

## Low-Power, Digital Temperature Sensor with SMAART Wire Interface

Check for Samples: [TMP104](#)

### FEATURES

- **Multiple Device Access (MDA):**
  - Global Read/Write Operations
- **SMAART Wire Interface**
- **Resolution: 8 Bits**
- **Accuracy:  $\pm 0.5^{\circ}\text{C}$  Typ ( $-10^{\circ}\text{C}$  to  $+100^{\circ}\text{C}$ )**
- **Low Quiescent Current:**
  - $3\ \mu\text{A}$  Active  $I_Q$  at 0.25 Hz
  - $1\ \mu\text{A}$  Shutdown
- **Supply Range: 1.4 V to 3.6 V**
- **Digital Output**
- **Package: 0.8-mm ( $\pm 5\%$ )  $\times$  1-mm ( $\pm 5\%$ ) 4-Ball WCSP (DSBGA)**

### APPLICATIONS

- **Handsets**
- **Notebooks**

### DESCRIPTION

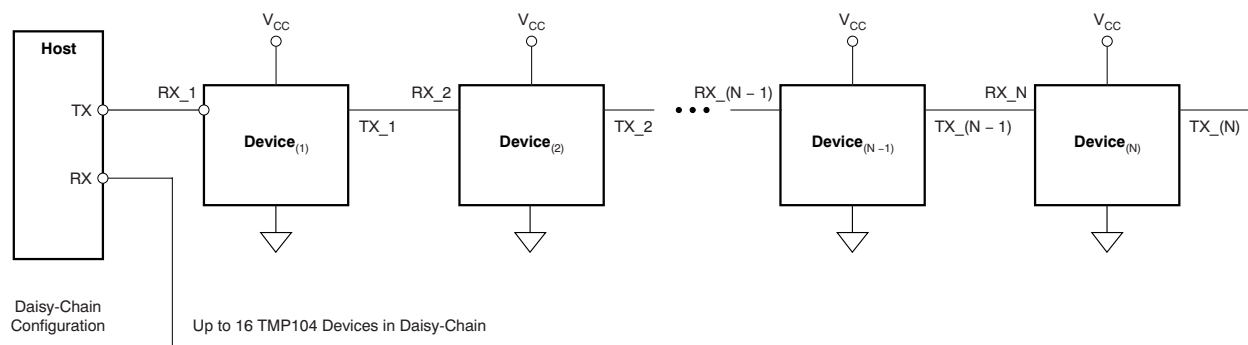
The TMP104 is a digital output temperature sensor in a four-ball wafer chip-scale package (WCSP). The TMP104 is capable of reading temperatures to a resolution of  $1^{\circ}\text{C}$ .

The TMP104 features a SMAART wire interface that supports daisy-chain configurations. In addition, the interface supports multiple device access (MDA) commands that allow the master to communicate with multiple devices on the bus simultaneously, eliminating the need to send individual commands to each TMP104 on the bus.

Up to 16 TMP104s can be tied together in parallel and easily read by the host. The TMP104 is especially ideal for space-constrained, power-sensitive applications with multiple temperature measurement zones that must be monitored.

The TMP104 is specified for operation over a temperature range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

### TYPICAL APPLICATION



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

All trademarks are the property of their respective owners.



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### PACKAGE/ORDERING INFORMATION<sup>(1)</sup>

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	PACKAGE MARKING	ORDERING NUMBER
TMP104	DSBGA-4	YFF	T4	TMP104YFFR
				TMP104YFFT

- (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or visit the device product folder at [www.ti.com](http://www.ti.com).

### ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

		TMP104	UNIT
Supply voltage		3.6	V
Input voltage		–0.3 to (V+) + 0.3	V
Operating temperature		–55 to +150	°C
Storage temperature		–60 to +150	°C
Junction temperature		+150	°C
ESD rating	Human body model (HBM)	2000	V
	Charged device model (CDM)	1000	V
	Machine model (MM)	200	V

- (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not supported.

### THERMAL INFORMATION

THERMAL METRIC <sup>(1)</sup>		TMP104	UNITS
		YFF	
		4 PINS	
$\theta_{JA}$	Junction-to-ambient thermal resistance	188.5	°C/W
$\theta_{JCTop}$	Junction-to-case (top) thermal resistance	2.1	
$\theta_{JB}$	Junction-to-board thermal resistance	35.1	
$\Psi_{JT}$	Junction-to-top characterization parameter	10.6	
$\Psi_{JB}$	Junction-to-board characterization parameter	35.1	
$\theta_{JBot}$	Junction-to-case (bottom) thermal resistance	N/A	

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

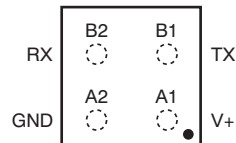
## ELECTRICAL CHARACTERISTICS

At  $T_A = +25^{\circ}\text{C}$  and  $V_+ = +1.4\text{ V}$  to  $+3.6\text{ V}$ , unless otherwise noted.

