111 0110   | F6  | –10     | 1.012851 |
| 1000 0000   | 80  | –128    | 1.073829 |

### 7.6.1.9 Remote Temperature Offset Register

The offset registers allow the TMP464 device to store any system offset compensation value that may result from precision calibration. The value in these registers is added to the remote temperature results upon every conversion. Each of the four temperature channels have an independent assigned offset register (addresses 40h, 48h, 50h, and 58h). Combined with the independent  $\eta$ -factor corrections, this function allows for very accurate system calibration over the entire temperature range for each remote channel. The format of these registers is the same as the temperature value registers with a range from +127.9375 to –128. Take care to program this register with sign extension, as values above +127.9375 and below –128 are not supported.

### 7.6.1.10 $\overline{\text{THERM}}$ Hysteresis Register

The  $\overline{\text{THERM}}$  Hysteresis register (address 38h) sets the value of the hysteresis used by the temperature comparison logic. All temperature reading comparisons have a common hysteresis. Hysteresis prevents oscillations from occurring on the  $\overline{\text{THERM}}$  and  $\overline{\text{THERM2}}$  outputs as the measured temperature approaches the comparator threshold (see the [THERM Functions](#) section). The resolution of the  $\overline{\text{THERM}}$  Hysteresis register is 1°C and ranges from 0°C to 255°C.

### 7.6.1.11 Local and Remote $\overline{\text{THERM}}$ and $\overline{\text{THERM2}}$ Limit Registers

Each of the four remote and the local temperature channels has associated independent  $\overline{\text{THERM}}$  and  $\overline{\text{THERM2}}$  Limit registers. There are five  $\overline{\text{THERM}}$  registers (addresses 39h, 42h, 4Ah, 52h, and 5Ah) and five  $\overline{\text{THERM2}}$  registers (addresses 39h, 43h, 4Bh, and 53h), 10 registers in total. The resolution of these registers is 0.5°C and ranges from +255.5°C to –255°C. See the [THERM Functions](#) section for more information.

Setting a  $\overline{\text{THERM}}$  limit to 255.5°C disables the  $\overline{\text{THERM}}$  limit comparison for that particular channel and disables the limit flag from being set in the  $\overline{\text{THERM}}$  Status register. This prevents the associated channel from activating the  $\overline{\text{THERM}}$  output.  $\overline{\text{THERM2}}$  limits, status, and outputs function similarly.

### 7.6.1.12 Block Read - Auto Increment Pointer

Block reads can be initiated by setting the pointer register to 80h to 84h. The temperature results are mirrored at pointer addresses 80h to 84h; temperature results for all the channels can be read with one read transaction. Setting the pointer register to any address from 80h to 84h signals to the TMP464 device that a block of more than two bytes must be transmitted before a design stop is issued. In block read mode, the TMP464 device auto increments the pointer address.

### 7.6.1.13 Lock Register

Register C4h allows the device configuration and limit registers to lock, as shown by the *Lock* column in [Table 3](#). To lock the registers, write 0x5CA6. To unlock the registers, write 0xEB19. When the lock function is enabled, reading the register yields 0x8000; when unlocked, 0x0000 is transmitted.

### 7.6.1.14 Manufacturer and Device Identification Plus Revision Registers

The TMP464 device allows the two-wire bus controller to query the device for manufacturer and device identifications (IDs) to enable software identification of the device at the particular two-wire bus address. The manufacturer ID is obtained by reading from pointer address FEh; the device ID is obtained from register FFh. Note that the most significant byte of the Device ID register identifies the TMP464 device revision level. The TMP464 device reads 0x5449 for the manufacturer code and 0x1468 for the device ID code for the first release.

