

# TMP108 低消費電力デジタル温度センサ、2 線式シリアル・インターフェイス搭載、WCSP パッケージ

## 1 特長

- 動的にプログラム可能な制限ウィンドウと過熱 / 低温アラート
- 精度 :  
 $\pm 0.75^{\circ}\text{C}$  (最大値)  $-20^{\circ}\text{C} \sim +85^{\circ}\text{C}$   
 $\pm 1^{\circ}\text{C}$  (最大値)  $-40^{\circ}\text{C} \sim +125^{\circ}\text{C}$
- 低い静止電流 :  
 アクティブ時  $6\mu\text{A}$  (最大値)  $-40^{\circ}\text{C} \sim +125^{\circ}\text{C}$
- 電源電圧範囲 :  $1.4\text{V} \sim 3.6\text{V}$
- 分解能 : 12 ビット ( $0.0625^{\circ}\text{C}$ )
- パッケージ :  $1.2\text{mm} \times 0.8\text{mm}$ 、6 ボール WCSP

## 2 アプリケーション

- スマートフォン / タブレットの熱管理
- バッテリー管理
- サーモスタット制御
- 低温 / 過熱保護
- 環境監視および HVAC

## 3 概要

TMP108 は、動的にプログラム可能な制限ウィンドウと低温 / 過熱アラート機能を備えたデジタル出力温度センサです。これらの機能により、コントローラやアプリケーション・プロセッサで頻繁に温度読み取りを行わなくても、温度制御を最適化できます。

TMP108 は SMBus および 2 線式インターフェイスに対応しており、最大 4 つのデバイスを 1 つのバスに接続して、SMBus のアラート機能を使用できます。

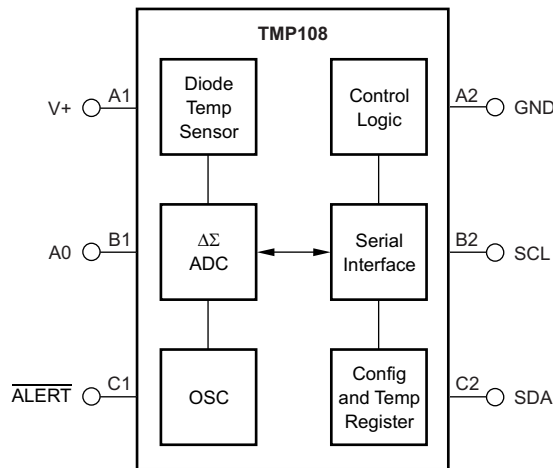
TMP108 は、さまざまな家電、コンピュータ、および環境用途で熱管理の最適化を実現するように設計されており、 $-40^{\circ}\text{C} \sim +125^{\circ}\text{C}$  の温度範囲で仕様が規定されています。

### 製品情報<sup>(1)</sup>

| 型番     | パッケージ     | 本体サイズ(公称)                            |
|--------|-----------|--------------------------------------|
| TMP108 | DSBGA (6) | $1.20\text{mm} \times 0.80\text{mm}$ |

(1) 提供されているすべてのパッケージについては、データシートの末尾にある注文情報を参照してください。

### ブロック図



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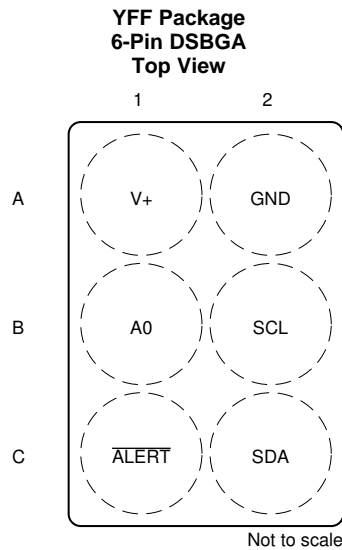
## 4 改訂履歴

2013年4月発行のものから更新

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|   |   |
|---|---|
| • 「ピン構成および機能」セクション、「ESD 定格」表、「機能説明」セクション、「デバイスの機能モード」セクション、「アプリケーションと実装」セクション、「電源に関する推奨事項」セクション、「レイアウト」セクション、「デバイスおよびドキュメントのサポート」セクション、「メカニカル、パッケージ、および注文情報」セクションを追加..... | 1 |
| • Changed supply voltage maximum value from: 3.6 V to: 4 V .....  | 3 |
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## 5 Pin Configuration and Functions



### Pin Functions

| PIN                       |     | I/O | DESCRIPTION   |
|---------------------------|-----|-----|---|
| NAME                      | NO. |     |   |
| A0                        | B1  | I   | Address selection pin. Connect to GND, V+, SDA, or SCL. |
| $\overline{\text{ALERT}}$ | C1  | O   | Alert output pin  |
| GND                       | A2  | —   | Ground  |
| SCL                       | B2  | I   | Input clock pin   |
| SDA                       | C2  | I/O | Input/output data pin                                   |
| V+                        | A1  | I   | Supply voltage (1.4 V to 3.6 V)                         |

## 6 Specifications

### 6.1 Absolute Maximum Ratings<sup>(1)</sup>

|                                       |                                  | MIN  | MAX                         | UNIT |
|---------------------------------------|----------------------------------|------|-----------------------------|------|
| Supply voltage                        |                                  |      | 4                           | V    |
| Input voltage                         | SDA and SCL <sup>(2)</sup>       | −0.5 | 4                           | V    |
|                                       | A0 and $\overline{\text{ALERT}}$ | −0.5 | $((V+) + 0.5)$ and $\leq 4$ | V    |
| Operating temperature                 |                                  | −55  | 150                         | °C   |
| Junction temperature                  |                                  |      | 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.

(2) If A0 is connected to SCL or SDA, the input voltage rating for A0 applies to SCL or SDA.

### 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), per JEDEC specification JESD22-C101 <sup>(2)</sup> | ±1000 |      |

(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

|                |                                | MIN | MAX  | UNIT |
|----------------|--------------------------------|-----|------|------|
| V+             | Supply voltage                 | 1.4 | 3.6  | V    |
| T <sub>A</sub> | Operating free-air temperature | –40 | +125 | °C   |

## 6.4 Thermal Information

| THERMAL METRIC          |  | TMP108      | UNIT |
|-------------------------|--|-------------|------|
|                         |  | YFF (DSBGA) |      |
|                         |  | 6 PINS      |      |
| θ <sub>JA</sub>         | Junction-to-ambient thermal resistance       | 132.7       | °C/W |
| θ <sub>JC(top)</sub>    | Junction-to-case(top) thermal resistance     | 1.7         | °C/W |
| θ <sub>JB</sub>         | Junction-to-board thermal resistance         | 23          | °C/W |
| ψ <sub>JT</sub>         | Junction-to-top characterization parameter   | 6           | °C/W |
| ψ <sub>JB</sub>         | Junction-to-board characterization parameter | 22.6        | °C/W |
| θ <sub>JC(bottom)</sub> | Junction-to-case(bottom) thermal resistance  | N/A         | °C/W |

## 6.5 Electrical Characteristics

At T<sub>A</sub> = +25°C, and V+ = +1.8 V, unless otherwise noted.

| PARAMETER                             |                        | TEST CONDITIONS  | MIN      | TYP   | MAX      | UNIT   |    |
|---------------------------------------|------------------------|--|----------|-------|----------|--------|----|
| TEMPERATURE INPUT                     |                        |  |          |       |          |        |    |
| Range                                 |                        |  | −40      |       | +125     | °C     |    |
| Accuracy (temperature error)          |                        | −20°C to +85°C   | −0.75    | ±0.15 | 0.75     | °C     |    |
|                                       |                        | −40°C to +125°C  | −1       | ±0.3  | 1        | °C     |    |
| Accuracy vs supply                    |                        |  | −0.3     | ±0.03 | 0.3      | °C/V   |    |
| DIGITAL INPUT/OUTPUT                  |                        |  |          |       |          |        |    |
| V <sub>IH</sub>                       | Input logic high level |  | 0.7 (V+) |       | V+       | V      |    |
| V <sub>IL</sub>                       | Input logic low level  |  | −0.5     |       | 0.3 (V+) | V      |    |
| I <sub>IN</sub>                       | Input current          | 0 V < V <sub>IN</sub> < (V+) +0.3 V                                    |          |       | 1        | μA     |    |
| V <sub>OL</sub>                       | Output logic low level | V+ > 2 V, I <sub>OUT</sub> = 3 mA                                      |          |       | 0.4      | V      |    |
|                                       |                        | V+ < 2 V, I <sub>OUT</sub> = 3 mA                                      |          |       | 0.2 (V+) | V      |    |
| <u>ALERT</u> internal pullup resistor |                        | <u>ALERT</u> to V+   | 80       | 100   | 120      | kΩ     |    |
| Resolution                            |                        |  | 12       |       |          | Bit    |    |
| Conversion time                       |                        | One-Shot mode  | 21       | 27    | 33       | ms     |    |
| Conversion modes                      |                        | CR1 = 0, CR0 = 0   | 0.25     |       |          | Conv/s |    |
|                                       |                        | CR1 = 0, CR0 = 1 (default)   | 1        |       |          | Conv/s |    |
|                                       |                        | CR1 = 1, CR0 = 0   | 4        |       |          | Conv/s |    |
|                                       |                        | CR1 = 1, CR0 = 1   | 16       |       |          | Conv/s |    |
| Timeout time                          |                        |  | 21       | 28    | 35       | ms     |    |
| POWER SUPPLY                          |                        |  |          |       |          |        |    |
| I <sub>Q</sub>                        | Quiescent current      | Serial bus inactive, CR1 = 0, CR0 = 1 (default)                        | 2        |       |          | 3.5    | μA |
|                                       |                        | Serial bus inactive, CR1 = 0, CR0 = 1 (default), −40°C to +125°C       |          |       |          | 6      | μA |
|                                       |                        | Serial bus active, SCL frequency = 400 kHz, CR1 = 0, CR0 = 1 (default) | 12       |       |          |        | μA |
|                                       |                        | Serial bus active, SCL frequency = 3.4 MHz, CR1 = 0, CR0 = 1 (default) | 82       |       |          |        | μA |
| I <sub>SD</sub>                       | Shutdown current       | Serial bus inactive  | 0.3      |       |          | 1      | μA |
|                                       |                        | Serial bus active, SCL frequency = 400 kHz                             | 10       |       |          |        | μA |
|                                       |                        | Serial bus active, SCL frequency = 3.4 MHz                             | 80       |       |          |        | μA |

