Datasheet	Rev. 1.05

MVT3000D Series
High Performance Digital Temperature Sensor

General Description

[Patents protected & patents pending]

MEMS Vision's temperature sensors are built by combining the company's revolutionary MoSiC™ technology with its extensive ASIC design experience. This combination enables high levels of performance, such as fast temperature measurements and high accuracy.

The technology also offers a very robust proprietary sensor-level protection, ensuring excellent stability against aging and harsh environmental conditions such as shock and volatile chemicals.

The highly miniaturized smart sensors are fully calibrated and provide standard digital I^{2}C outputs to enable plug-and-play integration. The output temperature resolution can be programmed for maximum flexibility and to minimize power consumption, depending on the application and operating conditions.

The micro-Watt levels of power consumption of these sensors make them the ideal choice for portable and remote applications.

MEMS Vision's temperature sensors offer the industry's most competitive performance-to-price value, for a wide range of applications and end users.

Features

Fast response time
- Down to 2 seconds time constant

High accuracy
- Temperature (MVT3001D): ±0.2°C typ. (-10 – 80°C)
Wide operating Range: -40 - 125°C

Configurable resolution
- 8, 10, 12 or 14 bits

Fully compliant I^{2}C interface

Extended supply voltage range of 1.8V – 5.5V

Very low power consumption
- 1.0 µA avg. current at one temperature meas. per second (8-bit res., 1.8V supply)

Small form factor for use in compact systems
- 3 × 2.4 × 0.8 mm DFN-style LGA package

User Benefits

- Long Term Stability and Reliability: Proprietary sensing structures and protection technology, robust biasing circuitry, and self-diagnosis algorithms ensure accurate and repeatable measurements.

- Digital Output: Allows for native interfacing with embedded system components such as off-the-shelf micro-controllers or FPGAs.

- Fully Calibrated System: Built-in digital sensor calibration ensures high accuracy measurements and linear behavior under varying sensing environments.

Applications

The MVT3000D series is ideal for use in environmental sensing for the consumer electronics, automotive, industrial, agricultural and other sectors. Some application examples include:

OEM products	Battery-powered systems	Smart phones and tablets
Instrumentation	Drying	HVAC systems
Medical equipment	Meteorology	Building automation
White goods	Refrigeration equipment	Data logging

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MVT3000D Series Datasheet

Table of Contents

List of Tables

List of Figures

Experts on Design-In

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Sensors and Power

MVT3000D Series Datasheet

1- Pin Configuration
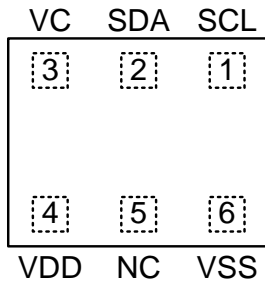

Fig. 1: Diagram of pin configuration (top view).
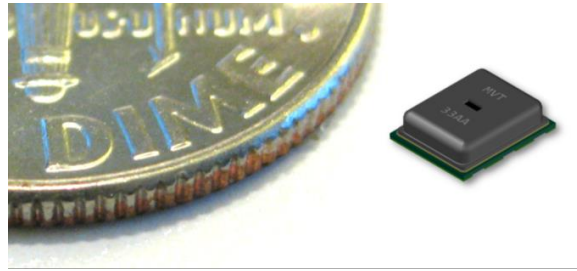
Fig. 2: DFN-style LGA package.

2- Pin Assignment and Connection Diagram

Table 1: Pin assignment.

Pin	Name	Function
1	SCL[1]	I^2C clock (up to 400 kHz)
2	SDA[1]	I^2C data
3	VC	A 0.1 µF decoupling capacitor[2]
4	VDD	Positive supply
5	NC	No connect
6	VSS	Negative supply or ground

[1]Requires a 2.2 kΩ pull-up resistor.
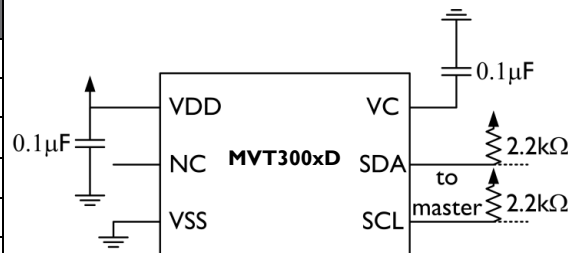[2]This capacitor may not be needed for all applications. Please contact MEMS Vision for details.

