

Description

The ZMOD4410 Gas Sensor Module is designed for detecting total volatile organic compounds (TVOC) and monitoring indoor air quality (IAQ) in different use cases. It is a 12-pin LGA assembly ($3.0 \times 3.0 \times 0.7$ mm) that consists of a gas sense element and a CMOS signal conditioning IC. The module's sense element consists of heater element on a Si-based MEMS structure and a metal oxide (MOx) chemiresistor. The signal conditioner controls the sensor temperature and measures the MOx conductivity, which is a function of the gas concentration.

The measurement results can be read via an I2C interface with the user's microprocessor, which processes the data to determine the TVOC concentration, IAQ rating, and estimated carbon dioxide (eCO₂) level. Alternatively, depending on the operation mode, the ZMOD4410 software can generate a control signal, which can trigger actions based on odor levels. With its low operating current consumption in Low-Power Operation Mode, the ZMOD4410 is an excellent choice for low-voltage and low-power battery applications. Built-in nonvolatile memory (NVM) stores the configuration and provides space for arbitrary user data.

Typical Applications

- Indoor air monitoring
- Monitor home, office, and personal environments for healthy conditions and comfort
- Detect hazardous materials and unhealthy conditions (e.g. fumes from construction materials)
- Automation based on indoor ambient air quality (HVAC, air purifiers, thermostats, etc.)

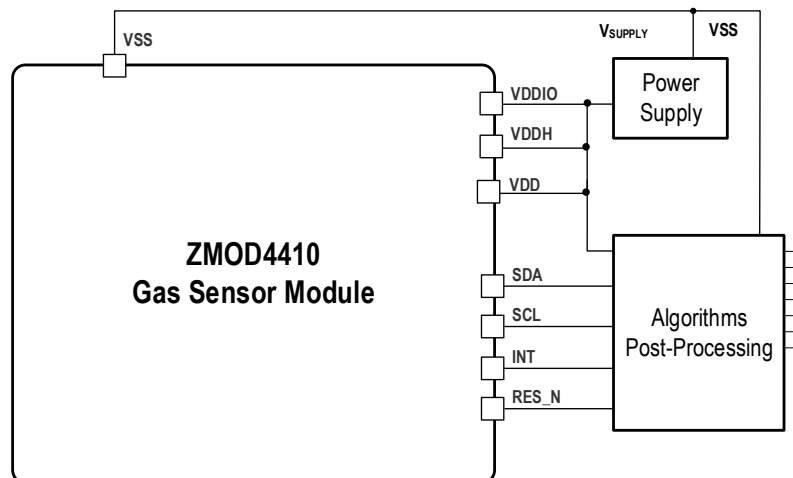
Available Support

- ZMOD4410 Evaluation Kit
- Manuals, application notes, blog, and white papers
- Instructional videos
- Programming libraries, example codes, and algorithm support to optimize performance
- Third-party certification for compliance with well-accepted international IAQ standards

Features

- Measurement of total organic compounds (TVOC) concentrations and indoor air quality (IAQ)
- Module algorithm estimates carbon dioxide level (eCO₂)
- Algorithm to set a control signal to trigger an external action based on IAQ and odor change
- Heater driver and regulation loop for constant heater voltage or constant heater resistance
- Internal auto-compensated temperature sensor; not stress sensitive
- I2C interface: up to 400kHz
- Configurable alarm/interrupt output with static and adaptive levels
- Adjustable ADC resolution for optimal speed versus resolution: 16-bit maximum
- Built-in nonvolatile memory (NVM) for user data
- Very low average power consumption down to 1mW
- Excellent for low-voltage and low-power battery applications
- No external trimming components required
- External reset pin (active-LOW)
- Customization for mobile and consumer applications
- Siloxane resistant
- Supply voltage: 1.7V to 3.6V
- Package: 12-LGA
- Assembly size: $3.0 \times 3.0 \times 0.7$ mm

ZMOD4410 Application Circuit



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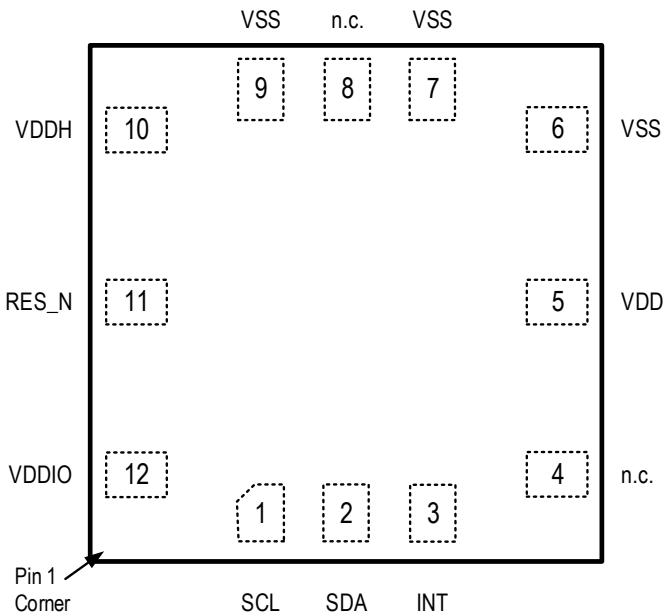
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1. Pin Assignments

Figure 1. ZMOD4410 Pin Assignments for 12-LGA Module – Top View



2. Pin Descriptions

Table 1. ZMOD4410 Pin Descriptions

Pin Number	Name	Type	Description
1	SCL	Input	Serial clock for the I2C interface.
2	SDA	Input/Output	Serial data for the I2C interface. Default 7-bit slave address: 32 _{HEX} .
3	INT	Output	Interrupt signal (push-pull)
4	n.c.	–	Do not connect.
5	VDD	Supply	Voltage supply for the ZMOD4410.
6	VSS	Ground	Ground reference for the ZMOD4410.
7	VSS	Ground	Ground reference for the ZMOD4410.
8	n.c.	–	Do not connect.
9	VSS	Ground	Ground reference for the ZMOD4410.
10	VDDH	Supply	Voltage supply for the integrated heater in the ZMOD4410.
11	RES_N	Input	ZMOD4410 reset; active low.
12	VDDIO	Supply	Voltage supply for I/O-interface in ZMOD4410.