## 6.6 Timing Diagrams

The TMP108 is two-wire and SMBus compatible. [Figure 1](#) to [Figure 4](#) describe the various operations on the TMP108. Parameters for [Figure 1](#) are defined in [Table 1](#). Bus definitions are:

**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, while the SCL line is high defines a start condition. Each data transfer is initiated with a start condition.

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

**Data Transfer:** The number of data bytes transferred between a start and a stop condition is not limited, and is determined by the master device. The receiver acknowledges the transfer of data. It is also possible to use the TMP108 for single-byte updates. To update only the MS byte, terminate communication by issuing a start or stop condition on the bus.

**Acknowledge:** Each receiving device, when addressed, must generate an acknowledge bit. A device that acknowledges must pull down the SDA line during the acknowledge clock pulse so that the SDA line is stable low during the high period of the acknowledge clock pulse. Setup and hold times must be taken into account. When a master receives data, the termination of the data transfer can be signaled by the master generating a *not-acknowledge* (1) on the last byte transmitted by the slave.

**Table 1. Timing Diagram Definitions**

|                         |  | FAST MODE |      | HIGH-SPEED MODE |     | UNIT |
|-------------------------|--|-----------|------|-----------------|-----|------|
|                         |  | MIN       | MAX  | MIN             | MAX |      |
| $f_{(SCL)}$             | SCL operating frequency, $V+ \geq 1.8\text{ V}$  | 0.001     | 0.4  | 0.001           | 3.4 | MHz  |
|                         | SCL operating frequency, $V+ < 1.8\text{ V}$   | 0.001     | 0.4  | 0.001           | 2.5 | MHz  |
| $t_{(BUF)}$             | Bus free time between stop and start conditions, $V+ \geq 1.8\text{ V}$                    | 1300      |      | 160             |     | ns   |
|                         | Bus free time between stop and start conditions, $V+ < 1.8\text{ V}$                       | 1300      |      | 260             |     | ns   |
| $t_{(HDSTA)}$           | Hold time after repeated start condition. After this period, the first clock is generated. | 600       |      | 160             |     | ns   |
| $t_{(SUSTA)}$           | Repeated start condition setup time  | 600       |      | 160             |     | ns   |
| $t_{(SUSTO)}$           | Stop condition setup time  | 600       |      | 160             |     | ns   |
| $t_{(HDDAT)}$           | Data hold time, $V+ \geq 1.8\text{ V}$   | 0         | 900  | 0               | 70  | ns   |
|                         | Data hold time, $V+ < 1.8\text{ V}$  | 0         | 900  | 0               | 130 | ns   |
| $t_{(SUDAT)}$           | Data setup time, $V+ \geq 1.8\text{ V}$  | 100       |      | 10              |     | ns   |
|                         | Data setup time, $V+ < 1.8\text{ V}$   | 100       |      | 50              |     | ns   |
| $t_{(LOW)}$             | SCL clock low period, $V+ \geq 1.8\text{ V}$   | 1300      |      | 160             |     | ns   |
|                         | SCL clock low period, $V+ < 1.8\text{ V}$  | 1300      |      | 260             |     | ns   |
| $t_{(HIGH)}$            | SCL clock high period  | 600       |      | 60              |     | ns   |
| $t_R, t_F - \text{SDA}$ | Data rise/fall time  |           | 300  |                 | 80  | ns   |
| $t_R, t_F - \text{SCL}$ | Clock rise/fall time   |           | 300  |                 | 40  | ns   |
| $t_R$                   | Clock/data rise time for $SCLK \leq 100\text{ kHz}$  |           | 1000 |                 |     | ns   |

## 6.6.1 Two-Wire Timing Diagrams

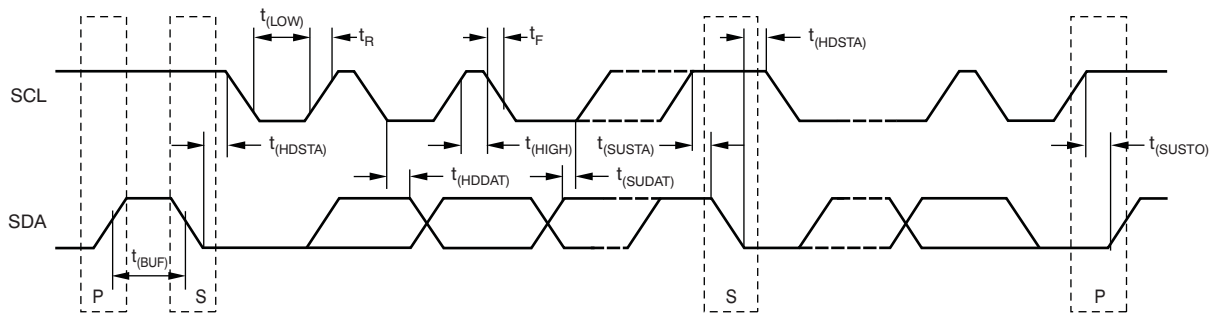
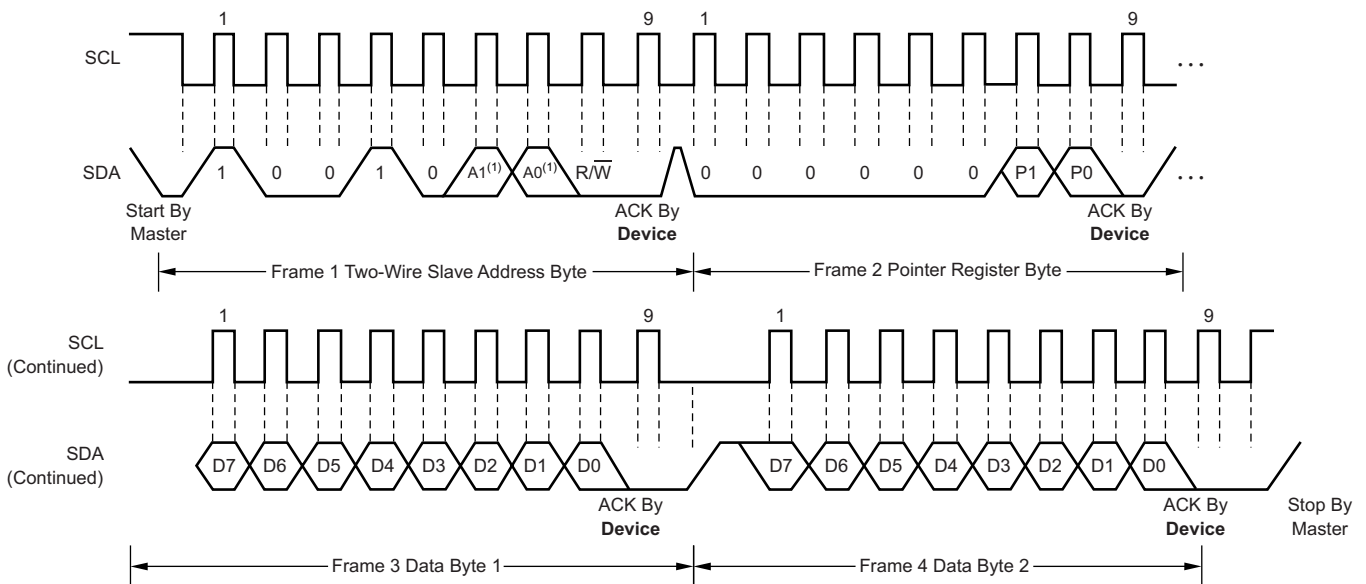
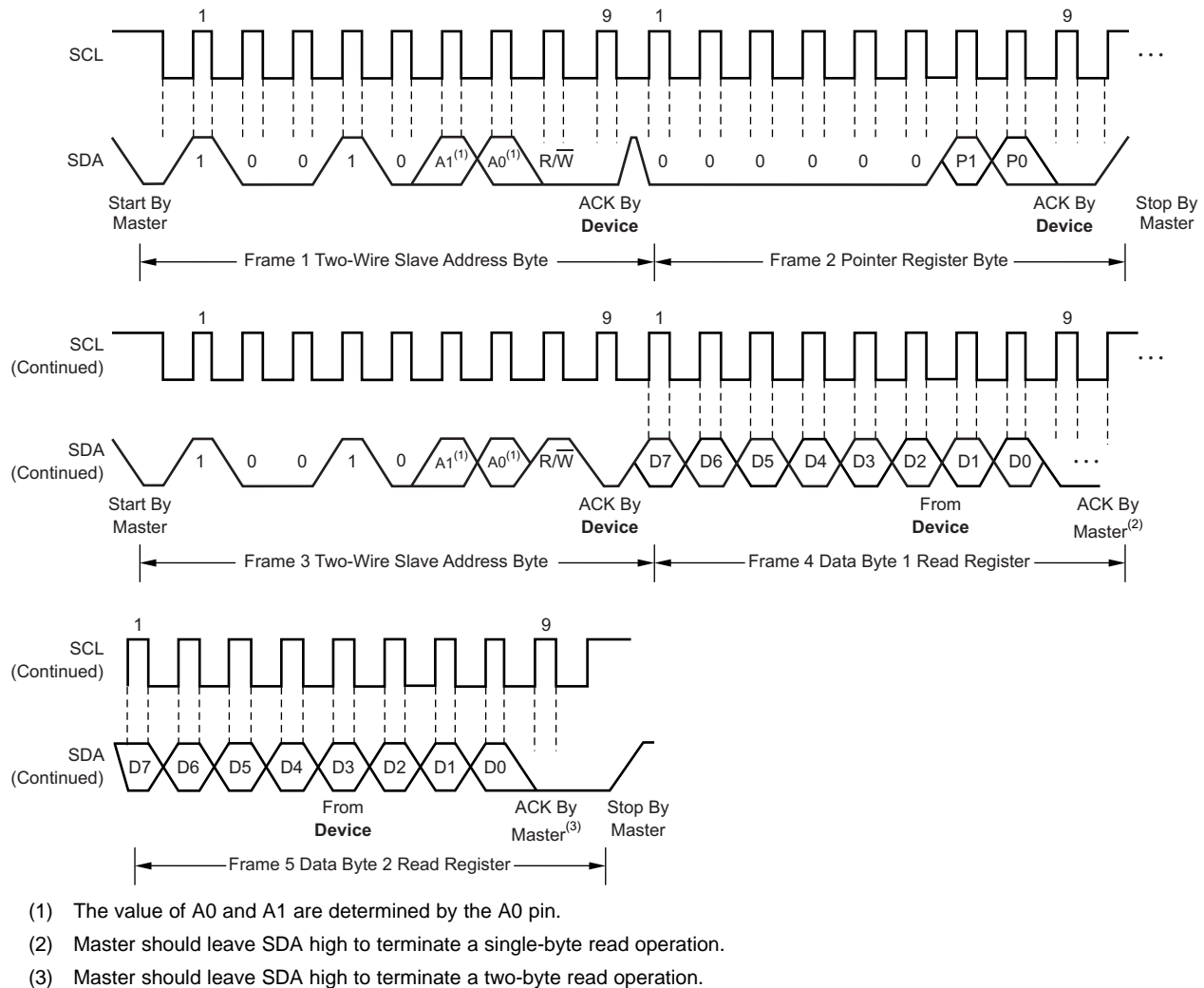