Fig. 3: Connection diagram.

3- Functional Description

The MVT3000D series is a fully digital sensor which accurately measures temperature levels.

An analog-to-digital converter (ADC) with a configurable resolution is interfaced with a highly accurate sensor in order to allow for the measurement of temperature. High precision biasing and clock generation ensures stable operation over a wide temperature range. The sensor can be used to measure the ambient temperature in real-time or be used for data-logging, and can interface with any I^2C compliant system for digital transmission of the acquired data.

Calibration data and compensation logic are integrated within the system, such that the chip does not require any user calibration, and is readily compensated for accurate operation over a wide range of temperature levels.
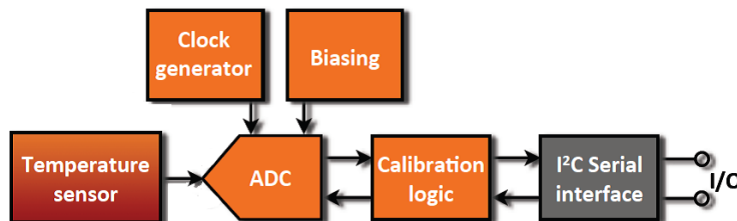

Fig. 4: MVT3000D series functional diagram.

MVT3000D Series Datasheet

4- Chip Performance Summary

Table 2: MVT3000D Series Specifications.

At T_A = +25°C, V_{DD} = +1.8 V to +5.5 V unless otherwise noted.

PARAMETER		CONDITION	MIN	TYP	MAX	UNITS
TEMPERATURE SENSOR						
Range			-40		125	°C
Accuracy Tolerance[3]	MVT3001D	-10°C to 80°C		±0.2	±0.3	°C
	MVT3004D	0°C to 70°C		±0.3	±0.5	
Resolution		8 bits	0.6	0.9	1.5	°C
		14 bits	0.01	0.015	0.025	
Response Time Constant[4] (τ_T)				> 2		sec.
Aging					0.02	°C/yr
Supply Voltage Dependency[5]		VDD>2.8 V		0.03	0.1	°C/V
		1.8 V<VDD<2.8 V		1.25	2.25	
CHIP TEMPERATURE RANGE						
Operating Range			-40		125	°C
Storage Range			-55		150	°C
MEASUREMENT TIME						
Wake-up Time				0.10		ms
8 bits Resolution		Including digital compensation		1.10		
10 bits Resolution				1.86		
12 bits Resolution				5.05		
14 bits Resolution				17.45		

[3]See Fig. 6 for more details.

[4]From initial value to 63% of total variation. Response time depends on system thermal mass and air flow.

[5]Sensor accuracy can be optimized for application-specific supply voltages upon request.

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MVT3000D Series Datasheet

Table 2 (cont'd): MVT3000D Series Specifications

PARAMETER		CONDITION	MIN	TYP	MAX	UNITS
SLEEP MODE						
Sleep Current[6]	I_{SD}	Chip inactive (-40 to 85°C)		0.6		µA
POWER SUPPLY						
Operating Supply Voltage	V_{DD}		1.8	3.3	5.5	V
Average Current[7]	I_Q	8 bits resolution one meas./s	1.0	1.5	1.7	µA
		10 bits resolution one meas./s	1.7	2.2	2.3	
		12 bits resolution one meas./s	3.8	4.9	5.0	
		14 bits resolution one meas./s	12.9	15.8	15.9	

[6]See Fig. 5 for more details.
[7]Mininum, typical, and maximum average currents are given at a 1.8V, 3.3V, and 5.5V V_{DD}, respectively.

