

## Description

The ZMOD4410 Gas Sensor Module is designed for detecting total volatile organic compounds (TVOC) and monitoring indoor air quality (IAQ). It is a 12-pin LGA assembly (3.0 x 3.0 x 0.7 mm) that consists of a gas sense element and a CMOS signal conditioning IC (IDT's ZSSC3250). 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 (eCO<sub>2</sub>) level. With its low operating current consumption, 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.)

## Physical Characteristics

- Wide operation temperature: -40°C to 65°C
- Supply voltage: 1.7V to 3.6V
- Package: 12-LGA
- Assembly size: 3.0 x 3.0 x 0.7 mm

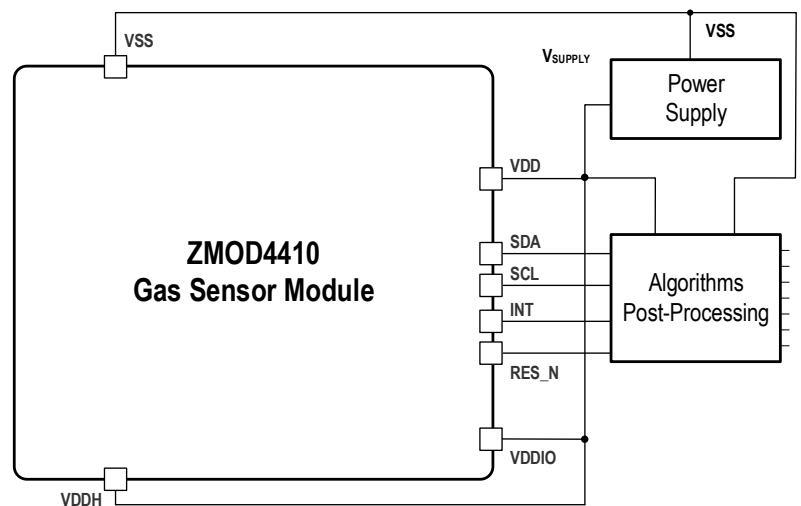
## Available Support

- ZMOD4410 Evaluation Kit
- Manuals, application notes, 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 (eCO<sub>2</sub>)
- Multiplexed input channel for heater, resistance, and temperature measurements
- 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
- Extremely low average power consumption in low  $\mu$ W range
- 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

## ZMOD4410 Application Circuit



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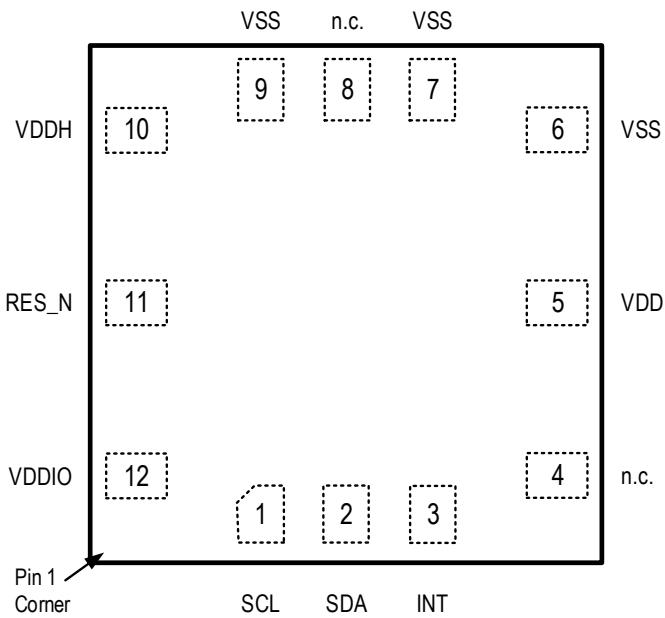
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## 1. Pin Assignments

**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 <sub>HEX</sub> .
3	INT	Output	Interrupt signal.
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 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 <sub>SS</sub>	Voltage Reference (VSS pin)		0	0	V
	Maximum Difference in Voltage between VDD and VDDH Pins		–	0.4	V
V <sub>DD</sub>	Maximum Analog Supply Voltage		-0.4	3.63	V
V <sub>DDIO</sub>	I/O Supply Voltage		-0.4	3.63	V
V <sub>A_IO</sub> , V <sub>D_IO</sub>	Maximum Voltage at all Analog and Digital I/O Pins		-0.5	V <sub>DD</sub> + 0.5	V
I <sub>IN</sub>	Input Current into any Pin Except Supply Pins (Latch-Up Immunity)		-100	100	mA
V <sub>HBM1</sub>	Electrostatic Discharge Tolerance – Human Body Model (HBM)		2000	–	V
V <sub>CDM</sub>	Electrostatic Discharge Tolerance – Charged Device Model (CDM) on Packaged Module		750	–	V
T <sub>OPERATION</sub>	Operation Temperature of MOx		300	300	°C
T <sub>STOR</sub>	Storage Temperature		-50	125	°C

### 4. Operating Conditions

Note: The reference for all voltages is V<sub>SS</sub>.