Figure 1. Two-Wire Timing Diagram

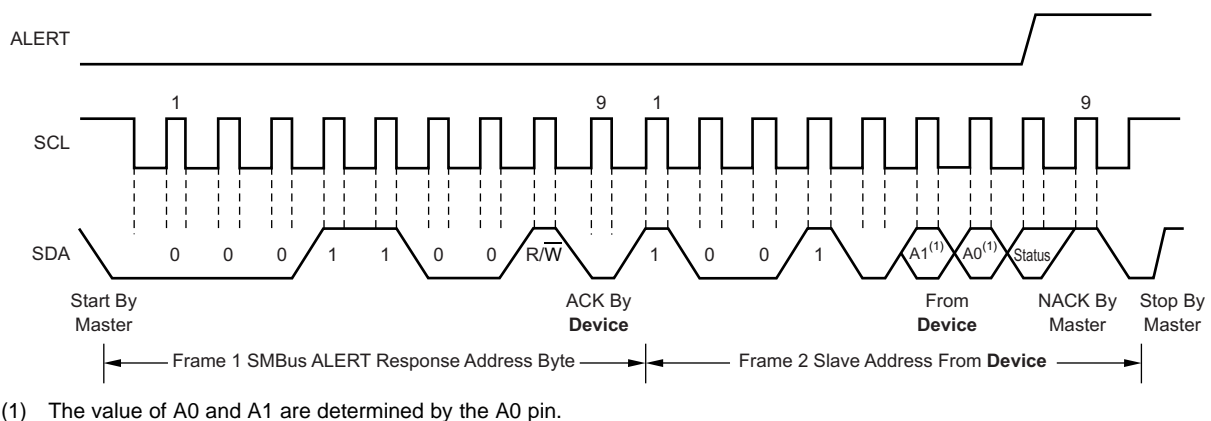


(1) The value of A0 and A1 are determined by the A0 pin.

Figure 2. Two-Wire Timing Diagram for Write Word Format



**Figure 3. Two-Wire Timing Diagram for Read Word Format**



**Figure 4. Timing Diagram for SMBus Alert**

## 6.7 Typical Characteristics

At  $T_A = +25^\circ\text{C}$  and  $V_+ = 1.8\text{ V}$ , unless otherwise noted.

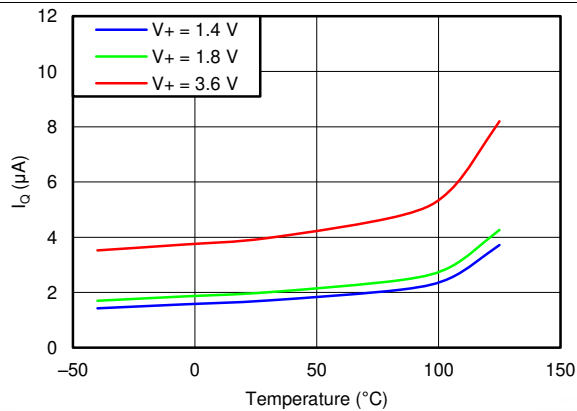


Figure 5. Quiescent Current vs Temperature (1 Conversion per Second)