5- Sleep Current

The sleep current of the MVT3000D series sensors depends on the operating temperature, as shown in Fig. 5. Note that there is no significant dependence of the sleep current on the supply voltage, V_{DD}.
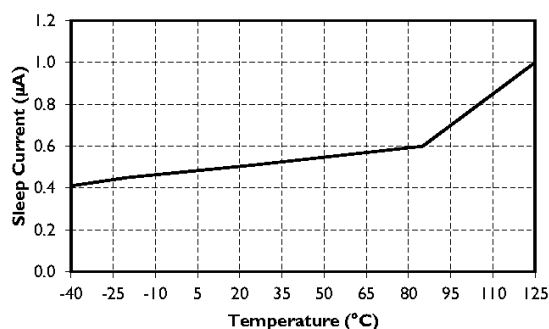

Fig. 5: Sleep current variation over temperature (at V_{DD} = 3.3V).

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MVT3000D Series Datasheet

6- Temperature Tolerances

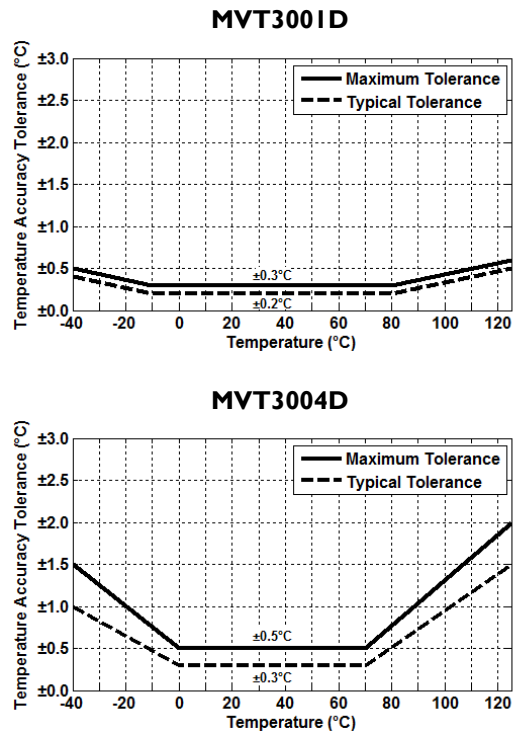The typical and maximum temperature accuracy tolerances for the MVT3000D series sensors are shown in Fig. 6.

Fig. 6: Temperature tolerances.

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Sensors and Power

MVT3000D Series Datasheet

7- User Guide

7.1   Sensor Communications

The MVT3000D series sensor communicates using a standard Inter-IC (I^2C) bus protocol. To accommodate multiple devices, the protocol uses two bi-directional open-drain lines: a Serial Data Line (SDA) and a Serial Clock Line (SCL). Because these are open-drain lines, pull-up resistors to VDD must be provided as shown in Fig. 7. Several slave devices can share the I^2C bus, but only one master device can be present on the line.
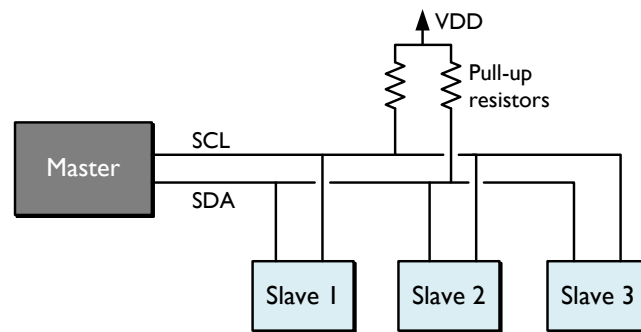

Fig. 7: Diagram of an I^2C interconnect with one master and three slave devices.

Each transmission is initiated when the master sends a '0' start bit (S), and the transmission is terminated when the master sends a '1' stop bit (P). ***These bits are exclusively transmitted while the SCL line is high.*** The waveforms corresponding to these conditions are illustrated in Fig. 8.
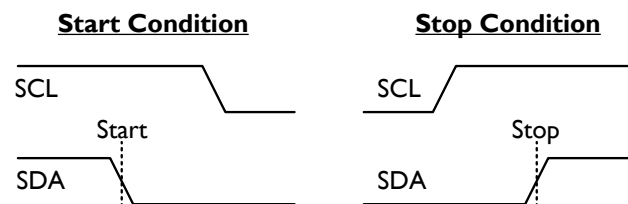

Fig. 8: I^2C bus start and stop conditions.