PARAMETER		TEST CONDITIONS	TMP104			UNIT
			MIN	TYP	MAX	
TEMPERATURE INPUT						
Range			−40		+125	°C
Accuracy (temperature error)		−10°C to +100°C, V+ = 1.8 V		±0.5	±2	°C
		−40°C to +125°C, V+ = 1.8 V		±1	±3	°C
		vs supply		±0.2	±0.5	°C/V
Resolution				1.0		°C
DIGITAL INPUT/OUTPUT						
V <sub>IH</sub>	Input logic levels		0.7 × (V+)		V+	V
V <sub>IL</sub>			−0.5		0.3 × (V+)	V
I <sub>IN</sub>	Input current	0 < V <sub>IN</sub> < (V+) + 0.3 V			1	μA
V <sub>OL</sub>	Output logic levels	V+ > 2 V, I <sub>OL</sub> = 1 mA	0		0.4	V
		V+ < 2 V, I <sub>OL</sub> = 1 mA	0		0.2 × (V+)	V
V+ > 2 V, I <sub>OH</sub> = 1 mA		(V+) − 0.4		V+	V	
V+ < 2 V, I <sub>OH</sub> = 1 mA		0.8 × (V+)		V+	V	
Resolution				8		Bit
Conversion time				26	35	ms
Conversion modes		CR1 = 0, CR0 = 0 (default)		0.25		Conv/s
		CR1 = 0, CR0 = 1		1		Conv/s
		CR1 = 1, CR0 = 0		4		Conv/s
		CR1 = 1, CR0 = 1		8		Conv/s
Timeout time		Interface		28		ms
SMAART wire interface		Serial baud rate	4.8		114	kbps
POWER SUPPLY						
Operating supply range			+1.4		+3.6	V
I <sub>Q</sub>	Quiescent current	Serial bus inactive, CR1 = 0, CR0 = 0 (default), V+ = 1.8 V		1.5	3	μA
		Serial bus active, CR1 = 0, CR0 = 0, V+ = 1.8 V		20		μA
I <sub>SD</sub>	Shutdown current	Serial bus inactive, V+ = 1.8 V		0.5	1	μA
TEMPERATURE						
Specified range			−40		+125	°C
Operating range			−55		+150	°C

## PIN CONFIGURATION

### YFF PACKAGE WCSP-4 (DSBGA-4) (TOP VIEW)



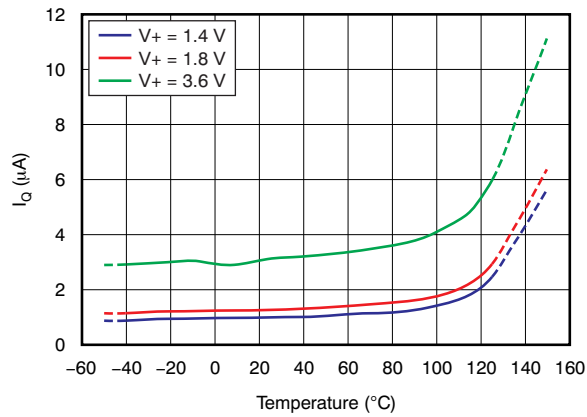
## PIN DESCRIPTIONS

PIN		DESCRIPTION
NO.	NAME	
A1	V+	Supply voltage
A2	GND	Ground
B1	TX	Serial data output pin (push-pull output)
B2	RX	Serial data input pin

## TYPICAL CHARACTERISTICS

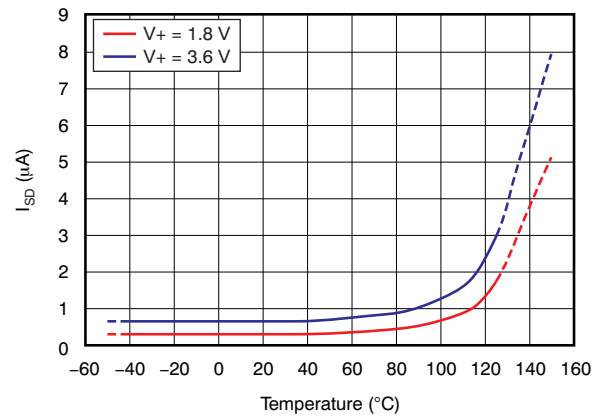
At  $T_A = +25^\circ\text{C}$  and  $V_+ = 1.8\text{ V}$ , unless otherwise noted.

**QUIESCENT CURRENT vs TEMPERATURE  
(0.25 Conversions per Second)**



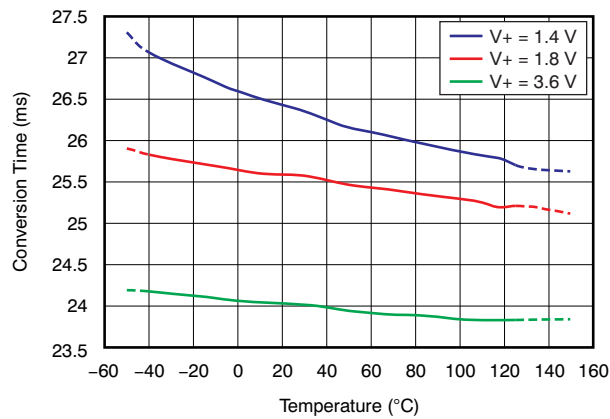
**Figure 1.**

**SHUTDOWN CURRENT vs TEMPERATURE**



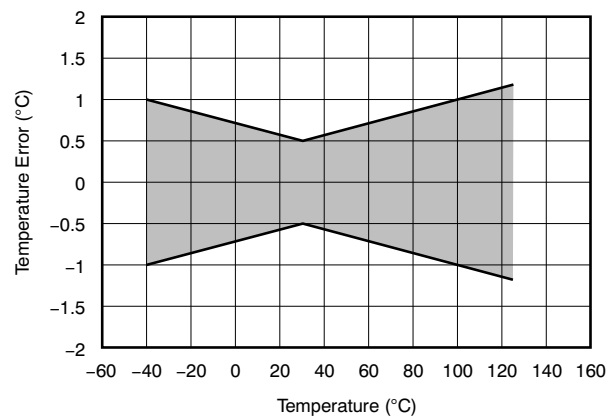
**Figure 2.**

**CONVERSION TIME vs TEMPERATURE**



**Figure 3.**

**TEMPERATURE ERROR vs TEMPERATURE**



**Figure 4.**

## APPLICATION INFORMATION

### GENERAL DESCRIPTION

The TMP104 is a digital output temperature sensor in a wafer chip-scale package (WCSP) that is optimal for thermal management and thermal profiling. The TMP104 includes a SMAART wire interface that is capable of communicating in a daisy-chain with up to 16 devices on a single bus. The interface requires two pins from the host; the first device in the daisy-chain receives data from the host and the last device in the daisy-chain returns data to the host. In addition, the TMP104 has the capability of executing multiple device access (MDA) commands that allow multiple TMP104s to respond to a single global bus command. MDA commands reduce communication time and power in a bus that contains multiple TMP104 devices. The TMP104 is specified over a temperature range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

The TMP104 also has the capability of configuring the bus in a transparent mode, where the input from the host is sent directly to the next device in the chain without delay. Additionally, the TMP104 can disconnect the chain and create a serial communication controlled by each TMP104 on the bus, thereby allowing each device to have configurable addressing and interrupt capabilities. The input pin, RX, is a high-impedance node. The output pin, TX, has an internal push-pull output stage that can drive the host to GND or V+.

