

TMP006/B 采用芯片级封装的红外热电堆传感器

1 特性

- 集成了MEMS热电堆以进行非接触式温度感测
- 用于冷接点参考的本地温度传感器
 - 0°C 至 60°C 范围内为 $\pm 1^\circ\text{C}$ (最大值)
 - -40°C 至 +125°C 范围内为 $\pm 1.5^\circ\text{C}$ (最大值)
- 两线制串行接口选项:
 - 与 I²C 和系统管理总线 (SMBus) 兼容
 - TMP006 的接口电压为 3.3V
 - TMP006B 的接口电压为 1.8V
 - 8 个可编程地址
- 低功耗
 - 电源: 2.2V 至 5.5V
 - 工作电流: 240 μA (典型值)
 - 关断电流: 1 μA (最大值)
- 紧凑型封装
 - 1.6mm x 1.6mm x 0.625mm DSBGA

2 应用

- 非接触式温度感测
 - 外壳温度
 - 激光打印机
 - 功率继电器
 - 保健与美容
 - HVAC 舒适度优化
- 气体浓度
- 火焰检测

3 说明

TMP006 和 TMP006B 是全集成 MEMS 热电堆传感器, 无需直接接触物体即可测量其温度。热电堆会吸收物体中波长介于 4 μm 至 16 μm 之间 (最终用户定义的视野范围) 的无源红外能量。

该传感器会通过 I²C 和 SMBus 兼容接口使用片上芯片热传感器测量对热电堆两端电压的相应变化进行数字化并报告。利用这一数据, 可通过外部处理器计算目标物体的温度。

TMP007 是 TMP006 或 TMP006B 的增强版。

TMP007 融合了 TMP006 和 TMP006B 的所有特性, 并且增添了数学引擎在芯片上执行所有公式运算, 以便能够直接从器件读取目标物体的温度。TMP007 还内置有非易失性存储器, 用于存储校准系数。

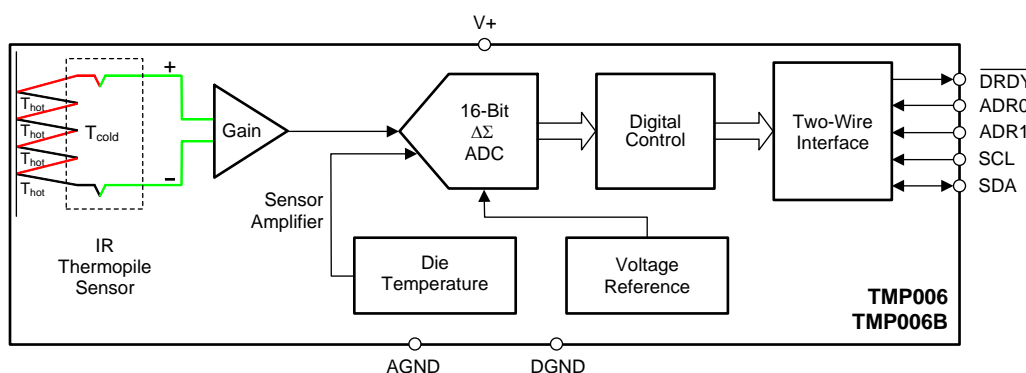
红外热电堆传感器的额定工作温度范围为 -40°C 至 +125°C。该器件可以测量超出器件工作温度范围的物体温度, 前提是器件本身未超出工作温度范围 (-40°C 至 +125°C)。

器件信息⁽¹⁾

器件型号	封装	封装尺寸 (标称值)
TMP006	DSBGA (8)	1.60mm x 1.60mm
TMP006B		

(1) 要了解所有可用封装, 请见数据表末尾的封装选项附录。

简化电路原理图



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4 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

Changes from Revision D (November 2014) to Revision E	Page
• 已更改特性，应用和说明部分	1
• 已更改简化电路原理图中的热电堆传感器部分	1
• Changed operating range minimum value in Absolute Maximum Ratings from -55°C to -40°C	5
• Changed Handling Ratings to ESD Ratings and moved storage temperature to Absolute Maximum Ratings	5
• Changed 图 3	7
• Changed thermopile sensor portion of functional block diagram	8
• Deleted text at the end of 2nd paragraph in <i>Field of View and Angular Response</i> section	10
• Added 图 8	10
• Changed T_{REG} to T_{DIE} in <i>Temperature Format</i> section	15

Changes from Revision C (December 2012) to Revision D	Page
• 已将整篇数据表中的所有 WCSP 更改为 DSBGA	1
• 已更改文档格式以符合最新数据表标准	1
• 已添加器件比较、处理额定值和建议运行条件表，特性描述，器件功能模式，寄存器映射，应用和实施，电源相关建议，布局，器件和文档支持以及机械、封装和可订购信息部分	1
• 已更改说明部分第一段中的文本	1
• 已将整篇数据表中的所有“本地温度”更改为“芯片温度”	1
• 已将首页上的柱状图移至典型特性部分	1
• 已添加简化电路原理图标题至首页图片	1
• 已更改简化电路原理图	1
• Deleted Package Information table	4
• Changed all T_{Object} to T_{OBJ} throughout data sheet	6
• Changed x- and y-axis labels in 图 1	7
• Changed text related to object temperature measurement in first paragraph of <i>Overview</i> section	8

• Changed 表 3	15
• Changed all V_{OBJECT} to V_{SENSOR} throughout datasheet	19
• Deleted <i>Pointer Register</i> section	19
• Changed Sensor Voltage Register name to Sensor Voltage Result Register	19
• Changed $T_{AMBIENT}$ to T_{DIE} throughout data sheet	19

Changes from Revision B (February 2012) to Revision C
Page

• 已添加 TMP006B 器件至数据表	1
• Changed Package Information table to include new TMP006B device with the TMP006, and show the different voltage for the two devices	4

Changes from Revision A (July 2011) to Revision B
Page

• Changed Output Error, <i>Calculate object temperature</i> parameter test conditions in Electrical Characteristics table	6
• 已更改 description of device ID to 0067h in <i>Manufacturer and Device ID Registers</i> section	20
• Changed FFh, <i>Reset value</i> bits D2, D1, and D0 values in 图 18.....	20
• Changed 图 23	28
• Changed 图 24	29
• Changed 图 25	30

Changes from Original (May, 2011) to Revision A
Page

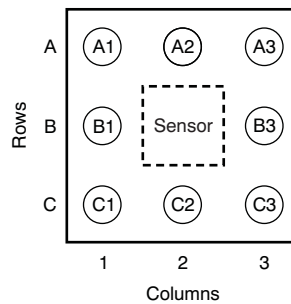
• 已添加 specifications for <i>ambient temperature sensor</i> parameter over 0°C to +60°C.....	6
• Revised 表 4	16

5 Device Comparison Table

PRODUCT	TWO-WIRE INTERFACE VOLTAGE
TMP006	3.3 V
TMP006B	1.8 V

6 Pin Configuration and Functions

**YZF Package
8-Pin DSBGA
(Top View, Not to Scale)**



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
ADR0	C1	Input	Address select pin
ADR1	B1	Input	Address select pin
AGND	A2	Power	Analog ground
DGND	A1	Power	Digital ground
$\overline{\text{DRDY}}$	C2	Output	Data ready, active low, open-drain; requires a pullup resistor to V+.
SCL	B3	Input	Serial clock line for two-wire interface, open-drain; requires a pullup resistor to V+.
SDA	C3	Input/output	Serial data line for two-wire interface, open-drain; requires a pullup resistor to V+.
V+	A3	Power	Positive supply (2.2 V to 5.5 V)

7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

		MIN	MAX	UNIT
Supply voltage, V_S	V+ pin		7	V
Input voltage	ADR1 pins	-0.5	$V_S + 0.5$	V
	SDA, SCL, \overline{DRDY} , ADR0 pins	-0.5	+7	V
Input current			10	mA
Temperature	Operating range	-40	+125	°C
	Junction temperature, $T_{J\max}$		+150	°C
	Storage range, T_{stg}	-65	+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.

7.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±2000
		Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	±500
		Machine model	±200

- (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.

7.3 Recommended Operating Conditions

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

	MIN	NOM	MAX	UNIT
Supply voltage, V_S	2.5	3.3	5.5	V
Operating temperature range	-40		+125	°C
Die temperature, T_{DIE}			125	°C
Object temperature, T_{OBJ}	See note ⁽¹⁾			°C

- (1) Object temperature is application dependent.

7.4 Thermal Information

THERMAL METRIC ⁽¹⁾		TMP006 TMP006B	UNIT
		YZF (DSBGA)	
		8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	123.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	69	
$R_{\theta JB}$	Junction-to-board thermal resistance	103	
ψ_{JT}	Junction-to-top characterization parameter	4.7	
ψ_{JB}	Junction-to-board characterization parameter	55	
$R_{\theta JC(bot)}$	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](#).

7.5 Electrical Characteristics

At $T_{DIE} = +25^{\circ}\text{C}$, $V_+ = 3.3\text{ V}$, and conversion time = 1 second, unless otherwise specified.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT ERROR						
Die temperature sensor		$T_{DIE} = 0^{\circ}\text{C}$ to $+60^{\circ}\text{C}$, $V_+ = 2.2\text{ V}$ to 5.5 V		± 0.5	± 1	$^{\circ}\text{C}$
		$T_{DIE} = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$, $V_+ = 2.2\text{ V}$ to 5.5 V		± 0.5	± 1.5	$^{\circ}\text{C}$
PSRR	Power-supply rejection ratio			0.1		$^{\circ}\text{C}/\text{V}$
	Calculate object temperature ⁽¹⁾	$T_{DIE} = +20^{\circ}\text{C}$ to $+60^{\circ}\text{C}$, $T_{OBJ} - T_{DIE} = -10^{\circ}\text{C}$ to $+30^{\circ}\text{C}$		± 1	± 3	$^{\circ}\text{C}$
	Field of view	50% responsivity		90		Degrees
TEMPERATURE MEASUREMENT						
Conversion time		CR2 = 0, CR1 = 0, CR0 = 0		0.25		Seconds
		CR2 = 0, CR1 = 0, CR0 = 1		0.5		Seconds
		CR2 = 0, CR1 = 1, CR0 = 0		1		Seconds
		CR2 = 0, CR1 = 1, CR0 = 1		2		Seconds
		CR2 = 1, CR1 = 0, CR0 = 0		4		Seconds
Resolution		Die temperature sensor		0.03125		$^{\circ}\text{C}$
		Thermopile sensor resolution		156.25		nV
SMBus COMPATIBLE INTERFACE						
V_{IH}	Logic input high voltage (SCL, SDA)	TMP006 only	2.1			V
		TMP006B only	1.4			V
V_{IL}	Logic input low voltage (SCL, SDA)	TMP006 only			0.8	V
		TMP006B only			0.4	V
	Hysteresis			100		mV
V_{OL}	Output low voltage (SDA)	$I_{OUT} = 6\text{ mA}$		0.15	0.4	V
	Output low sink current (SDA)		6			mA
	Logic input current	Forced to 0.4 V	-1		+1	μA
	Input capacitance (SCL, SDA, A0, A1)			3		pF
	Clock frequency		0.001		3.4	MHz
	Interface timeout		25	30	35	ms
DIGITAL OUTPUTS						
V_{OL}	Output low voltage ($\overline{\text{DRDY}}$)	$I_{OUT} = 4\text{ mA}$		0.15	0.4	V
I_{OH}	High-level output leakage current	$V_{OUT} = V_{DD}$		0.1	1	μA
	Output low sink current ($\overline{\text{DRDY}}$)	Forced to 0.4 V	4			mA
POWER SUPPLY						
V_S	Specified voltage range	$T_{DIE} = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$	2.2		5.5	V
POR	Power-on reset	$T_{DIE} = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$		1.6		V
I_Q	Quiescent current	Continuous conversion; see 表 7		240	325	μA
		Serial bus inactive, shutdown mode, TMP006 only		0.5	1.0	μA
		Serial bus inactive, shutdown mode, TMP006B only		1.5	5.0	μA
		Serial bus active, $f_S = 400\text{ kHz}$, shutdown mode		90		μA

(1) This parameter is tested in a fully-settled setup with no transients, in front of an ideal black body, with specified layout constraints, and after system calibration.