3. Absolute Maximum Ratings

Note: The absolute maximum ratings are stress ratings only. The ZMOD4410 might not function or be operable below and above the recommended operating conditions given 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 might affect device reliability. IDT does not recommend designing to the “Absolute Maximum Ratings.”

Table 2. Absolute Maximum Ratings

Symbol	Parameter	Conditions	Minimum	Maximum	Units
$V_{DD}, V_{DDH}, V_{DDIO}$	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 Module		750	–	V
$T_{OPERATION}$	Operation Temperature of MOx [a]		300	300	°C
T_{STOR}	Storage Temperature		-50	125	°C

[a] Does not apply for the 10min cleaning mode.

4. Operating Conditions

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

Table 3. Operating Conditions

Symbol	Parameter	Min	Typ	Max	Unit
V_{DD}	Supply Voltage	1.7	–	3.6	V
T_{AMB}	Ambient Temperature Range for Sensor Operation	-40	–	65	°C

5. Electrical Characteristics

Values below are valid at operating conditions unless noted otherwise.

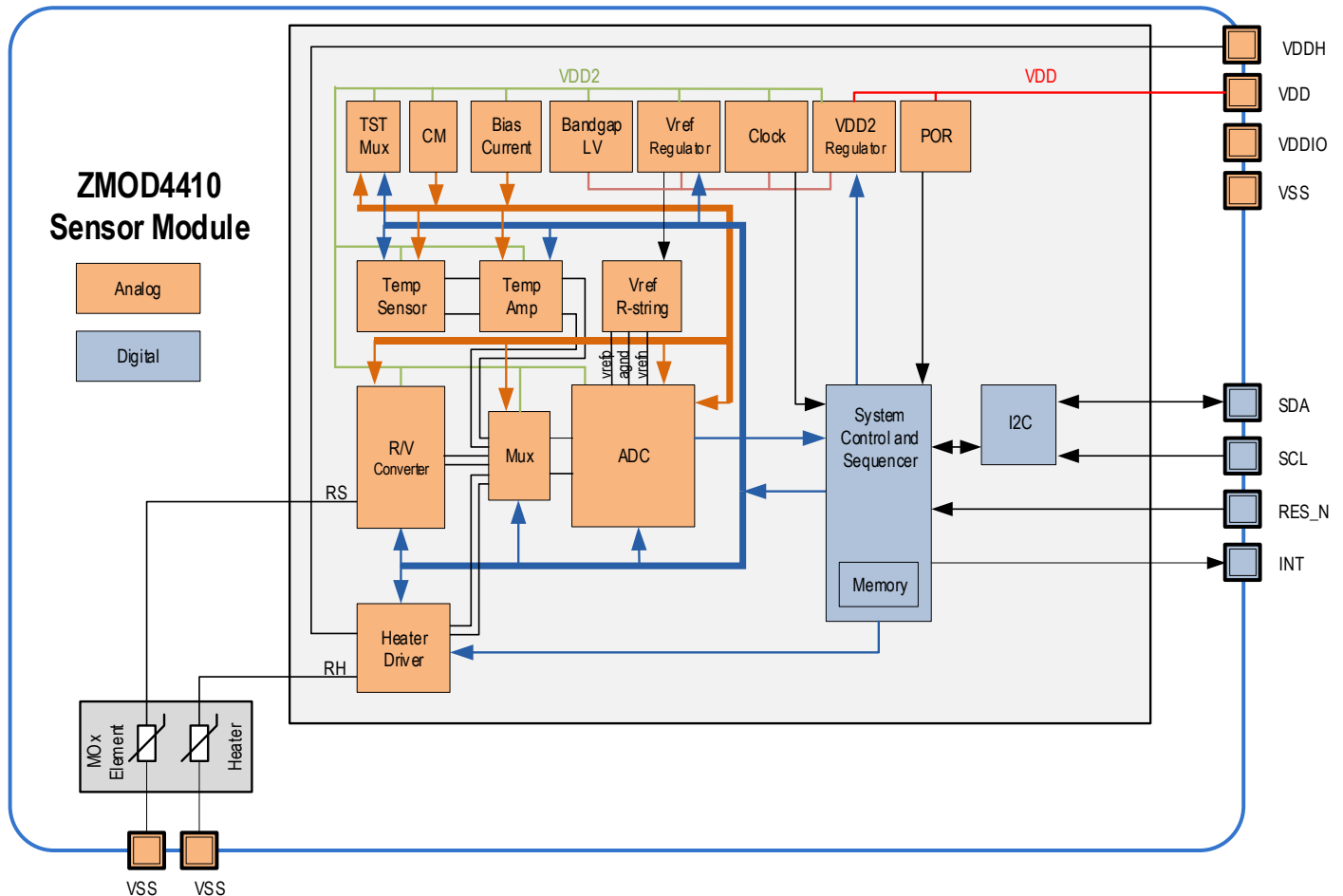
Table 4. ZMOD4410 Electrical Characteristics