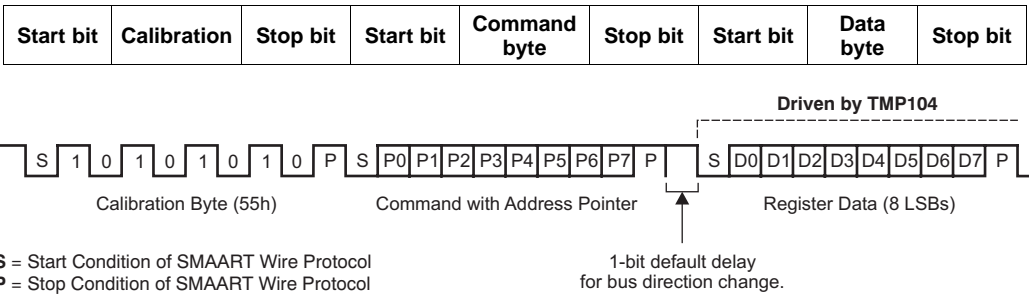
After an initialization sequence, each device on the bus is programmed with its own interface address that allows it to respond to its own address and also respond to general commands that permit the user to read or write to all of the devices on the bus without having to send its individual address and command to each individual device.

The temperature sensor in the TMP104 is the chip itself. Thermal paths run through the package bumps as well as the package. The lower thermal resistance of metal causes the bumps to provide the primary thermal path. To maintain accuracy in applications that require air or surface temperature measurement, care should be taken to isolate the package from ambient air temperature. A thermally-conductive adhesive can help to achieve accurate surface temperature measurement.

### COMMUNICATION PROTOCOL

Each communication of the SMAART wire protocol consists of 8-bit words, transferred least significant bit (LSB) first. Each 8-bit word begins with a *Start* bit that is logic low, and ends with a *Stop* bit that is logic high. By using a Start bit and Stop bit for each 8-bit word, the TMP104 can calibrate each word and maintain synchronous communication throughout the process. The host commences the communication by sending a Start bit followed by the calibration byte (55h), allowing the TMP104 to sync to the baud rate of the host, followed by the Stop bit. Then, another Start bit is sent, followed by the command register byte and a Stop bit. Finally, a third Start bit is sent followed by the data byte, where master sends data if the instruction is a write command, or the TMP104 breaks the chain and sends data if the instruction is a read command. The process finishes with a Stop bit. The sequence is shown in [Table 1](#) and [Figure 5](#).

**Table 1. Communication Format**



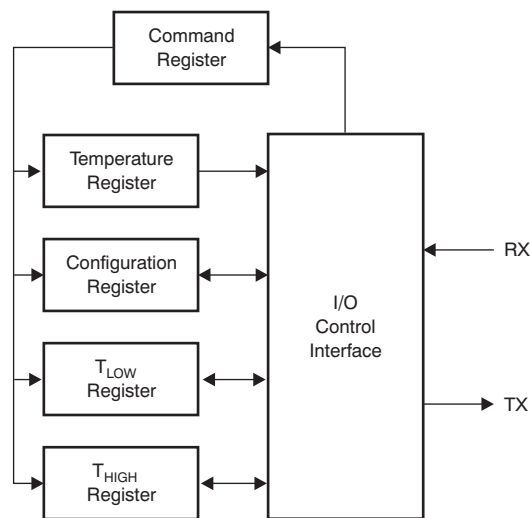
**Figure 5. Generic Communication BitStream**

The TMP104 has two dedicated pins for communication: TX and RX. Usually, these two pins are connected internally and the signal on the RX propagates to the TX; that is, the TMP104 works in a transparent mode. The TMP104 breaks this buffer configuration only when it must send data on the bus or during address assignment and alert procedures.

The TMP104 supports unique *address assignment* and *alert interrupt* procedures. There are general-call read and write commands that allow simultaneous reads or writes to all devices in the daisy-chain. The interface has built-in time outs (typically 28 ms) that return the interface to a known state if communication is disrupted.

## COMMAND REGISTER

Figure 6 shows the internal register structure of the TMP104. Communications between the registers are transferred through the interface in LSB-first order. The 8-bit Command Register, as shown in Table 2, is used to determine the type of instruction being addressed. These eight bits could either interpret a global instruction or an individual instruction, which is determined by the value of P7. When P7 = 0, the command byte interprets an individual instruction; when P7 = 1, the command byte interprets a global instruction.



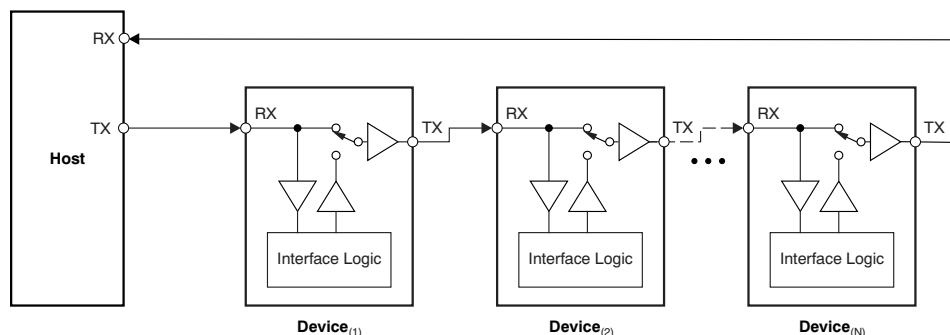
**Figure 6. Internal Register Structure**