Once the start condition has been set, the SCL line is toggled at the prescribed data-rate, clocking subsequent data transfers. Data on the SDA line is always sampled on the rising edge of the SCL line and must remain stable while SCL is high to prevent false Start or Stop conditions (see Fig. 8).

Following the start bit, address bits set the device targeted for communications, and a read/write bit indicates the transfer direction of any subsequent data. The master sends the unique 7-bit address of the desired device and a read/write bit set to '1' to indicate a read from slave to master, or to '0' to indicate a write from master to slave. All transfers consist of eight data bits and one response bit set to '0' for Acknowledge (ACK) or '1' for Not Acknowledge (NACK). After the acknowledge signal is received another data byte can be transferred, or the communication can be stopped with a stop bit.

The MVT3000D series sensor operates as a slave on the I^2C bus, and supports data rates of up to 400 kHz in accordance with the I^2C protocol. The default address of the sensor is 0x44. Custom I^2C addresses can be provided upon request (please contact support@mems-vision.com for details). The sensor can be interfaced with any I^2C master such as a microcontroller, and the master is responsible for generating the SCL signal for all communications with the MVT3000D series sensor.

MVT3000D Series Datasheet

The official I²C-bus specification and user manual documentation can be found at:
http://www.nxp.com/documents/user_manual/UM10204.pdf.

7.2   Performing Measurements with the MVT3000D Series

A measurement sequence consists of two steps, as illustrated in Fig. 9:

1. Wake up the MVT3000D series sensor from its sleep mode and initiate a measurement sequence by sending its I²C address and a write bit.

2. Once the temperature measurements are completed by the MVT3000D series chip, read the results by sending the I²C address of the sensor and a read bit. The sensor will then transmit the temperature data on the bus for the master to capture.
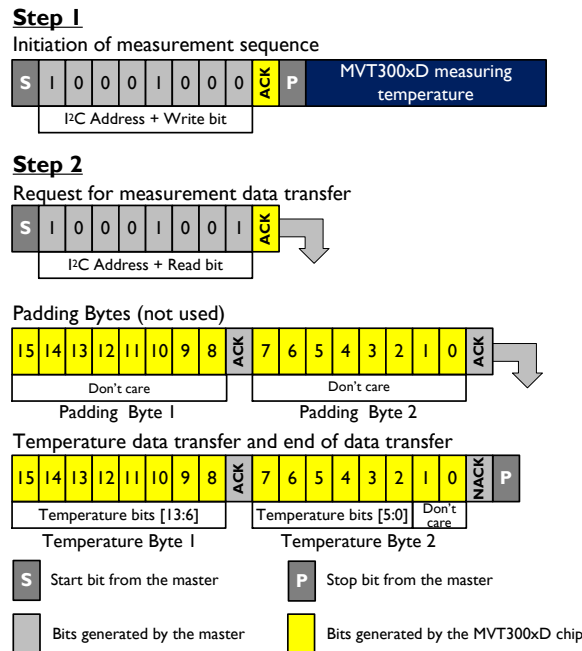

Fig. 9: Temperature measurement sequence.

The entire output from the MVT3000D series sensor is 4 bytes, with the 2 initially transmitted bytes being padding bytes which are not used (don't cares), and the latter 2 bytes being the temperature value bytes. The most significant bits of the temperature reading are first (Temperature byte 1) and are followed by the least significant bits (Temperature byte 2). The last two temperature bits ("don't care" bits) do not contain measurement data and should be discarded. As such, the temperature measurements are always scaled to 14-bits regardless of the selected resolution of the sensor. The temperature (in degrees Celsius) is obtained as follows:

$$\text{Temperature } [^\circ C] = \frac{\text{Temperature}[13:0]}{2^{14}-1} \times 165 - 40$$

Alternatively, if only 8-bit resolution is desired for the temperature output, the read can be terminated after the 2nd byte by issuing a NACK followed by a stop bit. The measurement time depends on the configured sensor resolution. Table 3 lists examples for different temperature resolution settings. For this calculation, the measurement times in Table 2 should be used, along with the 0.1 ms wake-up time. For example, a 12-bit temperature measurement results in a total measurement time of:

0.1 ms +5.05 ms = 5.15ms.