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
	Average Power ZMOD4410	Standard and Odor Operation Mode	–	23	–	mW
		Low Power Operation Mode	–	1	–	mW
I _{ACTIVE}	Supply Current, Active Mode including Heater Current during Standard and Odor Operation Modes	At V _{DD} = 1.8 V		13		mA
		At V _{DD} = 3.3V		7		mA
I _{SLEEP_Timer}	Supply Current, Sleep Mode ASIC with Wake-up Timer Active	Does not include heater current.	–	–	500	μA
I _{SLEEP}	Supply Current, Sleep Mode ASIC, No Wake-up Timer Active	Does not include sensor heater current.	–	450	–	nA
PSRR	Power Supply Rejection Ratio	V _{DD} ≥ 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 _{meas}	ADC Conversion Time	10-bit, no auto-zero.	–	0.238	–	ms
		10-bit, auto-zero.	–	0.476	–	ms
		16-bit, auto-zero.	–	3.36	–	ms
V _{ref}	Reference Voltage		–	1.5	–	V
I _{HTR_meas}	Heater Resistance Measurement Current	HTR_range=0	–	0.4	–	mA
		HTR_range=1	–	0.6	–	mA
		HTR_range=2	–	1.0	–	mA
t _{STA1}	Start-up Time: V _{DD} Ramp up to Interface Communication		–	–	1	ms
t _{STA2}	Start-up Time: V _{DD} Ramp up to Analog Operation		–	–	2.5	ms
t _{WUP1}	Wake-up Time for Sleep to Active Mode: Interface Communication		–	–	0.5	ms
t _{WUP2}	Wake-up Time for Sleep to Active Mode: Analog Operation		–	–	2	ms
f _{c,I2C}	I2C Clock Frequency		–	–	400	kHz
t _{VPP}	NVM Programming Time		–	6	16	ms
t _{RET_FTP}	Data Retention	85°C junction temperature	10	–	–	years

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
	NVM Programming Cycles		1000	–	–	cycles
	Default Communication Address	7-bit slave address	–	32 _{HEX}	–	–
	Blocking Capacitor for Power Supply	Recommended, ceramic type	100	–	–	nF

6. Block Diagram

Note: See section 12 for definitions of abbreviations.



7. Sensor Module Characteristics

7.1 Gas Sensor Module

The ZMOD4410 Gas Sensor Module is designed to detect typical TVOC contaminations based on studies and international standards for indoor air quality. Characteristic module parameters are shown in Table 5. The response time for a gas stimulation is always within a few seconds, depending on the TVOC and its concentration. An active or direct airflow onto the sensor module is not necessary since diffusion of ambient gas does not limit the sensor response time.

Table 5. Gas Sensor Module Specifications

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit ^[a]
	Measurement Range	Ethanol in air	0 0		1000 1000000	ppm ppb
	IAQ Specified Measurement Range ¹	Ethanol in air	160		30000	ppb
	Humidity Range	Non-condensing	0		90	% RH
S	Sensitivity over Lifetime	Resistance in air / resistance at 10ppm ethanol		15		Ω/Ω
	Repeatability	Variation in sensor signal		± 10		%
T-90	Sensor Response Time ^[b]	Time to change to 90% of end value		5		s

[a] The abbreviation ppm stands for “parts per million,” and ppb is an abbreviation for “parts per billion.” For example, 1 ppm equals 1000 ppb.

[b] Response times depend on TVOC gas and concentration.

7.2 Internal Temperature Sensor

Table 6. Internal Temperature Sensor

Parameter	Conditions	Minimum	Typical	Maximum	Unit
Temperature Resolution	Range: -40°C to +65°C	–	0.0165	–	°C/LSB
Tolerance	Without calibration	-5	–	5	K

¹ Umweltbundesamt, *Beurteilung von Innenraumluftkontaminationen mittels Referenz- und Richtwerten*, (Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz, 2007).

8. Gas Sensor Module Operation Modes and Characteristics

This section covers information on the different operation modes of the ZMOD4410. At present, three operation modes are released.

Family of IAQ software releases:

- Operation Mode 1: Standard – measurement of UBA levels for IAQ and eCO₂
- Operation Mode 2: Low Power – measurement of UBA levels for IAQ and eCO₂
- Operation Mode 3: Odor – control signal based on IAQ changes

Further, details for sensitivity, reliability, sample rates, and sensor influences are explained in detail in the following sections. All graphs and information show the typical responses that are to be expected from the sensor module upon exposure to a variety of test conditions. More technical detailed information on sensitivity, selectivity, and stability for all operation modes is given in IDT's *ZMOD4410 Application Note – TVOC Sensing*. For additional information, including application notes, white papers, blog, and manuals, visit www.idt.com/ZMOD4410.

8.1 Operation Mode 1: Standard – IAQ and eCO₂ and Operation Mode 2: Low Power – IAQ and eCO₂

These operation modes are used for absolute measurements of indoor air quality according to UBA with eCO₂. Both modes 1 and 2 have the same output signal and same sensor performance. The only difference is the sample rate:

- Standard Operation Mode (1) will provide continuous data depending on the customer application and MCU polling.
- Low-Power Operation Mode (2) has a fixed sampling interval of 6 seconds.

The following sections cover information on TVOC gases, concentrations, and thresholds given by the German Federal Environmental Agency (UBA)² and the US Environmental Protection Agency (EPA). These standards provide reliable information on indoor air quality and recommendations for air improvements if necessary.

8.1.1 Air Quality – UBA Levels

The algorithm provided by IDT for the user's microprocessor uses the output from the ZMOD4410 to determine the relative level of TVOC gases present (see IDT's *ZMOD4410 Programming Manual – Read Me*). The algorithm features an automated baseline correction function, ensuring that the module can learn from its environment and distinguish elevated levels of TVOC under all conditions. The proprietary metal oxide (MOx) used in the sensor ensures the ability of the sensor module to respond effectively to changing TVOC levels during long-term operation.

IDT has adopted the definition of TVOCs and their impact on user health and comfort proposed by the UBA; see Table 7. In Standard and Low-Power Operation Mode, the ZMOD4410 Gas Sensor Module is able to 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. Additional information on this topic is available in IDT's *ZMOD4410 White Paper – Overview of TVOC and Indoor Air Quality*.

The ZMOD4410 is able to respond reliably to all of the types of organic compounds that are typically found in indoor environments. To assess the response of the gas sensor module to the levels described in the UBA study, the module has been tested using several TO-15/17 multi-component TVOC standard defined by the EPA. The ZMOD4410 response to the EPA standard with the TVOC levels from UBA is shown in Figure 2. A third-party report and certification from an independent research lab is available on the IDT website confirming the very good conformity for IAQ measurements with respect to the UBA study and EPA standard.