**Table 2. Command Register Byte**

P7	P6	P5	P4	P3	P2	P1	P0
GLB	IN3/ID3	IN2/ID2	IN1/ID1	IN0/ID0	P1	P0	R/W

## GLOBAL INITIALIZATION AND ADDRESS ASSIGNMENT SEQUENCE

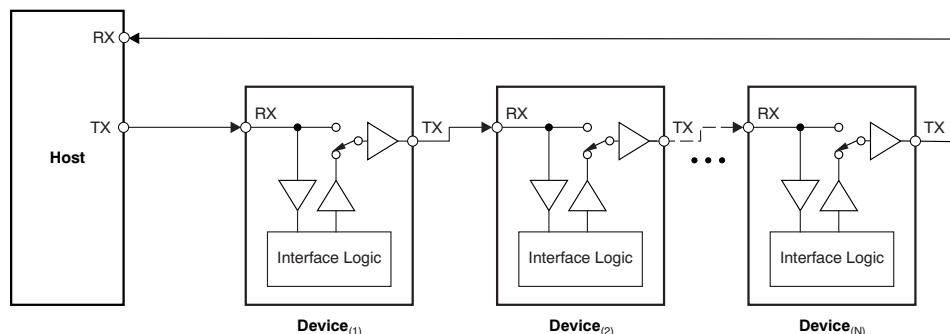
At device power-up, every TMP104 in the daisy-chain is connected in transparent mode, as shown in [Figure 7](#). The host must send the initialization command (P7-P0 = 10001100) in order for the bus to program its internal address depending on the number of devices on the bus.



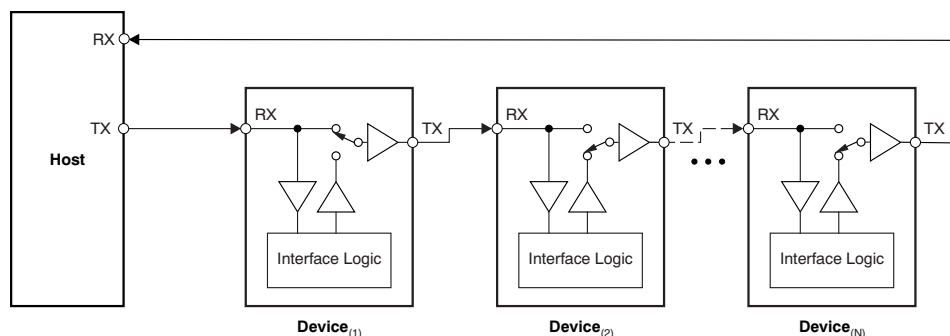
**Figure 7. TMP104 Daisy-Chain: Bus Status at Start of Global Initialization**

Each TMP104 in the chain interprets the initialization command byte and disconnects the chain, as shown in [Figure 8](#). The host must then send the address assignment command, consisting of P7-P4 = 1001 and P3-P0 = 0000, where P3-P0 represents the address of the first device in the chain; this word is stored internally as its device ID. The first device increments the unit in the device address and then reconnects the bus, as shown in [Figure 9](#). This address is then sent to the next device in the chain. Once all devices on the chain have received the respective addresses, the host receives the last programmed address on the chain + 1. The host can use this information to determine the total number of devices in the chain and the respective address of each device.

After the initialization sequence, every device can be addressed individually or through global commands. This global initialization sequence is a requirement and must be performed before any other communication.



**Figure 8. TMP104 Daisy-Chain: Bus Status at Start of Address Assignment**



**Figure 9. TMP104 Daisy-Chain: Bus Status After First Device Address Assignment**



## GLOBAL READ AND WRITE

The host can initiate a global read or write command to all TMP104s in the daisy-chain by sending the read/write command, consisting of P7-P3 = 11110. P2-P1 indicate the data register pointer, as shown in [Table 3](#), and P0 indicates read/write control. P0 = 0 indicates a global write command. The host must transfer one more byte of data for the register (indicated by bits P2-P1), and every TMP104 in the daisy-chain updates the appropriate register. P0 = 1 indicates a global read command. The TMP104 with the device ID of '0000' then breaks the bus connection, transmits the data from the register indicated by bits P2-P1, and then reconnects the bus. The TMP104 with the device ID of '0001' then repeats the same sequence, followed by the rest of the TMP104 devices in the daisy-chain.

**Table 3. Pointer Addresses**

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

## GLOBAL CLEAR INTERRUPT

The host can initiate a global clear interrupt command (P7-P0 = 10101001) to all TMP104s in the daisy-chain. Upon receiving this command, the TMP104 disables future interrupts (D7 in the Configuration Register is set to '0'). If a TMP104 has previously broken the bus connection and sent an interrupt (logic low on the bus), it now stops holding the bus low. The device sends the baud rate calibration command and clear interrupt command to the next TMP104 in the chain, and then reconnects the bus. In the case of multiple devices having active interrupts, the clear interrupt command propagates through the daisy-chain, disables all interrupts, and reconnects the bus across all devices.