MVT3000D Series Datasheet

Table 3: Measurement times (including wake-up time) at different resolution settings.

Resolution (bits)	Measurement time (ms)
8	1.20
10	1.96
12	5.15
14	17.55

7.3   Accessing the Sensor Non-volatile Memory

The MVT3000D series non-volatile memory stores its measurement resolution setting and its ID number. To change the sensor resolution or read the ID number, the master must place the MVT3000D series chip into programming mode while the chip is powering up. Figure 10 shows the sequence of commands needed to enter the programming mode, which must be sent within 10 ms after applying power to the sensor. The master must send the I^{2}C address and a Write bit followed by the command 0xA0|0x00|0x00.
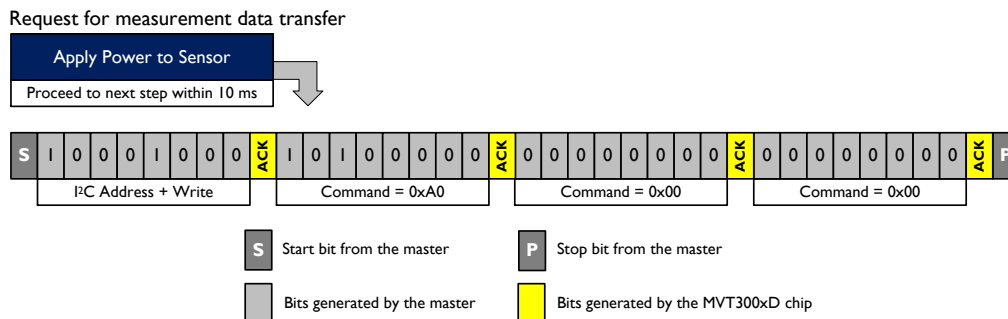

Fig. 10: Sequence of commands to enter the programming mode.

This command takes 120 μs to process, after which the master has access to the non-volatile memory registers listed in Table 4. All of these registers are 16 bits wide.

To return to normal sensor operation and perform measurements, the master must send the I^{2}C address and a Write bit, followed by the command: 0x80|0x00|0x00.

Table 4: Non-volatile memory registers.

Address	Register Description
0x11	Temperature Sensor Resolution – Read Register (bits [11:10])
0x51	Temperature Sensor Resolution – Write Register (bits [11:10])
0x1E	Read Sensor ID – Upper 2 bytes
0x1F	Read Sensor ID – Lower 2 bytes

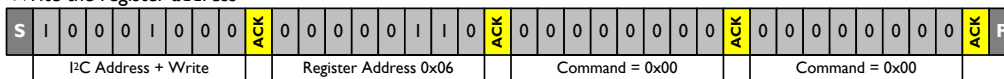### 7.3.1   Setting the Measurement Resolution

The MVT3000D series temperature measurement resolutions can be set to 8, 10, 12, or 14 bits by writing to the non-volatile memory, and are initially set to 14 bits by default. The procedure to set the sensor resolution is illustrated in Fig. 11. The temperature resolution can be read in register 0x11, respectively, or written in registers 0x51. The resolution information is stored in bits [11:10] of these registers, as listed in Table 5. All of the other bits in these registers must be left unchanged. As such,

MVT3000D Series Datasheet

before writing new resolution settings, the contents of the read registers must be read, and only bits [11:10] can be changed in the write registers. Once bits [11:10] are changed to set the desired resolution, the entire register must be written back to the MVT3000D series chip.

Step 1

Write the register address

Step 2

Read the register contents
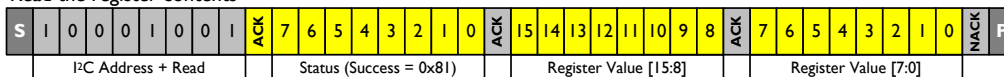
Step 3

Change bits [11:10] of the register to the desired resolution setting, *without changing the other bits*

Step 4

Write the register contents back
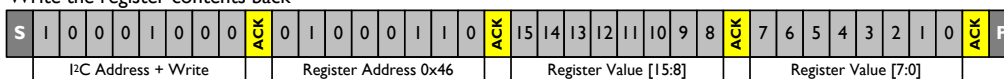
Fig. 11: Sequence of commands to modify the measurement resolution.