**Table 3. Operating Conditions**

Symbol	Parameter	Min	Typ	Max	Unit
V <sub>DD</sub>	Supply Voltage (limited performance below 1.7V <sup>[a]</sup> )	1.62	–	3.6	V
V <sub>DD</sub>	Supply Voltage <sup>[a]</sup>	1.7	–	3.6	V
T <sub>AMB</sub>	Ambient Temperature Range for Sensor Operation	-40	–	65	°C

[a] If V<sub>DD</sub> is ≥ 1.62V and ≤ 1.7V, the ZMOD4410 is operational but does not function within specified parameters.

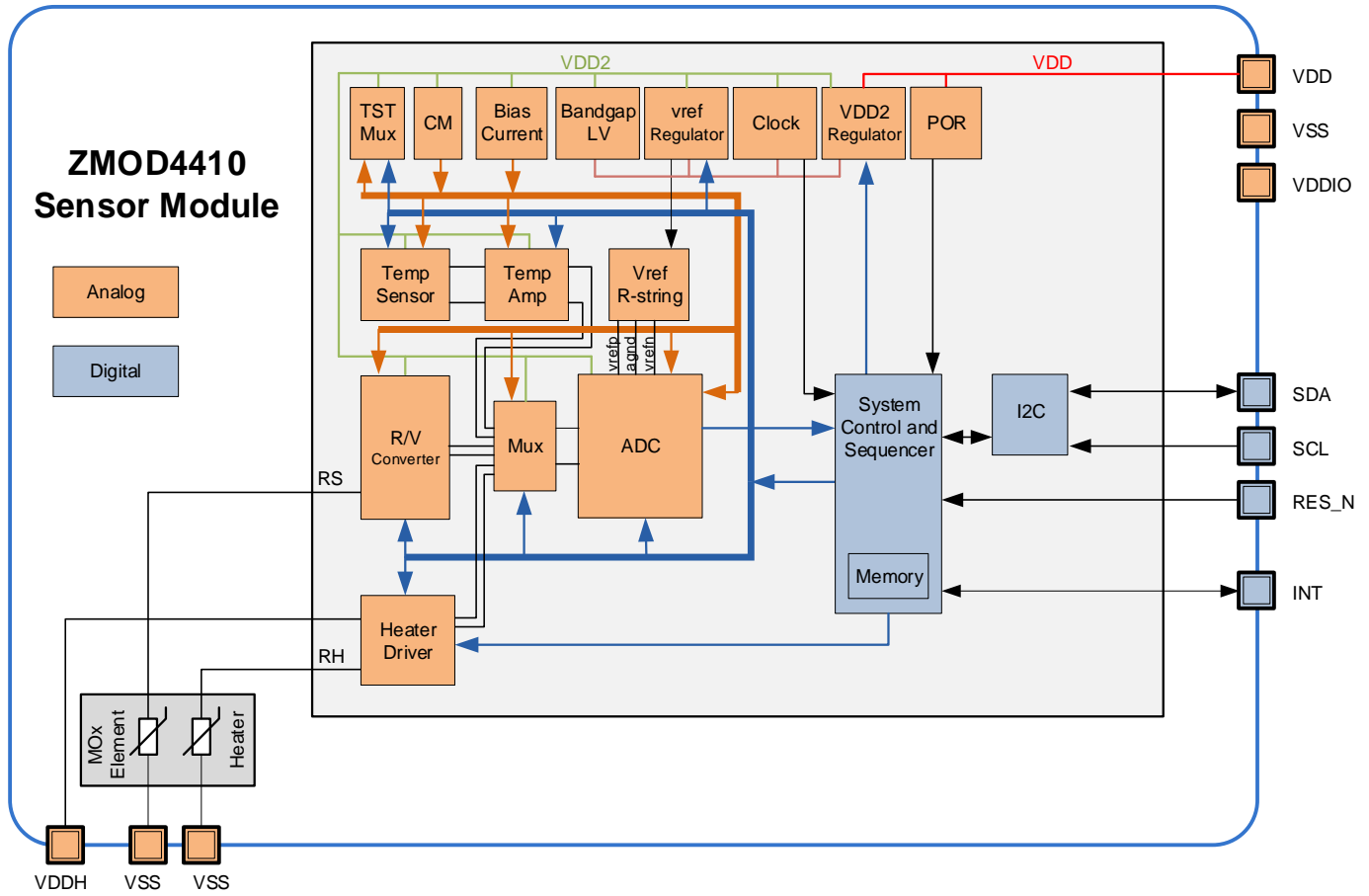
## 5. Electrical Characteristics

**Table 4. ZMOD4410 Electrical Characteristics**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
	Average Power ZMOD4410	MOx constant operation at 300°C.	–	14	–	mW
I <sub>ACTIVE</sub>	Supply Current, Active Mode ZMOD4410	Does include heater current.	–	7	–	mA
I <sub>ACTIVE</sub>	Supply Current, Active Mode ASIC	Does not include heater current.	–	2.8	3.0	mA
I <sub>SLEEP_Timer</sub>	Supply Current, Sleep Mode ASIC with Wake-up Timer Active	Does not include heater current.	–	–	500	µA
I <sub>SLEEP</sub>	Supply Current, Sleep Mode ASIC, No Wake-up Timer Active	Does not include sensor heater current.	–	450	–	nA
PSRR	Power Supply Rejection Ratio	V <sub>DD</sub> ≥ 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 <sub>ADC</sub>	ADC Resolution		10	–	16	Bit
t <sub>meas</sub>	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 <sub>ref</sub>	Reference Voltage		–	1.5	–	V
I <sub>HTR_meas</sub>	Heater Resistance Measurement Current	HTR_range=0	–	0.4	–	mA
		HTR_range=1	–	0.6	–	mA
		HTR_range=2	–	1.0	–	mA
t <sub>STA1</sub>	Start-up Time: V <sub>DD</sub> Ramp up to Interface Communication		–	–	1	ms
t <sub>STA2</sub>	Start-up Time: V <sub>DD</sub> Ramp up to Analog Operation		–	–	2.5	ms
t <sub>WUP1</sub>	Wake-up Time for Sleep to Active Mode: Interface Communication		–	–	0.5	ms
t <sub>WUP2</sub>	Wake-up Time for Sleep to Active Mode: Analog Operation		–	–	2	ms
f <sub>c,I2C</sub>	I2C Clock Frequency		–	–	400	kHz
t <sub>VPP</sub>	NVM Programming Time		–	6	16	ms
t <sub>RET_FTP</sub>	Data Retention	85°C junction temperature	10	–	–	years
