SGX SENSORTECH
An Amphenol Company

Datasheet

Gas Sensor for TVOC and Indoor Air Quality

SGX4410

Description

The SGX4410 Gas Sensor is designed for easy implementation to detect total volatile organic compounds (TVOC), and monitor indoor air quality (IAQ). The sensor works reliably in various conditions, including very humid and dusty applications with the possibility of water spray, condensation, or immersion.

The firmware configurable platform quickly enables different SGX4410 features based on machine learning algorithms and embedded artificial intelligence (AI) with SGX Sensortech pre-trained models and algorithms. This is used to determine and output TVOC concentration, IAQ rating according to UBA, estimated carbon dioxide (eCO2) level, and a relative IAQ rating based on total VOC. Alternate algorithms and firmware implementations can output an absolute TVOC concentration to meet Public Building Air Quality (PBAQ) standards, odor level changes, and discrimination between sulfur-based odors. With the ultra-low operating current consumption implementation, the SGX4410 is an excellent choice for low-voltage and ultra-low power battery applications.

Features

- AI-driven sensing with machine learning:
- Absolute TVOC & IAQ measurement (UBA standard)
  - Public Building Air Quality (PBAQ) compliance
  - Relative IAQ output (odor & TVOC changes)
  - eCO_2 estimation
  - Sulfur-odor discrimination
  - Auto-compensation for humidity, temperature & oxidizing gases
- High H_2 sensitivity (resistance output)
- Ultra-low power: down to 200 µW
- Siloxane resistant for long-term stability
- 10-year lifetime (JEDEC JESD47 qualified)
- Wide voltage: 1.7–3.6 V
- RoHS compliant
- Operating range: -40°C to +85°C
- IP67 option: water & dustproof version available
- Compact 12-LGA package:
  - 3.0 × 3.0 × 0.7 mm (standard)
  - 3.0 × 3.0 × 0.9 mm (IP67)

Applications

- **Indoor air monitoring** – compliant with UBA and Public Building Air Quality (PBAQ) standards
- **Versatile use** – monitor homes, offices, personal spaces, and bathrooms for health & comfort
- **Hazard detection** – identify harmful fumes and unhealthy conditions (e.g., emissions from construction materials)
- **Smart automation** – enable HVAC, air purifiers, thermostats, and kitchen hoods based on IAQ data
- **Flexible applications** – suitable for both indoor and outdoor devices (wearables, health bands, etc.)

Customized Field Application Support

- **Resources** – manuals, application notes, blogs
- **Firmware package** – example codes, API, pre-compiled libraries & algorithm support
- **Certified compliance** – third-party validated against international IAQ standards & state-of-the-art eCO_2 technology

Quality, Safety, Responsibility

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1. Overview

1.1 Block Diagram

Note: For definitions of abbreviations, see "Glossary."

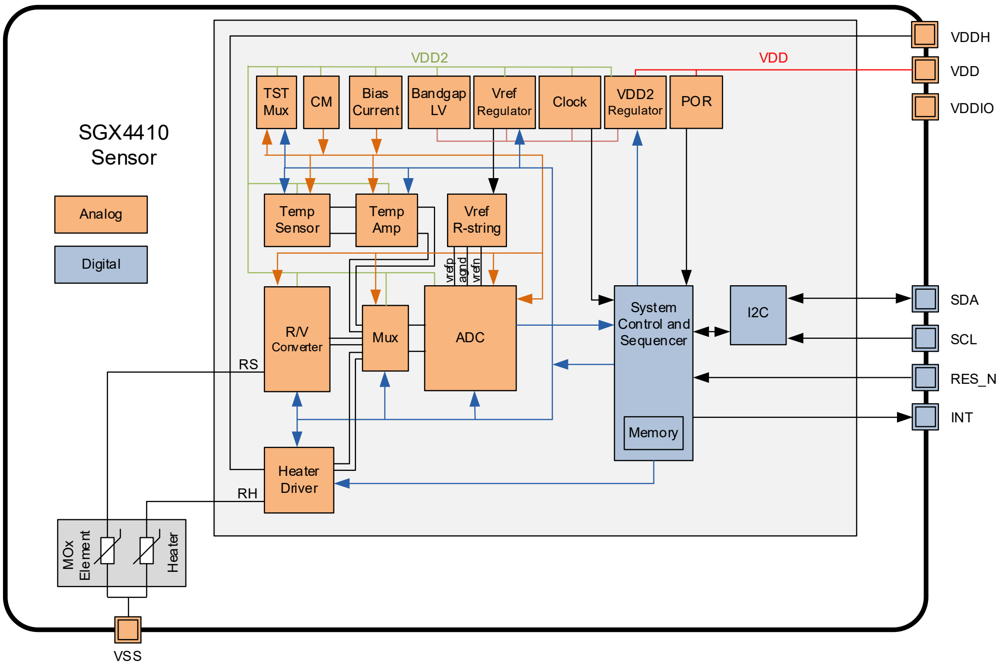

Figure 2. Block Diagram

1.2 Application Circuit

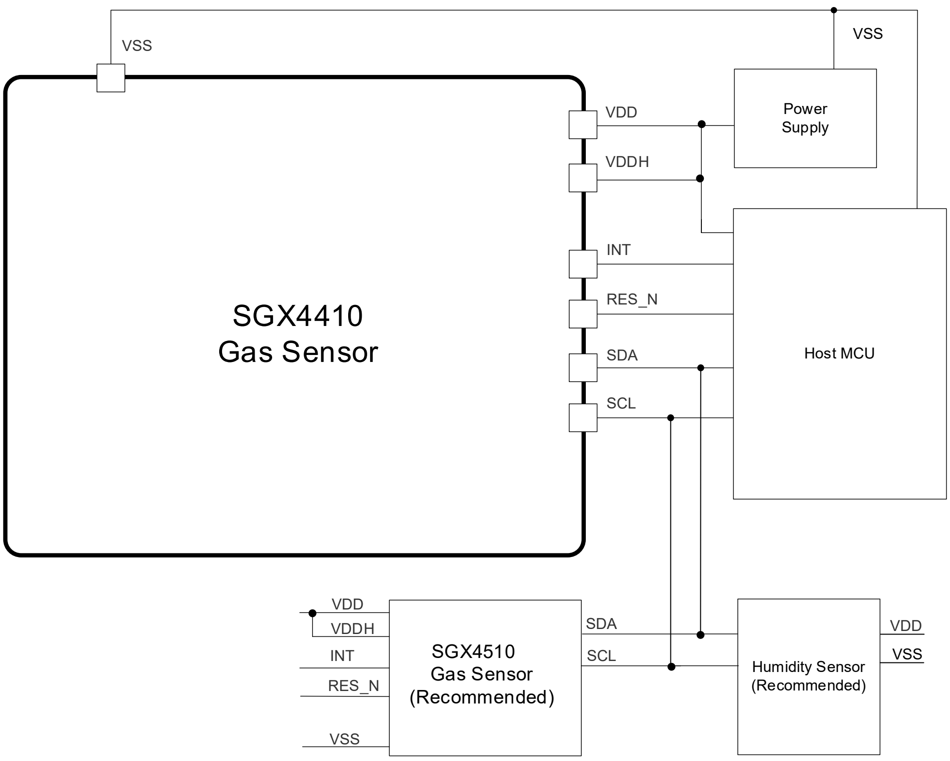

Figure 3. Application Circuit

2. Pin Information

2.1 Pin Assignments

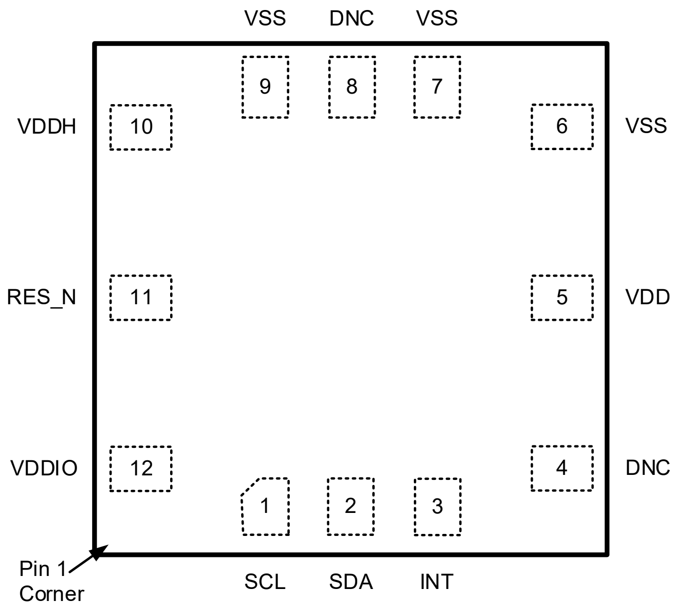

Figure 4. Pin Assignments for 12-LGA sensor – Top View

2.2 Pin Descriptions

Table 1. Pin Descriptions

Pin Number	Name	Type	Description
1	SCL	Input	Serial clock for the I^2C interface.
2	SDA	Input/Output	Serial data for the I^2C interface. Default 7-bit slave address: 32_{HEX}.
3	INT	Output	Interrupt signal (push-pull): ▪ HIGH when a measurement is running ▪ LOW when a measurement has finished *Note*: Use edge detection on falling edge!
4	DNC	-	Do not connect.
5	VDD	Supply	Voltage supply for the SGX4410.
6	VSS	Ground	Ground reference for the SGX4410.
7	VSS	Ground	Ground reference for the SGX4410.
8	DNC	-	Do not connect.
9	VSS	Ground	Ground reference for the SGX4410.
10	VDDH	Supply	Voltage supply for the integrated heater in the SGX4410.
11	RES_N	Input	SGX4410 reset; active low.
12	VDDIO	Supply	Voltage supply for I/O-interface in SGX4410.