Table 5: Register values for different resolution settings.

Resolution register bits [11:10]	Resolution (bits)
00_B	8
01_B	10
10_B	12
11_B	14

The sensor non-volatile memory requires 120 µs to load the data into the registers after step 1, and requires 14 ms to write the data after step 4. *Failure to comply with these processing times may result in data corruption and introduce errors in sensor measurements.*

7.3.2   Reading the Sensor ID Number

The sensor ID is a 32-bit number, and can be read in a similar fashion as illustrated in steps 1 and 2 of Fig. 11, using the appropriate register address values. The ID number is stored in two registers, with the upper and lower 16 bits stored in register addresses 0x1E and 0x1F, respectively.

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MVT3000D Series Datasheet

7.4   I²C Timing Specifications

The timing diagram for all I²C communications is shown in Fig. 12, and the minimum and maximum values for each critical timing parameter (e.g., setup times, hold times) are listed in Table 6.
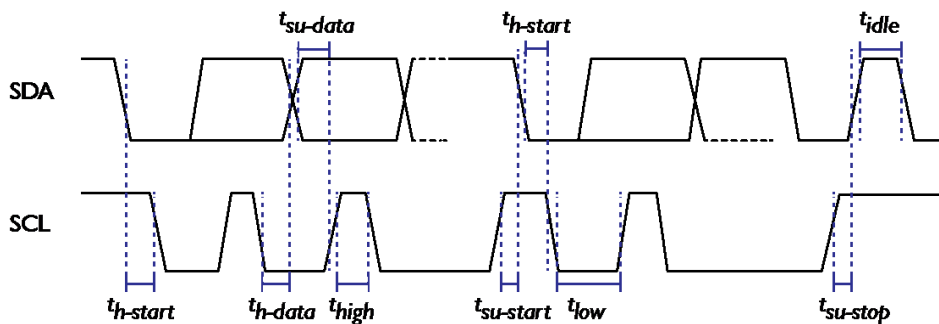

Fig. 12: I²C timing diagram.

Table 6: I²C timing parameters.

Parameter	Symbol	Min	Max	Units
SCL frequency	f_{SCL}	20		kHz
Start bit setup time	$t_{su\text{-}start}$	0.1		µs
Start bit hold time	$t_{h\text{-}start}$	0.1		µs
Minimum SCL low/high widths	$t_{low} \mid t_{high}$	0.6		µs
Data setup time	$t_{su\text{-}data}$	0.1		µs
Data hold time	$t_{h\text{-}data}$	0	0.5	µs
Stop bit setup time	$t_{su\text{-}stop}$	0.1		µs
SDA unused time between stop and start bit	t_{idle}	1		µs

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MVT3000D Series Datasheet

8- Package and PCB Information

The MVT3000D series sensors are packaged in a $3 \times 2.41 \times 0.8$ mm 6-pin dual-flat no-leads (DFN)-style LGA package.