## GLOBAL SOFTWARE RESET

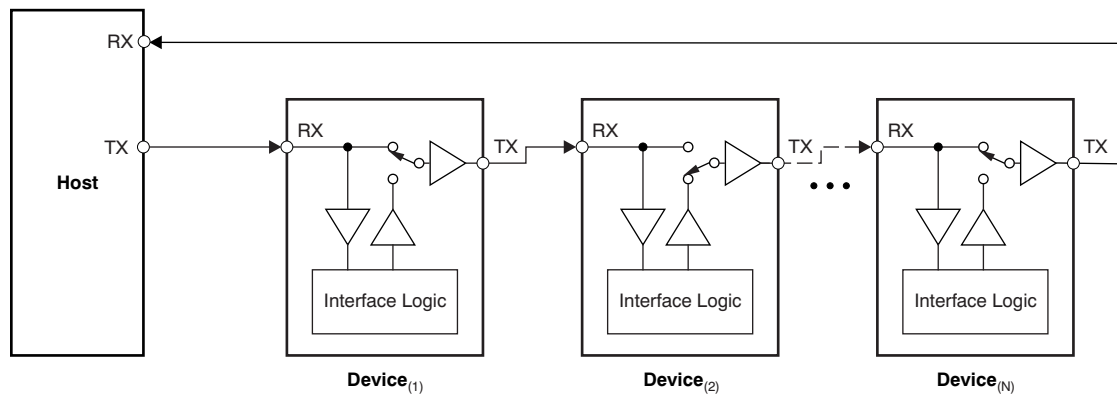
The host can initiate a global software reset command (P7-P0 = 10110100) to all TMP104s in the daisy-chain. Upon receiving this command, the TMP104 resets its internal registers except for the device ID, which is not reset, and reconnects the bus. If the bus is broken before the initiation of this command, all TMP104s before the broken bus point receive the command. If the host intends to initiate a global software reset across all TMP104s in the chain, this command must be transmitted multiple times until it echoes back to the host.

## INDIVIDUAL READ AND WRITE

The host can initiate an individual read/write command to a particular TMP104 in the daisy-chain by sending the read/write command. The read/write command consists of these parameters:

- P7 = 0
- P6-P3 = the device ID
- P2-P1 = the data register pointer; see [Table 3](#)
- P0 = indicates read/write control

P0 = 0 indicates an individual write command; the host must transfer one more byte of data for the register indicated by bits P2-P1. The TMP104 in the daisy-chain that corresponds to the device ID noted by bits P6-P3 then updates the appropriate register. P0 = 1 indicates an individual read command; as shown in [Figure 10](#), the TMP104 in the daisy-chain that corresponds to the device ID pointed by bits P6-P3 then breaks the bus, transmits the data from the register pointed by bits P2-P1, and reconnects the bus.



**Figure 10. TMP104 Daisy-Chain: Bus Status During Individual Read Operation of Second Device**

## TEMPERATURE REGISTER

The Temperature Register of the TMP104 is configured as an 8-bit, read-only register that stores the output of the most recent conversion. A single byte must be read to obtain data, and is described in [Table 4](#). The data format for temperature is summarized in [Table 5](#). One LSB equals 1°C.

**Table 4. Temperature Register**

D7	D6	D5	D4	D3	D2	D1	D0
T7	T6	T5	T4	T3	T2	T1	T0

Negative numbers are represented in binary twos complement format. Following power-up or reset, the Temperature Register reads 0°C until the first conversion is complete.

**Table 5. 8-Bit Temperature Data Format<sup>(1)</sup>**

TEMPERATURE (°C)	DIGITAL OUTPUT	
	BINARY	HEX
128	0111 1111	7F
127	0111 1111	7F
100	0110 0100	64
80	0101 0000	50
75	0100 1011	4B
50	0011 0010	32
25	0001 1001	19
0	0000 0000	00
–1	1111 1111	FF
–25	1110 0111	E7
–55	1100 1001	C9

(1) The resolution for the analog-to-digital converter (ADC) is 1°C/count, where *count* is equal to the digital output of the ADC.

For positive temperatures (for example, +50°C):

Twos complement is not performed on positive numbers. Therefore, simply convert the number to binary code, left-justified format. Denote a positive number with most significant bit (MSB) = 0.

Example:  $(+50^{\circ}\text{C})/(1^{\circ}\text{C}/\text{count}) = 50 = 32\text{h} = 0011\ 0010$

For negative temperatures (for example, –25°C):

Generate the twos complement of a negative number by complementing the absolute value binary number and adding 1. Denote a negative number with MSB = 1.

Example:  $(|-25^{\circ}\text{C}|)/(1^{\circ}\text{C}/\text{count}) = 25 = 19\text{h} = 0001\ 1001$

Twos complement format:  $1110\ 0110 + 1 = 1110\ 0111$

## CONFIGURATION REGISTER

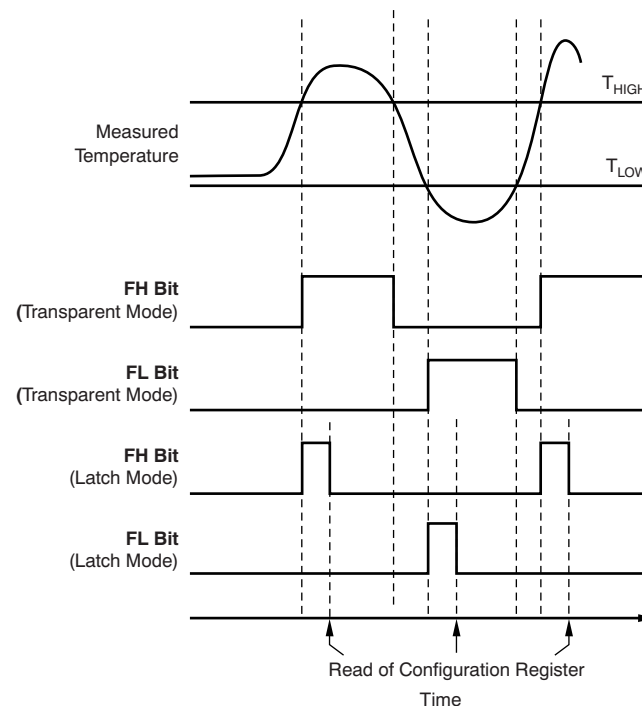
The Configuration Register is an 8-bit read/write register used to store bits that control the operational modes of the temperature sensor. Read/write operations are performed LSB first. The format and power-up/reset value of the Configuration Register is shown in [Table 6](#).