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

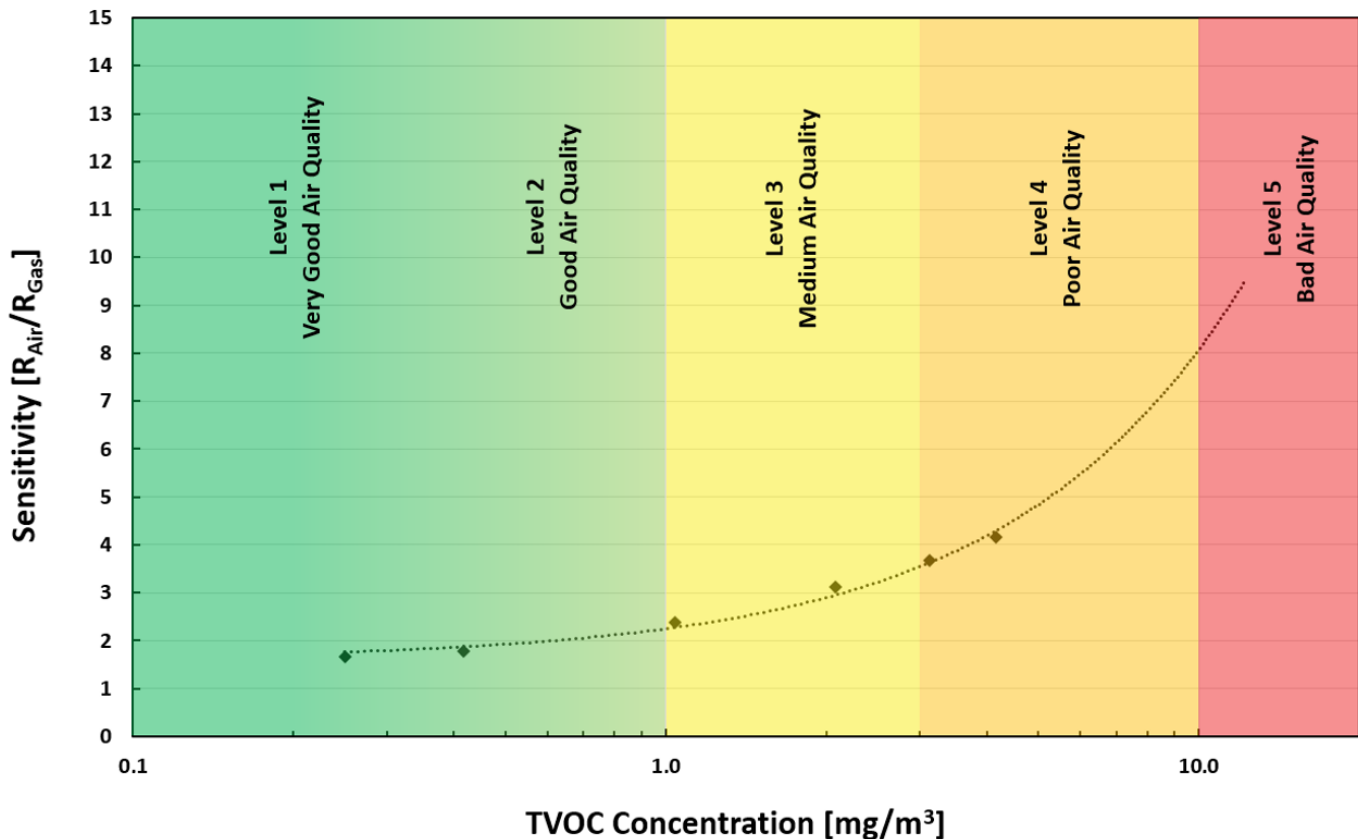
Table 7. Level of Air Quality Based on TVOC Levels Described by the UBA

IDT IAQ Rating	Reference Level ²	Air Information	TVOC (mg/m ³) [a]	Air Quality
≤ 1.99	Level 1	Clean Hygienic Air (target value)	< 0.3	Very Good
2.00 to 2.99	Level 2	Good Air Quality (if no threshold value is exceeded)	0.3 to 1.0	Good
3.00 to 3.99	Level 3	Noticeable Comfort Concerns (not recommended for exposure > 12 months)	1.0 to 3.0	Medium
4.00 to 4.99	Level 4	Significant Comfort Issues (not recommended for exposure > 1 month)	3.0 to 10.0	Poor
≥ 5.00	Level 5	Unacceptable Conditions (not recommended)	> 10.0	Bad

[a] Conversion from mg/m³ to ppm for most 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.

Figure 2. Typical ZMOD4410 Response to Levels of TVOC Described by the UBA using an EPA Standard Mixture

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



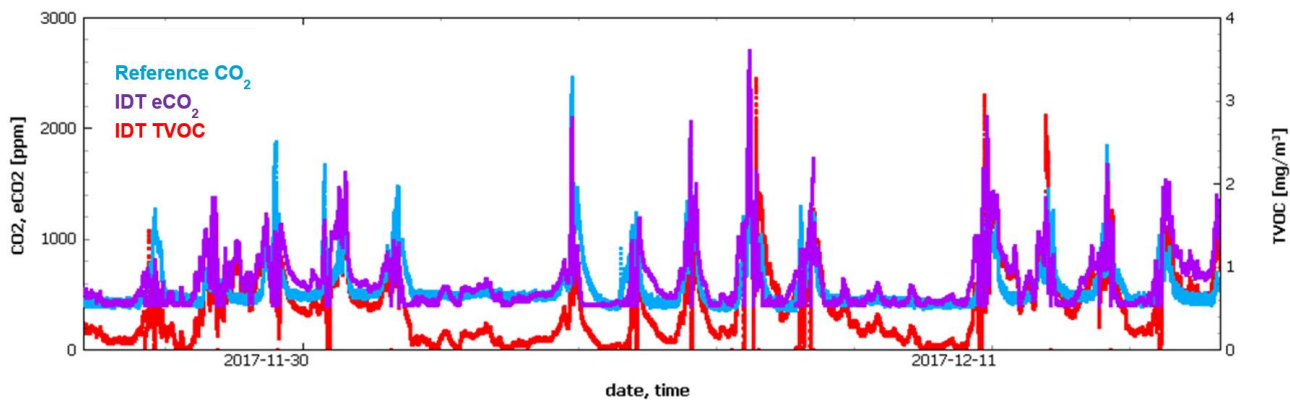
8.1.2 Air Quality – Estimated Carbon Dioxide Correlation (eCO₂)