3. Specifications

3.1 Absolute Maximum Ratings

Caution: The absolute maximum ratings are stress ratings only. The SGX4410 may not be operable outside the recommended operating conditions in Table 2. Stresses exceeding the absolute maximum ratings will change the sensor accuracy, lead to imprecision, and eventually cause irreversible damage to the device. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. SGX Sensortech does not recommend designing to the “Absolute Maximum Ratings”.

Note: The reference for all voltages is V_{SS}.

Table 2. Absolute Maximum Ratings

Symbol	Parameter	Minimum	Maximum	Unit
V_{DD}, V_{DDH}, V_{DDIO}	Maximum Analog and I/O Supply Voltage	-0.4	3.63	V
V_{A_IO}, V_{D_IO}	Maximum Voltage at all Analog and Digital I/O Pins	-0.5	V_{DDIO} + 0.5	V
	Maximum Difference in Voltage between VDD and VDDH Pins	-	0.4	V
I_{IN}	Input Current into any Pin except Supply Pins (Latch-Up Immunity)	-100	100	mA
V_{HBM1}	Electrostatic Discharge Tolerance – Human Body Model (HBM)	-	2000	V
V_{CDM}	Electrostatic Discharge Tolerance – Charged Device Model (CDM) on Packaged	-	750	V
$T_{AMB\text{-}MAX}$	Maximum Ambient Temperature Range of Sensor	-40	125	°C
T_{STOR}	Storage Temperature	-50	125	°C
$T_{OPERATION}$	Operation Temperature of Sensing Element [1]	-	550	°C

1. Controlled via API in firmware and EVK software.

3.2 Electrical Characteristics

The following values are valid at operating conditions unless noted otherwise.

Note: The reference for all voltages is V_{SS}.

Table 3. Electrical Characteristics

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
V_{DD}	Recommended Supply Voltage		1.7	-	3.6	V
P_{AVG}	Average Power	IAQ 2nd Gen and Sulfur Odor operation [1] V_{DD} = 1.8V	-	5.95	-	mW
		ULP operation [1] V_{DD} = 1.8V	-	0.197	-	mW
		PBAQ operation [1] V_{DD} = 1.8V	-	0.98	-	mW
I_{PEAK}	Peak Supply Current	VDD = 1.8V	-	26.99	-	mA
		VDD = 3.3V	-	16.32	-	mA
I_{AVG}	Average Supply Current	IAQ 2nd Gen and Sulfur Odor operation [1] V_{DD} = 1.8V	-	3.31	-	mA
		IAQ 2nd Gen and Sulfur Odor operation [1] V_{DD} = 3.3V	-	2.32	-	mA
I_{AVG}	Average Supply Current	ULP operation [1] V_{DD} = 1.8V	-	0.109	-	mA
		ULP operation [1] V_{DD} = 3.3V	-	0.078	-	mA
I_{AVG}	Average Supply Current	PBAQ operation [1] V_{DD} = 1.8V	-	0.546	-	mA
		PBAQ operation [1] V_{DD} = 3.3V	-	0.385	-	mA
I_{SLEEP}	Current during measurement delays	Sleep Mode ASIC	-	450	-	nA
PSRR	Power Supply Rejection Ratio	$V_{DD} \geq 2.0V$	-	30	-	dB
	Timing Accuracy (Valid for Measurements Only, Sleep Timer is ±20%)	At room temperature; for timings derived from the internal clock.	-2	-	2	%
		Over-temperature range; for timings derived from the internal clock.	-0.1	-	0.1	%/K
r_{ADC}	ADC Resolution	-	10	-	16	Bit
t_{STA1}	Start-up Time: V_{DD} Ramp up to Interface Communication	-	-	-	1	ms
$f_{C,I2C}$	I^2C Clock Frequency	-	-	-	400	kHz
t_{VPP}	NVM Programming Time	-	-	6	16	ms

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
t_{RET_FTP}	Data Retention	85°C junction temperature	10	-	-	years
-	NVM Programming Cycles	-	1000	-	-	cycles
-	Default I²C Communication Address	7-bit slave address	-	32_{HEX}	-	-
-	Blocking Capacitor for Power Supply	Ceramic type; recommended to be placed close to gas sensor	100	-	-	nF
VIH	Logic Voltage Level High	Applies for RES_N, SCL, and SDA	0.7* V_{DDIO}	-	-	-
VIL	Logic Voltage Level Low	Applies for RES_N, SCL, and SDA	-	-	0.3* V_{DDIO}	-

1. Operation modes are explained in Description of Operation Modes and Related Outputs.

4. Description of Operation Modes and Related Outputs

The SGX architecture leverages different “Methods of Operation” (Operation Modes), which use time, temperature, and signatures from gases that enable unique signals from a highly trained machine learning system and makes use of embedded artificial intelligence (AI) technology. This section discusses the different operation modes of the SGX4410 as well as their corresponding outputs and properties. An overview is provided in Table 4.

The following operation modes and corresponding firmware packages are released [1]:

- **IAQ 2nd Gen**: IAQ and TVOC Firmware – 2nd generation algorithms (recommended for new designs)
- **ULP**: IAQ and TVOC Firmware for Ultra-Low Power
- **PBAQ**: IAQ and TVOC Firmware for Public Building Air Quality (PBAQ) Standards
- **Sulfur Odor**: Sulfur-based Odor Discrimination Firmware

Note: On one physical device only one operation mode should run continuously. Switching of modes should not be done during device operation.

Table 4. Overview of Output and Properties for Different Operation Modes

	Output						Properties	
Operation Mode	**IAQ Rating**	**TVOC [mg/m³] and [ppm]**	**eCO2 [ppm]**	**Relative IAQ Rating**	**Odor Intensity Level and Classifier**	**Raw Resistance Signal [Ohm]**	**Ultra-low Power**	**Support Building Standards**
IAQ 2nd Gen	✓	✓	✓	✓	-	✓	-	-
ULP	✓	✓	✓	✓	-	✓	✓	-
PBAQ	✓	✓[1]	-	✓	-	✓	-	✓
Sulfur Odor	-	-	-	-	✓	✓	-	-

1. Due to low TVOC concentrations expected for PBAQ operation, the concentration is given in [µg/m³] and [ppb].

By default, the IAQ 2nd Gen operation should be used for new designs due to best accuracy over wide TVOC detection range compared to other operation modes. Table 5 provides an overview of recommended SGX4410 operation modes including their sample rate and the warm-up (stabilization) samples after each power-on. The warm-up times are fixed, and algorithm results should be considered only after the warm-up.

Table 5. Sample Rates, Warm-Up Samples and Time for SGX4410 Operation Modes

Operation Mode	Sample Rate [Seconds]	Warm-Up Samples Upon Start	Warm-Up Time [Minutes]
IAQ 2nd Gen	3	60	3
ULP	90	10	15
PBAQ	5	36	3
Sulfur Odor	3	60	3

[1] The previous IAQ 1st Generation, IAQ 1st Generation Low Power and Odor operation modes are legacy and not recommended for new designs.

The following sections provide information on TVOC gases, concentrations, and thresholds given by the German Federal Environmental Agency (UBA)[2] and the US Environmental Protection Agency (EPA) and for Public Building Standards. These standards provide reliable information on indoor air quality and recommendations for air improvements if necessary. Furthermore, the non-standardized relative IAQ output and the CO2 estimation is described. All graphs and information show the typical responses that are to be expected from the sensor upon exposure to a variety of test conditions.

4.1 IAQ Levels According to UBA

The IAQ 2nd Gen, ULP, and PBAQ algorithms provided for the user's microprocessor use the output from the SGX4410 to determine the level of TVOC gases present (see *SGX4410 Programming Manual – Read Me*; see also section 4.6). The algorithms feature an automated baseline correction function, ensuring that the can learn from its environment and distinguish elevated levels of TVOC under all conditions. The proprietary metal oxide (MOx) used in the sensor allows it to respond effectively to changing TVOC levels during long-term operation.

SGX Sensortech has adopted the definition of TVOCs and their impact on user health and comfort proposed by the UBA (see Table 6). The SGX4410 can detect the presence of elevated TVOC levels as described in the UBA study.[2]

There are many sources of poor indoor air quality that can elevate TVOC levels in the typical home or office environments, and the types of TVOC that might be present can vary widely.

Table 6. Level of Indoor Air Quality Based on TVOC Levels Described by UBA

SGX Sensortech IAQ Rating	Reference Level	Air Information	TVOC (mg/m^3) [1]	Air Quality
≤ 1.9	Level 1	Clean Hygienic Air (target value)	< 0.3	Very Good
2.0 to 2.9	Level 2	Good Air Quality (if no threshold value is exceeded)	0.3 to 1.0	Good
3.0 to 3.9	Level 3	Noticeable Comfort Concerns (not recommended for exposure > 12 months)	1.0 to 3.0	Medium
4.0 to 4.9	Level 4	Significant Comfort Issues (not recommended for exposure > 1 month)	3.0 to 10.0	Poor
≥ 5.0	Level 5	Unacceptable Conditions (not recommended)	> 10.0	Bad

1. Conversion from mg/m^3 to ppm for many common TVOC is by the factor approximately 0.5 (for example, $10mg/m^3$ equals approximately 5ppm). Conversion from ppm to ppb and from mg/m^3 to $\mu g/m^3$ is by the factor 1000 (for example, 0.1ppm equals 100ppb).

[2] Umweltbundesamt, *Beurteilung von Innenraumluftkontaminationen mittels Referenz- und Richtwerten*, (Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz, 2007).