## 8 Application and Implementation

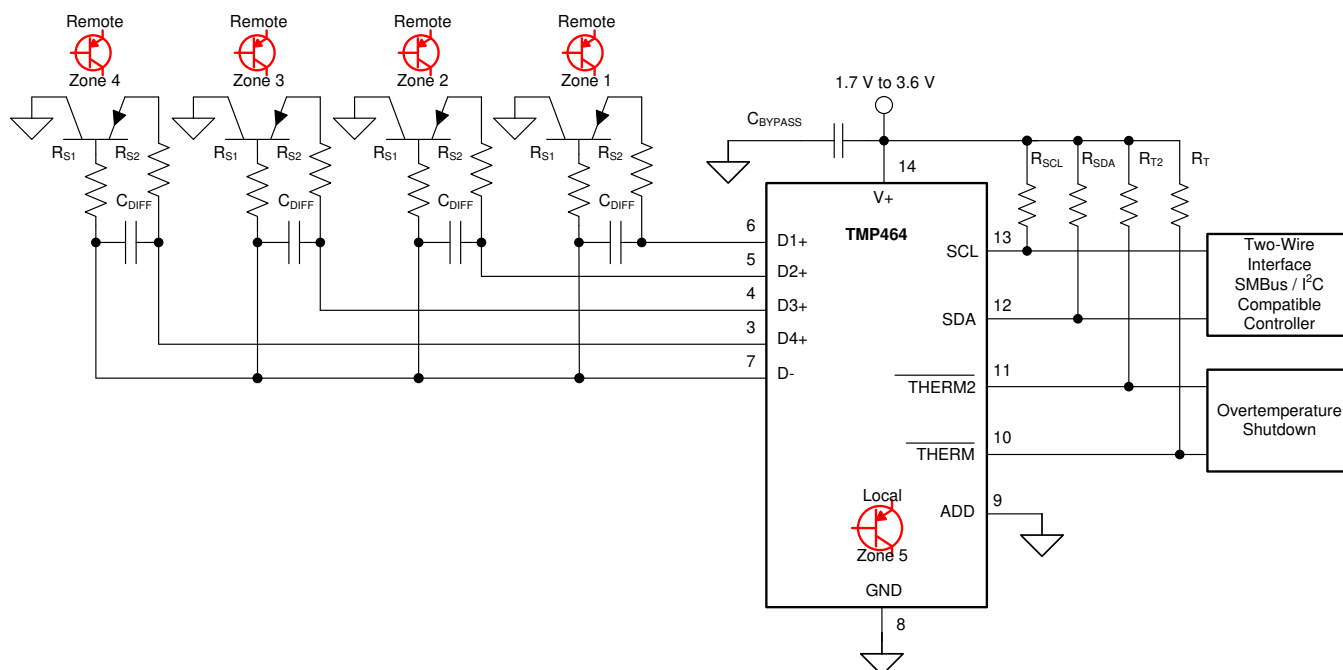
### NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 8.1 Application Information

The TMP464 device requires a transistor connected between the D+ and D– pins for remote temperature measurement. Tie the D+ pin to D– if the remote channel is not used and only the local temperature is measured. The SDA, ALERT, and THERM pins (and SCL, if driven by an open-drain output) require pullup resistors as part of the communication bus. TI recommends a 0.1-μF power-supply decoupling capacitor for local bypassing. Figure 20 and Figure 21 illustrate the typical configurations for the TMP464 device.