**Table 6. Configuration and Power-Up/Reset Format**

D7	D6	D5	D4	D3	D2	D1	D0
INT_EN	CR1	CR0	FH	FL	LC	M1	M0
0	0	0	0	0	0	1	0

### Temperature Watchdog Function (FH, FL)

The TMP104 contains a watchdog function that monitors device temperature and compares the result to the values stored in the temperature limit registers ( $T_{HIGH}$  and  $T_{LOW}$ ) in order to determine if the device temperature is within these set limits. If the temperature of the TMP104 becomes greater than the value in the  $T_{HIGH}$  register, then the flag-high bit (FH) in the Configuration Register is set to '1'. If the temperature falls below value in the  $T_{LOW}$  register, then the flag-low bit (FL) is set to '1'. If both flag bits remain '0', then the temperature is within the temperature *window* set by the temperature limit registers, as shown in [Figure 11](#).



**Figure 11. Temperature Flag Functional Diagram**

The latch bit (LC) in the Configuration Register is used to latch the value of the flag bits (FH and FL) until the master issues a read command to the Configuration Register. The flag bits are set to '0' if a read command is received by the TMP104, or if  $LC = 0$  and the temperature is within the temperature limits. The power-on default values for these bits are  $FH = 0$ ,  $FL = 0$ , and  $LC = 0$ .

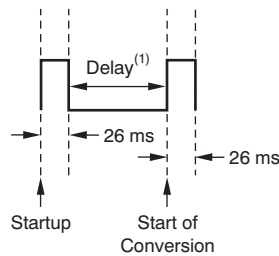
## Conversion Rate (CR1, CR0)

The conversion rate bits (CR1 and CR0), located in the Configuration Register, configure the TMP104 for conversion rates of 8 Hz, 4 Hz, 1 Hz, or 0.25 Hz (default). The TMP104 has a typical conversion time of 26 ms. To achieve different conversion rates, the TMP104 performs a single conversion and then powers down and waits for the appropriate delay set by CR1 and CR0. [Table 7](#) shows the settings for CR1 and CR0.

**Table 7. Conversion Rate Settings**

CR1	CR0	CONVERSION RATE
0	0	0.25 Hz (default)
0	1	1 Hz
1	0	4 Hz
1	1	8 Hz

After power-up or general-call reset, the TMP104 immediately starts a conversion, as shown in [Figure 12](#). The first result is available after 26 ms (typical). The active quiescent current during conversion is 40  $\mu$ A (typical at +25°C, V+ = 1.8 V). The quiescent current during delay is 1.0  $\mu$ A (typical at +25°C, V+ = 1.8 V).



(1) Delay is set by CR1 and CR0.

**Figure 12. Conversion Start**

## Conversion Modes

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

Shutdown mode saves maximum power by shutting down all device circuitry other than the serial interface, reducing current consumption to typically less than 0.5  $\mu$ A. Shutdown mode is enabled when bits M1 and M0 (in the Configuration Register) read '00'. The device shuts down when the current conversion is completed.

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

The TMP104 features a One-Shot Temperature Measurement mode. When the device is in Shutdown mode, writing '01' to bits M1 and M0 starts a single temperature conversion. During the conversion, bits M1 and M0 read '01'. The device returns to the shutdown state at the completion of the single conversion. After the conversion, bits M1 and M0 read '00'. This feature is useful for reducing power consumption in the TMP104 when continuous temperature monitoring is not required.

As a result of the short conversion time, the TMP104 can achieve a higher conversion rate. A single conversion typically takes 26 ms and an individual read can take place in less than 300  $\mu$ s. When using One-Shot mode, 30 or more conversions per second are possible.

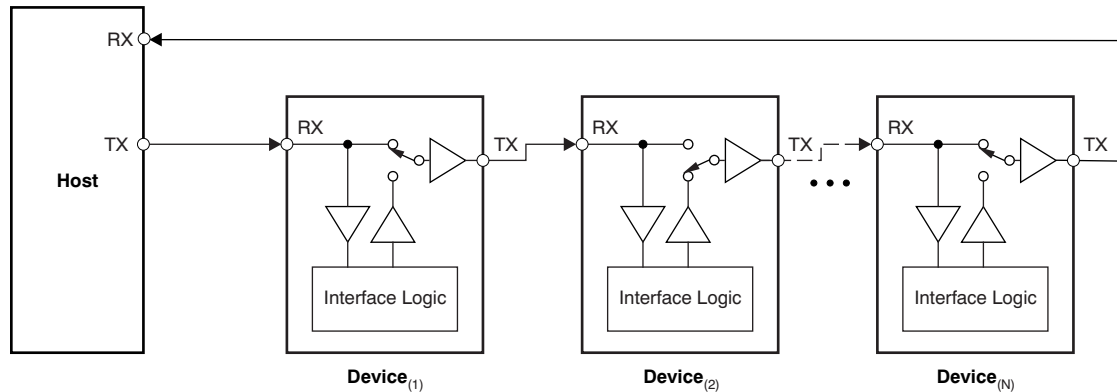
### Continuous Conversion Mode (M1 = 1)

When the TMP104 is in Continuous Conversion mode (M1 = 1), continuous conversions are performed at a rate determined by the conversion rate bits, CR1 and CR0 (in the Configuration Register). The TMP104 performs a single conversion, and then powers down and waits for the appropriate delay set by CR1 and CR0. See [Table 7](#) for CR1 and CR0 settings.

## Interrupt Functionality (INT\_EN)

The TMP104 interrupts the host by disconnecting the bus and issuing an interrupt request by holding the bus low if all of these conditions are met, as shown in [Figure 13](#):

- INT\_EN in the Configuration Register is set to '1';
- The temperature result is higher than the value in the  $T_{HIGH}$  register or lower than the value in the  $T_{LOW}$  register (as indicated by a '1' in either FL or FH);
- The bus is logic high and idle for more than 28 ms.



**Figure 13. TMP104 Daisy-Chain:  
Bus Status During an Interrupt Request (Logic Low) from Second Device**

The interrupt on the bus is latched regardless of the status of LC. Writing a '1' to INT\_EN automatically sets the LC bit. The TMP104 holds the bus low until one of the following events happen:

- Global Interrupt Clear command received;
- Global Software Reset command received;
- A power-on reset event occurs.