A very reliable correlation can be made based on TVOC levels for situations where an elevated carbon dioxide (CO₂) concentration is caused by human occupancy, although the sensor module is not directly responsive to CO₂. IDT has developed a robust, patent pending, correlation between elevated VOCs and CO₂ attributable to human occupancy in a wide variety of living spaces, including homes and offices. The correlation is able to predict the CO₂ level as shown in Figure 3. Additional details for IDT's CO₂ correlation are available in IDT's *ZMOD4410 Application Note – Estimating Carbon Dioxide*.

Table 8. Measurement of Estimated CO₂ Levels (eCO₂)

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
eCO ₂	Estimated CO ₂ Range	Human occupied space (home, office, etc.)	400		5000	ppm
	Estimated CO ₂ Accuracy	Versus reference nondispersive Infrared (NDIR) reference instrument		±25		%

Figure 3. Typical Graph of CO₂ Correlation



8.2 Operation Mode 3: Odor

Operation Mode 3 can be used to control an external device, such as a fan or ventilation system, based on the IAQ changes.

IDT provides firmware and algorithms, which allow the ZMOD4410 to learn its environment. The gas sensor module will only respond to changes in the ambient conditions by detecting changes in the relative ambient TVOC concentration. When a user-defined threshold is exceeded, an I/O control signal (trigger) based on the algorithm output may control an external device. Recommendation: Activate the external device for at least a few minutes (stop delay time) to ensure air quality improvement and avoid an on-off activation at the threshold limit.

Table 9. Control Parameters for Odor Operation

Parameter	Conditions	Typical Value	Unit
Learning Time Environment	Typical value valid for sample rate of 10 seconds	60	min
Sensor Response Time	Sample rate dependent, typically 1 sample	10	s
Threshold Trigger	Change of raw sensor signal; recommended difference: 30%	1.3	–
Stop Delay	Stop delay for external device; defines minimum activation time	2	min

When using the ZMOD4410 Evaluation Kit, the AD5 pin (GPIO) on connector K3 on the ZMOD4410 HiCom Communication Board is the trigger control signal output that is set to HIGH/LOW for Operation Mode 3. For more details, refer to the *ZMOD4410 Evaluation Kit User Manual*.

8.3 Conditioning and Stability

The ZMOD4410 will respond to TVOC immediate upon start-up; however, a conditioning period of 48 hours in an ambient environment is recommended to improve stability and get maximum performance. Best results are achieved with continuous operation, as the module algorithm is able to learn about the environment over time.

Figure 4 shows the ZMOD4410 sensor module’s raw data response during standard operation (Mode 1) to clean air with 30%RH and its response to 5ppm, 10ppm, and 20ppm ethanol mixed in clean air. The result is a very stable, fast changing, and repeatable sensor signal with a high sensitivity. Signal stability even at high TVOC indoor air quality contaminations is shown in Figure 5.