	NVM Programming Cycles		1000	–	–	cycles

## 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.

**Table 5. Gas Sensor Module Specifications**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit <sup>[a]</sup>
	Measurement Range	Ethanol in air	0		1000	ppm
	Specified Measurement Range <sup>1</sup>	Ethanol in air	160		30000	ppb
	Humidity Range	Non-condensing	0		90	% RH
S	Sensitivity over Lifetime	Resistance in air / resistance at 10ppm ethanol	2	15		
	Repeatability	Variation in sensor signal		±10		%
T-90	Response Time	Time to change to 90% of end value		5	30	sec

[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.

### 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

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



## 8. Gas Sensor Module Sensitivity Characteristics

This section covers information on TVOC gases, concentrations, and thresholds given by the German Federal Environmental Agency (UBA)<sup>2</sup> and the US Environmental Protection Agency (EPA). These standards provide reliable information on indoor air quality and recommendations for air improvements if necessary. 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.

For additional information, including application notes, white papers, and manuals, visit [www.idt.com/ZMOD4410](http://www.idt.com/ZMOD4410).

### 8.1 Air Quality – TVOC

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 *ZMOD44xx Programming Manual with ZMOD4410 Example*). 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. The ZMOD4410 Gas Sensor Module is able to detect the presence of elevated TVOC levels as described in the UBA study.<sup>2</sup>

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

IDT IAQ Rating	Reference Level <sup>2</sup>	Air Information	TVOC (mg/m <sup>3</sup> ) [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/m<sup>3</sup> to ppm for most common TVOC is by the factor approximately 0.5; for example, 10mg/m<sup>3</sup> equals approximately 5ppm. Conversion from ppm to ppb is by the factor 1000; for example, 0.1ppm equals 100ppb.