4.2 TVOC for Air Quality Standards

The TVOC output for IAQ 2nd Gen operation is tailored to the ranges described by UBA (compare with Table 6). While the PBAQ operation mode is used for absolute measurements of TVOC to meet Public Building Air Quality (PBAQ) standards released globally.[3][4] PBAQ standards promote health, cognitive scores, and well-being in buildings. Several aspects of environmental parameters are evaluated, including TVOC.

TVOC sensors must have very high resolution in the low µg/m^3 (ppb) concentration range, which is fulfilled using the SGX Sensortech SGX4410 gas sensor with the PBAQ algorithm firmware. A comparison with a reference is shown in Figure 5 and ranges are described in section 5.2.

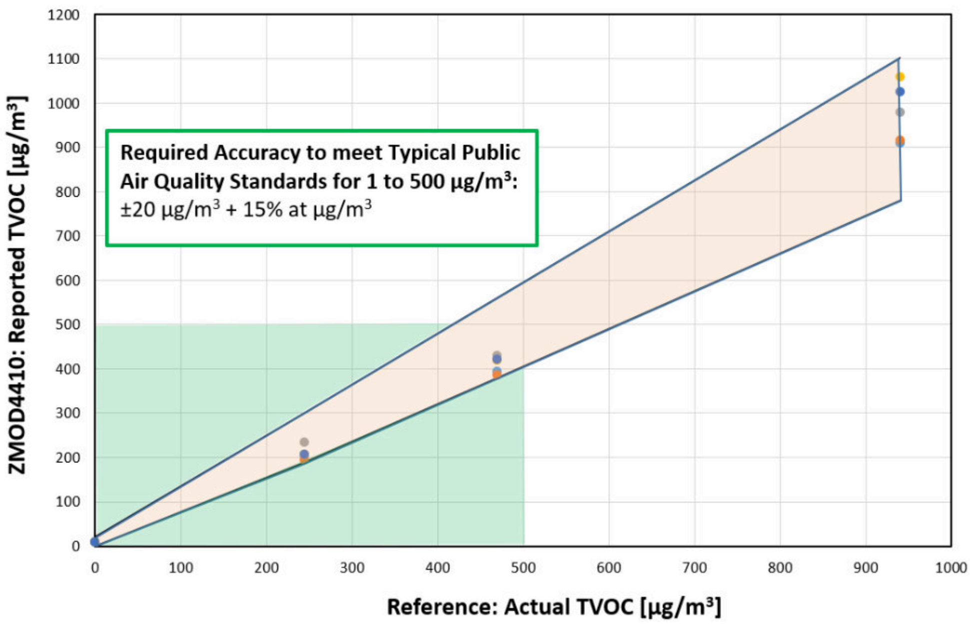

Figure 5. TVOC Measurement According to Typical PBAQ Standards using SGX4410

The downloadable firmware and evaluation kit software for the SGX4410 allows it to meet different Public Building Air Quality standards. However, it should be highlighted that PBAQ standards usually require calibration of the final product itself. In addition, all sensors measuring air quality parameters need to be recalibrated or replaced annually. To receive the *SGX Sensortech PBAQ Calibration Guidelines* with detailed information on calibration procedure, contact SGX Sensortech via the contact information on the website. An additional parameter provided is the relative IAQ output to enable further possibilities of accreditation.

4.3 Relative IAQ Output

The relative IAQ output is available for IAQ 2nd Gen, ULP, and PBAQ mode. The advantage of this output is an easy establishment of threshold limits to trigger actions (for example, turn on a fan for ventilation) in which case no absolute TVOC concentration readings are needed. Also, this algorithm behaves similar to the human nose, in which small concentration changes are rapidly detected with high sensitivity while very slow changes are suppressed. The sensor will react immediately to all TVOC, but the algorithm uses a time constant of 24 hours for a full decay. In the case where no change in air quality takes place within this time, the algorithm will

[3] IWBI, WELL Performance Verification Guidebook (International WELL Building Institute PBC), 2023.
For more information about the WELL standard, see WELL; for information about the WELL specification, see specification.

[4] Regenerative Ecological, Social, and Economic Targets (RESET), Air Standards for Accredited Monitors v2.0, 2018.
For more information about the RESET standard, see RESET; for information about the RESET specification, see specification.

converge to an index of 100. This scale index is defined in the style of the EPA scale for Outdoor Air Quality [5] as shown in Figure 6.

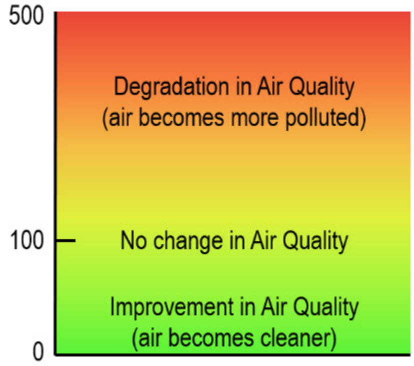

Figure 6. Scale of the Relative IAQ

Figure 7 provides a comparison of the IAQ output (see section 4.1) and the Relative IAQ output for a week of data collection in an indoor environment. Events such as opening a window during the day and night and trends in TVOC are clearly visible on both outputs. While the Relative IAQ appears smoother, it is more sensitive to changes in TVOC and begins to adapt (decrease) at high TVOC exposures over time.

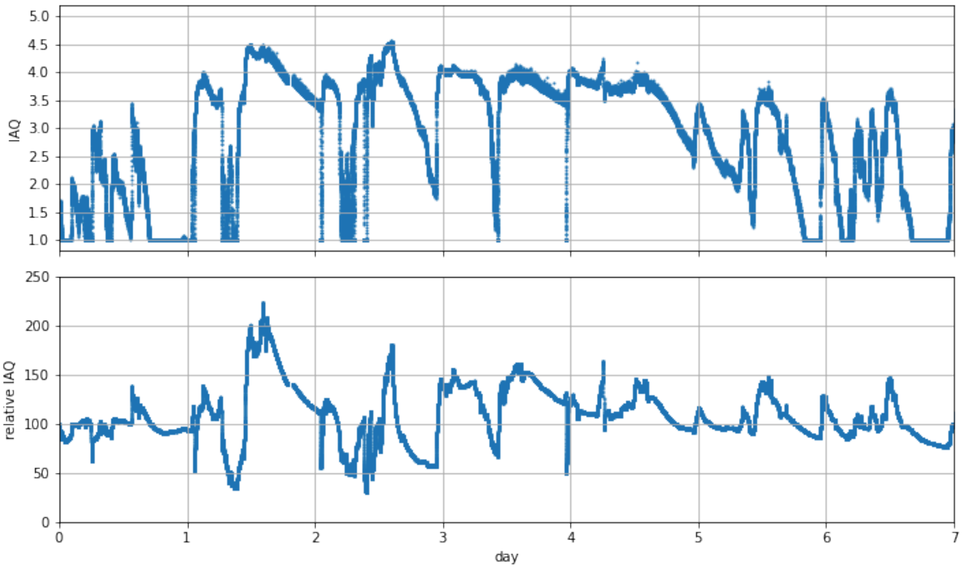

Figure 7. Comparison of IAQ and Relative IAQ

4.4 Estimated Carbon Dioxide Correlation (eCO_2)

A very reliable correlation can be made based on TVOC levels for situations where an elevated carbon dioxide (CO_2) concentration is caused by human occupancy, although the sensor is not directly responsive to CO_2. SGX Sensortech has developed a robust, patent pending, correlation algorithm between elevated TVOCs and CO_2 attributable to human occupancy in a wide variety of living spaces, including homes and offices.

The measurement range for the eCO2 has its minimum at the atmospheric background level at 400ppm and ranges up to 5000ppm. The correlation can predict the CO_2 level as shown in Figure 8. Additional details about SGX Sensortech' CO_2 correlation algorithm are available in the *SGX4410 Application Note – Estimating Carbon Dioxide.* The Estimated Carbon Dioxide output is available for IAQ 2nd Gen and ULP operation mode.

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[5] For more information on Outdoor Air Quality and how to detect it, see the SGX4510 product page.

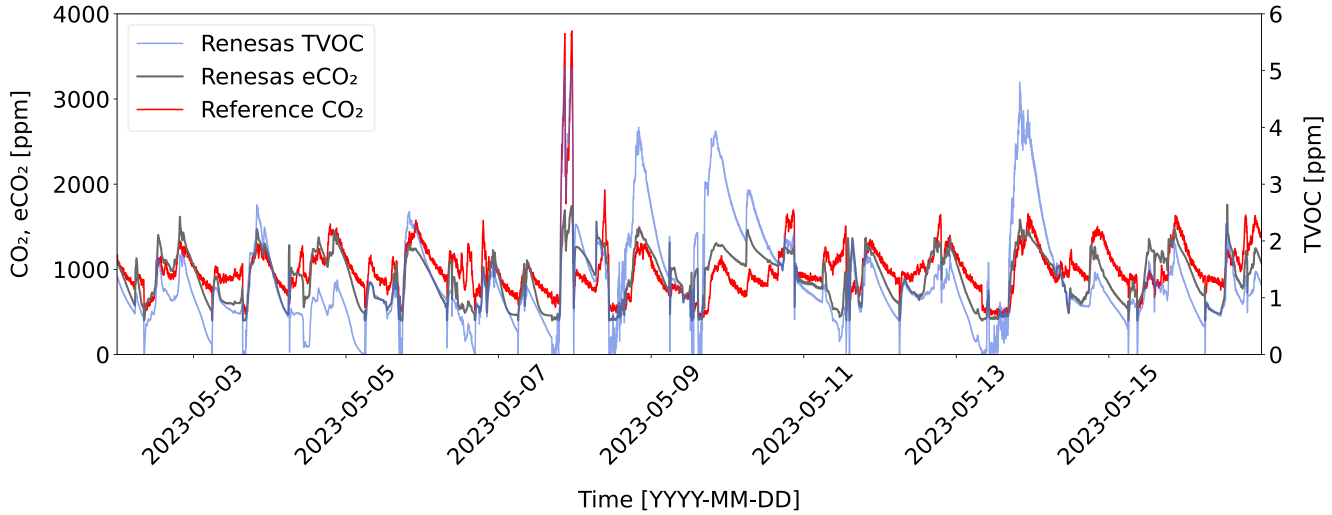

Figure 8. Typical Graph of CO_2 Estimation in an Application

4.5 Sulfur-based Odor Discrimination (Sulfur Odor)

The Sulfur Odor operation mode can be used to identify whether a sulfur-smelling odor is present. When the target gas families have been defined through analysis, a sweeping method allows for chemical discrimination. A machine learning embedded artificial intelligence (AI) algorithm makes use of a MOx surface temperature array to get to a selectivity approach.