7.6 Typical Characteristics

At $T_{DIE} = +25^{\circ}\text{C}$ and $V_S = 3.3\text{ V}$, unless otherwise noted.

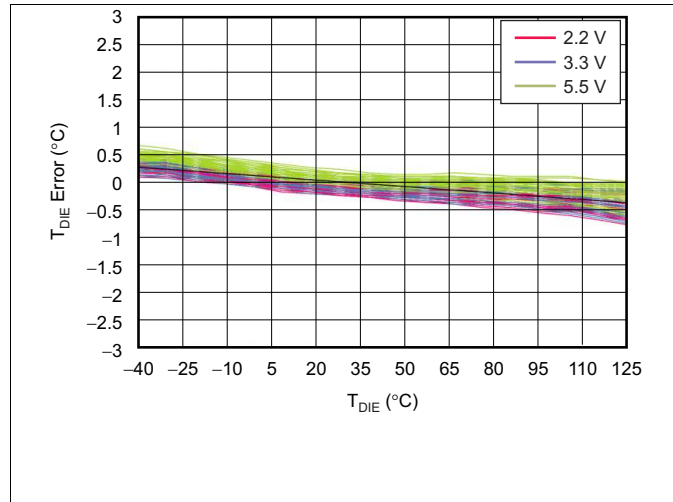


图 1. Typical Die Temperature Error

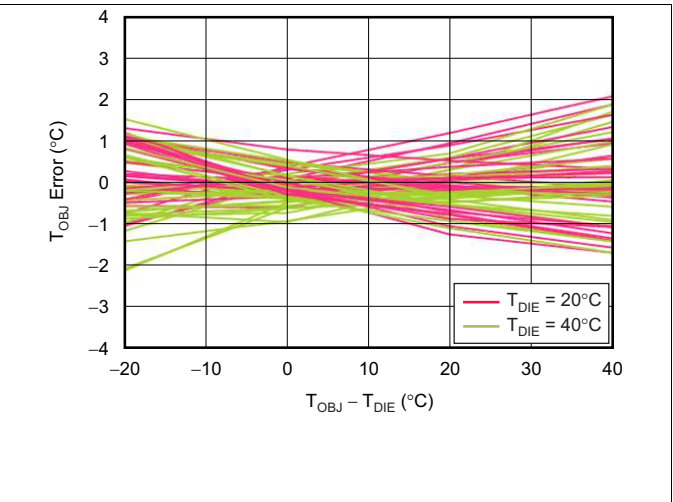


图 2. Typical Object Temperature Error

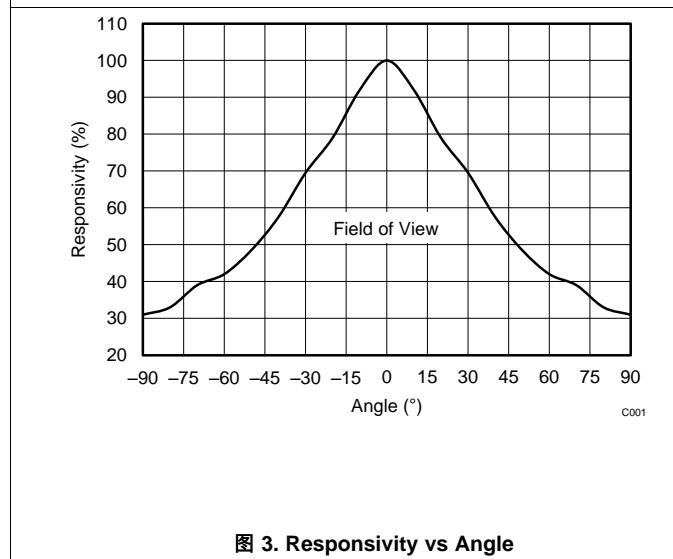


图 3. Responsivity vs Angle

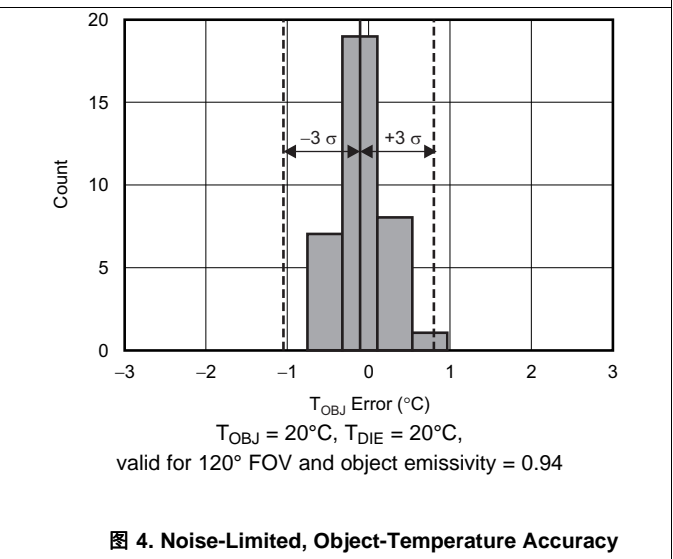


图 4. Noise-Limited, Object-Temperature Accuracy

8 Detailed Description

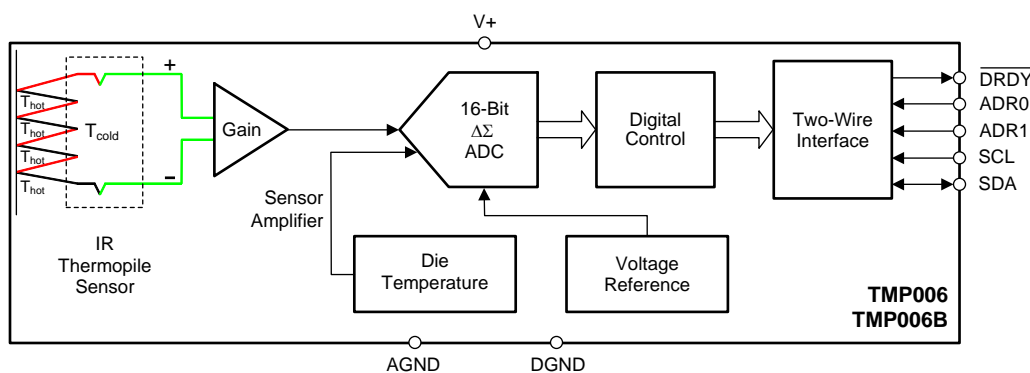
8.1 Overview

The TMP006 and TMP006B are digital temperature sensors that are optimal for thermal management and thermal protection applications where remote noncontact sensing is desired. The TMP006 and TMP006B use a two-wire interface (I²C and SMBus compatible), and are specified over the die temperature range of –40°C to +125°C. The TMP006 and TMP006B measure object temperatures over a range limited only by the maximum sensor voltage (5.12 mV). The TMP006 and TMP006B contain registers for holding configuration information, temperature measurement results, and sensor voltage measurement. Die temperature and sensor voltage measurements are used to calculate the object temperature.

The TMP006 and TMP006B provide both die temperature and thermopile sensor voltage outputs in a small DSBGA chip-scale package. The die temperature sensor in both the TMP006 and TMP006B is integrated on-chip; the thermal path runs through the DSBGA solder balls. The low thermal resistance of the solder balls provides the thermal path to maintain the chip at the temperature of the die environment.

The top side of the DSBGA package must face the object that is being measured with an unobstructed view in order to accurately measure the temperature. Refer to the user guide [TMP006 Layout and Assembly Guidelines \(SBOU108\)](#) for more details.

8.2 Functional Block Diagram



8.3 Feature Description

The TMP006 and TMP006B sense the IR radiation emitted by all objects. The spectrum of the radiation depends only on the temperature and is given by Planck's law, as shown in [公式 1](#):

$$B_{\lambda}(T, \lambda) = \frac{2hc^2}{\lambda^5} \left(\frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1} \right) \text{ watts / cm}^2 / \mu\text{m}$$

where

- h = Planck's constant
- c = speed of light
- k_B = Boltzmann's constant
- λ = wavelength in microns

(1)

Feature Description (接下页)

The intensity of radiation from the object is determined by the emissivity (ϵ), a material-dependent property that scales the spectral response so that $0 < \epsilon < 1$. For an ideal black body, the radiation is at a maximum for a given temperature and $\epsilon = 1$. The temperature is measured on the kelvin scale where 0 K is absolute zero, or -273.15°C . Room temperature (25°C) is approximately 298.13 K. The emission spectra for objects at or near room temperature are shown in 图 5. For these temperatures, the majority of the radiation emitted is in the wavelength range of 3 μm to 20 μm .

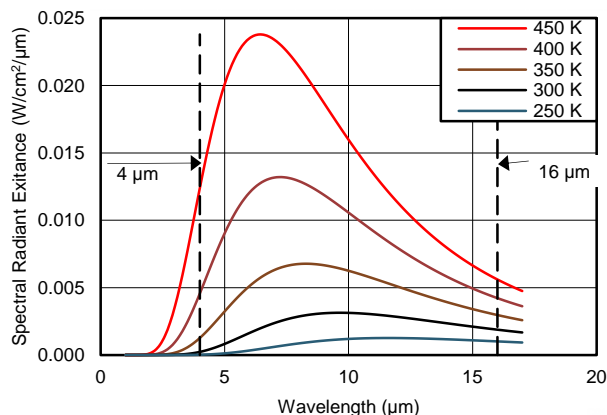


图 5. Black Body Emission Spectrum and Response

8.3.1 Spectral Responsivity

The TMP006 and TMP006B are optimized to sense IR radiation emitted by objects from approximately 250 K (-23°C) to 400 K (127°C), with maximum sensitivity from approximately 4 μm to 16 μm . The relative spectral response of the TMP006 and TMP006B is shown in 图 6.