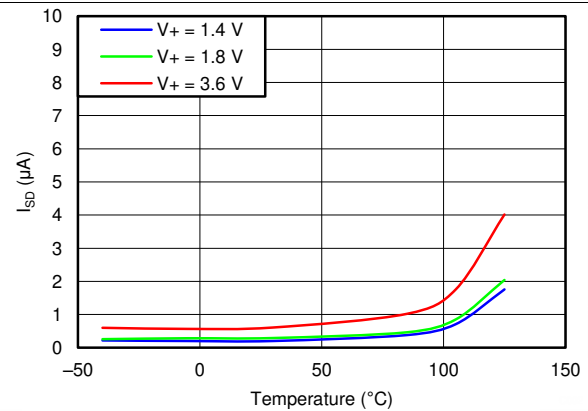


Figure 6. Shutdown Current vs Temperature

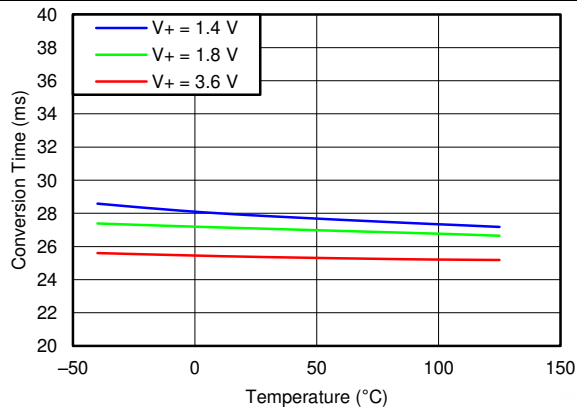


Figure 7. Conversion Time vs Temperature

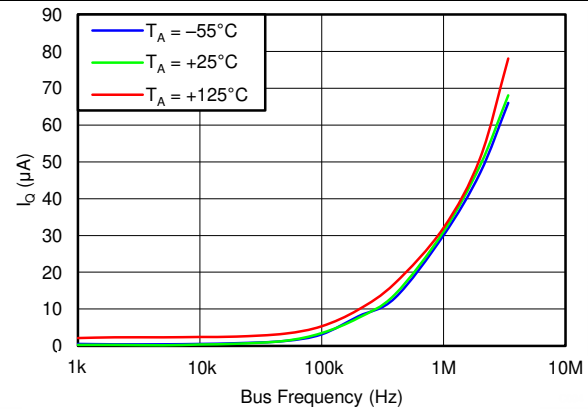


Figure 8. Quiescent Current vs Bus Frequency

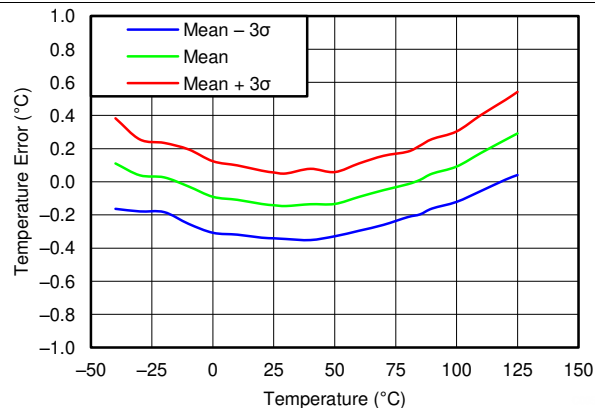


Figure 9. Temperature Error vs Temperature

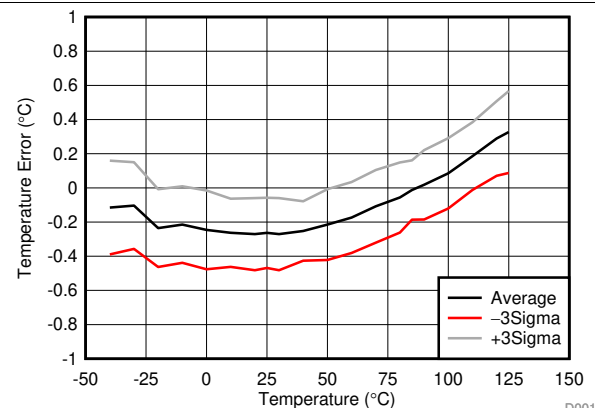


Figure 10. Temperature Error at  $+25^\circ\text{C}$

D001

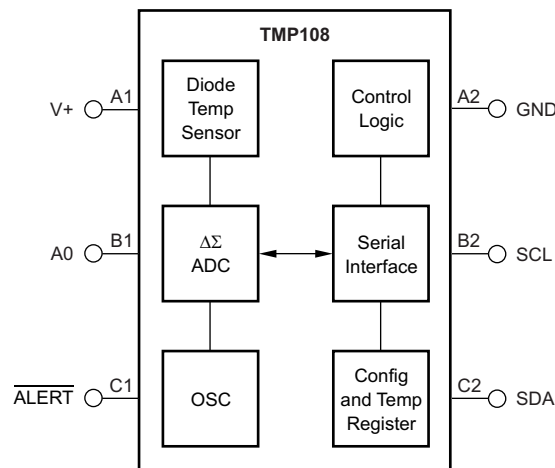
## 7 Detailed Description

### 7.1 Overview

The TMP108 is a digital temperature sensor optimal for thermal management and thermal protection applications. The TMP108 is two-wire and SMBus Interface compatible, and is specified over a temperature range of –40°C to +125°C.

The TMP108 temperature sensor is the chip itself. The solder bumps provide the primary thermal path as a result of the lower thermal resistance of metal. The temperature sensor result is equivalent to the local temperature of the printed-circuit board (PCB) on which the sensor is mounted.

### 7.2 Functional Block Diagram



### 7.3 Feature Description

#### 7.3.1 Serial Interface

The TMP108 operates as a slave device only on the two-wire bus and SMBus. Connections to the 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 TMP108 supports the transmission protocol for both fast (1 kHz to 400 kHz) and high-speed (1 kHz to 3.4 MHz) modes. All data bytes are transmitted MSB first.

#### 7.3.2 Serial Bus Address

To communicate with the TMP108, the master must first communicate with 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 either a read or write operation. The TMP108 features an address pin that allows up to four devices to be addressed on a single bus. The TMP108 latches the status of the address pin at the start of a communication. [Table 2](#) describes the pin logic levels and the corresponding address values. Other values for the fixed address bits are available by request.

**Table 2. Address Pin and Slave Addresses**

| DEVICE TWO-WIRE ADDRESS |  | A0 PIN CONNECTION |
|-------------------------|--|-------------------|
| TMP108                  |  |                   |
| 1001000                 |  | Ground            |
| 1001001                 |  | V+                |
| 1001010                 |  | SDA               |
| 1001011                 |  | SCL               |

### 7.3.3 Bus Overview

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, initiate a start condition by pulling the data line (SDA) from a high to a low logic level while SCL is high. All slaves on the bus shift in the slave address byte, and the last bit indicates whether a read or write operation follows. During the ninth clock pulse, the slave being addressed responds to the master by generating an acknowledge bit and pulling SDA low.

Data transfer is then initiated and sent over eight clock pulses followed by an acknowledge bit. During data transfer, SDA must remain stable while SCL is high because any change in SDA while SCL is high is interpreted as a start or stop signal.

After all data have been transferred, the master generates a stop condition indicated by pulling SDA from low to high, while SCL is high.

### 7.3.4 Writing and Reading Operation

Accessing a particular register on the TMP108 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  $\overline{R/\overline{W}}$  bit low. Every write operation to the TMP108 requires a value for the pointer register (see [Figure 2](#)).

When reading from the TMP108, 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 the register pointer for a read operation, a new value must be written to the pointer register. This action is accomplished by issuing a slave address byte with the  $\overline{R/\overline{W}}$  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  $\overline{R/\overline{W}}$  bit high to initiate the read command. See [Figure 3](#) for details of this sequence. If repeated reads from the same register are desired, it is not necessary to continually send the pointer register bytes because the TMP108 stores the pointer register value until it is changed by the next write operation.

Note that register bytes are sent with the most significant byte first, followed by the least significant byte.

### 7.3.5 Slave Mode Operations

The TMP108 can operate as a slave receiver or slave transmitter.

#### 7.3.5.1 Slave Receiver Mode:

The first byte transmitted by the master is the slave address, with the  $\overline{R/\overline{W}}$  bit low. The TMP108 then acknowledges reception of a valid address. The next byte transmitted by the master is the pointer register. The TMP108 then acknowledges reception of the pointer register byte. The next byte or bytes are written to the register addressed by the pointer register. The TMP108 acknowledges reception of each data byte. The master can terminate data transfer by generating a start or stop condition.

#### 7.3.5.2 Slave Transmitter Mode:

The first byte transmitted by the master is the slave address, with the  $\overline{R/\overline{W}}$  bit high. The slave acknowledges reception of a valid slave address. The next byte is transmitted by the slave and is the most significant byte of the register indicated by the pointer register. The master acknowledges reception of the data byte. The next byte transmitted by the slave is the least significant byte. The master acknowledges reception of the data byte. The master can terminate data transfer by generating a not-acknowledge bit on reception of any data byte, or by generating a start or stop condition.

### 7.3.6 SMBus Alert Function

The TMP108 supports the SMBus alert function. When the TMP108 operates in interrupt mode ( $TM = 1$ ), the ALERT pin may be connected as an SMBus alert signal. When a master senses that an alert condition is present on the ALERT line, the master sends an SMBus alert command (00011001) to the bus. If the ALERT pin is active, the device acknowledges the SMBus alert command and responds by returning its slave address on the SDA line. The eighth bit (LSB) of the slave address byte indicates whether the alert condition is caused by the temperature exceeding  $T_{HIGH}$  or falling below  $T_{LOW}$ . The LSB is high if the temperature is greater than  $T_{HIGH}$ , or low if the temperature is less than  $T_{LOW}$ . See [Figure 4](#) for details of this sequence.

If multiple devices on the bus respond to the SMBus alert command, arbitration during the slave address portion of the SMBus alert command determines which device clears its alert status first. If the TMP108 wins the arbitration, its **ALERT** pin becomes inactive at the completion of the SMBus alert command. If the TMP108 loses the arbitration, its **ALERT** pin remains active.

### 7.3.7 General Call

The TMP108 responds to a two-wire general call address (0000000) if the eighth bit is 0. The device acknowledges the general call address and responds to commands in the second byte. If the second byte is 00000100, the TMP108 latches the status of the address pin, but does not reset. If the second byte is 00000110, the TMP108 internal registers are reset to power-up values. The TMP108 does not support the general address acquire command.

### 7.3.8 High-Speed (Hs) Mode

In order for the two-wire bus to operate at frequencies above 400 kHz, the master device must issue an SMBus Hs-mode master code (00001xxx) as the first byte after a start condition to switch the bus to high-speed operation. The TMP108 does not acknowledge this byte, but does switch its input filters on SDA and SCL and its output filters on SDA to operate in Hs-mode, allowing transfers at up to 3.4 MHz. After the Hs-mode master code has been 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 TMP108 switches the input and output filters back to fast-mode operation.

### 7.3.9 Timeout Function

The TMP108 resets the serial interface if SCL or SDA are held low for 28 ms (typical) between a start and stop condition. If the TMP108 is pulled low, it releases the bus and then waits for a start condition. To avoid activating the timeout function, it is necessary to maintain a communication speed of at least 1 kHz for the SCL operating frequency.

## 7.4 Device Functional Modes

The mode bits, M1 and M0, can be set to three different modes: shutdown, one-shot, or continuous conversion.

### 7.4.1 Shutdown Mode (M1 = 0, M0 = 0)

Shutdown mode saves power by shutting down all device circuitry other than the serial interface, thus reducing current consumption to typically less than 0.5  $\mu$ A. Shutdown mode is enabled when M1 and M0 = 00. The device shuts down when current conversion is completed.