This operation mode classifies the odors in “sulfur” (sulfur-based) and “acceptable” (organic based) and shows an intensity level of the smell. Acceptable odors are, for example, originate from air refreshers, soaps, perfumes, etc., while bad smelling sulfur-based odors originate from personal odors in bathrooms. Because impression of smell is very unique, there may be overlaps with how people perceive odors. To integrate this in an algorithm, a highly trained Neural Network is using typical chemical signatures from Hydrogen sulfide (H_2S) and Dimethyl sulfide (DMS, C_2H_6S). A range of organic sulfur compounds are considered from the low ppb to the ppm range. The typical sample rate is 3 seconds, but the algorithm may need a few samples for the correct classification.

The Sulfur Odor firmware was developed based on known commercially available products that represent both bad and acceptable odors. Other places with unknown chemical signatures can lead to incorrect algorithm results. Training the sensor and developing the discrimination for other gases and applications may be considered for future releases.

4.6 Sensor Algorithm and Firmware

To operate the SGX4410, the software and libraries provided by SGX Sensortech should be used. The algorithm for the user’s microprocessor always uses the raw output signals from the SGX4410, which are resistances, to determine the level of gases present. Depending on the microprocessor and compiler used, the firmware and its algorithms require 20 to 40 kB flash size. All algorithms feature an automated baseline correction function, ensuring that the sensor can learn from its environment and distinguish elevated levels of gases under all conditions. The proprietary metal oxide (MOx) used in the sensor ensures that the sensor can respond effectively to changing TVOC during long-term operation. Thus, the user focus should always be on the relevant output parameters: The IAQ level according to UBA, the TVOC concentration (available in mg/m^3 and as Ethanol equivalent in ppm), and/or the estimation of carbon dioxide (eCO_2).

For implementing the sensor in a customer-specific application, detailed information on the programming is available. More information and guidance on the firmware integration, architecture, and supported platforms are available in the SGX4410 Programming Manual - Read Me. Code Examples in C and additional firmware descriptions for API, HAL, libraries, etc., are included at no cost in the downloadable firmware package from the SGX4410 product page.

5. Sensor Characteristics

This section describes general sensor specific characteristics like measurement and operational ranges. In addition, details for accuracy, sensitivity, reliability, sample rates, and sensor influences are explained in detail in the following sections. Additional technical information on sensitivity, selectivity, and stability for all operation modes is available in SGX Sensortech' SGX4410 Application Note – TVOC Sensing.

5.1 General Characteristics

The SGX4410 Gas Sensor is designed to detect typical TVOC contaminations based on studies and international standards for indoor air quality. In parallel to TVOC detection, it also responds impressively, but not selectively, to Hydrogen (H_2) in the full parts-per-million range. General characteristic sensor parameters are shown in Table 7. The response time for a gas stimulation is always within a few seconds, depending on the specific gas molecule and its concentration. An active or direct airflow onto the sensor is not necessary because diffusion of ambient gas does not limit the sensor's response time.

Table 7. Gas Sensor Specifications During Operation

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
-	Raw Resistance Measurement Range	Ethanol or Hydrogen in air	0	-	1000	ppm [1]
-	IAQ and TVOC specified Measurement Range to meet UBA [2]	Ethanol in air	160	-	10000	ppb [1]
-	IAQ and TVOC specified Measurement Range for PBAQ	Ethanol in air	1	-	2000	µg/m³
-	Cross-sensitivity on TVOC output	Compensated TVOC increase after stimulation with oxidizing gas (10ppb ozone) [3]	-	0	-	ppm
		Uncompensated TVOC increase after stimulation with oxidizing gas (10ppb ozone)	-	1.2	-	ppm
RH_{AMB}	Humidity Range for Sensor Operation	All SGX operations except PBAQ operation, Non-condensing	0	-	90	% RH
		Specification to meet PBAQ, Non-condensing	-	50	-	% RH
T_{AMB_O}	Temperature Range for Sensor Operation	Qualified maximum temperature range without hardware damage	-40	-	+85	°C
T_{AMB_A}	Temperature Range for Algorithm Operation	All operation modes except PBAQ, Non-condensing	-40	-	+65	°C
		Specification according to PBAQ, Non-condensing	-	21	-	°C
T-80	Sensor Response Time [4]	Samples needed to change to 80% of end value (all operation modes except ULP)	-	15	-	Samples

1. Conversion from mg/m³ to ppm for many common TVOC is by the factor approximately 0.5 (for example, 10mg/m³ equals approximately 5ppm). Conversion from ppm to ppb is by the factor 1000 (for example, 0.1ppm equals 100ppb).
2. Source: Umweltbundesamt, Beurteilung von Innenraumluftkontaminationen mittels Referenz- und Richtwerten, (Bundesgesundheitsblatt – Gesundheitsforschung – Gesundheitsschutz, 2007).
3. For compensation, the gas sensor SGX4510 is needed.
4. Response times depend on TVOC gas and concentration.

Important: The SGX4410 also can detect safety-relevant gases for indoor air, such as carbon monoxide (CO); however, the sensor is not designed to detect these interferants reliably and therefore it is not approved for use in any safety-critical or life-protecting applications. It must not be used in such applications, and SGX Sensortech disclaims all liability for any such use.

5.2 Sensitivity, Accuracy and Consistency

All SGX Sensortech gas sensors come with electrical and chemical factory calibration with data stored in the sensor's nonvolatile memory (NVM). Using the algorithms provided by SGX Sensortech and the calibration coefficients in the NVM will lead to stable measurement of the IAQ levels according to UBA discussed in section 4.1 with a maximum deviation of ±1 category over the sensor's lifetime.

The SGX4410 can respond reliably to all types of organic compounds that are typically found in indoor environments. To assess the response of the gas sensor to the levels described in the UBA study, the sensor has been tested using several TO-15/17 multi-component TVOC standards defined by the EPA. The SGX4410 response to the EPA standard with the TVOC levels from UBA is shown in Figure 9. A third-party report and certification from an independent research lab are available on the SGX Sensortech website that confirms the good conformity for IAQ measurements with respect to the UBA study and EPA standard.

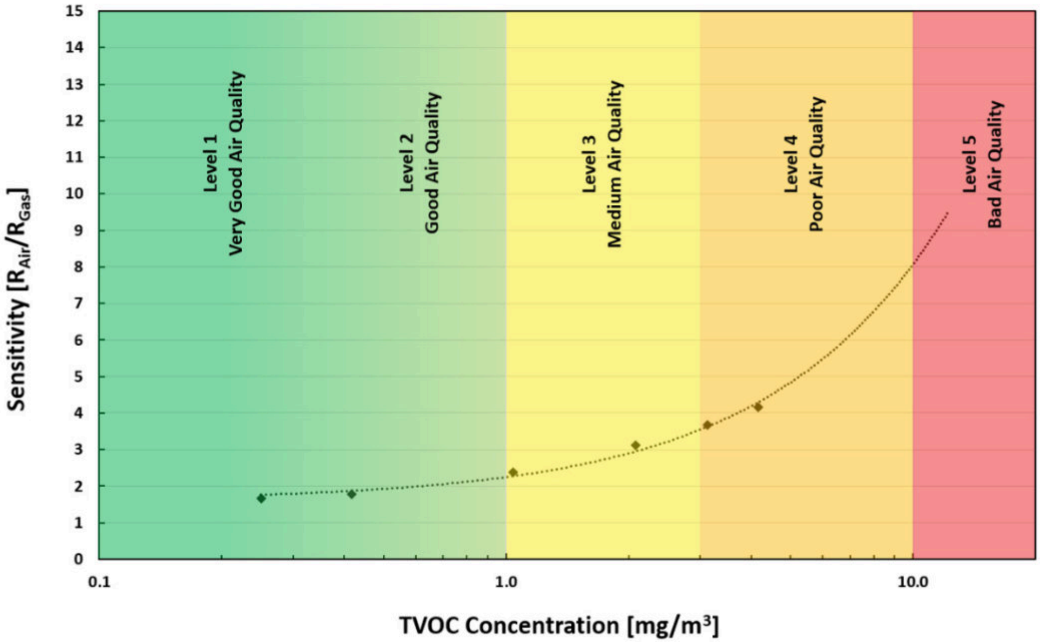

Figure 9. Typical SGX4410 Response to Levels of TVOC Described by UBA Using EPA Standard Mixture

Note: TVOC is a subset comprising 25 of the EPA's TO-15/17 certified mixtures.

Typical IAQ accuracy and consistency in an appropriate system implementation are displayed in Table 8 and Figure 10. The accuracy for SGX Sensortech eCO_2 algorithm was verified on more than 20000 measurements and is shown in Figure 11. To meet a PBAQ standard a TVOC sensor must fulfill a specification as typically seen in Table 9.