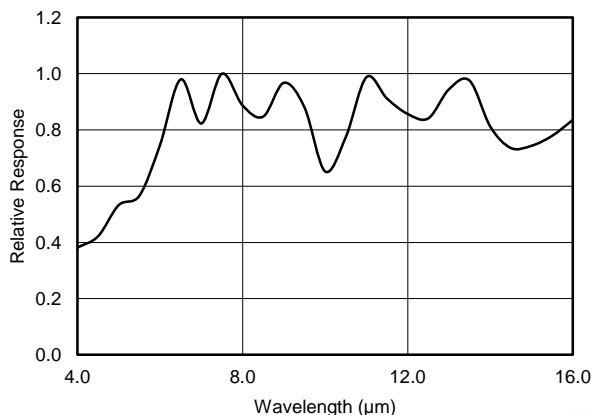


图 6. Relative Spectral Response vs Wavelength

Feature Description (接下页)

8.3.2 Field of View and Angular Response

The TMP006 and TMP006B sense all radiation within a defined field of view (FOV). The FOV (or full-angle of θ) is defined as 2Φ . These devices contain no optical elements, and thus sense all radiation within the hemisphere to the front of the device. 图 3 shows the angular dependence of the sensor response and the relative power for a circular object that subtends a half angle of Φ . 图 7 defines the angle Φ in terms of object diameter and distance. 图 7 assumes that the object is well approximated as a plane that is perpendicular to the sensor axis.

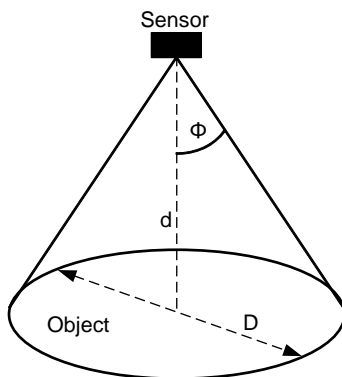
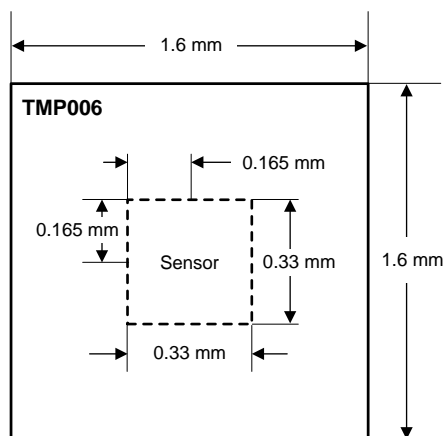


图 7. FOV Geometry Definition

In this case, the maximum contribution is from the portion of the object directly in front of the TMP006 or TMP006B ($\Phi = 0$); with the sensitivity per solid angle, $dR/d\Phi$ decreases as Φ increases. Approximately 50% of the energy sensed by the TMP006 and TMP006B is within a FOV (θ) = 90° .

This discussion is for illustrative purposes only; in practice the angular response ($dR/d\Phi$) of the TMP006 and TMP006B to the object is affected by the object orientation, the number of objects, and the precise placement relative to the TMP006 or TMP006B. 图 8 shows the thermopile sensor dimensions.



NOTE: Thermopile sensor is centered in the device.

图 8. Thermopile Sensor Dimensions

Feature Description (接下页)

8.3.3 Thermopile Principles and Operation

The TMP006 and TMP006B sense radiation by absorbing the radiation on a hot junction. The thermopile then generates a voltage proportional to the temperature difference between the hot junction, T_{hot} , and the cold junction, T_{cold} .

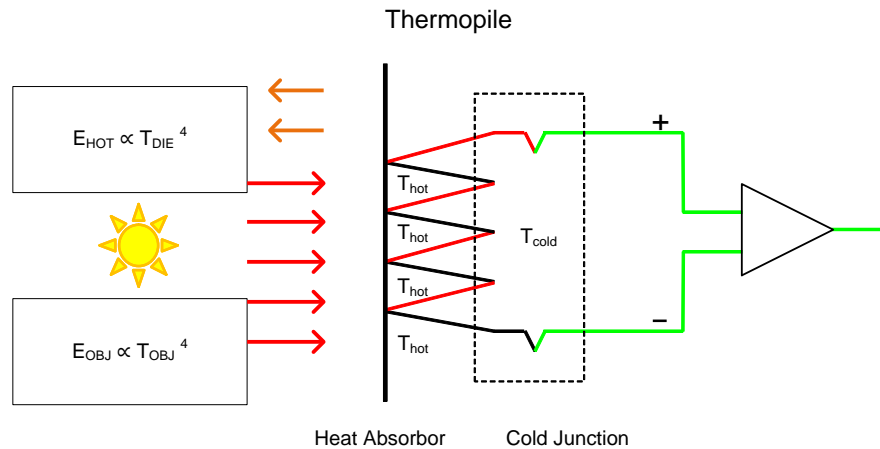


图 9. Principle of Thermopile Operation

The cold junction is thermally grounded to the die, and is effectively T_{DIE} , the die temperature. In thermal equilibrium, the hot junction is determined by the object temperature, T_{OBJ} . The energy emitted by the object, E_{OBJ} , minus the energy radiated by the die, E_{DIE} , determines the temperature of the hot junction. The output voltage, V_{OUT} , is therefore determined by the relationship shown in 公式 2:

$$V_{OUT} = V_{SENSOR} = C \times (T_{HOT} - T_{COLD}) \propto (T_{OBJ}^4 - T_{DIE}^4)$$

where

- C is a constant depending on the design of the sensing element. (2)

Note that the sensor voltage is related to both the object temperature and the die temperature. A fundamental characteristic of all thermopiles is that they measure temperature *differentials*, not *absolute* temperatures. The TMP006 and TMP006B contain a highly-accurate, internal temperature sensing element to measure T_{DIE} . Estimate T_{OBJ} by using V_{SENSOR} and T_{DIE} . For each 250-ms conversion cycle, the TMP006 and TMP006B measure a value for V_{SENSOR} and for T_{DIE} , which are then placed in their respective registers.

For each conversion cycle, the device generates an analog-to-digital converter (ADC) value for T_{DIE} and V_{SENSOR} . Bits CR2 to CR0 determine the number of T_{DIE} and sensor ADC results to average before they are loaded into the respective registers for readout.

After power-on reset (POR), the TMP006 and TMP006B start in four conversions per second (CR[2:0] = 010). In general, for a mode with N conversions, the local temperature, T_{DIE} , result is updated at the end of the N th ADC conversion with the value shown in 公式 3:

$$T_{DIE} = \frac{1}{N} \sum_{X=1}^N \text{Local Temp Conversion}_X$$

Similarly, the sensor voltage result is updated at the end of the N th sensor ADC conversion with the value shown in 公式 4:

$$V_{SENSOR} = \frac{1}{N} \sum_{X=1}^N \text{Sensor Conversion}_X$$

The total conversion time and averages per conversion can be optimized to select the best combination of update rate versus noise for an application. Additionally, low-power conversion mode is available. In CR settings 101, 110, and 111, the device inserts a standby time before the beginning of the next conversion or conversions.

The method and requirements for estimating T_{OBJ} are described in the next section.

Feature Description (接下页)

8.3.4 Object Temperature Calculation

The TMP006 and TMP006B generate a sensor voltage, V_{Sensor} , in register 00h that is representative of the energy radiated by the object. In an ideal situation, the Stefan-Boltzman law relates the energy radiated by an object to its temperature by the relationship shown in 公式 5:

$$\text{Energy}_{\text{Rad}} = \varepsilon \sigma T_{\text{OBJ}}^4$$

where

- σ = Stefan-Boltzman constant = $5.7 \times 10^{-12} \text{ W/cm}^2/\text{K}^4$
- ε = Emissivity, $0 < \varepsilon < 1$, an object dependent factor, $\varepsilon = 1$ for a perfect black body

A similar relationship holds for the sensing element itself that radiates heat at a rate determined by T_{DIE} . The net energy absorbed by the sensor is then given by the energy absorbed from the object minus the energy radiated by the sensor, as shown in 公式 6:

$$V_{\text{SENSOR}} \propto E_{\text{ABSORBED}} - E_{\text{RADIATED}} = \varepsilon \sigma (T_{\text{OBJ}}^4 - T_{\text{DIE}}^4) \quad (6)$$

In an ideal situation, the sensor voltage relates to object temperature as shown in 公式 7:

$$T_{\text{OBJ}} = \sqrt[4]{T_{\text{DIE}}^4 + \frac{V_{\text{SENSOR}}}{\varepsilon \sigma}} \quad (7)$$

$$T_{\text{OBJ}} = \sqrt[4]{T_{\text{DIE}}^4 + \left(\frac{f\{V_{\text{OBJ}}\}}{S} \right)}$$

where

- S is a system-dependent parameter incorporating the object emissivity (ε), FOV, and sensor characteristics. The parameters S0, A1, and A2 are used in determining S.
- $f(V_{\text{OBJ}})$ is a function that compensates for heat flow other than radiation, such as convection and conduction, from nearby objects. The parameters B0, B1, and B2 are used to tune this function to a particular system and environment.

The coefficients affect object temperature measurement as described in 表 1.

表 1. Calibration Coefficient Definitions

COEFFICIENT	PURPOSE	CALIBRATION	COMMENT
S0	FOV and emissivity of object	Application and object dependent	Default values based on black body with $\varepsilon = 0.95$, and 110° FOV
A1, A2	Device properties	Factory set	Default values based on typical sensor characteristics
C	Device properties	Factory set	Default values based on typical sensor characteristics
B0, B1, B2	Corrects for energy sources	Environment dependent	Calibrate in end-application environment

8.3.5 Calibration

The TMP006 and TMP006B default coefficients are calibrated with a black body of emissivity, $\varepsilon = 0.95$, and an FOV (θ) = 110°. Use these coefficients for applications where the object emissivity and geometry satisfy these conditions. For applications with different object emissivity or geometry, calibrate the TMP006 or TMP006B to accurately reflect the object temperature and system geometry. Accuracy is affected by device-to-device or object-to-object variation. For the most demanding applications, calibrate each device individually.

As an overview the calibration procedure includes:

1. Defining the environmental variation range (die and object temperature range, supply voltage, temperature change speed, sampling rate and so on).
2. Making the die temperature measurements and IR sensor voltage measurements over the environmental range.
3. Generate an optimal set of coefficients based on the collected data set.

The best temperature precision is available if every device is calibrated individually. Alternatively, if all the units in the application use the same coefficients, then calibrate a statistically significant number of devices.

Recalibration may be required under any or all of the following conditions:

1. Board layout is changed.
2. Object or objects in the field of view changed.
3. Object distance changed.
4. Angle between device surface and direction to the object changed.
5. Object and local temperature range changed outside the environmental calibration range.
6. Object and local temperature transients significantly changed.
7. Supply voltage changed more than 1 V.
8. Air convection or conduction near the device.

For further information and methods for calibration, refer to user guide [SBOU142, TMP007 Calibration Guide](#)

8.3.6 Sensor Voltage Format

The TMP006 and TMP006B provide 16 bits of data in binary two's complement format. The positive full-scale input produces an output code of 7FFFh and the negative full-scale input produces an output code of 8000h. The output clips at these codes for signals that exceed full-scale. 表 2 summarizes the ideal output codes for different input signals. 图 10 illustrates code transitions versus input voltage. Full-scale is a 5.12-mV signal. The LSB size is 156.25 nV.

表 2. Input Signal Versus Ideal Output Code⁽¹⁾

SENSOR SIGNAL	OUTPUT CODE
FS $(2^{15} - 1)/2^{15}$ (5.12 mV)	7FFFh
+FS/2 ¹⁵ (156.25 nV)	0001h
0	0
-FS/2 ¹⁵ (-156.25 nV)	FFFFh
-FS (-5.12 mV)	8000h

(1) FS = Full-scale value.