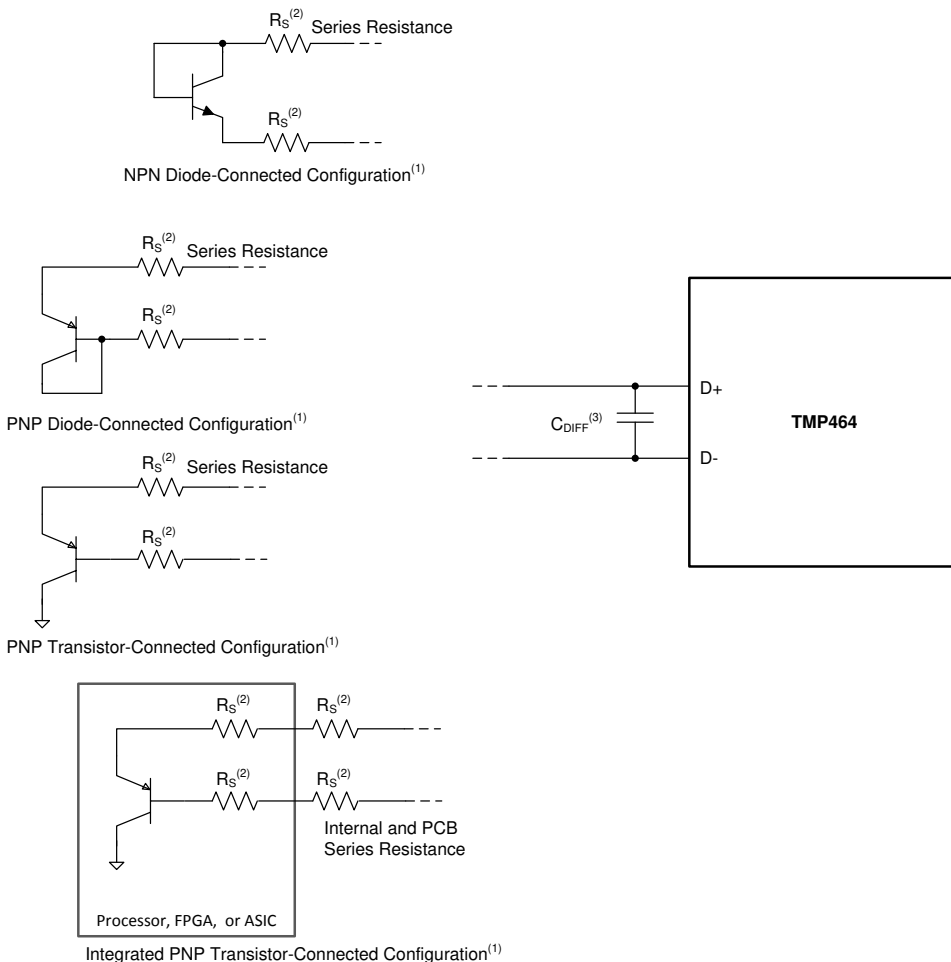
### 8.2 Typical Application



Copyright © 2017, Texas Instruments Incorporated

- (1) The diode-connected configuration provides better settling time. The transistor-connected configuration provides better series resistance cancellation. TI recommends a MMBT3904 or MMBT3906 transistor with an  $\eta$ -factor of 1.008.
- (2)  $R_S$  (optional) is < 1 kΩ in most applications.  $R_S$  is the combined series resistance connected externally to the D+, D– pins.  $R_S$  selection depends on the application.
- (3)  $C_{DIFF}$  (optional) is < 1000 pF in most applications.  $C_{DIFF}$  selection depends on the application; see Figure 7.
- (4) Unused diode channels must be tied to D–.

**Figure 20. TMP464 Basic Connections Using a Discrete Remote Transistor**



Copyright © 2017, Texas Instruments Incorporated

## Typical Application (continued)

$$T_{ERR} = \left( \frac{\eta - 1.008}{1.008} \right) \times (273.15 + T(^{\circ}\text{C}))$$

where

- $T_{ERR}$  = error in the TMP464 device because  $\eta \neq 1.008$
- $\eta$  = ideality factor of the remote temperature sensor
- $T(^{\circ}\text{C})$  = actual temperature, and

(4)

In Equation 4, the degree of delta is the same for  $^{\circ}\text{C}$  and K.

For  $\eta = 1.004$  and  $T(^{\circ}\text{C}) = 100^{\circ}\text{C}$ :

$$T_{ERR} = \left( \frac{1.004 - 1.008}{1.008} \right) \times (273.15 + 100^{\circ}\text{C})$$

$$T_{ERR} = -1.48^{\circ}\text{C}$$

(5)

If a discrete transistor is used as the remote temperature sensor with the TMP464 device, then select the transistor according to the following criteria for best accuracy:

- Base-emitter voltage is  $> 0.25\text{ V}$  at  $7.5\text{ }\mu\text{A}$ , at the highest-sensed temperature.
- Base-emitter voltage is  $< 0.95\text{ V}$  at  $120\text{ }\mu\text{A}$ , at the lowest-sensed temperature.
- Base resistance is  $< 100\text{ }\Omega$ .
- Tight control of  $V_{BE}$  characteristics indicated by small variations in  $h_{FE}$  (50 to 150).

Based on these criteria, TI recommends using a MMBT3904 (NPN) or a MMBT3906 (PNP) transistor.