Figure 4. ZMOD4410 Typical Response Time and Signal Stability for TVOC Exposure

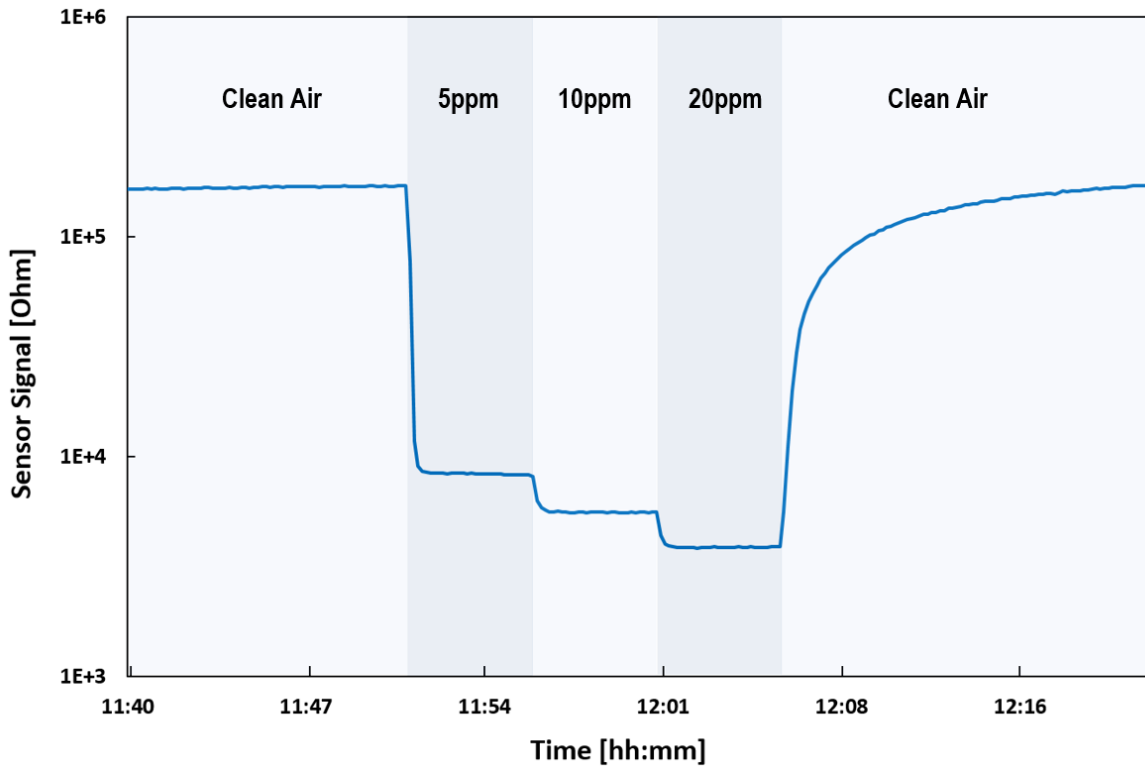
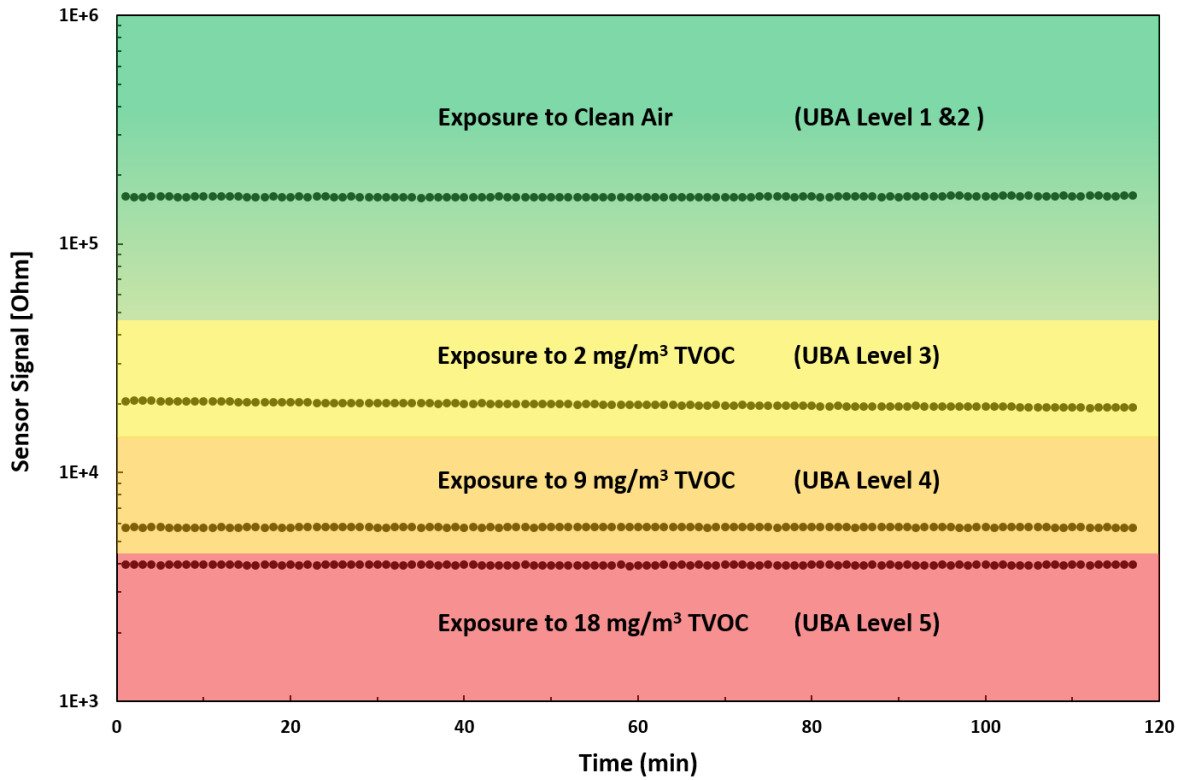
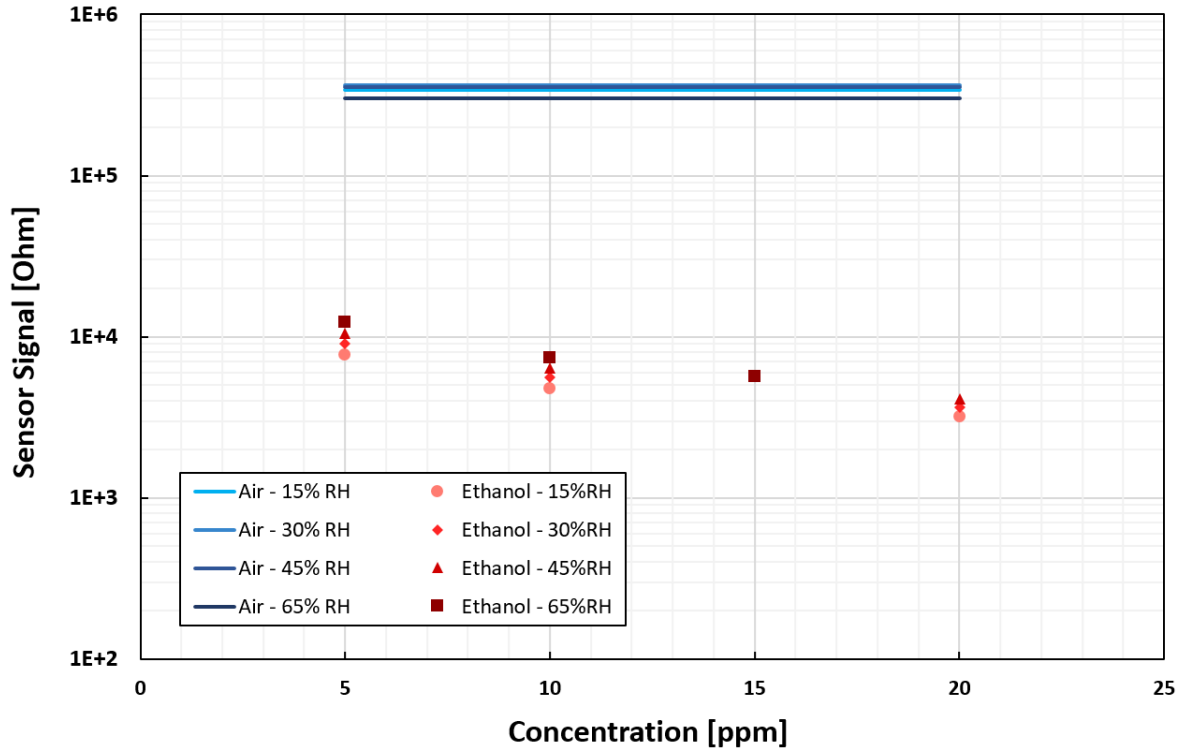


Figure 5. Sensor Module Response to Exposures at Different TVOC Concentrations for 2 Hours Each

8.4 Environmental Temperature and Humidity

Although the sensor module is tested, qualified, and functional in the range of -40°C to +65°C, the best performance according to its calibration is achieved in the temperature range of 0°C to +40°C. Figure 6 shows the module’s response during standard operation (Mode 1) to variations in the range from 15% to 65% relative humidity for different ethanol concentrations.