8.1   Package Drawing

The mechanical drawing of the LGA package is shown in Fig. 13, and a suitable land pattern for soldering the sensor to a PCB is shown in Fig. 14.
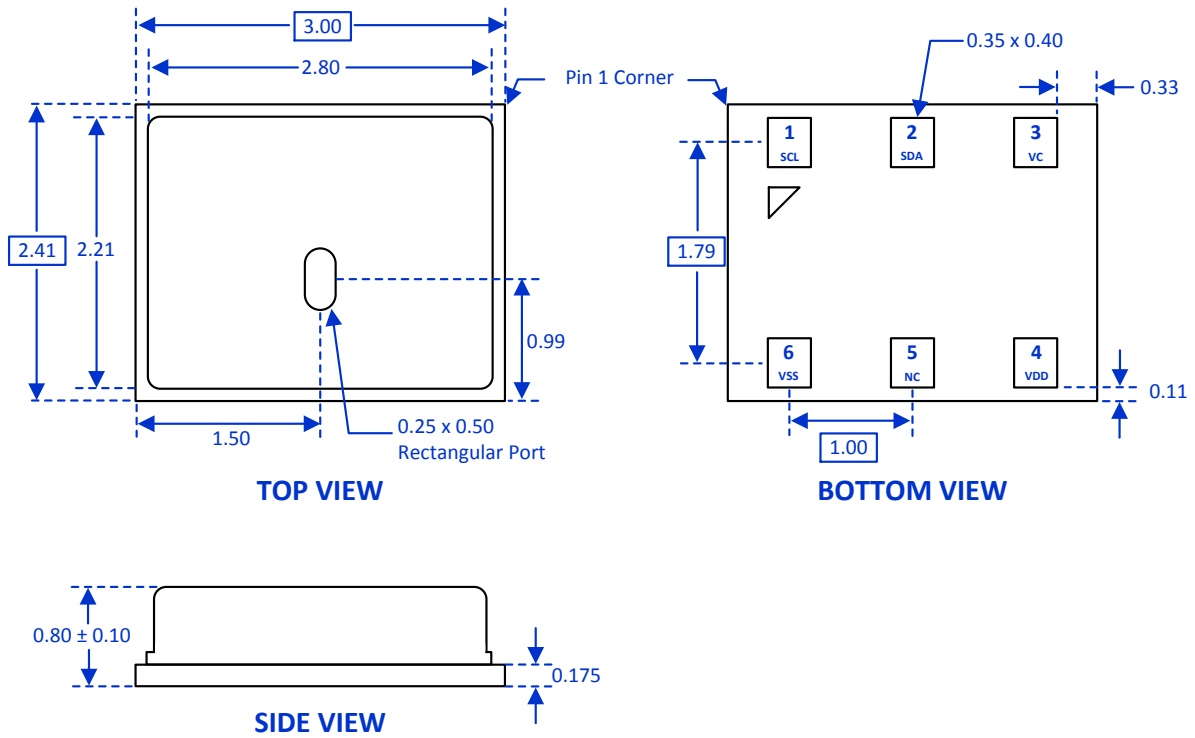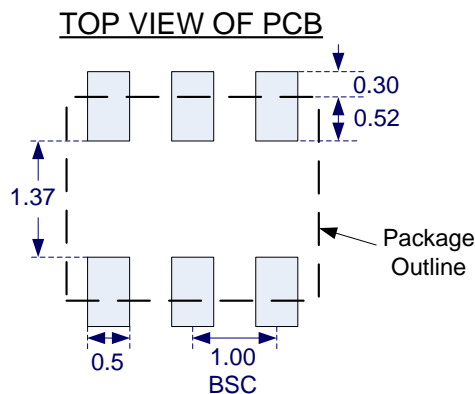

Fig. 13: LGA package drawing.

Fig. 14: LGA package land pattern (top view).

MVT3000D Series Datasheet

8.2   Tape and Reel Information

The MVT3000D series sensors can be shipped in tape and reel packaging, enclosed in sealed anti-static bags. Standard packaging sizes are 400, 1500, and 2500 units (please contact MEMS Vision for other volumes). The tape has a 470mm leader (117 pockets) and a 410mm trailer (103 pockets). A drawing of the packaging tape is shown in Fig. 15, which also shows the sensor orientation.
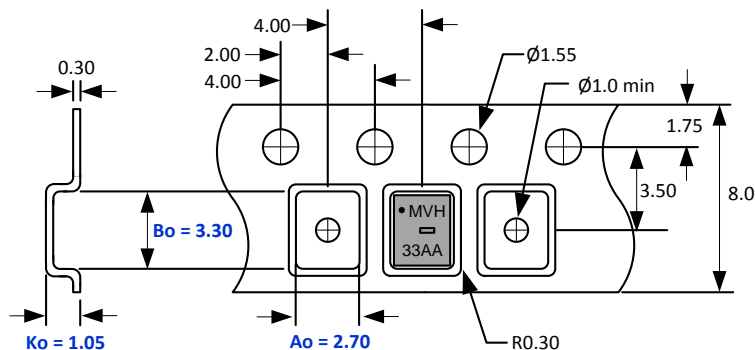
Fig. 15: Packaging tape drawing.