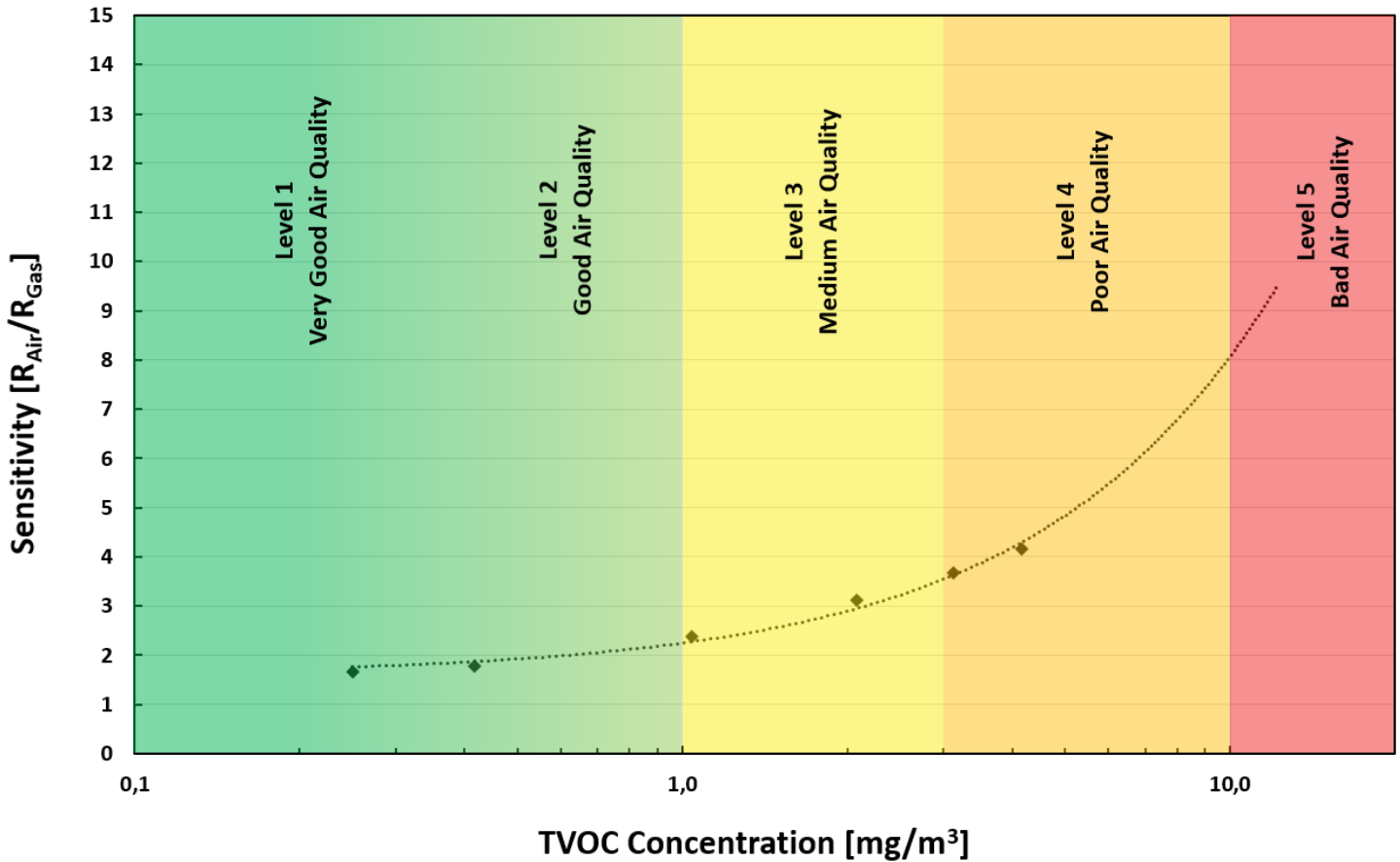
There are many sources of poor indoor air quality that can elevate TVOC levels in the typical home or office environments, and the types of TVOC that might be present can vary widely. Additional information on this topic is available in IDT's *ZMOD4410 White Paper – TVOC and Indoor Air Quality*.

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 a TO-15 66 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.