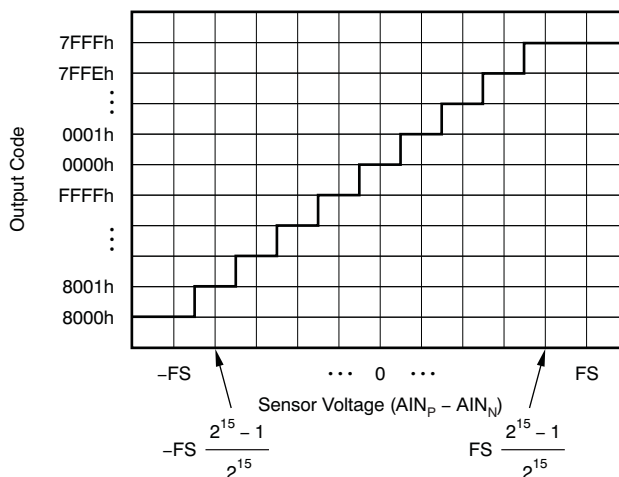


图 10. Code Transition Diagram

8.3.7 Temperature Format

The temperature register data format of the TMP006 and TMP006B is reported in a binary twos complement signed integer format, as 表 3 shows, with 1 LSB = 1 / 32°C = 0.03125.

表 3. Temperature Data Format

TEMPERATURE (°C)	DIGITAL OUTPUT (BINARY)	SHIFTED HEX
150	0100 1011 0000 0000	12C0
125	0011 1110 1000 0000	0FA0
100	0011 0010 0000 0000	0C80
80	0010 1000 0000 0000	0A00
75	0010 0101 1000 0000	0960
50	0001 1001 0000 0000	0640
25	0000 1100 1000 0000	0320
0.03125	0000 0000 0000 0100	0001
0	0000 0000 0000 0000	0000
-0.03125	1111 1111 1111 1100	FFFF
-0.0625	1111 1111 1111 1000	FFFE
-25	1111 0011 0111 0000	FCDC
-40	1110 1011 1111 1100	FAFF
-55	1110 0100 0111 1100	F91F

Converting the integer temperature result of the TMP006 and TMP006B to physical temperature is done by right-shifting the last two LSBs followed by a divide-by-32 of T_{DIE} to obtain the physical temperature result in degrees Celsius. T_{DIE} is the 14-bit signed integer contained in the corresponding register. The sign of the temperature is the same as the sign of the integer read from the TMP006 and TMP006B. In twos complement notation, the MSB is the sign bit. If the MSB is 1, the integer is negative and the absolute value can be obtained by inverting all bits and adding 1. An alternative method of calculating the absolute value of negative integers is $abs(i) = i \text{ xor } \text{FFFF} + 1$.

8.3.8 Serial Interface

The TMP006 and TMP006B initially start up with typical settings consisting of a conversion rate of one conversion per second (as specified in the *Electrical Characteristics*). The internal structure of the digital interface is shown in 图 11.

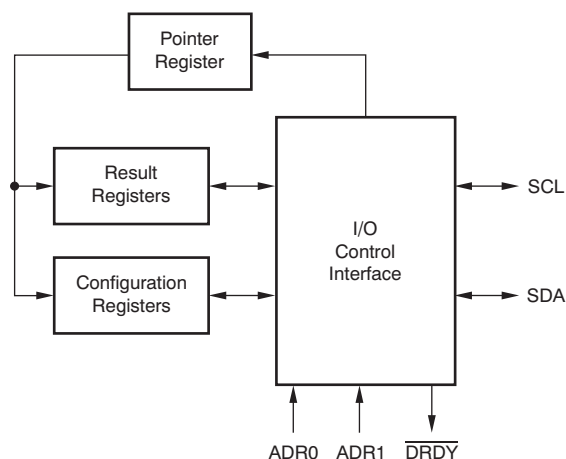


图 11. Internal Structure

The TMP006 and TMP006B operate only as a slave device on the two-wire bus. Connections to either bus are made via 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 TMP006 and TMP006B support the transmission protocol for fast (1 kHz to 400 kHz) and high-speed (1 kHz to 3.4 MHz) modes. All data bytes are transmitted MSB first.

8.3.8.1 Serial Bus Address

To communicate with the TMP006 or TMP006B, the master must first address slave devices via a slave address byte. The slave address byte consists of seven address bits and a direction bit that indicates the intent to execute a read or write operation.

The TMP006 and TMP006B feature two address pins to allow up to eight devices to be addressed on a single bus. 表 4 describes the pin logic levels used to properly connect up to eight devices. The state of the ADR0 and ADR1 pins is sampled on every bus communication and should be set before any activity on the interface occurs.

表 4. TMP006 and TMP006B Address Pins and Slave Addresses

ADR1	ADR0	SMBus Address
0	0	1000000
0	1	1000001
0	SDA	1000010
0	SCL	1000011
1	0	1000100
1	1	1000101
1	SDA	1000110
1	SCL	1000111

8.3.8.2 Read and Write Operations

Access a particular register on the TMP006 and TMP006B by writing the appropriate value to the pointer register. The pointer value is the first byte transferred after the slave address byte with the R/W bit low. Every write operation to the TMP006 and TMP006B requires a value for the pointer (see 图 12). When reading from the TMP006 or TMP006B, the last value stored in the pointer 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. This transaction is accomplished by issuing a slave address byte with the R/W bit low, followed by the pointer byte. No additional data are required. The master can then generate a START condition and send the slave address byte with the R/W bit high to initiate the read command. If repeated reads from the same register are desired, it is not necessary to continually send the pointer bytes because the TMP006 and TMP006B retain the pointer value until it is changed by the next write operation. Note that register bytes are sent MSB first, followed by the LSB.

8.3.8.3 Two-Wire Timing Diagrams

The TMP006 and TMP006B use a two-wire interface (I²C and SMBus-compatible). 图 12 and 图 13 illustrate the timing for the various operations on the TMP006 and TMP006B. Parameters for 图 12 are defined in 表 5. Bus definitions are given below.

表 5. Two-Wire Timing Diagram Definitions

PARAMETER	TEST CONDITIONS	FAST MODE		HIGH-SPEED MODE		UNIT
		MIN	MAX	MIN	MAX	
f _{SCL}	SCL operating frequency, V _S > 1.7 V	0.001	0.4	0.001	3.4	MHz
f _{SCL}	SCL operating frequency, V _S < 1.7 V	0.001	0.4	0.001	2.75	MHz
t _{BUF}	Bus free time between STOP and START condition	600		160		ns
t _{HDSTA}	Hold time after repeated START condition. After this period, the first clock is generated.	100		100		ns
t _{SUSTA}	Repeated START condition setup time	100		100		ns
t _{SUSTO}	STOP condition setup time	100		100		ns
t _{HDDAT}	Data hold time	0 ⁽¹⁾		0 ⁽²⁾		ns
t _{SUDAT}	Data setup time	100		10		ns
t _{LOW}	SCL clock low period, V _S > 1.7 V	1300		160		ns
t _{LOW}	SCL clock low period, V _S < 1.7 V	1300		200		ns
t _{HIGH}	SCL clock high period	600		60		ns
t _F	Clock/data fall time		300			ns
t _R	Clock/data rise time		300		160	ns
t _R	Clock/data rise time for SCLK ≤ 100 kHz		1000			ns

- (1) For cases with fall time of SCL less than 20 ns and/or the rise or fall time of SDA less than 20 ns, the hold time should be greater than 20 ns.
- (2) For cases with a fall time of SCL less than 10 ns and/or the rise or fall time of SDA less than 10 ns, the hold time should be greater than 10 ns.

Bus Idle: Both SDA and SCL lines remain high.

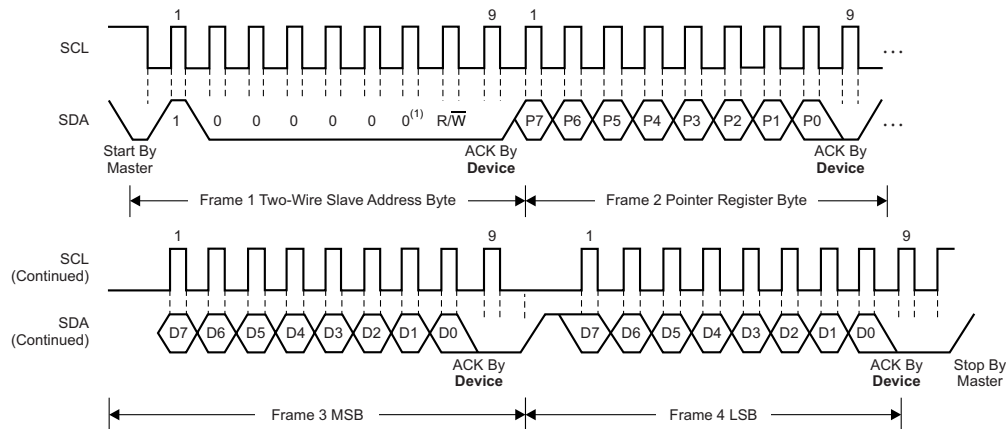
Start Data Transfer: A change in the state of the SDA line from high to low while the SCL line is high defines a START condition. Each data transfer is initiated with a START condition.

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 terminates with a STOP or a repeated START 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.

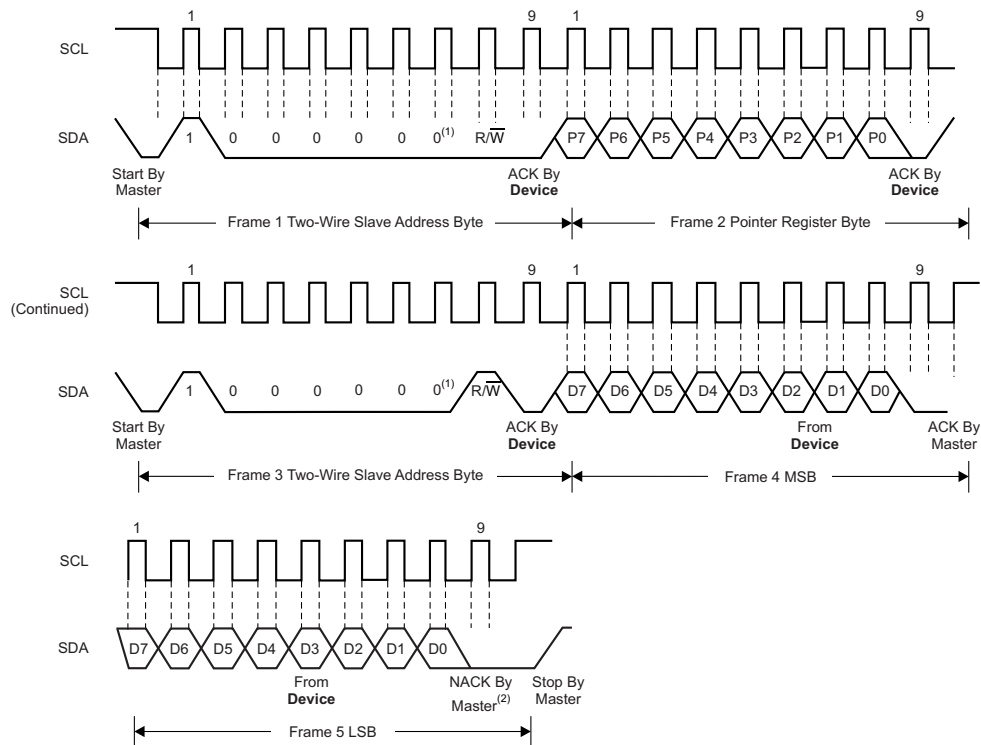
Acknowledge: Each receiving device, when addressed, is obliged to generate an Acknowledge bit. A device that acknowledges must pull down the SDA line during the Acknowledge clock pulse in such a way that the SDA line is stable low during the high period of the Acknowledge clock pulse. Setup and hold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

In order for the two-wire bus to operate at frequencies above 400 kHz, the master device must issue a High-speed mode (Hs-mode) master code (0000100X) as the first byte after a START condition to switch the bus to high-speed operation. The TMP006 and TMP006B do not acknowledge this byte, but switch the input filters on SDA and SCL and the output filter 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 TMP006 and TMP006B switch the input and output filter back to fast-mode operation.