### 7.4.2 One-Shot Mode (M1 = 0, M0 = 1)

The TMP108 features a *one-shot* temperature measurement mode. When the device is in shutdown mode, writing a '01' to the M1 and M0 bits starts a single temperature conversion. During the conversion, the M1 and M0 bits read 01. The device returns to the shutdown state at the completion of the single conversion. After the conversion, the M1 and M0 bits read 00. This feature is useful for reducing the power consumption of the TMP108 when continuous temperature monitoring is not required.

As a result of the short conversion time, the TMP108 can achieve a higher conversion rate. A single conversion typically takes 27 ms and a read can take place in less than 20  $\mu$ s. However, when using one-shot mode, 30 or more conversions per second are possible.

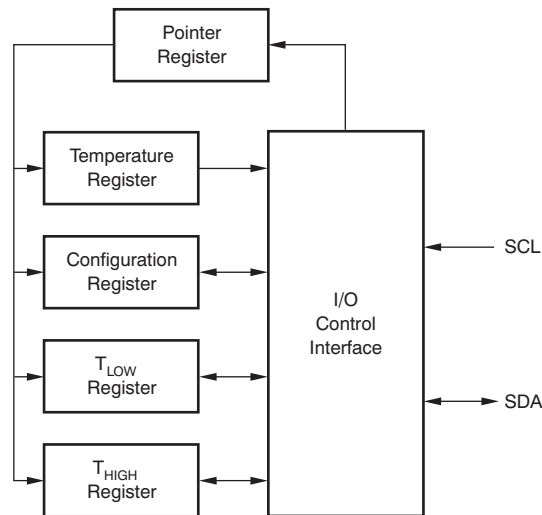
### 7.4.3 Continuous Conversion Mode (M1 = 1)

When the TMP108 is in continuous conversion mode (M1 = 1), a single conversion is performed at a rate determined by the conversion rate bits (CR1 and CR0 in the configuration register). The TMP108 performs a single conversion, and then goes in standby and waits for the appropriate delay set by the CR1 and CR0 bits. See [Table 10](#) for CR1 and CR0 settings.

## 7.5 Programming

### 7.5.1 Pointer Register

Figure 11 shows the internal register structure of the TMP108. Use the 8-bit pointer register to address a given data register. The pointer register uses the two LSBs (see Table 12) to identify which of the data registers respond to a read or write command. Table 3 identifies the bits of the pointer register byte. Table 4 describes the pointer address of the registers available in the TMP108. The power-up reset value of the P1 and P0 bits is 00.



**Figure 11. Internal Register Structure**

**Table 3. Pointer Register Byte**

| P7 | P6 | P5 | P4 | P3 | P2 | P1            | P0 |
|----|----|----|----|----|----|---------------|----|
| 0  | 0  | 0  | 0  | 0  | 0  | Register Bits |    |

**Table 4. Pointer Addresses**

| P1 | P0 | REGISTER                                  |
|----|----|---|
| 0  | 0  | Temperature register (read only, default) |
| 0  | 1  | Configuration register (read/write)       |
| 1  | 0  | T <sub>LOW</sub> register (read/write)    |
| 1  | 1  | T <sub>HIGH</sub> register (read/write)   |

### 7.5.2 Temperature Register

The temperature register is configured as a 12-bit, read-only register that stores the output of the most recent conversion. Two bytes must be read to obtain data, as shown in Table 5 and Table 6. Note that byte 1 is the most significant byte, followed by byte 2, the least significant byte. The first 12 bits are used to indicate temperature. There is no requirement to read the least significant byte if that information is not needed (for example, for resolution lower than 1°C). Table 7 summarizes the temperature data format. One LSB equals 0.0625°C. Negative numbers are represented in binary two's complement format. Following power-up or reset, the temperature register reads 0°C until the first conversion is complete. The unused bits in the temperature register always read 0.

**Table 5. Byte 1 of Temperature Register**

| D7  | D6  | D5 | D4 | D3 | D2 | D1 | D0 |
|-----|-----|----|----|----|----|----|----|
| T11 | T10 | T9 | T8 | T7 | T6 | T5 | T4 |

**Table 6. Byte 2 of Temperature Register**

| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|
| T3 | T2 | T1 | T0 | 0  | 0  | 0  | 0  |

**Table 7. Temperature Data Format<sup>(1)</sup>**

| TEMPERATURE (°C) | DIGITAL OUTPUT |     |
|------------------|----------------|-----|
|                  | BINARY         | HEX |
| 128              | 0111 1111 1111 | 7FF |
| 127.9375         | 0111 1111 1111 | 7FF |
| 100              | 0110 0100 0000 | 640 |
| 80               | 0101 0000 0000 | 500 |
| 75               | 0100 1011 0000 | 4B0 |
| 50               | 0011 0010 0000 | 320 |
| 25               | 0001 1001 0000 | 190 |
| 0.25             | 0000 0000 0100 | 004 |
| 0                | 0000 0000 0000 | 000 |
| –0.25            | 1111 1111 1100 | FFC |
| –25              | 1110 0111 0000 | E70 |
| –55              | 1100 1001 0000 | C90 |

(1) The temperature sensor ADC resolution is 0.0625°C/count.

**Table 7** does not supply a full list of all temperatures. Use the following rules to obtain the digital data format for a given temperature.

To convert positive temperatures to a digital data format:

Divide the temperature by the resolution. Then, convert the result to binary code with a 12-bit, left-justified format, and MSB = 0 to denote a positive sign.

Example:  $(+50^{\circ}\text{C}) / (0.0625^{\circ}\text{C}/\text{count}) = 800 = 320\text{h} = 0011\ 0010\ 0000$

To convert negative temperatures to a digital data format:

Divide the absolute value of the temperature by the resolution, and convert the result to binary code with a 12-bit, left-justified format. Then, generate the two's complement of the result by complementing the binary number and adding one. Denote a negative number with MSB = 1.

Example:  $(|-25^{\circ}\text{C}|) / (0.0625^{\circ}\text{C}/\text{count}) = 400 = 190\text{h} = 0001\ 1001\ 0000$

Two's complement format:  $1110\ 0110\ 1111 + 1 = 1110\ 0111\ 0000$

### 7.5.3 Configuration Register

The configuration register is a 16-bit read and write register used to store bits that control the operational modes of the temperature sensor. Read and write operations are performed MSB first. The format and power-up (reset) default value of the configuration register is shown in **Table 8**, followed by an explanation of the register bits. Other options for the default values are available by request.

**Table 8. Configuration and Power-Up/Reset Format**

| BYTE | D7  | D6  | D5   | D4   | D3 | D2 | D1 | D0 |
|------|-----|-----|------|------|----|----|----|----|
| 1    | ID  | CR1 | CR0  | FH   | FL | TM | M1 | M0 |
|      | 0   | 0   | 1    | 0    | 0  | 0  | 1  | 0  |
| 2    | POL | 0   | HYS1 | HYS0 | 0  | 0  | 0  | 0  |
|      | 0   | 0   | 0    | 1    | 0  | 0  | 0  | 0  |

#### 7.5.3.1 Hysteresis Control (HYS1 and HYS0)

When operating in comparator mode, the hysteresis control bits (HYS1 and HYS0) configure the hysteresis for the limit comparison of the TMP108 to 0°C, 1°C, 2°C, or 4°C. The default hysteresis is 1°C. **Table 9** shows the settings for HYS1 and HYS0.

**Table 9. Hysteresis Settings**

| HYS1 | HYS0 | HYSTERESIS    |
|------|------|---------------|
| 0    | 0    | 0°C           |
| 0    | 1    | 1°C (default) |
| 1    | 0    | 2°C           |
| 1    | 1    | 4°C           |

### 7.5.3.2 Polarity (POL)

The polarity of the  $\overline{\text{ALERT}}$  pin can be programmed using the POL bit. If POL = 0 (default), the  $\overline{\text{ALERT}}$  is active low. For POL = 1, the  $\overline{\text{ALERT}}$  pin is active high, and the state of the  $\overline{\text{ALERT}}$  pin is inverted.

### 7.5.3.3 Thermostat Mode (TM)

The thermostat mode bit indicates to the device whether to operate in comparator mode (TM = 0, default) or interrupt mode (TM = 1). For more information on comparator and interrupt modes, see the [High- and Low-Limit Registers](#) section.

### 7.5.3.4 Temperature Watchdog Flags (FL and FH)

The TMP108 uses temperature watchdog flags in the configuration register that indicate the result of comparing the device temperature at the end of every conversion to the values stored in the temperature limit registers ( $T_{\text{HIGH}}$  and  $T_{\text{LOW}}$ ). If the temperature of the TMP108 exceeds the value in the  $T_{\text{HIGH}}$  register, then the flag-high bit (FH) in the configuration register is set to 1. If the temperature falls below the value in the  $T_{\text{LOW}}$  register, then the flag-low bit (FL) is set to 1. If both flag bits remain 0, then the temperature is within the temperature range set by the temperature limit registers. In interrupt mode, when any of the flags is set by an under- or overtemperature event, the SMBus ALERT Response only clears the pin and not the flags. Reading the configuration register clears both the flags and the pin.