Figure 6. Humidity Influence at Different VOC Concentrations



8.5 Accuracy

All IDT gas sensor modules come with electrical and chemical factory calibration with data stored in the module’s nonvolatile memory (NVM). Using the software provided by IDT and the calibration coefficients in the NVM will lead to stable measurement of the UBA level discussed in section 8.1.1 with a maximum deviation of 1 category over the module’s lifetime.

Users who require an absolute measurement with the maximum achievable accuracy are advised to re-calibrate the sensor with a known organic compound. This enables an absolute accuracy of ±15% in standard operation (Mode 1); see Table 10. For some environments, an interference response to siloxanes is of concern; however, IDT’s ZMOD4410 has proven to be resistant against siloxanes. A maximum potential life-time exposure has been simulated in all ZMOD4410 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, refer to IDT’s *ZMOD4410 Application Note – TVOC Sensing*.

Table 10. Typical ZMOD4410 Sensor Module Accuracy Achievable with Calibration

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
	Accuracy	With additional calibration		±15		%
	Durability to Siloxanes	Change in sensitivity		±5		%

9. Package Outline Drawings

The package outline drawings are appended at the end of this document and are accessible from the link below. The package information is the most current data available.

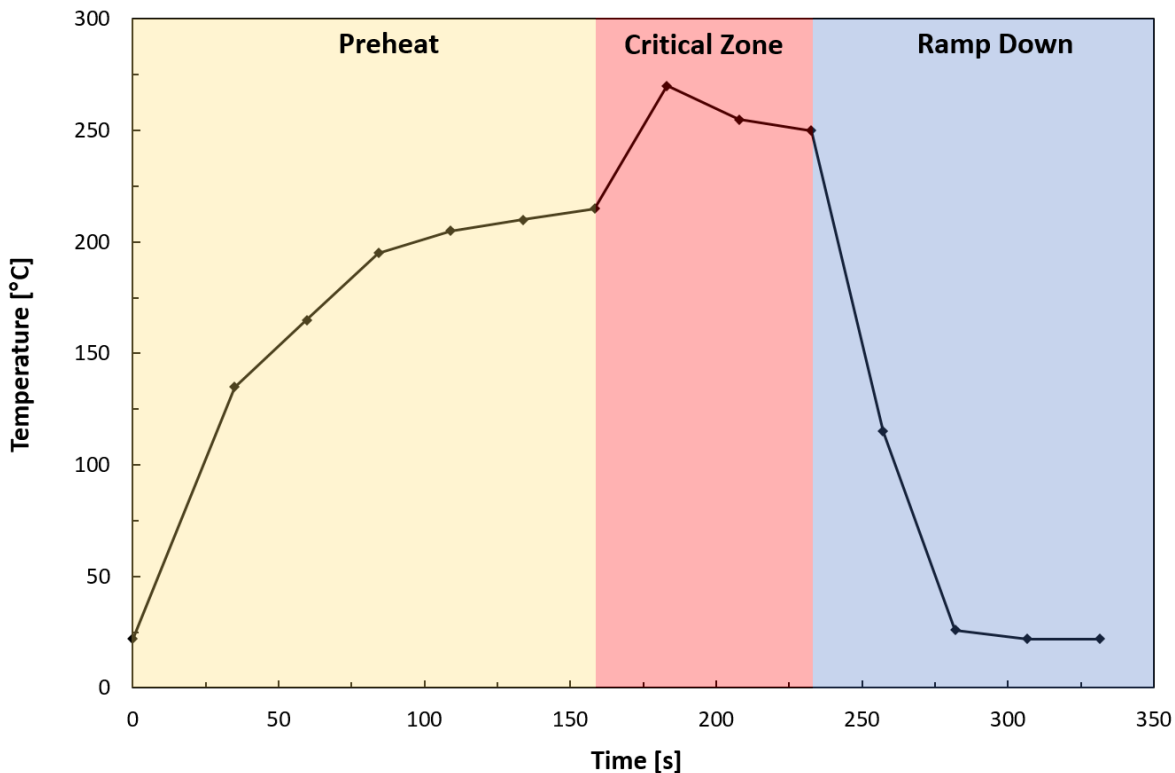
<https://www.idt.com/document/psc/12-lga-package-outline-drawing-30-x-30-x-07-mm-body-05-x-10-mm-pitch-lgg12d1>

10. Assembly Restrictions, Operation, and Integration Notes

When implementing the ZMOD4410 in electrical circuit boards, it should be understood that a gas sensor module might 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 ZMOD4410 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 7. After assembly, an outgassing of the PCB and electronic components must be considered, especially when operating the sensor module at elevated temperatures. This will ultimately influence the sensor signal and may dominate the air quality reading. A PCB heat treatment before assembling the ZMOD4410 is recommended. After the gas sensor module assembly, no coating, cleaning, or ultrasonic bath should be applied to the PCB. Also, after assembly, IDT recommends cleaning the sensor module by operating it at 450°C for 10 min to remove any contamination of solder vapor.

To operate the ZMOD4410, the software and libraries provided by IDT can be used. For implementing the sensor module in a customer-specific application, detailed information on the programming is available. The *ZMOD4410 Programming Manual - Read Me* explains documentation, libraries, and code examples for an easy integration.