(1) Slave address 1000000 shown. Slave address changes for the TMP006 and TMP006B depend on the ADR1 and ADR0 pin connection. See 表 4 for more details.

图 12. Two-Wire Timing Diagram For Write Word Format



(1) Slave address 1000000 shown.
 (2) Master must leave SDA high to terminate a two-byte read operation.

图 13. Two-Wire Timing Diagram For Two-Byte Read Format

8.4 Device Functional Modes

The TMP006 and TMP006B operate in two modes: continuous and shutdown. A software reset function is also available. Selecting the desired operating mode is done by writing to the configuration register conversion mode select bits MOD[2:0]. The duration of the analog-to-digital (A/D) conversion is determined by the conversion rate bits CR[2:0] and is listed in 表 7. Continuous mode, on the other hand, performs an A/D conversion followed by a low-power delay in order to reduce the average power consumption. Multiple options for the conversion time and delay time are available in order to select the desired power and noise performance. Initiating power-down has an immediate effect; it aborts the current conversion and puts the device into a low-power shutdown mode. RST, or software reset, is also immediate and initializes all memory locations with the respective reset values.

8.5 Register Maps

The TMP006 and TMP006B contain data registers that hold configuration information, temperature measurement results, and status information.

表 6. Register Map

POINTER (HEX)	REGISTER	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
00h	Sensor voltage	V15	V14	V13	V12	V11	V10	V9	V8	V7	V6	V5	V4	V3	V2	V1	V0
01h	Local temperature	T13	T12	T11	T10	T9	T8	T7	T6	T5	T4	T3	T2	T1	T0	0	0
02h	Configuration	RST	MOD3	MOD2	MOD1	CR3	CR2	CR1	EN	DRDY	0	0	0	0	0	0	0
FEh	Manufacturer ID	ID15	ID14	ID13	ID12	ID11	ID10	ID9	ID8	ID7	ID6	ID5	ID4	ID3	ID2	ID1	ID0
FFh	Device ID	ID15	ID14	ID13	ID12	ID11	ID10	ID9	ID8	ID7	ID6	ID5	ID4	ID3	ID2	ID1	ID0

8.5.1 Sensor Voltage Result (V_{SENSOR}) Register (address = 00h) [reset = 0000000000000000]

The sensor voltage register is a 16-bit result register in binary twos complement format. One least significant bit (LSB) is 156.25 nV. The full-scale value is a ± 5.12 mV signal. Data from this register (图 14) are used in conjunction with data from the Temperature register to calculate the object temperature. 图 14 summarizes the Sensor Voltage register. The equation for the resultant object temperature is discussed in the *TMP006 User Guide (SBOU107)*.

图 14. Sensor Voltage Result (V_{SENSOR}) Register

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
V15	V14	V13	V12	V11	V10	V9	V8	V7	V6	V5	V4	V3	V2	V1	V0
R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

8.5.2 Temperature (T_{DIE}) Register (address = 01h) [reset = 0000000000000000]

The temperature register of the TMP006 and TMP006B is configured as a 14-bit, read-only register (as shown in 图 15) that stores the result of the most recent conversion for the die temperature, T_{DIE} . Following power-up or a software reset, the Temperature Register reads 0°C (0000h) until the first conversion is complete.

图 15. Temperature (T_{DIE}) Register

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
T13	T12	T11	T10	T9	T8	T7	T6	T5	T4	T3	T2	T1	T0	—	—
R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

8.5.3 Configuration Register (address = 02h) [reset = 0111010000000000]

图 16 describes the configuration register. This register determines the operational modes, conversion rate, DRDY control, initiates a single conversion, performs a software reset, or puts the device into shutdown mode. This register is read/write, and the pointer address is 02h.

图 16. Configuration Register

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RST	MOD2	MOD1	MOD0	CR2	CR1	CR0	EN	$\overline{\text{DRDY}}$	—	—	—	—	—	—	—
R/W-0h	R/W-1h	R/W-1h	R/W-1h	R/W-0h	R/W-1h	R/W-0h	R/W-0h	R/W-0h	R/W-0h	R/W-0h	R/W-0h	R/W-0h	R/W-0h	R/W-0h	R/W-0h

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Bit [15] RST: Software reset bit

 0 = Normal operation, this bit self clears
 1 = Software reset

Bits [14:12] MOD[2:0]: Mode of operation

 000 = Power-down
 111 = Sensor and die continuous conversion (MOD)

Bits [11:9] CR[2:0]: ADC conversion rate

See 表 7.

Bit [8] EN: $\overline{\text{DRDY}}$ enable bit

 0 = $\overline{\text{DRDY}}$ pin disabled
 1 = $\overline{\text{DRDY}}$ pin enabled

Bit [7] $\overline{\text{DRDY}}$: Data ready bit

 0 = Conversion in progress
 1 = Object voltage and ambient temperature results are ready to read. A temperature or sensor voltage read or a write to the Configuration Register is required to clear the condition.

Bits [6:0] Unused [6:0]
表 7. Conversion Rate

CR2	CR1	CR0	CONVERSION RATE (conversions/sec)	TOTAL NUMBER OF AVERAGED SAMPLES	AVERAGE I_Q (μA)	PEAK-PEAK NOISE OF THE T_{OBJ} RESULT ($^{\circ}\text{C}$)
0	0	0	4	1	240	0.5
0	0	1	2	2	240	0.35
0	1	0	1	4	240	0.25 (default)
0	1	1	0.5	8	240	0.18
1	0	0	0.25	16	240	0.125

8.5.4 Manufacturer and Device ID Registers

The TMP006 and TMP006B have two identification registers: manufacturer ID (address FEh) shown in 图 17, and device ID (address FFh) shown in 图 18. The manufacturer ID reads 5449h and the device ID is 0067h.

8.5.4.1 Manufacturer ID Register (address = FEh) [reset = 0101010001001001]
图 17. Manufacturer ID Register

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID15	ID14	ID13	ID12	ID11	ID10	ID9	ID8	ID7	ID6	ID5	ID4	ID3	ID2	ID1	ID0
R-0h	R-1h	R-0h	R-1h	R-0h	R-1h	R-0h	R-0h	R-0h	R-1h	R-0h	R-0h	R-1h	R-0h	R-0h	R-1h

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

8.5.4.2 Device ID Register (address = FFh) [reset = 000000001100111]
图 18. Device ID Register

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID15	ID14	ID13	ID12	ID11	ID10	ID9	ID8	ID7	ID6	ID5	ID4	ID3	ID2	ID1	ID0
R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-0h	R-1h	R-1h	R-0h	R-0h	R-1h	R-1h	R-1h

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

9 Application and Implementation

注

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.

9.1 Application Information

The TMP006 and TMP006B are a complete IR thermopile sensor system on a chip that includes the sensing element, signal conditioner, and ADC. These devices are ideal for applications where the object cannot be placed in thermal contact with a conventional temperature sensor. Common reasons for noncontact temperature sensing are:

- Distance; the object is too far away, or in an inconvenient location for wired connections.
- The object is in motion.
- Direct contact of the object is inconvenient or uncomfortable (for example, skin).
- The object is a fluid (that is, liquid or gas).
- The object is hazardous (for example, acid or flammable).
- The object is in a hazardous state (for example, high voltage).

9.2 Typical Application

9.2.1 Wide-Range Calibration Example: $T_{OBJ} = 0^{\circ}\text{C}$ to 60°C , Common vs Unit Calibration

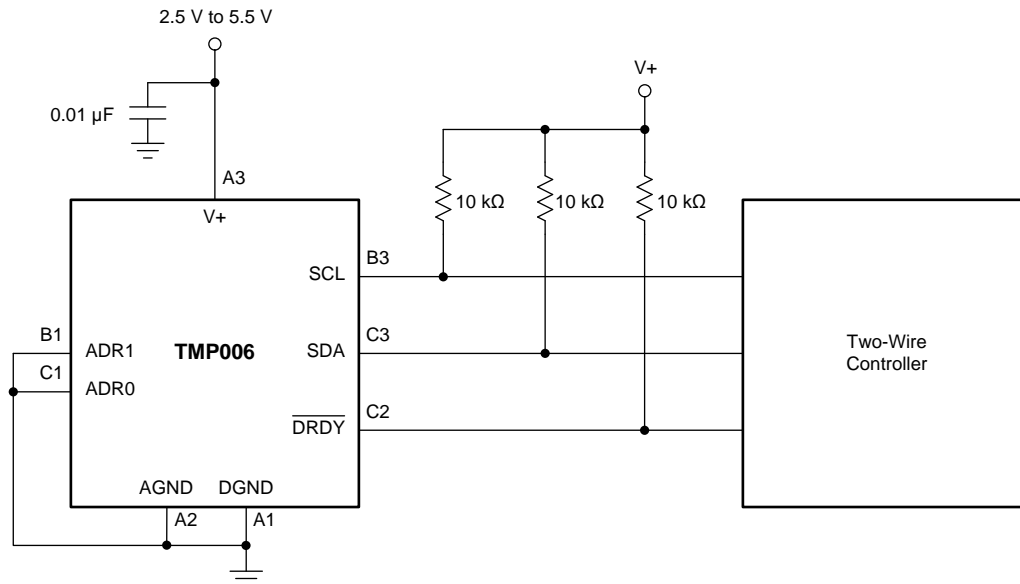


图 19. Typical Application Circuit

Typical Application (接下页)

9.2.1.1 Design Requirements

For this application, the system must operate over the environment described in 表 8.

表 8. Wide-Range Parameters

DESIGN PARAMETER	EXAMPLE VALUE	COMMENT
N	32	Number of devices in calibration set
Minimum T _{DIE}	0°C	Minimum expected die temperature
Maximum T _{DIE}	60°C	Maximum expected die temperature
Minimum T _{OBJ}	0°C	Minimum expected object temperature
Maximum T _{OBJ}	60°C	Maximum expected object temperature
ε	0.95	Object emissivity
Field of view	110°	Field of view subtended by object
Conversion rate	1 sample/second	

Select a set of values for T_{DIE} and T_{OBJ} to generate the calibration set. At a minimum, include the four extreme points of the temperature ranges desired. In practice, it is best to include a number of intermediate points as well. This example uses the values shown in 表 9, with an X marking the values chosen for measurement.