8.3   Soldering Information

Standard reflow ovens can be used to solder the MVT3000D series sensor to the PCB. The peak temperature (T_P) for use with the JEDEC J-STD-020D standard soldering profile is 260°C. For manual soldering, the contact time should be limited to 5 seconds at up to 350°C. In either case, if solder paste is used, it is recommended to use 'no-clean' solder paste to avoid the need to wash the PCB.

Note that reflow soldering is recommended for optimal performance. The recommended lead-free (RoHS compliant) reflow soldering profile is shown in Fig. 16.
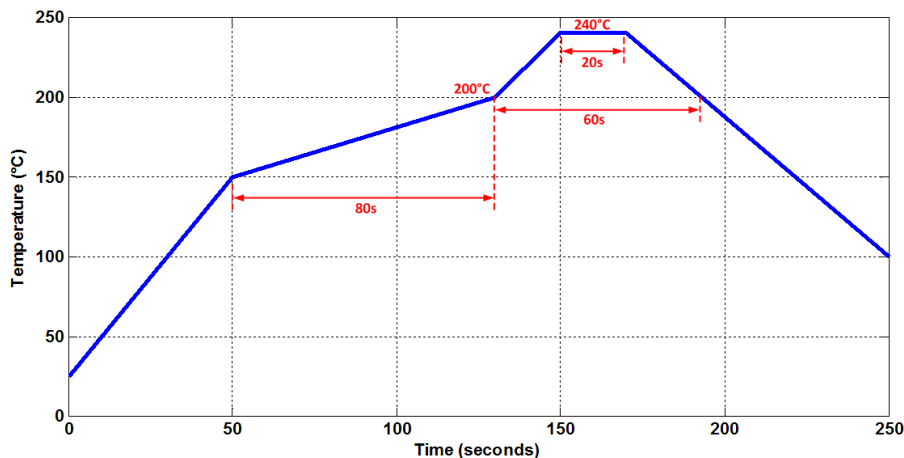

Fig. 16: Recommended lead-free soldering profile

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MVT3000D Series Datasheet

8.4 PCB Layout Considerations

When designing the PCB, undesired heat transfer paths to the MVT3000D series chip must be minimized. Excessive heat from other components on the PCB will result in inaccurate temperature measurements. As such, *solid metal planes for power supplies should be avoided in the vicinity of the sensor* since these will act as thermal conductors. To further reduce the heat transfer from other components on the board, openings can be milled into the PCB as shown in Fig. 17.
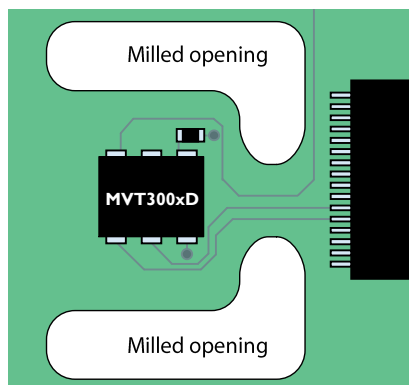
Fig. 17: Thermal isolation of sensor using milled PCB openings.

9- Storage and Handling Information

Once the sensors are removed from their original packaging, it is recommended to store them in antistatic bags.

The nominal storage conditions for the MVT3000D series chip are at temperatures in the range of 0 to 50°C and at humidity levels below 80% RH.

10-   Part Numbers

Evaluation Board	
MVEVB3	MVT3000D series evaluation board and USB cable
MVT3001D	
MVT3001D	MVT3001D 3 × 2.4 × 0.8 mm 6-pin DFN-style LGA package
MVT3001D-M	MVT3001D sensor module, for use with the MVEVB3 evaluation board
MVTEVB3-K1	Evaluation kit, includes MVEVB3 and MVT3001D-M (x3)
MVT3004D	
MVT3004D	MVT3004D 3 × 2.41 × 0.8 mm 6-pin DFN-style LGA package
MVT3004D-M	MVT3004D sensor module, for use with the MVEVB3 evaluation board
MVTEVB3-K4	Evaluation kit, includes MVEVB3 and MVT3004D-M (x3)

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