### 8.2.2 Detailed Design Procedure

The local temperature sensor inside the TMP464 is influenced by the ambient air around the device but mainly monitors the PCB temperature that it is mounted to. The thermal time constant for the TMP464 device is approximately two seconds. This constant implies that if the ambient air changes quickly by  $100^{\circ}\text{C}$ , then the TMP464 device takes approximately 10 seconds (that is, five thermal time constants) to settle to within  $1^{\circ}\text{C}$  of the final value. In most applications, the TMP464 package is in electrical (and therefore thermal) contact with the printed-circuit board (PCB), and subjected to forced airflow. The accuracy of the measured temperature directly depends on how accurately the PCB and forced airflow temperatures represent the temperature that the TMP464 device is measuring. Additionally, the internal power dissipation of the TMP464 device can cause the temperature to rise above the ambient or PCB temperature. The internal power is negligible because of the small current drawn by the TMP464 device. Equation 6 can be used to calculate the average conversion current for power dissipation and self-heating based on the number of conversions per second and temperature sensor channel enabled. Equation 7 shows an example with local and all remote sensor channels enabled and conversion rate of 1 conversion per second; see the [Electrical Characteristics](#) table for typical values required for these calculations. For a 3.3-V supply and a conversion rate of 1 conversion per second, the TMP464 device dissipates 0.143 mW ( $PD_{IQ} = 3.3\text{ V} \times 43\text{ }\mu\text{A}$ ) when both the remote and local channels are enabled.

$$\begin{aligned} \text{Average Conversion Current} = & (\text{Local Conversion Time}) \times (\text{Conversions Per Second}) \times (\text{Local Active } I_Q) + \\ & (\text{Remote Conversion Time}) \times (\text{Conversions Per Second}) \times (\text{Remote Active } I_Q) \times (\text{Number of Active Channels} + \\ & (\text{Standby Mode}) \times [1 - ((\text{Local Conversion Time}) + (\text{Remote Conversion Time}) \times (\text{Number of Active} \\ & \text{Channels})) \times (\text{Conversions Per Second})] \end{aligned}$$

(6)

(7)

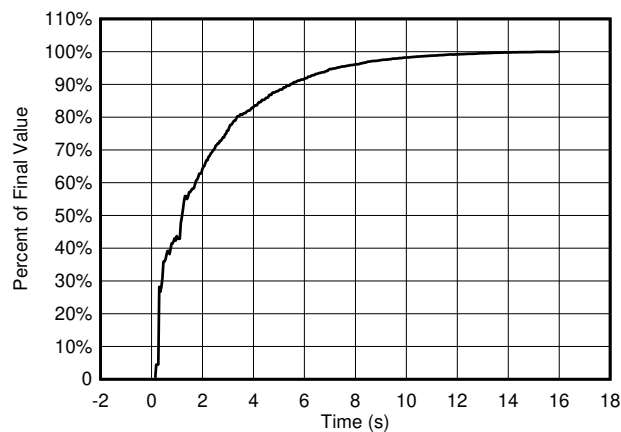
## Typical Application (continued)

$$\begin{aligned}
 \text{Average Conversion Current} &= (16 \text{ ms}) \times \left( \frac{1}{\text{sec}} \right) \times (240 \text{ } \mu\text{A}) \\
 &+ (16 \text{ ms}) \times \left( \frac{1}{\text{sec}} \right) \times (200 \text{ } \mu\text{A}) \times (4) \\
 &+ (15 \text{ } \mu\text{A}) \times \left[ 1 - ((16 \text{ ms}) + (16 \text{ ms}) \times (4)) \times \left( \frac{1}{\text{sec}} \right) \right] \\
 &= 43 \text{ } \mu\text{A}
 \end{aligned}
 \tag{8}$$

The temperature measurement accuracy of the TMP464 device depends on the remote and local temperature sensor being at the same temperature as the monitored system point. If the temperature sensor is not in good thermal contact with the part of the monitored system, then there is a delay between the sensor response and the system changing temperature. This delay is usually not a concern for remote temperature-sensing applications that use a substrate transistor (or a small, SOT-23 transistor) placed close to the monitored device.

### 8.2.3 Application Curve

Figure 22 shows the typical step response to submerging a TMP464 device (initially at 25°C) in an oil bath with a temperature of 100°C and logging the local temperature readings.