表 9. Wide-Range Measurement Values

T _{OBJ}	T _{DIE}			
	0°C	20°C	40°C	60°C
0°C	X	X	X	X
20°C	X	X	X	X
40°C	X	X	X	X
60°C	X	X	X	X

9.2.1.2 Detailed Design Procedure

Before attempting to calibrate the system, it is necessary to establish the stability of the system. Noise is a measure of precision, which is the random deviation from the mean of the distribution. For a Gaussian (or normal) distribution, the precision is typically characterized by the standard deviation (sensor noise), σ.

9.2.1.2.1 Wide-Range Calibration

To begin calibration, select an object temperature (T_{OBJ}) and a value for the die temperature (T_{DIE}). With these system temperatures stable, take a statistically significant number of samples of V_{Sensor} (results shown in register 00h).

In this example, 64 samples were taken.

To compensate for first order drift in system temperatures, it is often useful to normalize the data set. For this purpose, for each temperature set, the sensor voltage data (given in register 00h) is normalized by first finding the best fit line of the form shown in 公式 9:

$$\text{Sensor (mV)} = a \times \text{SampleNo} + b \quad (9)$$

The normalized data for each data set is then calculated as shown in 公式 10:

$$\text{Sensor}_{\text{NORM}} \text{ (mV)} = \text{Sensor}_{\text{MEAS}} - (a \times \text{SampleNo} + b) \quad (10)$$

The normalized data, V_{Sensor_norm}, is centered on zero mean, and is first-order corrected for long-term drift. The standard deviation for each data set is then calculated to estimate the sensor noise, σ. Verify that the data are limited by white noise and no other effects. For a sensor-noise-limited data set, v_{SENSOR} σ is typically < 1 μV, and preferably < 0.5 μV after first-order correction for drift, as described previously. If this condition is not satisfied, then the calibration accuracy is limited by external system factors (for example, convection or conduction). Repeat this process for each combination of T_{OBJ} and T_{DIE} for which the calibration is to be performed. The normalized data are used only for evaluating the suitability of the data set for calibration, and not for the actual calibration itself.

For calibration, the mean value, $\langle V_{\text{SENSOR}} \rangle$, is calculated for each combination of T_{OBJ} and T_{DIE} , as shown in [表 10](#). Using the mean value minimizes error introduced by random noise. Based on the means, a set of coefficients is generated based on a user-selected optimization criteria for [公式 7](#). Common criteria are minimizing the maximum error, minimizing the average error, and so on. For a detailed discussion of optimization methods, see user guide [SBOU142, TMP007 Calibration Guide](#).

表 10. Mean Values

T_{OBJ}	T_{DIE}			
	0°C	20°C	40°C	60°C
0°C	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$
20°C	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$
40°C	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$
60°C	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$	$\langle V_{\text{SENSOR}} \rangle$

9.2.1.2.2 Verifying the Calibration

The next step is to use the generated coefficients to verify the calibration, and determine the accuracy of the system. For common calibration (C), the same coefficients are used for all devices; in unit calibration (U) the coefficients are calculated for each device. Common calibration includes device-to-device variation, and thus is less accurate, but much easier to implement. Unit calibration is more accurate, and eliminates device variation, but requires more effort to implement. The choice depends on the application requirements for accuracy versus implementation effort.

Mean calibration error at each point is defined as shown in [公式 11](#):

$$E_{\text{MEAN}} = \frac{1}{N} \sum_1^N (T_{\text{OBJ_PREDICT}} - T_{\text{OBJ_ACTUAL}})$$

where

- $T_{\text{OBJ_PREDICT}}$ is the temperature based on the calibration coefficients.
- $T_{\text{OBJ_ACTUAL}}$ is the known object temperature, measured independently.
- N is the number of devices in the calibration set. (11)

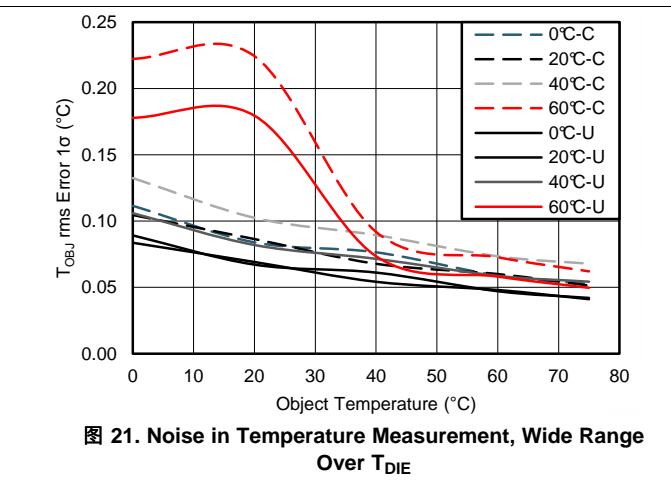
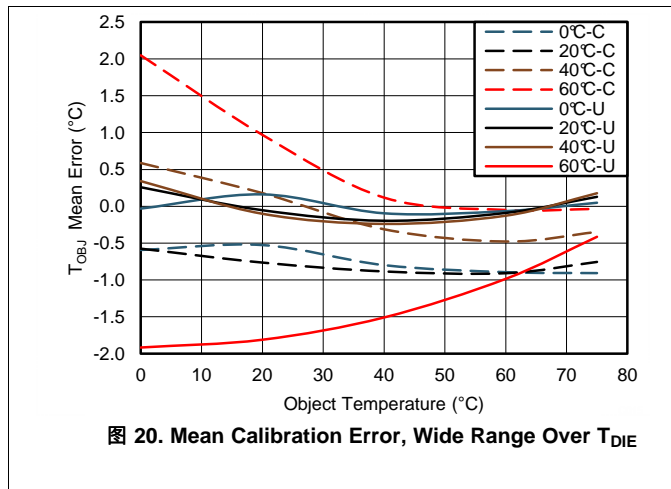
The mean error graph (see [图 20](#)) provides an efficient method of understanding how the systematic errors vary across the temperature ranges of interest. This graph also provides a means of weighing the benefits and efforts of common versus unit calibration for a particular application.

Note that calibration does not affect the temporal random noise observed, as shown in [图 21](#). The standard deviation of the temperature error is independent of the calibration if the random error is dominated by the sensor noise and not external system factors, such as convection and conduction. For common calibration, the total standard deviation increases because of the effects of device-to-device variation. This standard deviation is calculated in the usual way, by substituting $T_{\text{OBJ_PREDICT}}$ for the mean in the standard deviation formula.

The accuracy is then defined as the mean calibration error plus the random errors from all sources. For this example application, use the criteria shown in [公式 12](#):

$$\text{Accuracy} = \text{Mean Calibration Error} \pm 3 \text{ Standard Deviations} \quad (12)$$

9.2.1.3 Application Curves



9.3 System Examples

9.3.1 Use of NEP, NETD, and Responsivity in Estimating System Performance

It is often necessary to estimate system performance as part of the design process. A key system parameter is temperature accuracy for a given set of parameters. 表 11 lists example parameters for estimating system performance.

表 11. Estimating System Performance Parameters

DESIGN PARAMETER	EXAMPLE VALUE	COMMENT
Object distance	10 mm	Distance to object
Object diameter	15 mm	Object size and geometry
ϵ	0.95	Object emissivity
T _{DIE}	23°C	Die temperature
T _{OBJ}	30°C	Maximum expected object temperature
FOV	110°	Field of view subtended by object
Responsivity (R ₀)	10.8 V/W	Responsivity for T _{DIE} = 25°C, $\theta = 0^\circ$
Responsivity (R)	9 V/W	Responsivity for 110° FOV
Sensor rms noise	0.20 μ V	RMS sensor noise at T _{DIE} = 25°C
NEP	30 nW	Thermal power equivalent to rms sensor noise
Conversion rate	1 SPS	SPS = samples per second

The system accuracy is a function of T_{OBJ}, T_{DIE}, ϵ , and radiation transfer.

The radiation transfer factor is system dependent, and is affected by the object distance and geometry (for example, planar versus curved surfaces, or presence of lenses). For an planar object perpendicular to the detector axis (see 图 7), the radiation transfer follows the well-known $\sin^2(\theta)$ result. This expression can be used with a radiation transfer function responsivity value of 9 V/W to estimate system performance.

Because of the angular dependence of the TMP006 and TMP006B detector response, a more accurate representation for the same radiative transfer function geometry is shown in 公式 13:

$$\frac{2}{3}(1 - \cos^3\theta)R_0$$

where

- R₀ is the responsivity of the detector to a point source at an angle normal to the detector ($\theta = 0$ in 图 7. R₀ has a value of ~10.8 V/W at 25°C. (13)

The responsivity value of 9 V/W is based on a system with a 110° FOV.

Using the device-specific radiation transfer expression and R_0 , the detector response is shown in [公式 14](#):

$$V_{\text{SENSOR}} = \frac{2}{3} \varepsilon_{\text{OBJ}} \sigma_B (T_{\text{OBJ}}^4 - T_{\text{DIE}}^4) A_{\text{det}} (1 - \cos^3 \theta) R_0$$

where

- ε_{OBJ} is the emissivity of the object (0.95).
- B is the Stefan-Boltzmann constant ($5.67 \times 10^{-12} \text{ W/cm}_2 / \text{K}^4$).
- T_{OBJ} is the object temperature (273 K + 30°C).
- T_{DIE} is the detector temperature (273 K + 23°C).
- A_{det} is the detector active area ($1.09 \times 10^{-3} \text{ cm}^2$)
- θ is the half-angle subtended by the object as viewed from the detector.
- R_0 is the responsivity ($\sim 10.8 \text{ V/W}$ for the specified temperatures).

(14)

The value of $\cos \theta$ is shown in [公式 15](#):

$$\cos \theta = \frac{2r}{\sqrt{4r^2 + D^2}} = 0.800$$

where

- r is the distance between the detector and the object (10 mm).
- D is the diameter of the object (15 mm).

(15)

Differentiating with respect to object temperature, a small change in temperature creates a small change in the measured voltage given by [公式 16](#):

$$\Delta V_{\text{OUT}} = \frac{8}{3} \varepsilon_{\text{OBJ}} \sigma_B T_{\text{OBJ}}^3 A_{\text{det}} (1 - \cos^3 \theta) R_0 \Delta T_{\text{OBJ}}$$

(16)

Substituting values for the parameters yields [公式 17](#):

$$\Delta V_{\text{SENSOR}} = 2.3 \frac{\mu\text{V}}{\text{K}} \times T_{\text{OBJ}}$$

(17)

The sensor rms noise at $T_{\text{DIE}} = 25^\circ\text{C}$ is $\sim 0.25 \mu\text{V}$; thus, the rms variation in temperature measurement is as shown in [公式 18](#):

$$\Delta T_{\text{OBJ}} = \frac{\text{Sensor}_{\text{rms noise}}}{\Delta V_{\text{OUT}}} = \frac{0.25 \mu\text{V}}{2.3 \mu\text{V/K}} \approx 110 \text{ mK}$$

(18)

The peak-to-peak noise is approximately six times the rms noise; therefore, estimate an accuracy of approximately $\pm 0.33^\circ\text{C}$.