Figure 7. Typical Solder Profile



11. Test and Calibration

As a unique feature, all sampled gas sensor modules are fully tested during IDT's final test. The final test parameters in Table 11 are applied for each ZMOD4410. All sensor modules are pre-stabilized in the final test although the user might see a small change in the module's raw signal during an initial warm-up phase during the first operation. The gas sensor module qualification is based on JEDEC (JESD47) and its subsequent standard (JESD22, JESD78 etc.).

Table 11. Final Test Parameters

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

12. Glossary

Term	Description
ADC	Analog-to-Digital Converter
CDM	Charged Device Model
CM	Common Mode Generator
HBM	Human Body Model
LGA	Land Grid Array
LV	Low Voltage
MOx	Metal Oxide
MSL	Moisture Sensitivity Level
Mux	Multiplexer
n.a.	Not Applicable
NVM	Nonvolatile Memory
POR	Power On Reset
SSC	Sensor Signal Conditioner
TST	Test
TVOC	Total Volatile Organic Compounds
UBA	Umweltbundesamt (German Federal Environmental Agency)

13. Ordering Information

Orderable Part Number	Description and Package	MSL Rating	Carrier Type	Temperature
ZMOD4410AI1V	ZMOD4410 Sensor Module, 3.0 × 3.0 × 0.7 mm 12-LGA	1	Tray	-40°C to +65°C
ZMOD4410AI1R	ZMOD4410 Sensor Module, 3.0 × 3.0 × 0.7 mm 12-LGA	1	Reel	-40°C to +65°C
ZMOD4410-EVK-HC	ZMOD4410 Evaluation Kit including the ZMOD4410 Sensor Board, ZMOD4410 HiCom Communication Board (USB Interface), and Micro-USB Cable. (The ZMOD4410 Evaluation Software is available for download free of charge on www.IDT.com/ZMOD4410-EVK .)			

14. Document Revision History

Revision Date	Description of Change
November 2, 2018	<ul style="list-style-type: none"> ▪ Update with Low Power Operation Method.
September 24, 2018	<ul style="list-style-type: none"> ▪ Update for operation methods for trigger/control signal option. ▪ Update for power consumption and minor update in electrical characteristics. ▪ Update references.
September 1, 2018	Initial release.



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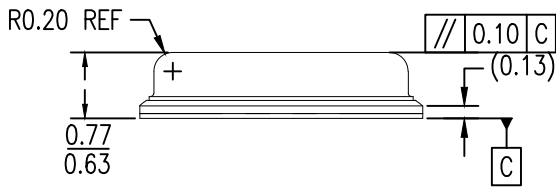
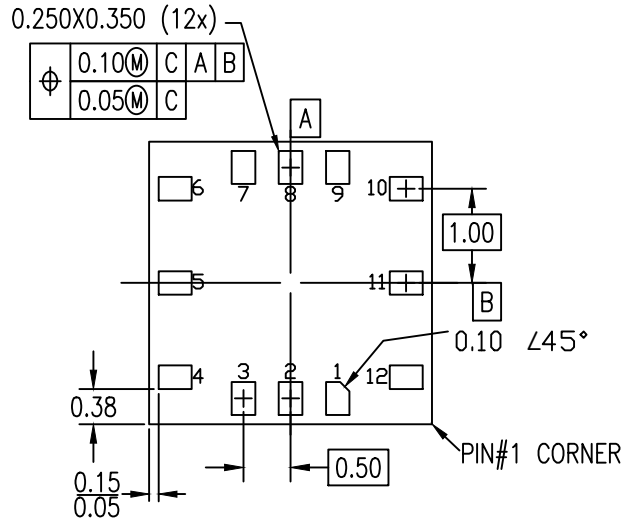
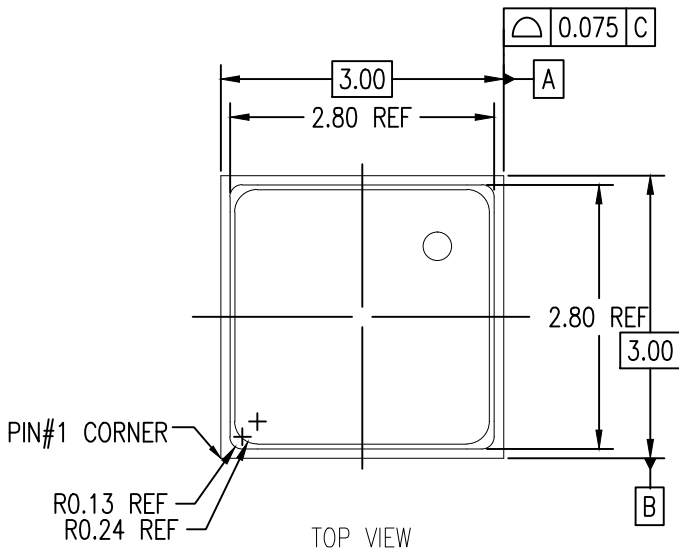
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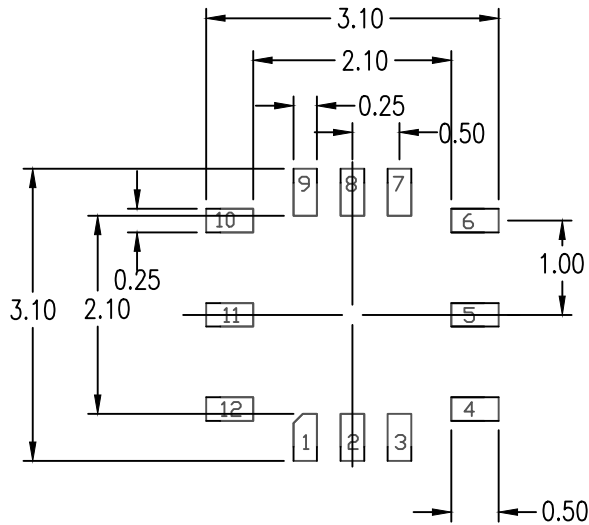
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NOTES:

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



RECOMMENDED LAND PATTERN DIMENSION

NOTES:

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

Package Revision History		
Date Created	Rev No.	Description
Sept 19, 2017	Rev 00	Initial Release