**Figure 22. TMP464 Temperature Step Response of Local Sensor**

## 9 Power Supply Recommendations

The TMP464 device operates with a power-supply range from 1.7 V to 3.6 V. The device is optimized for operation at a 1.8-V supply, but can measure temperature accurately in the full supply range.

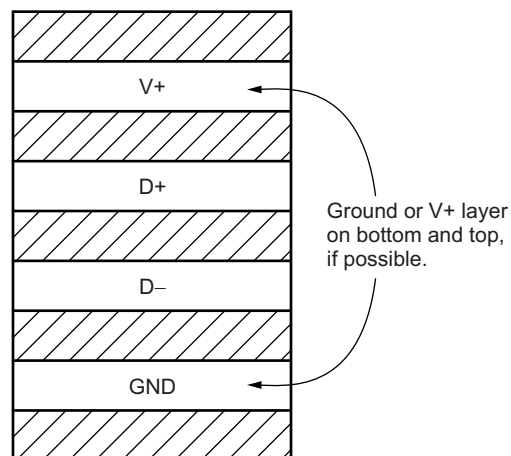
TI recommends a power-supply bypass capacitor. Place this capacitor as close as possible to the supply and ground pins of the device. A typical value for this supply bypass capacitor is 0.1  $\mu\text{F}$ . Applications with noisy or high-impedance power supplies may require additional decoupling capacitors to reject power-supply noise.

## 10 Layout

### 10.1 Layout Guidelines

Remote temperature sensing on the TMP464 device measures very small voltages using very low currents; therefore, noise at the device inputs must be minimized. Most applications using the TMP464 device have high digital content, with several clocks and a multitude of logic-level transitions that create a noisy environment. Layout must adhere to the following guidelines:

1. Place the TMP464 device as close to the remote junction sensor as possible.
2. Route the D+ and D– traces next to each other and shield them from adjacent signals through the use of ground guard traces, as shown in [Figure 23](#). If a multilayer PCB is used, bury these traces between the ground or V+ planes to shield them from extrinsic noise sources. TI recommends 5-mil (0.127 mm) PCB traces.
3. Minimize additional thermocouple junctions caused by copper-to-solder connections. If these junctions are used, make the same number and approximate locations of copper-to-solder connections in both the D+ and D– connections to cancel any thermocouple effects.
4. Use a 0.1-μF local bypass capacitor directly between the V+ and GND of the TMP464. For optimum measurement performance, minimize filter capacitance between D+ and D– to 1000 pF or less. This capacitance includes any cable capacitance between the remote temperature sensor and the TMP464.
5. If the connection between the remote temperature sensor and the TMP464 is wired and is less than eight inches (20.32 cm) long, use a twisted-wire pair connection. For lengths greater than eight inches, use a twisted, shielded pair with the shield grounded as close to the TMP464 device as possible. Leave the remote sensor connection end of the shield wire open to avoid ground loops and 60-Hz pickup.
6. Thoroughly clean and remove all flux residue in and around the pins of the TMP464 device to avoid temperature offset readings as a result of leakage paths between D+ and GND, or between D+ and V+.



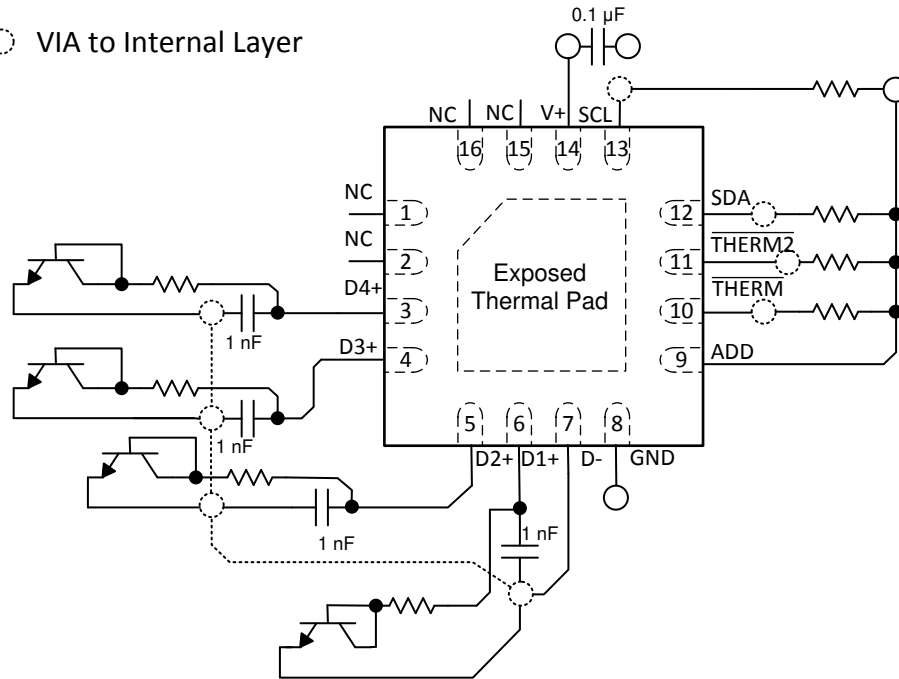
NOTE: Use a minimum of 5-mil (0.127 mm) traces with 5-mil spacing.