This estimate can also be made using the noise-equivalent power (NEP), noting that NEP is the ratio of noise to responsivity, as shown in [公式 19](#):

$$\text{NEP} = \frac{\Delta V_{\text{OUT}}}{R_0} = \frac{8}{3} \varepsilon_{\text{OBJ}} \sigma_B T_{\text{OBJ}}^3 A_{\text{det}} (1 - \cos^3 \theta) \Delta T_{\text{OBJ}} = \left(213 \frac{\text{nW}}{\text{K}} \right) \Delta T_{\text{OBJ}}$$

(19)

Assuming the system is sensor-noise limited, the NEP is $\sim 30 \text{ nW}$ at 25°C , as shown in [公式 20](#):

$$\Delta T_{\text{OBJ}} = \frac{30 \text{ nW}}{213 \text{ nW/K}} \approx 140 \text{ mK}$$

(20)

Again, the peak-to-peak noise is approximately 6X the rms noise; therefore estimate an accuracy of approximately $\pm 0.42^\circ\text{C}$.

The different results from these two techniques is because of estimated values used for some parameters. The purpose of these techniques is not to obtain exact answers, but rather to quickly estimate the feasibility of a system implementation based on basic system parameters. These examples are intended only as guidelines; the specific values for the parameters depend on the specific system details.

10 Power-Supply Recommendations

The TMP006 and TMP006B are designed to operate with a power supply voltage (V_S) of between 2.5 V and 5.5 V. This input supply must be well regulated. The die temperature measurement (T_{DIE}) dependence on supply voltage is typically 20 m°C/V for $T_{DIE} > 0^\circ\text{C}$. The power-on reset (POR) has a nominal value of 1.9 V at $T_{DIE} = 25^\circ\text{C}$. The POR increases with decreasing die temperature. Place the decoupling capacitor (0.01 μF recommended) as close as possible to the device without obstructing the field of view.

11 Layout

11.1 Layout Guidelines

The IR thermopile sensor in the TMP006 and TMP006B is as susceptible to conducted and radiant IR energy from below the sensor on the PCB as it is to the IR energy from objects in its forward-looking field of view. When the area of PCB below the TMP006 or TMP006B is at the same temperature as the die or substrate of the TMP006 or TMP006B, heat is not transferred between the IR sensor and the PCB. However, temperature changes on a closely-placed target object or other events that lead to changes in system temperature can cause the PCB temperature and the TMP006 or TMP006B temperature to drift apart from each other. This drift in temperatures can cause a heat transfer between the IR sensor and the PCB to occur. Because of the small distance between the PCB and the bottom of the sensor, this heat energy will be conducted (as opposed to radiated) through the thin layer of air between the IR sensor and the PCB below it. This heat conduction causes offsets in the IR sensor voltage readings and ultimately leads to temperature calculation errors. To prevent and minimize these errors, the TMP006 and TMP006B layouts must address critical factors:

Thermally isolate the TMP006 and TMP006B from the rest of the PCB and any heat sources on it. Provide a stable thermal environment to reduce the noise in the measurement readings

图 22 illustrates the concept of thermally isolating the TMP006 and TMP006B from the PCB and external heat sources such as other components, air currents, and so on.

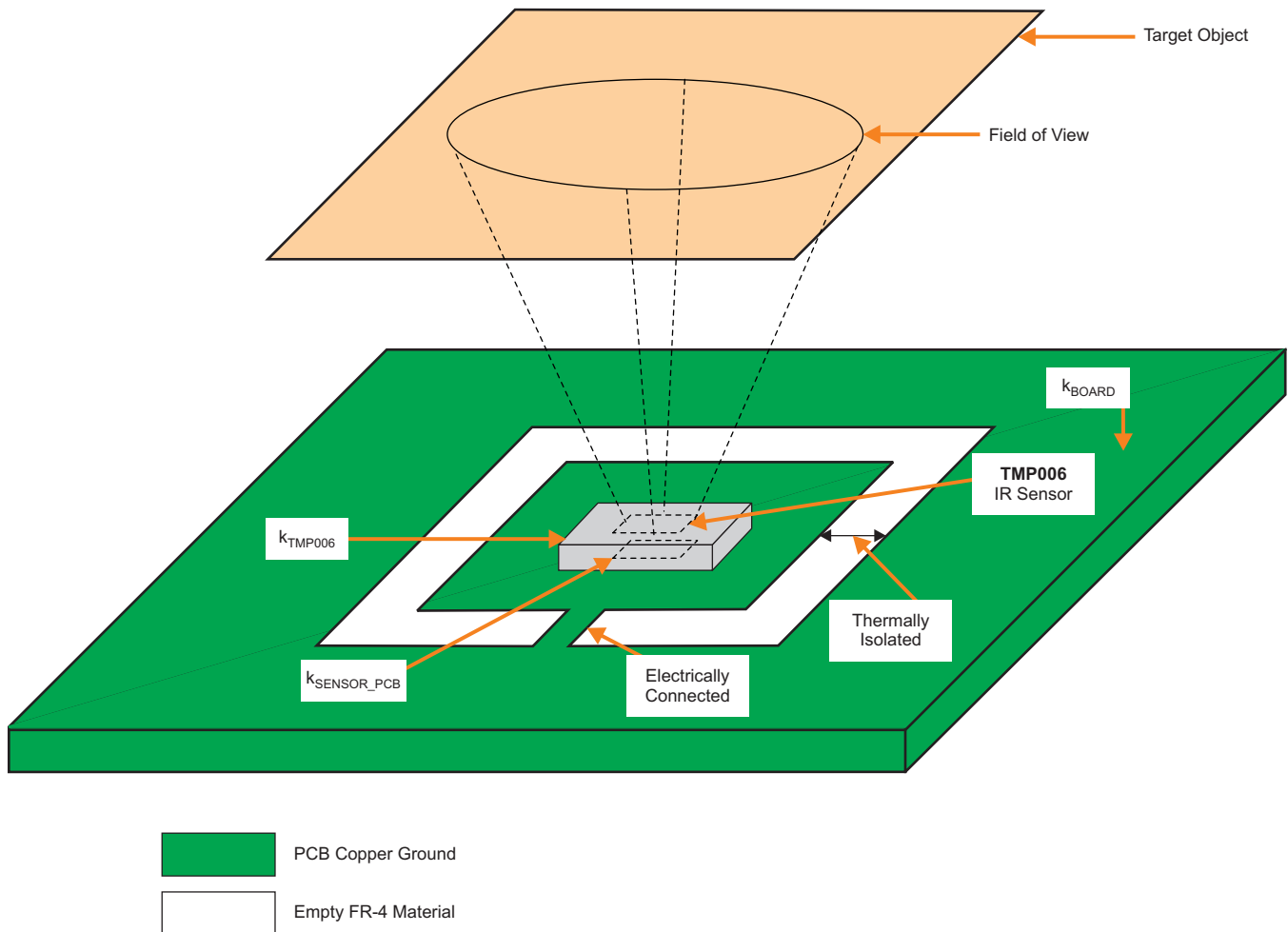


图 22. Principle of TMP006 and TMP006B Thermal Isolation

11.2 Layout Examples

For more detailed information, refer to [SBOU108](#) — *TMP006 Layout and Assembly Guidelines*.

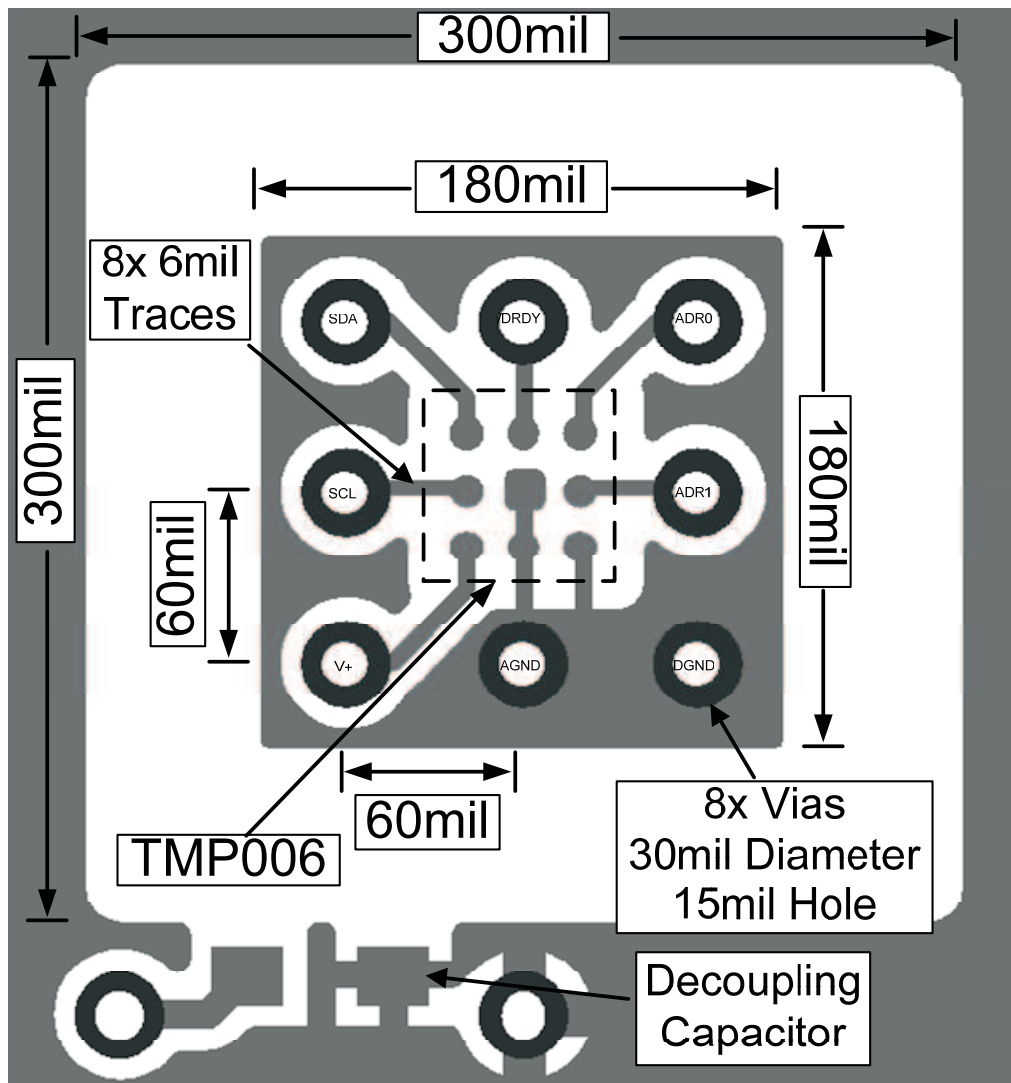


图 23. Top Layer

Layout Examples (接下页)

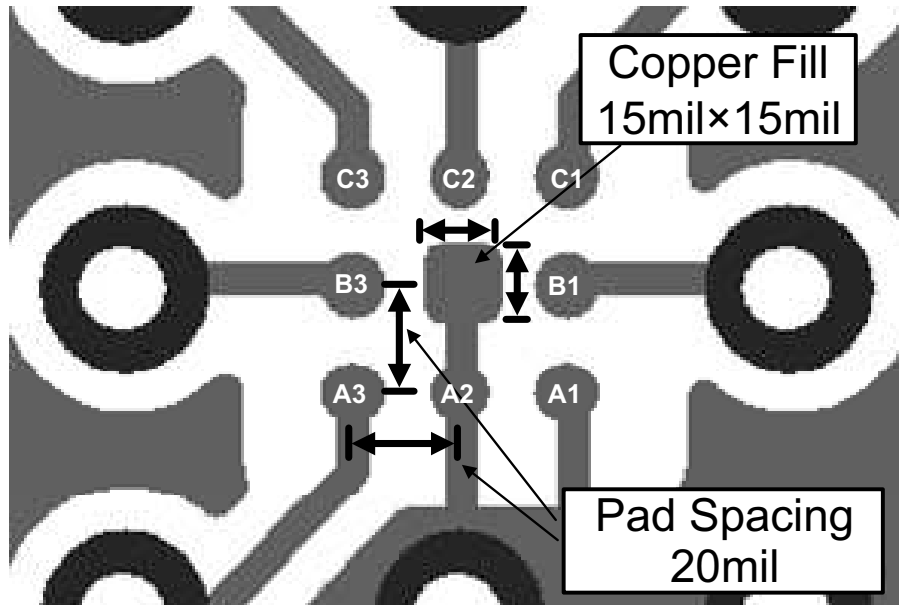


图 24. Enlarged View

Use a 12-mil pad and 15-mil solder balls for A1, A2, A3, B1, B3, C1, C2 and C3.