Each of these events clears INT\_EN; the TMP104 does not issue future interrupts until the host writes '1' to bit D7 in the Configuration Register to re-enable future interrupts.

In a system with enabled interrupts, it is possible for a TMP104 on the bus to issue an interrupt at the same time that the host starts a communication sequence. To avoid this scenario, it is recommended that the host should check the status on the receiving side of the bus after transmitting the calibration byte. If it is '1', then the host can continue with the communication. If it is '0', one of the TMP104 devices on the bus is issuing an alert and the host must transmit a Global Interrupt Clear command.

## TEMPERATURE LIMIT REGISTERS

The  $T_{HIGH}$  and  $T_{LOW}$  registers are used to store the temperature limit thresholds for the TMP104 watchdog function. At the end of each temperature measurement, the TMP104 compares the temperature results to each of these limits. If the temperature result is greater than the  $T_{HIGH}$  limit, then the FH bit in the Configuration Register is set to '1'. If the temperature result is less than the  $T_{LOW}$  limit, then the FL bit in the Configuration Register is set to '1'; see [Figure 11](#).

[Table 8](#) and [Table 9](#) describe the format for the  $T_{HIGH}$  and  $T_{LOW}$  registers. Power-up reset values for  $T_{HIGH}$  and  $T_{LOW}$  are:  $T_{HIGH} = +60^{\circ}\text{C}$  and  $T_{LOW} = -10^{\circ}\text{C}$ . The format of the data for  $T_{HIGH}$  and  $T_{LOW}$  is the same as for the Temperature Register.

**Table 8.  $T_{HIGH}$  Register**

D7	D6	D5	D4	D3	D2	D1	D0
H7	H6	H5	H4	H3	H2	H1	H0

**Table 9.  $T_{LOW}$  Register**

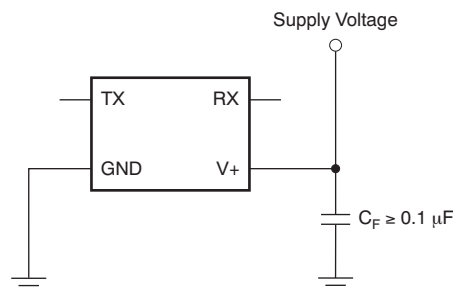
D7	D6	D5	D4	D3	D2	D1	D0
L7	L6	L5	L4	L3	L2	L1	L0

## TIMEOUT FUNCTION

A timeout mechanism is implemented on the TMP104 to allow for re-synchronization of the SMAART wire interface if synchronization between the host and the TMP104 is lost for 28 ms (typical). If the timeout period expires between the calibration byte and the command byte, or between the command byte and any data byte, or between any data bytes, the TMP104 resets the SMAART wire interface circuitry so that it expects the baud rate calibration command to restart. Every time a byte is transmitted on the SMAART wire interface, this timeout period restarts.

## NOISE

The TMP104 is a very low-power device and generates very low noise on the supply bus. Applying a bypass capacitor to the  $V_{+}$  pin of the TMP104 can further reduce any noise the TMP104 might propagate to other components.  $C_F$  in [Figure 14](#) should be greater than 0.1  $\mu\text{F}$ .



**Figure 14. Noise Reduction**

## SMAART WIRE INTERFACE TIMING SPECIFICATIONS

Figure 15 illustrates the key timing and jitter considerations for the SMAART wire interface. Table 10 contains the timing specifications for ensured, reliable operation. During a transaction, the baud rate must remain within  $\pm 1\%$  of its initialization byte value; however, the baud rate can change from transaction to transaction. There is an allowed delay between each byte transfer of less than 28 ms, which is the bus inactivity timeout check for the TMP104 SMAART wire interface.

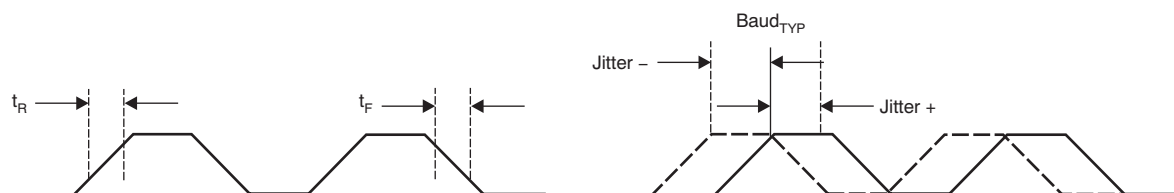


Figure 15. SMAART Wire Timing Diagram

Table 10. Timing Diagram Definitions

PARAMETER		MIN	MAX	UNIT
Baud		4.8 k	114 k	Bits/s
$t_R$	Clock/data rise time		0.5	%Baud
$t_F$	Clock/data fall time		0.5	%Baud
Jitter			$\pm 1$	%Baud



## REVISION HISTORY

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

Changes from Original (November 2011) to Revision A	Page
• Changed <i>one-wire UART-style interface</i> to <i>SMAART wire interface</i> throughout document .....	1
• Changed description of protocol in <i>Communication Protocol</i> section .....	6
• Updated <a href="#">Figure 5</a> .....	6

## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
TMP104YFFR	ACTIVE	DSBGA	YFF	4	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-40 to 125	T4	<a href="#">Samples</a>
TMP104YFFT	ACTIVE	DSBGA	YFF	4	250	TBD	Call TI	Call TI	-40 to 125	T4	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side 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

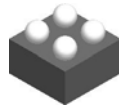
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TMP104YFFR	DSBGA	YFF	4	3000	180.0	8.4	0.86	1.06	0.69	4.0	8.0	Q1

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TMP104YFFR	DSBGA	YFF	4	3000	182.0	182.0	20.0