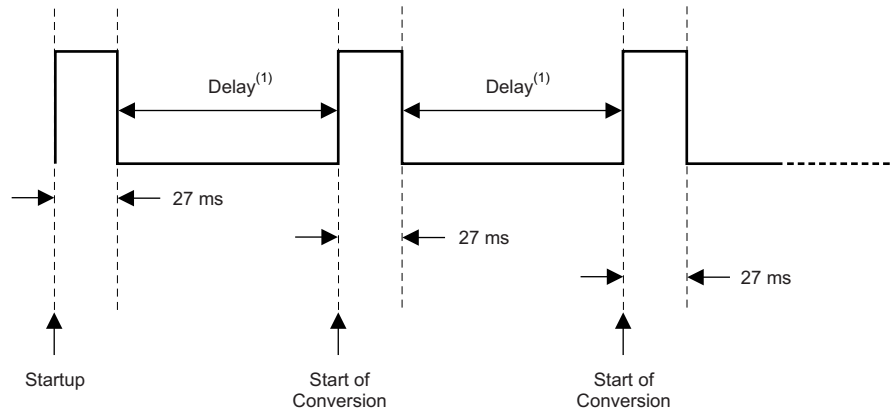
### 7.5.3.5 Conversion Rate

The conversion rate bits, CR1 and CR0, configure the TMP108 for conversion rates of 0.25 Hz, 1 Hz, 4 Hz, or 16 Hz. The default rate is 1 Hz. The TMP108 has a typical conversion time of 27 ms. To achieve different conversion rates, the TMP108 makes a conversion, and then powers down and waits for the appropriate delay set by CR1 and CR0. [Table 10](#) shows the settings for CR1 and CR0.

**Table 10. Conversion Rate Settings**

| CR1 | CR0 | CONVERSION RATE | $I_q$ (TYP)      |
|-----|-----|-----------------|------------------|
| 0   | 0   | 0.25 Hz         | 1 $\mu\text{A}$  |
| 0   | 1   | 1 Hz (default)  | 2 $\mu\text{A}$  |
| 1   | 0   | 4 Hz            | 5 $\mu\text{A}$  |
| 1   | 1   | 16 Hz           | 18 $\mu\text{A}$ |

After power-up or a general-call reset, the TMP108 immediately starts a conversion, as shown in Figure 12. The first result is available after 27 ms (typical). The active quiescent current during conversion is 40  $\mu$ A (typical at +25°C). The quiescent current during delay is 0.7  $\mu$ A (typical at +25°C).



(1) Delay is set by the CR1 and CR0 bits in the configuration register.

**Figure 12. Conversion Start**

### 7.5.4 High- and Low-Limit Registers

In comparator mode ( $TM = 0$ ), the  $\overline{ALERT}$  pin becomes active when the temperature exceeds the value in the  $T_{HIGH}$  register or drops below the value in the  $T_{LOW}$  register. The  $\overline{ALERT}$  pin remains active until the temperature returns to a value that is within the range set by:

$$(T_{LOW} + HYS) \text{ and } (T_{HIGH} - HYS)$$

where

- HYS is the hysteresis set by the hysteresis control bits (HYS1 and HYS0). (1)

In interrupt mode ( $TM = 1$ ), the  $\overline{ALERT}$  pin becomes active when the temperature exceeds the value in the  $T_{HIGH}$  register or drops below the value in the  $T_{LOW}$  register, and remains active until a read operation of the configuration register occurs (also clears the values latched in the watchdog flags, FL and FH), or the device successfully responds to the SMBus alert response address. The  $\overline{ALERT}$  pin is also cleared by resetting the device with the general call reset command.

Both operational modes are represented in Figure 13 and Figure 14.

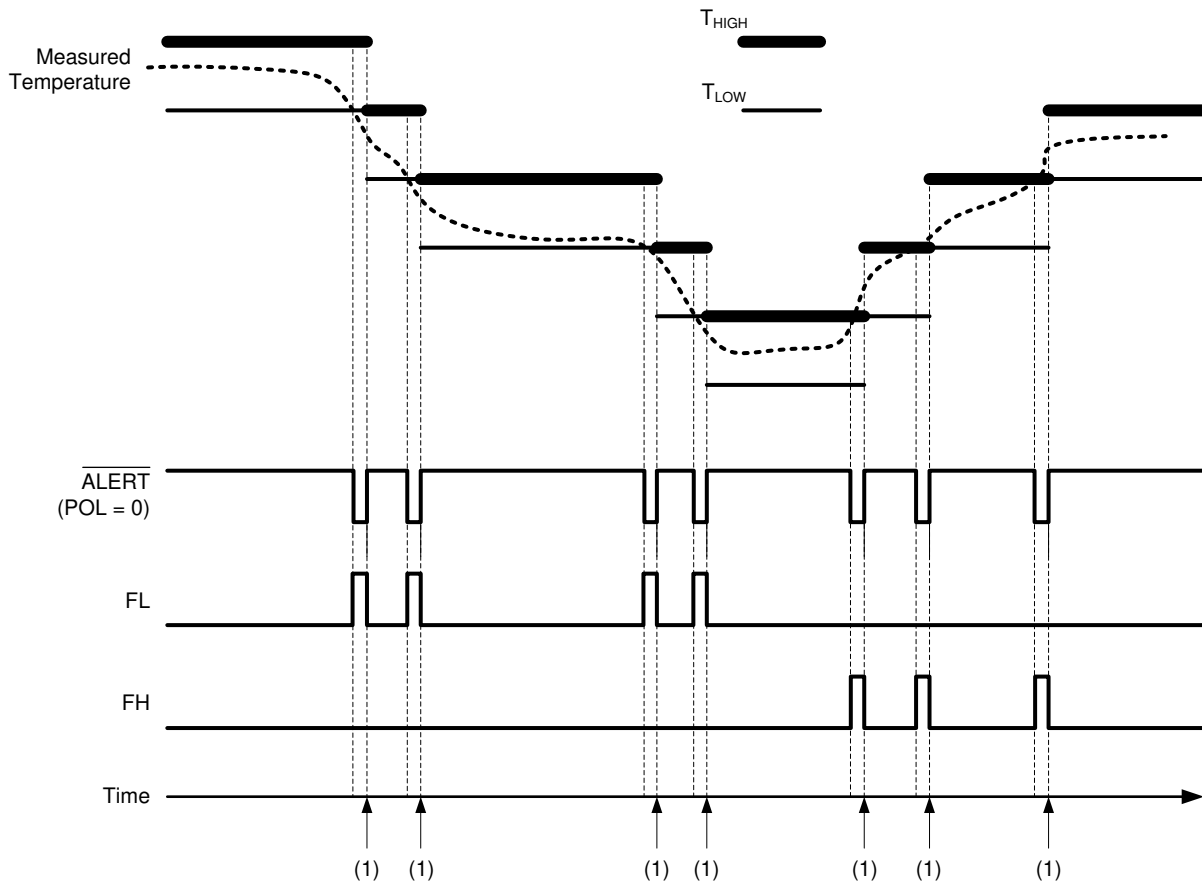
Table 11 and Table 12 describe the format for the  $T_{HIGH}$  and  $T_{LOW}$  registers. Note that the most significant byte is sent first, followed by the least significant byte. Power-up (reset) default values are  $T_{HIGH} = +127.9375^{\circ}\text{C}$  (0x7FF8) and  $T_{LOW} = -128^{\circ}\text{C}$  (0x8000). These values ensure that upon power-up, the limit window is set to maximum, and the  $\overline{ALERT}$  pin does not become active until the desired limit values are programmed in the registers. Other default values for the temperature limits are available by request. The format of the data for  $T_{HIGH}$  and  $T_{LOW}$  is the same as for the temperature register.

**Table 11. Bytes 1 and 2 of  $T_{HIGH}$  Register**

| BYTE | D7  | D6  | D5 | D4 | D3 | D2 | D1 | D0 |
|------|-----|-----|----|----|----|----|----|----|
| 1    | H11 | H10 | H9 | H8 | H7 | H6 | H5 | H4 |
| BYTE | D7  | D6  | D5 | D4 | D3 | D2 | D1 | D0 |
| 2    | H3  | H2  | H1 | H0 | 0  | 0  | 0  | 0  |