Table 8. Typical SGX4410 Sensor Performances

Parameter	Conditions	Minimum	Typical	Maximum	Unit
Accuracy for IAQ	Full UBA range [1]	-	± 1	-	IAQ
Accuracy for IAQ Ultra-Low Power	Full UBA range [2]	-	± 1	-	IAQ
Consistency for IAQ	Part-to-Part Variation [3]	-	± 10	-	%

1. With a 95% confidence based on more than 26500 measurements with 280 sensor sensors.
2. With 82% confidence based on more than 3500 measurements with 104 sensors.
3. Based on more than 30000 measurements with 380 sensors.

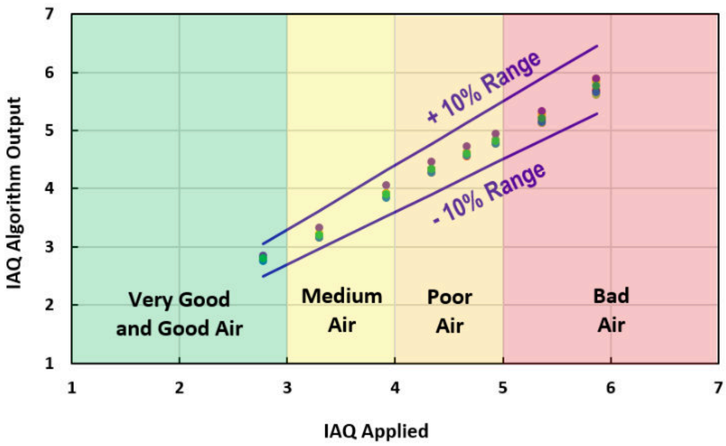

Figure 10. IAQ Accuracy and Consistency

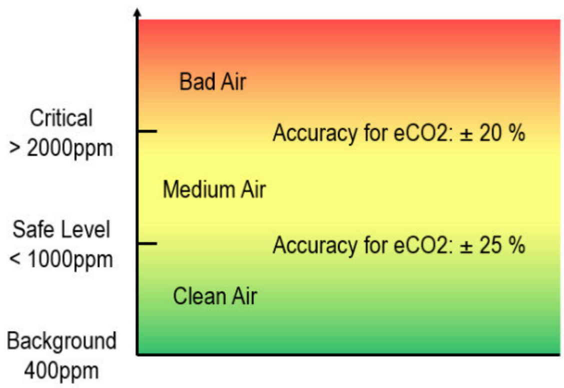

Figure 11. Concentration Dependent Accuracy for eCO2[6]

Table 9. Typical Sensor Requirement to Meet a PBAQ Standard

Parameter	Unit	Typical Range	Typical Accuracy	Resolution	Calibration Gas
TVOC	ppb or µg/m^3	1 to 2000 µg/m^3 [1]	(± 20 µg/m^3 + 15%) at 1 to 1000 µg/m^3	1 µg/m^3	Ethanol

1. Maximum output for this algorithm capped at 6000µg/m³.

[6] eCO2 accuracy can only be achieved if no artificial or non-human VOC sources are present.

5.3 Conditioning, Sensor Self-Check Status, and Stability

The cleaning conditions the sensor material and helps to remove contaminants (for example, solder flux and vapors). The cleaning process takes 1 minute [7]. Cleaning can only be performed once during the lifetime of the sensor and is recommended after PCB assembly (for example, during final production test or at the end customer). The cleaning function automatically ensures that cleaning is performed only once. This is done by writing a control bit into the sensor's NVM. It is important not to interrupt the cleaning process while it is running.

The SGX4410 will respond to TVOC immediately upon start-up; however, a conditioning period of at least 48 hours of continuous operation in an ambient environment is recommended to improve stability and obtain maximum performance.

The sensor has a self-check for its general functionality. With every measurement the algorithm performs an internal check of resistances to identify potential damage (in other words, a damage error). If a damage error lasts longer than 60 minutes then the following are possible reasons:

- Improper or open solder contacts
- High contamination on sensor material surface
- Broken MEMS membrane
- MOx material delamination
- Oxygen depletion on sensor surface
- Sometimes an extremely high VOC stimulation can cause a damage error output

The following measures can solve this issue:

- Check your production to ensure proper soldering. Use a proper soldering paste with correct temperature profile (see Assembly Restrictions, Operation, Integration Notes, and Storage).
- Find the source of sensor surface contamination during production (for example, solder vapors, cleaning chemicals) and try to avoid them. Make sure to have executed the cleaning procedure after the assembly.
- Make sure the sensor’s vent hole is not blocked because of protection paints or high dust/dirt accumulation.
- Do not use or store the sensor in an atmosphere without oxygen (for example, pure nitrogen).

Note: The self-check functionality is not available for the Sulfur-Odor Discrimination operation mode.

[7] For Sulfur Odor operation the cleaning takes 10 minutes.

Figure 12 shows the SGX4410 sensor’s raw data response to clean air with 30%RH and its response to 5ppm, 10ppm, and 20ppm ethanol mixed in clean air. The sensor signal is a very stable, fast changing, and repeatable sensor signal with a high sensitivity.

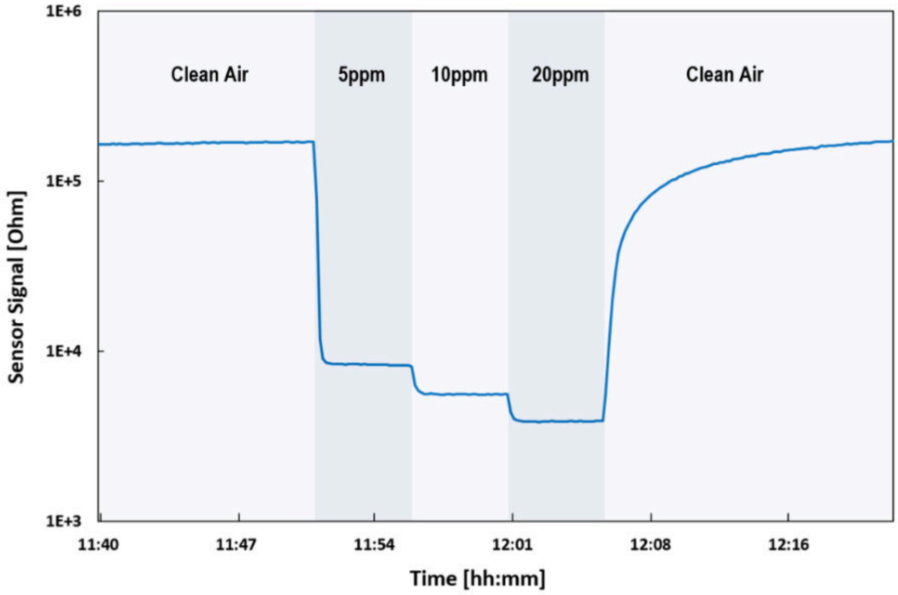

Figure 12. SGX4410 Typical Response Time and Signal Stability for TVOC Exposure

5.4 Environmental Influences

Although the SGX4410 sensor is tested, qualified, and functional in the range of -40°C to +85°C, the best performance according to its calibration is achieved in the temperature range of 0°C to +40°C. Figure 13 shows the sensor’s response to variations in the range from 15% to 65% relative humidity for different ethanol concentrations.

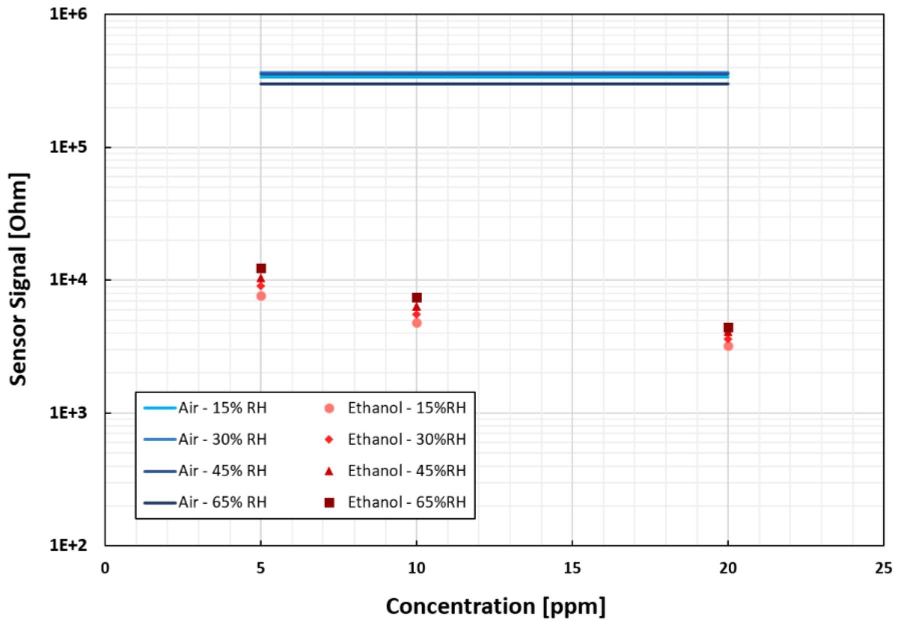

Figure 13. Humidity Influence at Three Different TVOC Concentrations

Temperature or relative humidity compensation are not required but are recommended for best performance. Use a humidity and temperature sensor in conjunction with the SGX4410 whenever possible. If relative humidity and temperature values are provided to the algorithm, the SGX4410 automatically uses these values for compensation. If no humidity and temperature sensor is available, provide the algorithm with the default temperature = -300°C. This enables the internal temperature measurement of the SGX4410. If no humidity data is provided, this parameter is recommended to be set to 50% RH for standard indoor applications. The Sulfur Odor Discrimination algorithm does not support or require any temperature or humidity compensation.