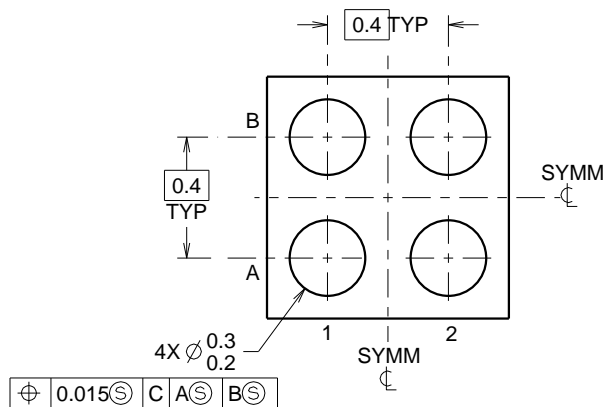
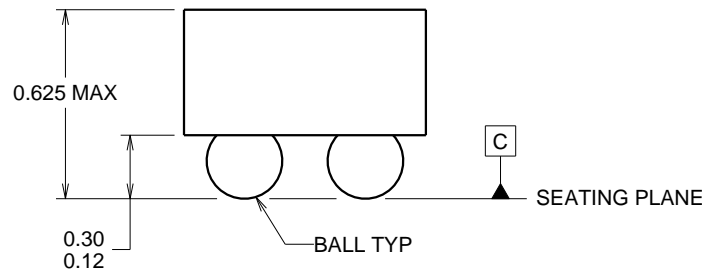
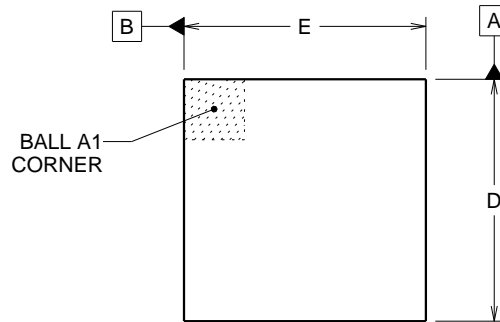


# PACKAGE OUTLINE

YFF0004

DSBGA - 0.625 mm max height

DIE SIZE BALL GRID ARRAY



D: Max = 0.99 mm, Min = 0.93 mm

E: Max = 0.79 mm, Min = 0.73 mm

4219460/A 02/2014

## NOTES:

NanoFree Is a trademark of Texas Instruments.

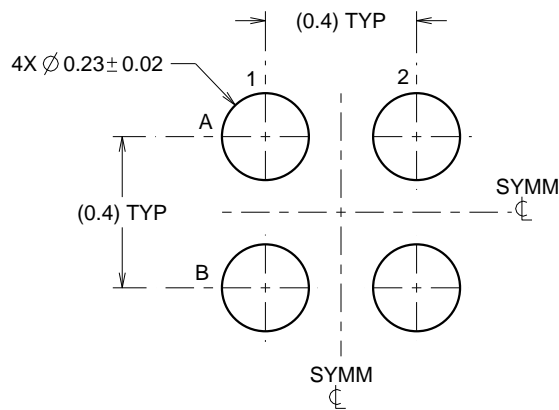
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. NanoFree™ package configuration.

# EXAMPLE BOARD LAYOUT

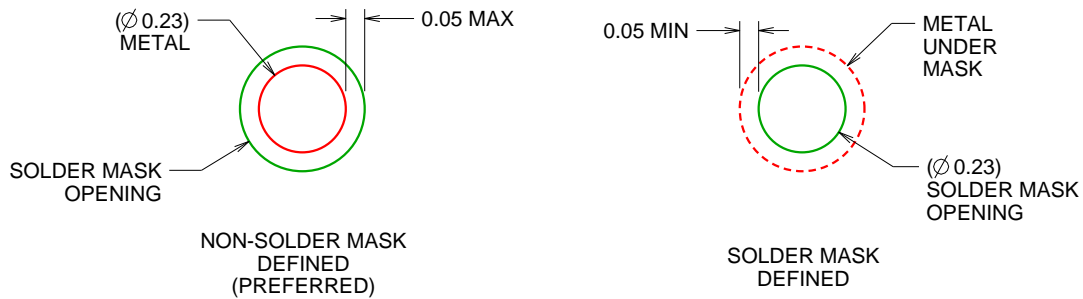
YFF0004

DSBGA - 0.625 mm max height

DIE SIZE BALL GRID ARRAY



LAND PATTERN EXAMPLE  
SCALE:50X



SOLDER MASK DETAILS  
NOT TO SCALE

4219460/A 02/2014

NOTES: (continued)

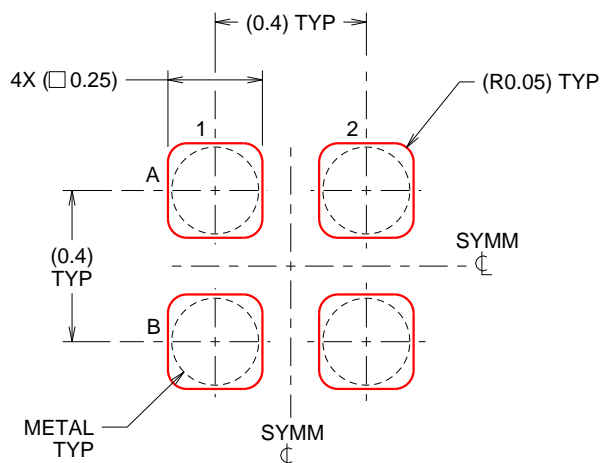
4. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints.  
For more information, see Texas Instruments literature number SBVA017 ([www.ti.com/lit/sbva017](http://www.ti.com/lit/sbva017)).

## EXAMPLE STENCIL DESIGN

YFF0004

DSBGA - 0.625 mm max height

DIE SIZE BALL GRID ARRAY



SOLDER PASTE EXAMPLE  
BASED ON 0.1 mm THICK STENCIL  
SCALE:50X

4219460/A 02/2014

NOTES: (continued)

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

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Applications Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

### TI E2E Community

[e2e.ti.com](http://e2e.ti.com)