**Figure 23. Suggested PCB Layer Cross-Section**



## 10.2 Layout Example

- VIA to Power or Ground Plane
- VIA to Internal Layer



**Figure 24. TMP464 Layout Example**

## 11 Device and Documentation Support

### 11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://ti.com). In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 11.2 Community Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

### 11.3 Trademarks

E2E is a trademark of Texas Instruments.

SMBus is a trademark of Intel Corporation.

All other trademarks are the property of their respective owners.

### 11.4 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### 11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

| Orderable part number        | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">TMP464AIRGTR</a> | Active        | Production           | VQFN (RGT)   16 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | T464                |
| TMP464AIRGTR.A               | Active        | Production           | VQFN (RGT)   16 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | T464                |
| TMP464AIRGTRG4.A             | Active        | Production           | VQFN (RGT)   16 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | T464                |
| <a href="#">TMP464AIRGTT</a> | Obsolete      | Production           | VQFN (RGT)   16 | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | T464                |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## TAPE AND REEL INFORMATION



\*All dimensions are nominal

| Device       | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TMP464AIRGTR | VQFN         | RGT             | 16   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TMP464AIRGTR | VQFN         | RGT             | 16   | 3000 | 367.0       | 367.0      | 35.0        |

**RGT 16**

**GENERIC PACKAGE VIEW**

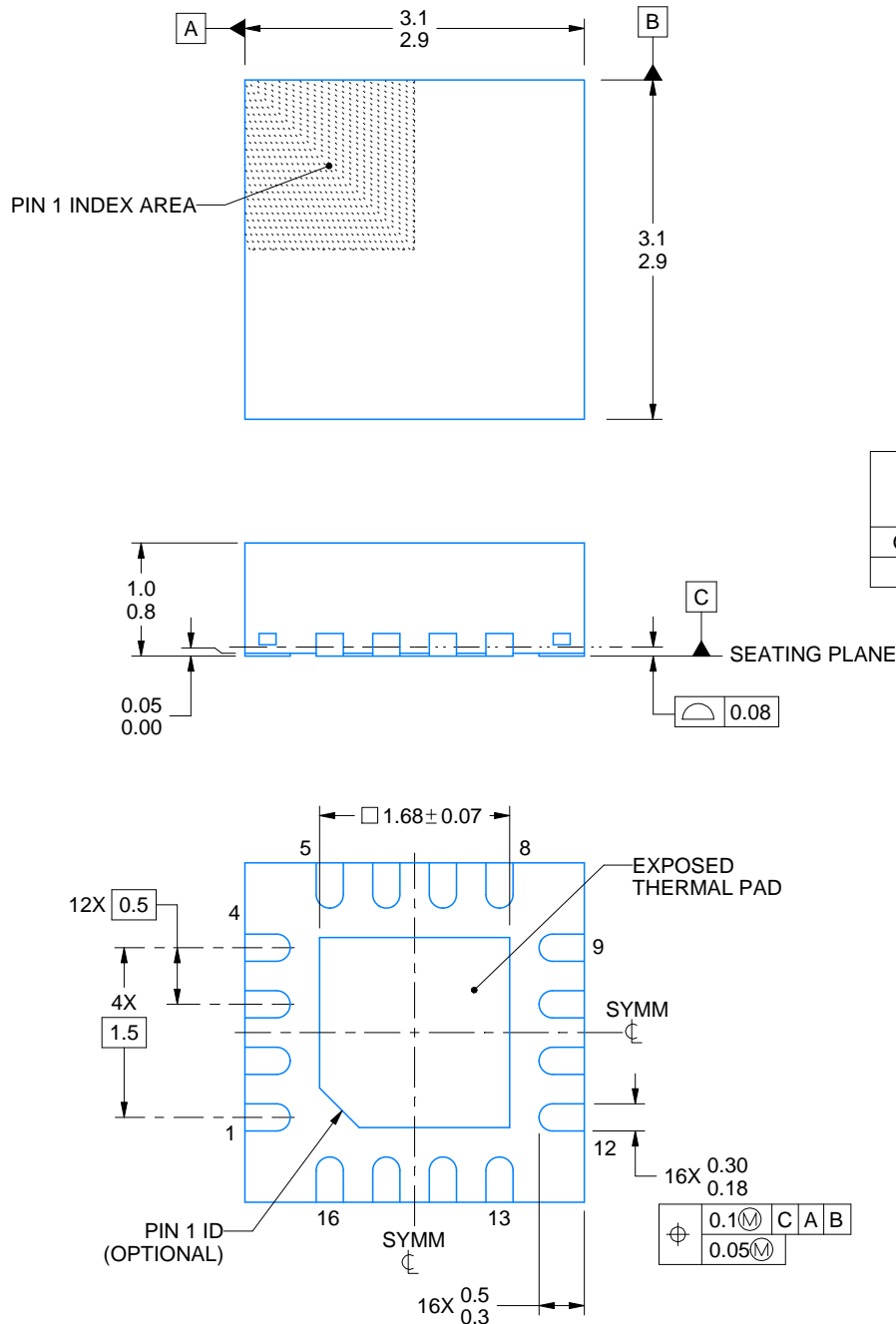
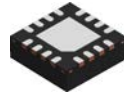
**VQFN - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4203495/1



4222419/D 04/2022

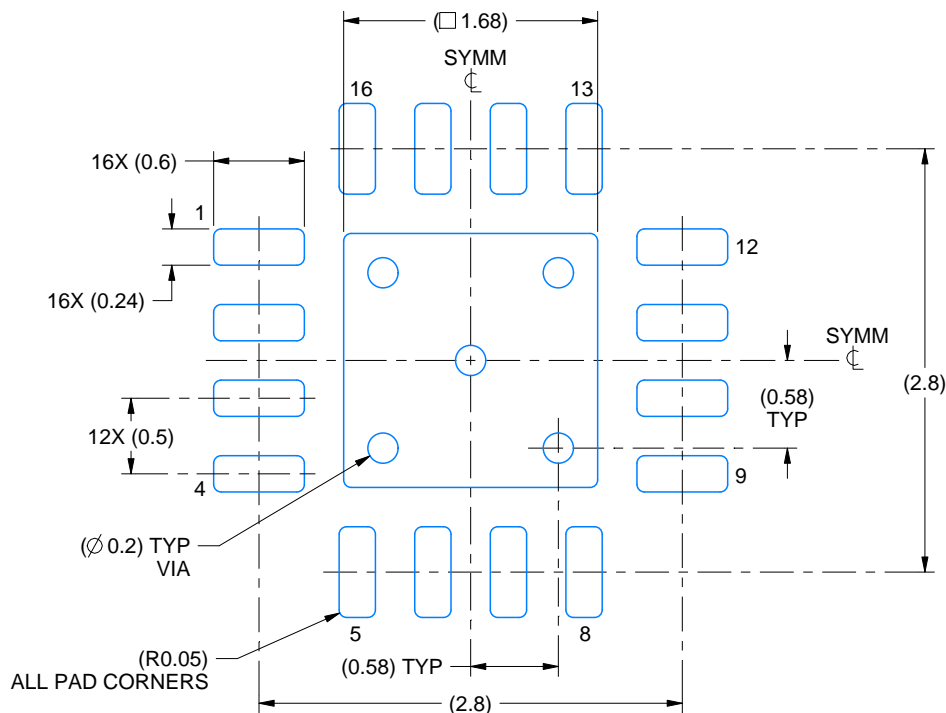
## NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