For some environments, an interference response to siloxanes is of concern; however, the SGX4410 has proven to be resistant against siloxanes. A maximum potential lifetime exposure has been simulated in all SGX4410 operation modes by applying the chemicals D4 (octamethylcyclotetrasiloxane) and D5 (decamethylcyclopentasiloxane) in high concentration for several hundred hours. For more information on test conditions and results, see SGX4410 Application Note – TVOC Sensing.

Outdoor air including oxidizing gases may interfere with the SGX4410's TVOC reading. In this use case, SGX Sensortech also recommends using the sensor SGX4510 Gas Sensor for Ozone and Nitrogen Dioxide for compensation. SGX4410 can identify oxidizing gases with the help of SGX4510 and reduce the influence on their outputs.[8] The compensation is automatically activated after 30 minutes.[9] For most indoor environments this compensation is not necessary since these gases occur mainly outdoors and are not stable indoors.

6. Assembly Restrictions, Operation, Integration Notes, and Storage

When implementing the SGX4410 in electrical circuit boards a gas sensor may react to chemicals during the assembly process and to outgassing components, such as resins from the printed circuit board (PCB) assembly. A standard soldering profile can be used to assemble the SGX4410 on the user's PCB and should fulfill the IPC/JEDEC J-STD-020C Standard ("Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices"). A typical lead-free reflow solder profile is shown in Figure 14. After assembly, an outgassing of the PCB and electronic components must be considered, especially when operating the sensor at elevated temperatures. This will ultimately influence the sensor signal and may dominate the air quality reading.

A PCB heat treatment before assembling the SGX4410 is recommended. After the gas sensor assembly, no coating, cleaning, or ultrasonic bath should be applied to the PCB. A cleaning cycle should be executed when the sensor is the first time on power to remove contaminations from assembly or storage of sensor parts. This thermal MOx cleaning will remove major contaminations of solder vapor from the MOx surface. In the case where the sensor does not show full performance after a cleaning cycle, a change to the protection sticker package is recommended (see Ordering Information). Store the sensor in an antistatic metallic bag with a low TVOC background after the sensor is removed from its original packaging or the assembled PCB is populated. The optimal storage conditions are < 1ppm TVOC, < 10ppb O_3, < 10ppb NO_2, 10°C to 50°C, and humidity levels within 20% to 80%RH. If the sensor is stored within these conditions, no sensor degradation is expected for a shelf life of at least 10 years (storage time). If the sensor is stored outside of these conditions for extended periods of time, the readings can exhibit a temporary offset. The sensor can be reconditioned and brought back to its calibration state by operating for 24 hours to 48 hours in clean air.

Note: The sensor must not be stored in pure nitrogen. This will lead to sensor failure.

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[8] The Sulfur Odor mode does not have this feature.

[9] For ULP mode the compensation is activated after 15 minutes.

To receive the complete *SGX Sensortech Environmental Sensor Guidelines* with detailed information on assembly, material outgassing, test and validation procedures, contact SGX Sensortech via the Technical Support page. A short version is available on the product webpage.

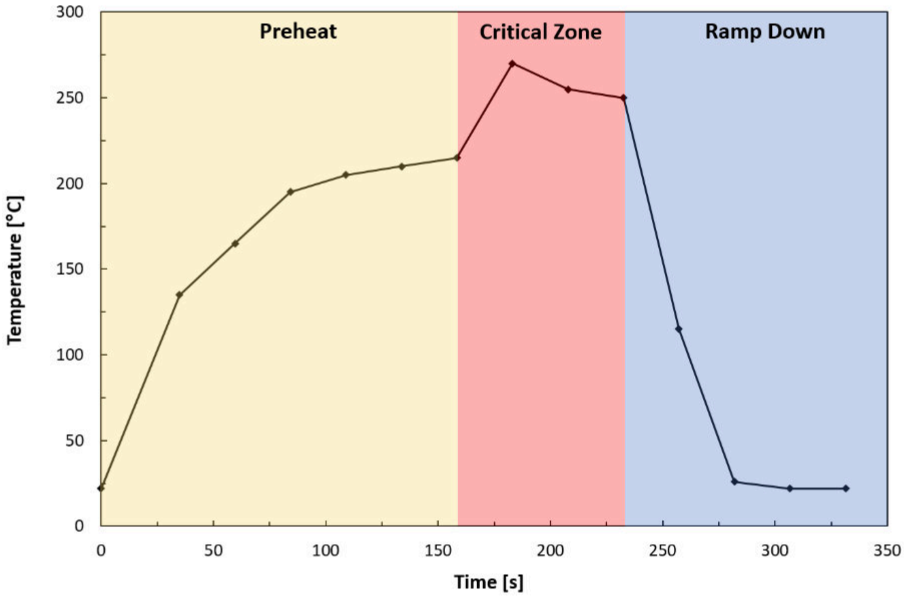


Figure 14. Typical Solder Profile

7. Test and Calibration

As a unique feature, all sampled gas sensors are fully tested during SGX Sensortech' final test. The final test parameters in Table 10 are applied for each SGX4410. All sensor sensors are pre-stabilized in the final test although the user may see a small change in the sensor's signal during an initial warm-up phase during the first operation. The gas sensor qualification is based on JEDEC (JESD47) and its subsequent standard (JESD22, JESD78, etc.); it has been qualified for a lifetime of 10 years. SGX Sensortech has proven a MOx lifetime of over 20+ years in actual continuous operation in conditions without exposures to stressful environments.

Table 10. Final Test Parameters

Test	Test Object	Parameters	Test Results Saved in NVM?
Electrical	ASIC	Voltages, current consumption, frequencies, scan pattern	No
Electrical	sensor	Calibration conditions, tracking ID, resistances	Yes
Gas	sensor	Sensitivity parameters (slope and intercept) at stimulation with different gas concentrations	Yes
Gas	sensor	Pre-stabilization	No

8. I^2C Interface and Data Transmission Protocol

The I^2C slave device interface supports various bus speeds: Standard Mode (≤100kHz) and Fast Mode (≤400kHz).

By default, the 7-bit slave address for the serial I^2C data interface is set to 32_{HEX}. The implemented data transmission protocol is similar to the one used for conventional EEPROM devices. The register to read/write is selected by a register address pointer. This address pointer must be set during an I^2C write operation. For read access, a repeated START condition but no STOP condition should be sent. After transmission of a register, the address pointer is automatically incremented. A STOP condition ends the whole transmission. An increment from the address FF_{HEX} rolls over to 00_{HEX}. The bus clear procedure (in other words, send nine clock pulses) is not implemented. To use a bus clear, the SGX4410's RES_N pin must be kept low while sending the nine clock pulses. I^2C bus scans must stay within a valid range below reserved address 0x78.

For an example of the I^2C data transmission protocol, see Figure 15. For information on I^2C bus timing, see Figure 16. For I^2C bus characteristics, see Table 11, which explains how to set up the interface. All other values are according to the I^2C standard. Although the SGX4410 has an I^2C interface, the user is not intended to modify any registers because a configuration change will affect the sensor sensor's performance, reliability, and accuracy. The API provided with the downloadable firmware package on the website manages all necessary sensor communication.

To validate the general MCU-specific I^2C read/write driver without the use of SGX Sensortech libraries, write random values to registers 0x88 to 0x8B and read them afterwards. After this register testing, erase the testing code and reset the device by disconnecting the power support; otherwise the device may not operate properly.