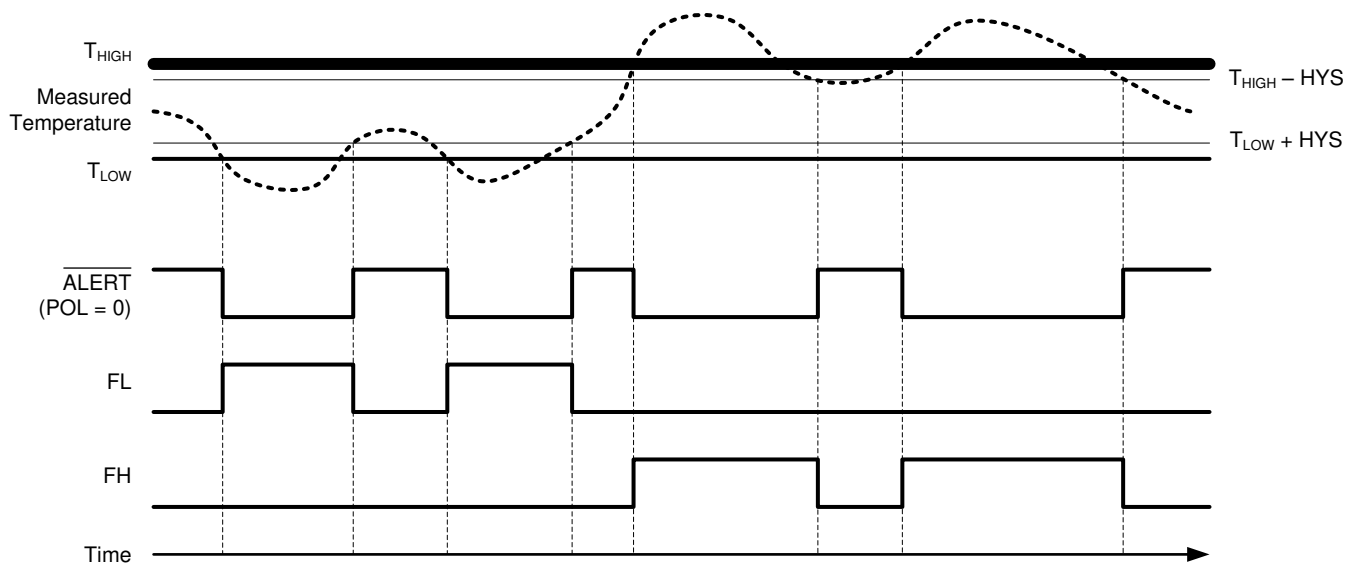
**Table 12. Bytes 1 and 2 of  $T_{LOW}$  Register**

| BYTE | D7  | D6  | D5 | D4 | D3 | D2 | D1 | D0 |
|------|-----|-----|----|----|----|----|----|----|
| 1    | L11 | L10 | L9 | L8 | L7 | L6 | L5 | L4 |
| BYTE | D7  | D6  | D5 | D4 | D3 | D2 | D1 | D0 |
| 2    | L3  | L2  | L1 | L0 | 0  | 0  | 0  | 0  |



(1) Update  $T_{HIGH}$  and  $T_{LOW}$  limit. Read the configuration register to clear the flags and the  $\overline{ALERT}$  pin.

**Figure 13. Interrupt Mode**



**Figure 14. Comparator Mode**

## 8 Application and Implementation

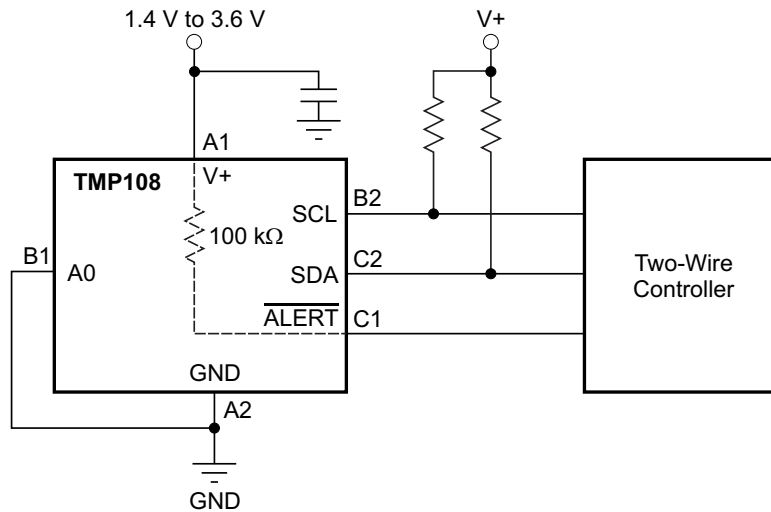
### NOTE

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 TMP108 is used to measure the temperature of the board location where the device is mounted. The programmable address options allow up to four locations on the board to be monitored with a single serial bus.

### 8.2 Typical Application



**Figure 15. Typical Application Circuit**

#### 8.2.1 Design Requirements

The TMP108 only requires pullup resistors on SCL and SDA, but TI also recommends to use a 0.01-μF bypass capacitor as shown in [Figure 15](#). There is an internal 100-kΩ pullup resistor connected to supply on the ALERT pin. If required, use an external resistor of smaller value on the ALERT pin for a stronger pullup to V+. The SCL and SDA lines can be pulled up to a supply that is equal to or higher than V+ through the pullup resistors. To configure one of four different addresses on the bus, connect A0 to either V+, GND, SCL, or SDA. If A0 is connected to SCL or SDA, make their pullup supply equal to V+.

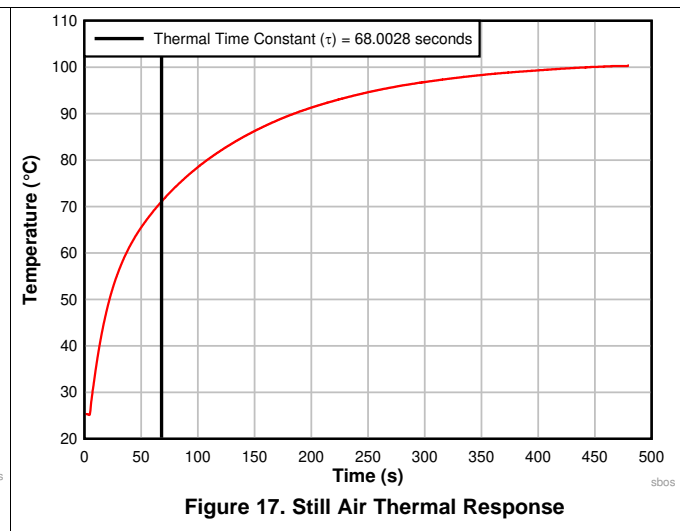
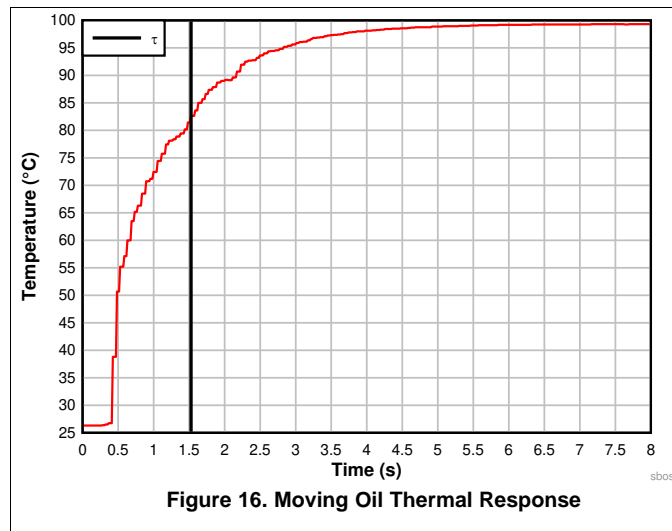
#### 8.2.2 Detailed Design Procedure

The TMP108 devices must be placed in close proximity to the heat source that must be monitored, with a proper layout for good thermal coupling. This placement ensures that temperature changes are captured within the shortest possible time interval. To maintain accuracy in applications that require air or surface temperature measurement, take care to isolate the package and leads from PCB heat sources.

## Typical Application (continued)

### 8.2.3 Application Curves

Figure 16 shows the step response of the TMP108 device to a submersion in an oil bath of 100°C from room temperature (25°C.) The time constant, or the time for the output to reach 63% of the input step, is about 1 second. Figure 17 shows the step response of the TMP108 device to an insertion in an air chamber of 100°C from room temperature (25°C.) The time-constant is 68 seconds. The time-constant result depends on the printed-circuit board (PCB) that the TMP108 device is mounted. For this test, the PCB is 0.5 in x 0.5 in, and the PCB thickness is 32 mils.



## 9 Power Supply Recommendations

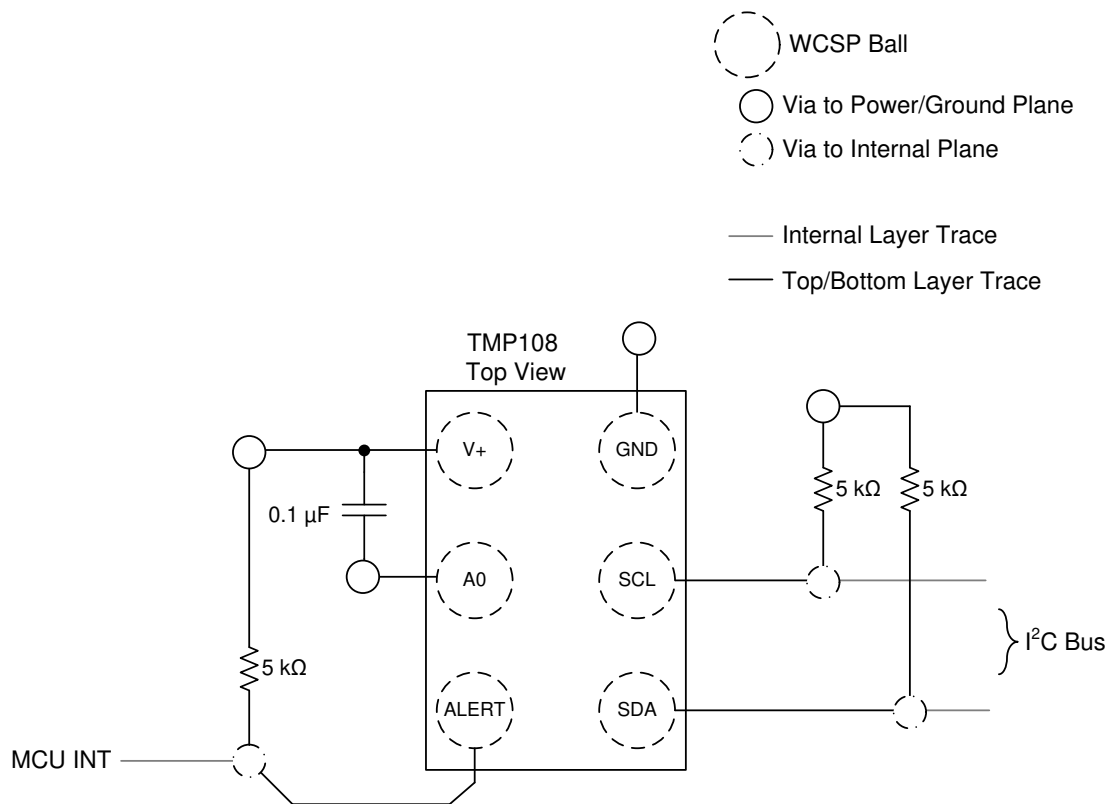
The TMP108 operates on a power supply range from 1.4 V to 3.6 V. A power-supply bypass capacitor is required, which must be placed as close to the supply and ground pins of the device as possible. A typical supply bypass capacitor is 100 nF.