Layout Examples (接下页)

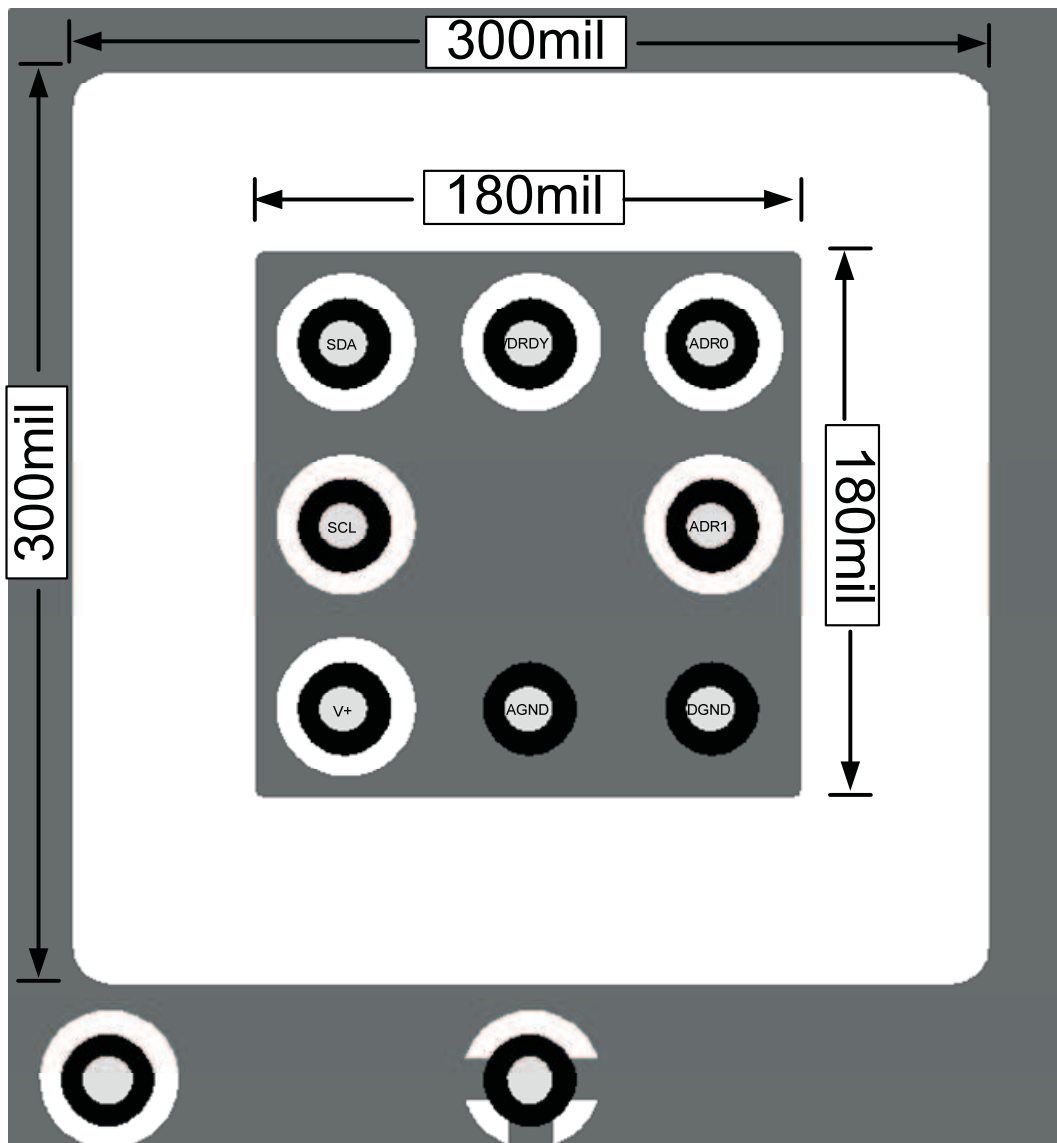


图 25. Bottom Layer

12 器件和文档支持

12.1 器件支持

12.1.1 器件命名规则

此器件性能由信号、响应度和传感器噪声表示。此传感器噪声可由原始传感器电压表示，或者由具有已知光传递函数的基准系统表示。

响应度 一个电压测量值由热电堆生成成为器件上热辐射入射的一个函数。响应度测量单位 V/W。通常情况下，入射辐射单位 μW ，而传感器输出电压单位为 μV 。

传感器噪声 此噪声电压是传感器的固有电压，单位 nV。这个参数取决于转换时间。

噪声等效功率 (NEP) 检测器确实能够检测出的最小热功率差；测量单位 nW。NEP 是传感器噪声和响应度的函数。

噪声等效温度差 (NETD) 检测器确实能够检测出的最小温度差；测量单位 mK。NETD 是传感器噪声、响应度和系统特定光路径的函数。

为了进行比较，NETD 被指定给没有透镜的基准系统，以及具有一个理想（非吸收）F/1 透镜的基准系统。

12.2 文档支持

12.2.1 相关文档

《TMP007 校准指南》，[SBOU142](#)。

《TMP006 布局和组装准则》，[SBOU108](#)。

12.3 相关链接

表 12 列出了快速访问链接。范围包括技术文档、支持与社区资源、工具和软件，并且可以快速访问样片或购买链接。

表 12. 相关链接

器件	产品文件夹	样片与购买	技术文档	工具与软件	支持与社区
TMP006	请单击此处	请单击此处	请单击此处	请单击此处	请单击此处
TMP006B	请单击此处	请单击此处	请单击此处	请单击此处	请单击此处

12.4 商标

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12.5 静电放电警告



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ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

12.6 术语表

[SLYZ022](#) — TI 术语表。

这份术语表列出并解释术语、首字母缩略词和定义。

13 机械、封装和可订购信息

以下页中包括机械、封装和可订购信息。这些信息是针对指定器件可提供的最新数据。这些数据会在无通知且不对本文档进行修订的情况下发生改变。欲获得该数据表的浏览器版本，请查阅左侧的导航栏。

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TMP006BIYZFR	OBSOLETE	DSBGA	YZF	8		TBD	Call TI	Call TI		T006B	
TMP006BIYZFT	OBSOLETE	DSBGA	YZF	8		TBD	Call TI	Call TI		T006B	

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device 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 Device Marking for that device.

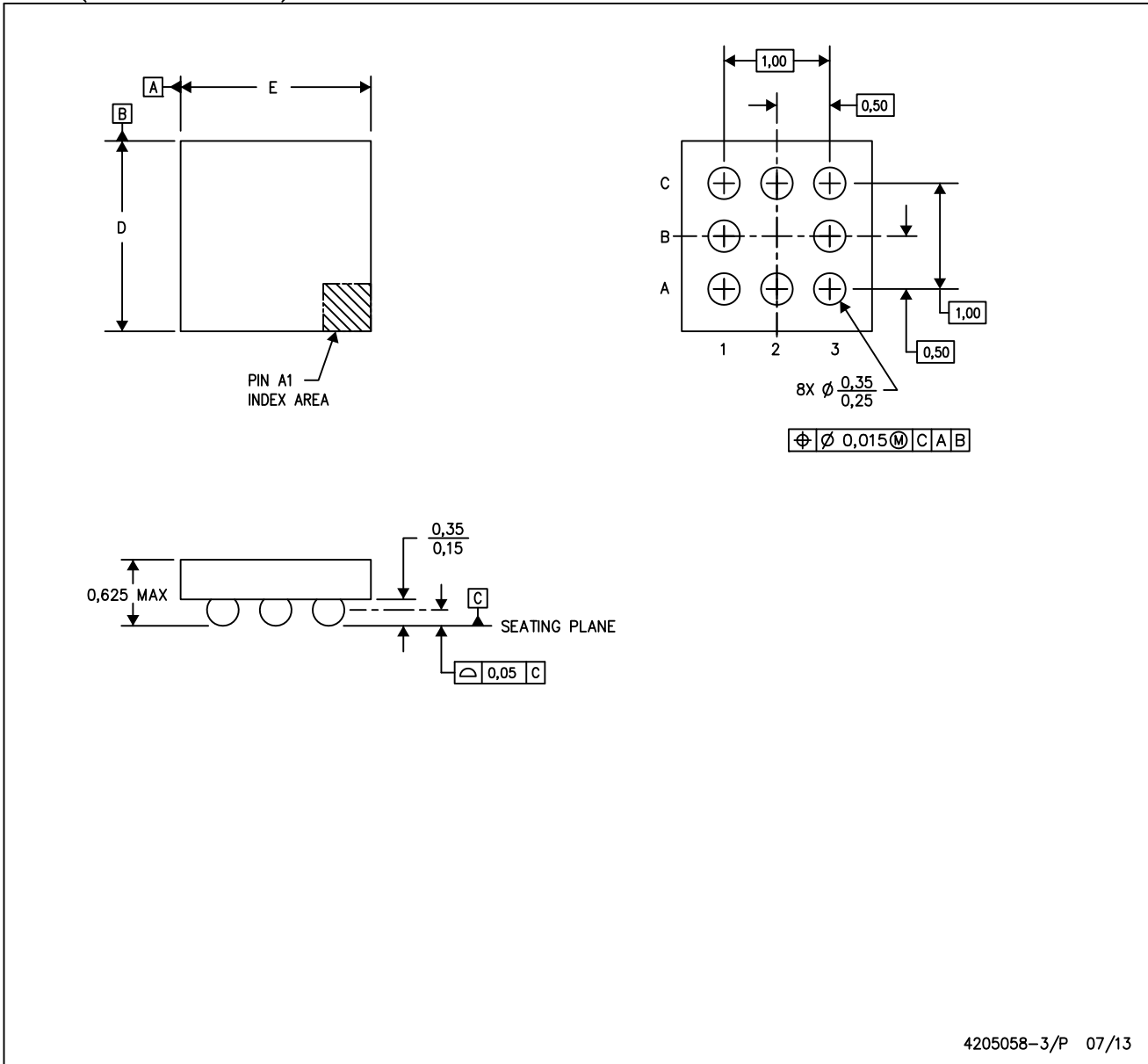
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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YZF (S-XBGA-N8)

DIE-SIZE BALL GRID ARRAY



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - C. NanoFree™ package configuration.

NanoFree is a trademark of Texas Instruments.

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