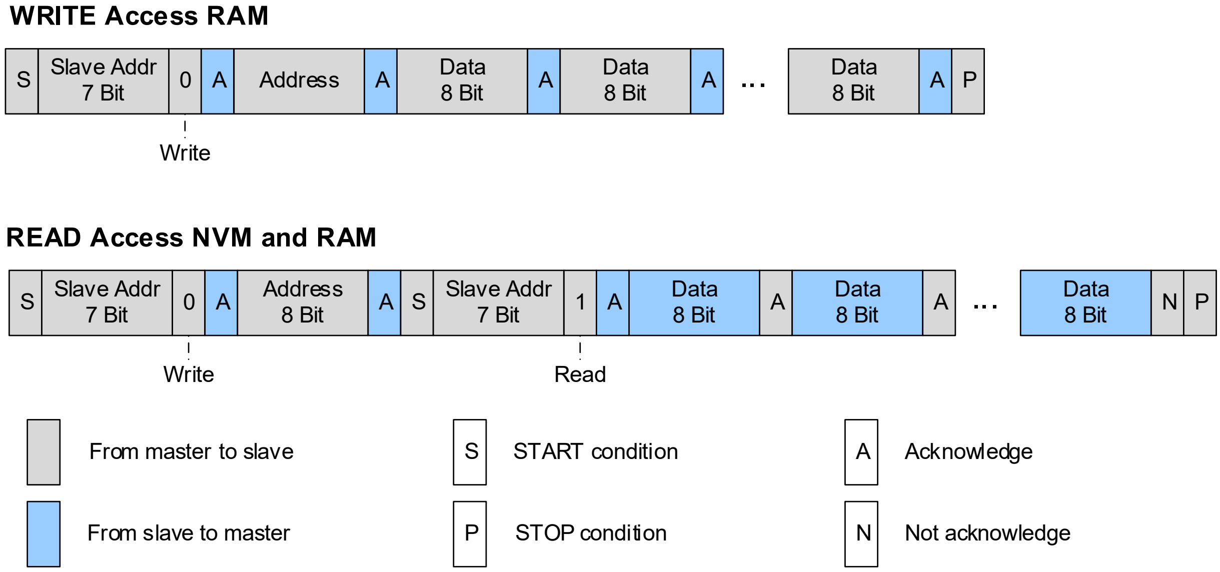


Figure 15. I^2C Data Transmission Protocol

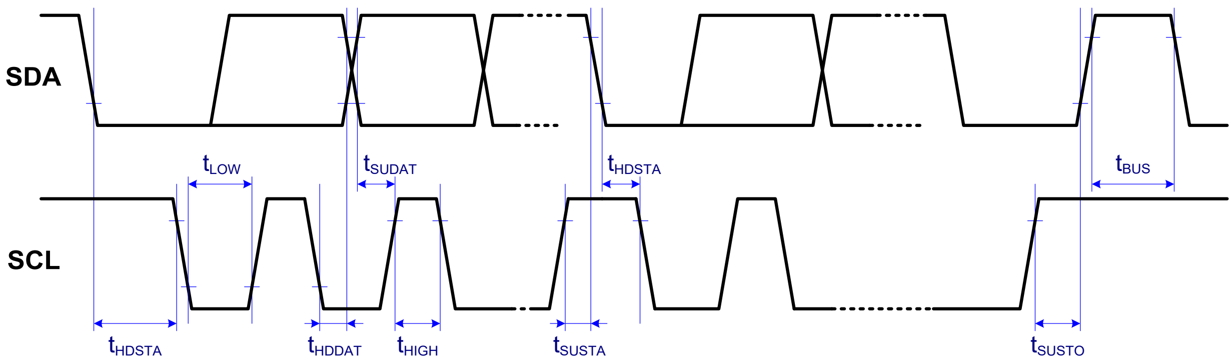


Figure 16. Bus Timing

Table 11. Bus Timing Characteristic

Parameter	Symbol	Standard Mode	Fast Mode	Unit
Maximum SCL clock frequency	f_{SCL}	100	400	kHz
Minimum START condition hold time relative to SCL edge	t_{HDSTA}	0.1	0.1	µs
Minimum SCL clock low width	t_{LOW}	0.2	0.3	µs
Minimum SCL clock high width	t_{HIGH}	0.1	0.1	µs
Minimum START condition setup time relative to SCL edge	t_{SUSTA}	0.1	0.1	µs
Minimum data hold time on SDA relative to SCL edge	t_{HDDAT}	0	0	µs
Minimum data setup time on SDA relative to SCL edge	t_{SUDAT}	0.1	0.1	µs
Minimum STOP condition setup time on SCL	t_{SUSTO}	4	0.6	µs
Minimum bus free time between stop condition and start condition	t_{BUS}	4.7	1.3	µs

9. Glossary

Term	Description
ADC	Analog-to-Digital Converter
AI	Artificial Intelligence
CDM	Charged Device Model
CM	Common Mode Generator
HBM	Human Body Model
IAQ 1st Gen	Indoor Air Quality algorithm using traditional computing methods (legacy)
IAQ 2nd Gen	Indoor Air Quality algorithm using machine learning AI
LGA	Land Grid Array
LV	Low Voltage
MOx	Metal Oxide
MSL	Moisture Sensitivity Level
Mux	Multiplexer
n.a.	Not Applicable
NC	Do not connect
NVM	Nonvolatile Memory
PBAQ	Public Building Air Quality
POR	Power-On Reset
SDA	Serial Data
SCL	Serial Clock
SSC	Sensor Signal Conditioner
TST	Test
TVOC	Total Volatile Organic Compounds
UBA	Umweltbundesamt (German Federal Environmental Agency)
ULP	Ultra-Low Power

10. Package Outline Drawings

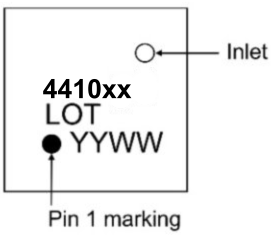
The SGX4410's different packages are listed in Table 12.

Table 12. Package Options

Part Number	Version	Comment	Package Link
SGX4410-A1	Standard	Standard package	LGG12D1 package
SGX4410-A2	Sticker	This package shipped with a sticker on top of the lid to protect sensor during assembly. *Note*: The sticker has to be removed after assembly.	
SGX4410-A3	Waterproof	This package uses a membrane to get IP67 rating.	LGG12D2 package
SGX4410-A4	Waterproof + Sticker	This package uses a membrane to get IP67 rating and is shipped with a sticker on top of the lid to protect sensor during assembly. *Note*: The sticker has to be removed after assembly.	

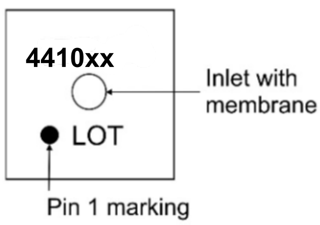
11. Marking Diagrams

Without membrane (SGX4410-A1 and -A2)



- Line 1 is the truncated part number. "X" is the package version.
- Line 2 – "LOT" denotes the assembly lot number.
- Line 3 – "YYWW" are the last two digit of the year and week that the part was assembled.

With membrane (SGX4410-A3 and -A4)



- Line 1 is the truncated part number. "X" is the package version.
- Line 2 – "LOT" denotes the assembly lot number.

12. Ordering Information

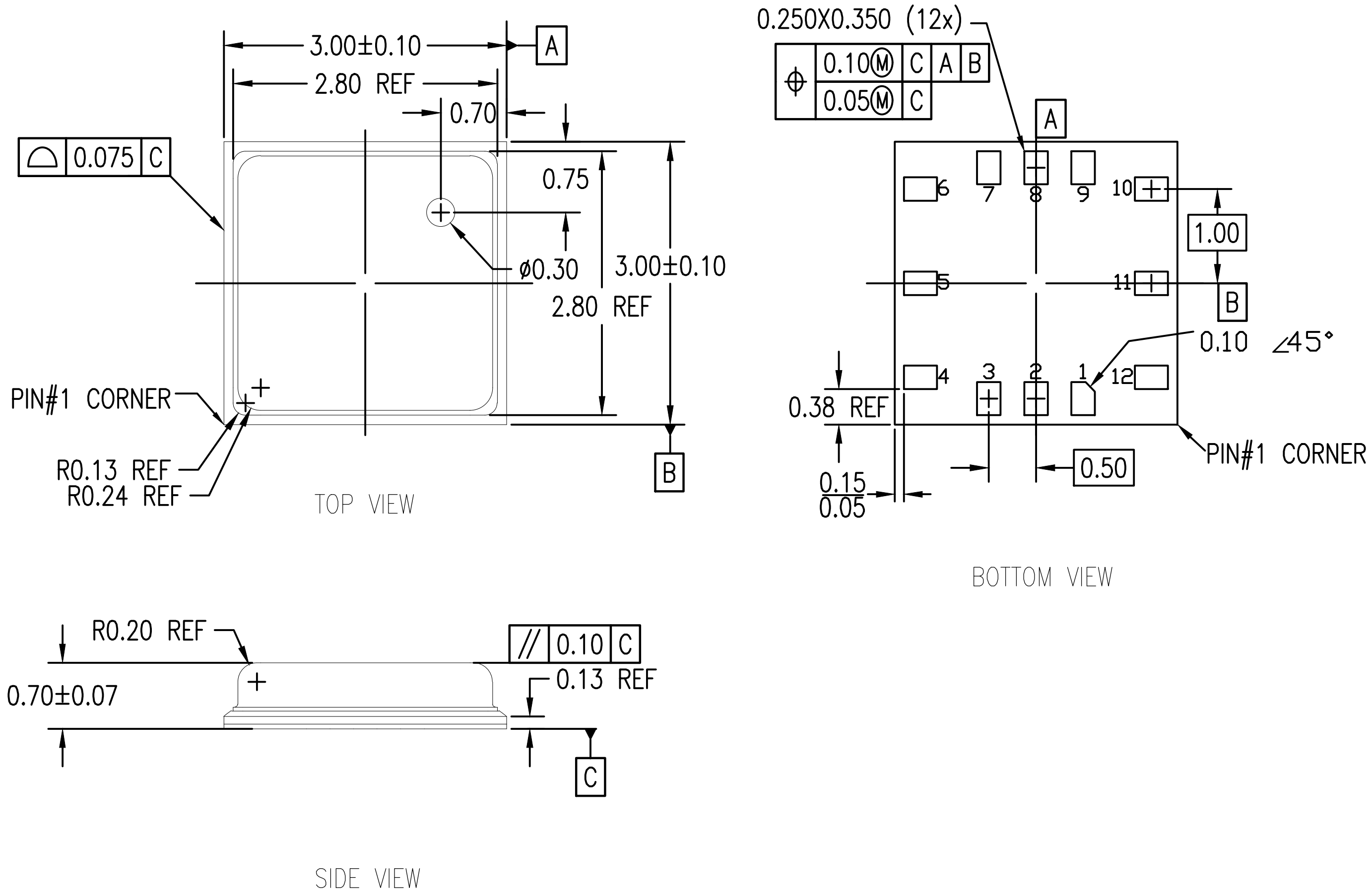
Part Number	Description and Package	MSL Rating	Carrier Type	Temp. Range	Order Quantity
SGX4410-A1V	SGX4410 Sensor, 3.0 × 3.0 × 0.7 mm 12-LGA	3	Tray	-40°C to +85°C	490
SGX4410-A1R	SGX4410 Sensor, 3.0 × 3.0 × 0.7 mm 12-LGA	3	Reel	-40°C to +85°C	4000
SGX4410-A2V	SGX4410 Sensor, 3.0 × 3.0 × 0.7 mm 12-LGA, shipped with removable protection sticker	3	Tray	-40°C to +85°C	490
SGX4410-A2R	SGX4410 Sensor, 3.0 × 3.0 × 0.7 mm 12-LGA, shipped with removable protection sticker	3	Reel	-40°C to +85°C	4000
SGX4410-A3V	SGX4410 Sensor, 3.0 × 3.0 × 0.9 mm 12-LGA, IP67 rating	3	Tray	-40°C to +85°C	490
SGX4410-A3R	SGX4410 Sensor, 3.0 × 3.0 × 0.9 mm 12-LGA IP67 rating	3	Reel	-40°C to +85°C	4000
SGX4410-A4V	SGX4410 Sensor, 3.0 × 3.0 × 0.9 mm 12-LGA, shipped with removable protection sticker and IP67 rating	3	Tray	-40°C to +85°C	490
SGX4410-A4R	SGX4410 Sensor, 3.0 × 3.0 × 0.9 mm 12-LGA, shipped with removable protection sticker and IP67 rating	3	Reel	-40°C to +85°C	4000