## 10 Layout

### 10.1 Layout Guidelines

Place the power-supply bypass capacitor as close as possible to the supply and ground pins. The recommended value of this bypass capacitor is 0.01  $\mu\text{F}$ . Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies. Pull up the open-drain output pins (SDA, SCL and ALERT) through 5-k $\Omega$  pullup resistors.

### 10.2 Layout Example



**Figure 18. TMP108 Layout**

## 11 デバイスおよびドキュメントのサポート

### 11.1 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、[ti.com](http://ti.com)のデバイス製品フォルダを開いてください。右上の「アラートを受け取る」をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取れます。変更の詳細については、修正されたドキュメントに含まれている改訂履歴をご覧ください。

### 11.2 サポート・リソース

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.

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### 11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 12 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

## 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="#">TMP108AIYFFR</a> | Active        | Production           | DSBGA (YFF)   6 | 3000   LARGE T&R      | Yes         | SNAGCU                               | Level-1-260C-UNLIM                | -40 to 125   | T8                  |
| TMP108AIYFFR.B               | Active        | Production           | DSBGA (YFF)   6 | 3000   LARGE T&R      | Yes         | SNAGCU                               | Level-1-260C-UNLIM                | -40 to 125   | T8                  |
| <a href="#">TMP108AIYFFT</a> | Obsolete      | Production           | DSBGA (YFF)   6 | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | T8                  |

<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.

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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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TMP108AIYFFR | DSBGA        | YFF             | 6    | 3000 | 180.0              | 8.4                | 0.89    | 1.29    | 0.69    | 4.0     | 8.0    | Q1            |

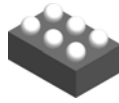
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TMP108AIYFFR | DSBGA        | YFF             | 6    | 3000 | 182.0       | 182.0      | 20.0        |

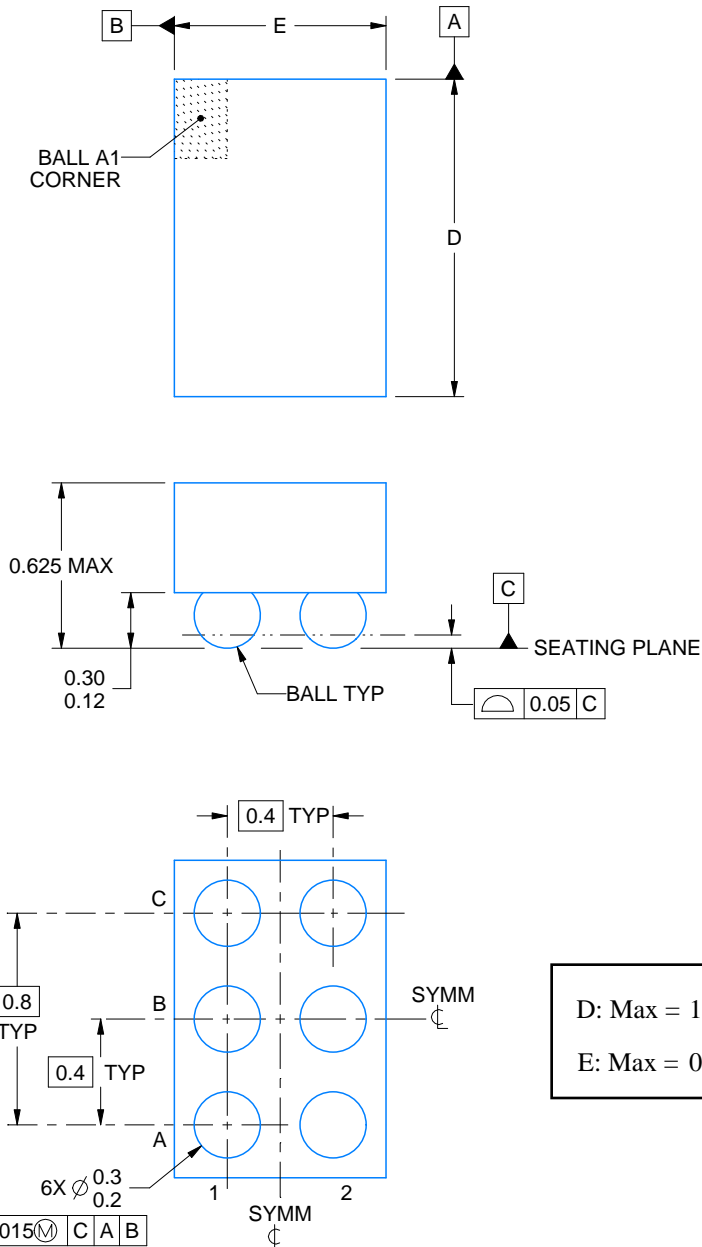
YFF0006



# PACKAGE OUTLINE

DSBGA - 0.625 mm max height

DIE SIZE BALL GRID ARRAY



4223785/A 06/2017

## NOTES:

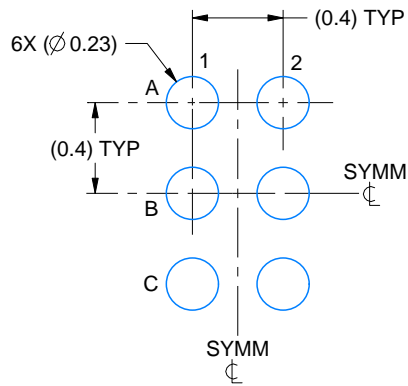
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

# EXAMPLE BOARD LAYOUT

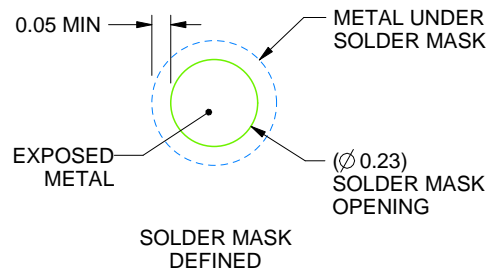
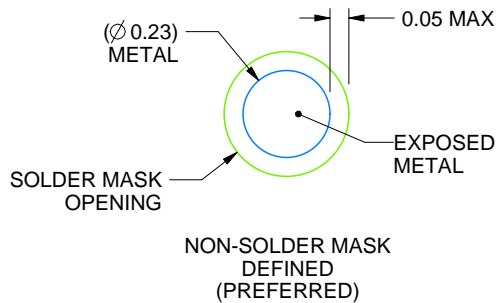
YFF0006

DSBGA - 0.625 mm max height

DIE SIZE BALL GRID ARRAY



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:30X



SOLDER MASK DETAILS  
NOT TO SCALE

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NOTES: (continued)

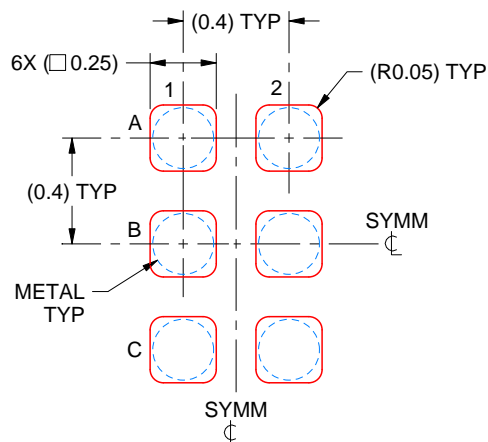
3. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. For more information, see Texas Instruments literature number SNVA009 ([www.ti.com/lit/snva009](http://www.ti.com/lit/snva009)).

## EXAMPLE STENCIL DESIGN

YFF0006

DSBGA - 0.625 mm max height

DIE SIZE BALL GRID ARRAY



SOLDER PASTE EXAMPLE  
BASED ON 0.1 mm THICK STENCIL  
SCALE:35X

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NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

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