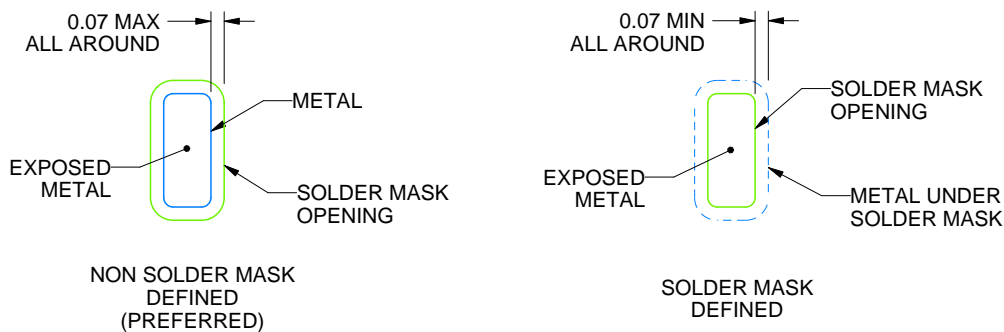
**RGT0016C**

## VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:20X



## SOLDER MASK DETAILS

4222419/D 04/2022

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

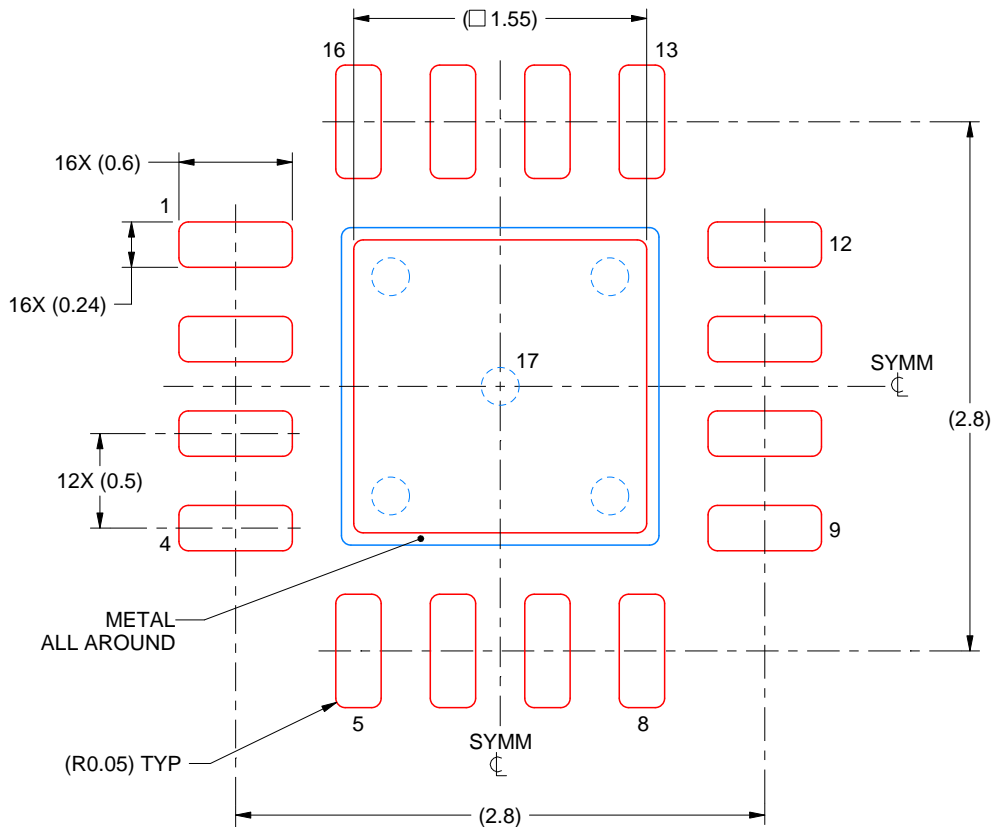


# EXAMPLE STENCIL DESIGN

RGT0016C

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



**SOLDER PASTE EXAMPLE**  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 17:  
85% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE  
SCALE:25X

4222419/D 04/2022

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2025, Texas Instruments Incorporated