13. Revision History

Revision	Date	Description
1.0	Feb 06, 2026	Updated Product Nomenclature Initial release

12-LGA, Package Outline Drawing

3.0 x 3.0 x 0.7 mm Body, 0.5 x 1.0 mm Pitch

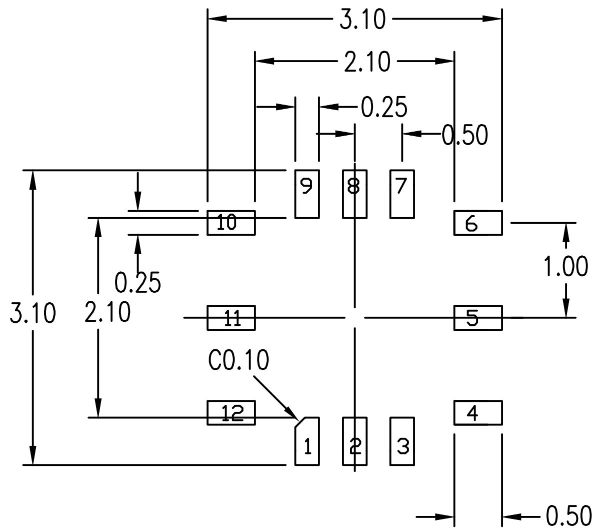


NOTES:

1. ALL DIMENSIONING AND TOLERANCING CONFORM TO ANSI Y14.5M−1982
2. ALL DIMENSION ARE IN MILLIMETERS.
3. UNLESS SPECIFIED, THE TOLERANCE OF +/−0.05MM APPLIES TO DIMENSIONS OF 2 DECIMALS, AND +/−0.012MM APPLIES TO DIMENSIONS OF 3 DECIMALS.

12-LGA, Package Outline Drawing

3.0 x 3.0 x 0.7 mm Body, 0.5 x 1.0 mm Pitch



RECOMMENDED LAND PATTERN DIMENSION

NOTES:

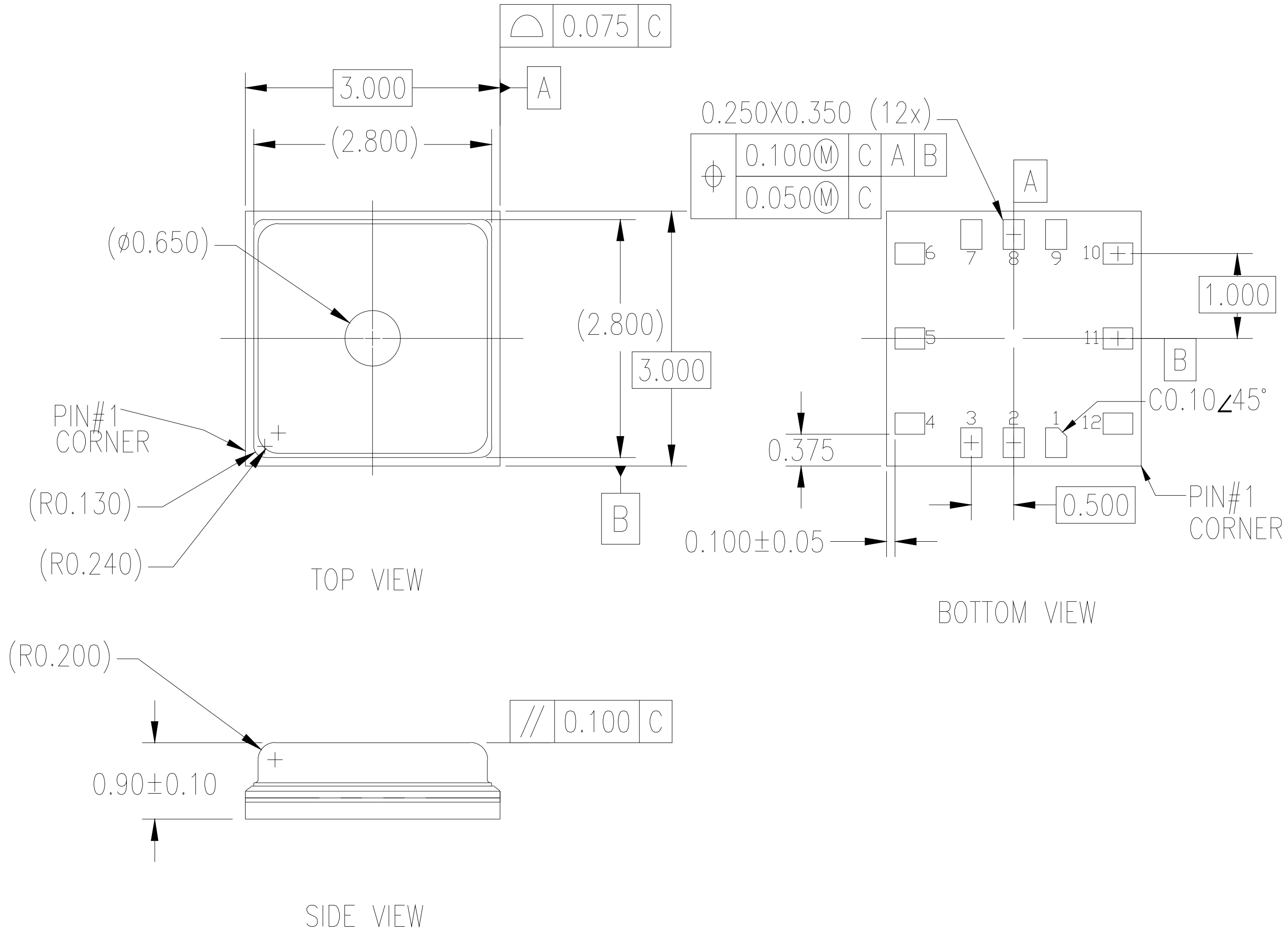
1. ALL DIMENSION ARE IN MM. ANGLES IN DEGREES.
2. TOP DOWN VIEW. AS VIEWED ON PCB.
3. NSMD LAND PATTERN ASSUMED.
4. LAND PATTERN RECOMMENDATION PER IPC-7351B GENERIC REQUIREMENT FOR SURFACE MOUNT DESIGN AND LAND PATTERN.

Package Revision History

Date Created	Rev No.	Description
Sept 12, 2019	Rev 01.	Add Dimension on Gal Inlet Hole
Dec 17, 2019	Rev 02	Add Location Dimension Gal Inlet
Mar 10, 2021	Rev 03	Add Tolerance for Entire Body
Apr 27, 2022	Rev 04	Remove PDF SHX
June 20, 2023	Rev 05	Changed body size tolerance to standard tolerance

12-LGA, Package Outline Drawing

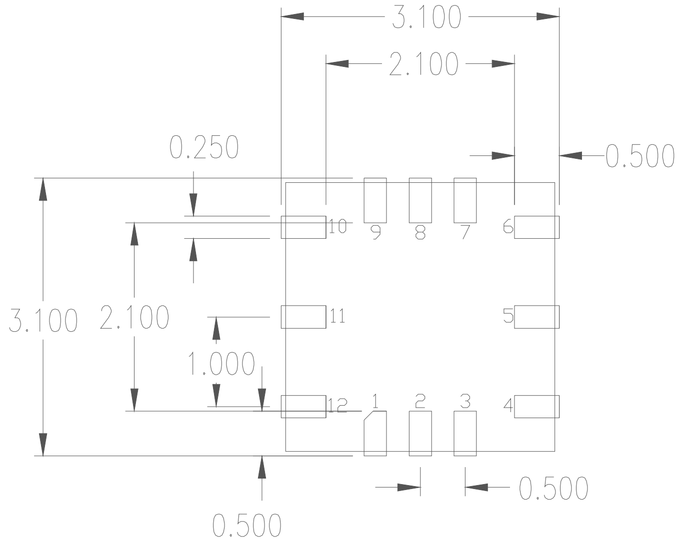
3.0 x 3.0 x 0.9 mm Body, 0.5 x 1.0 mm Pitch



NOTES:
1. ALL DIMENSIONING AND TOLERANCING CONFORM TO ANSI Y14.5M−1982
2. ALL DIMENSION ARE IN MILLIMETERS

12-LGA, Package Outline Drawing

3.0 x 3.0 x 0.9 mm Body, 0.5 x 1.0 mm Pitch



RECOMMENDED LAND PATTERN DIMENSION

NOTES:
1. ALL DIMENSION ARE IN MM. ANGLES IN DEGREES
2. TOP DOWN VIEW ON PCB
3. LAND PATTERN RECOMMENDATION PER IPC-7351B GENERIC REQUIREMENT FOR SURFACE MOUNT DESIGN AND LAND PATTERN

Date Created	Rev No.	Package Revision History
April 24, 2020	Rev 00	Initial release