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

**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.



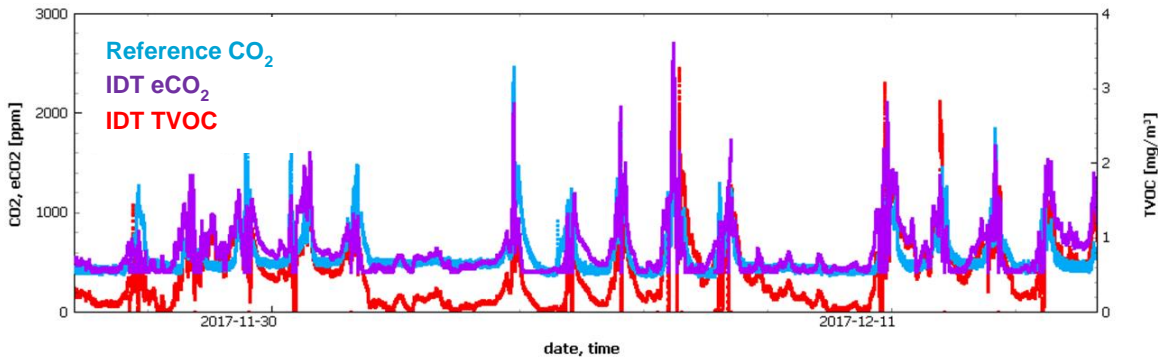
## 8.2 Air Quality – Estimated Carbon Dioxide Correlation (eCO<sub>2</sub>)

A very reliable correlation can be made based on TVOC levels for situations where an elevated carbon dioxide (CO<sub>2</sub>) concentration is caused by human occupancy, although the sensor module is not directly responsive to CO<sub>2</sub>. IDT has developed a robust, patent pending, correlation between elevated VOCs and CO<sub>2</sub> attributable to human occupancy in a wide variety of living spaces, including homes and offices. The correlation is able to predict the CO<sub>2</sub> level as shown in Figure 3. Additional details for IDT's CO<sub>2</sub> correlation are available in IDT's *ZMOD4410 Application Note – Estimating Carbon Dioxide*.

**Table 8. Measurement of Estimated CO<sub>2</sub> Levels (eCO<sub>2</sub>)**

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

**Figure 3. Typical Graph of CO<sub>2</sub> Correlation**

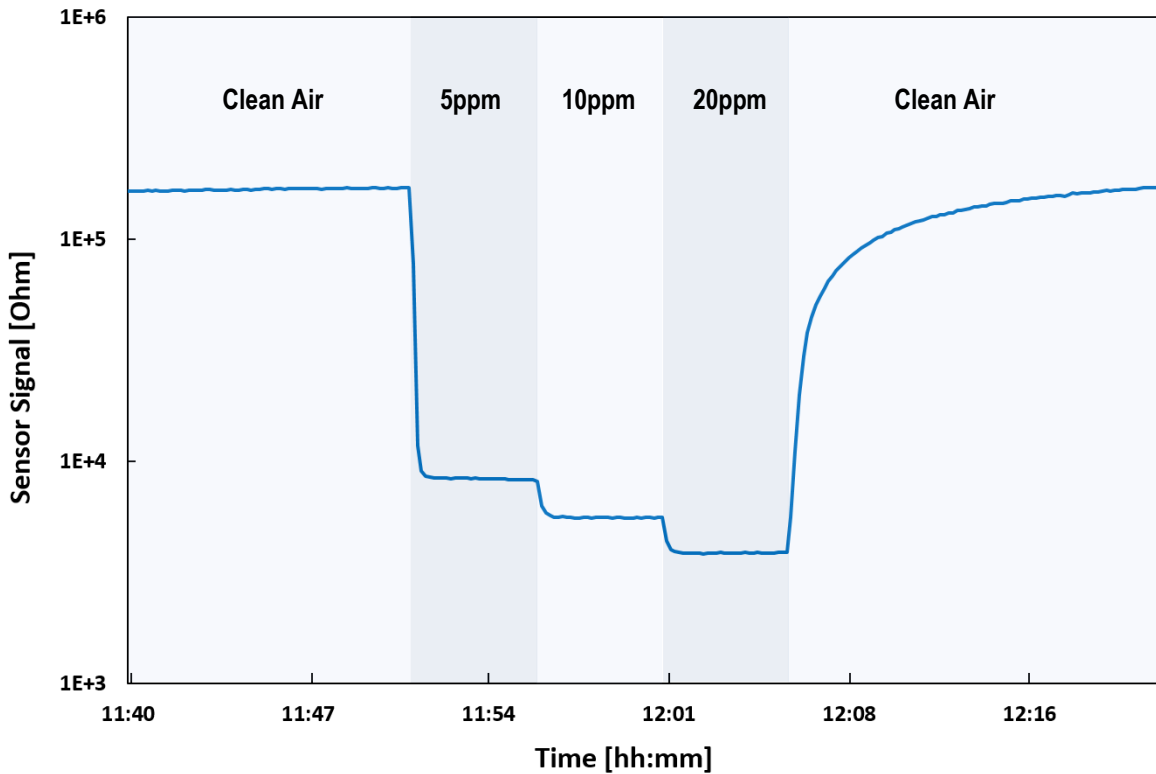


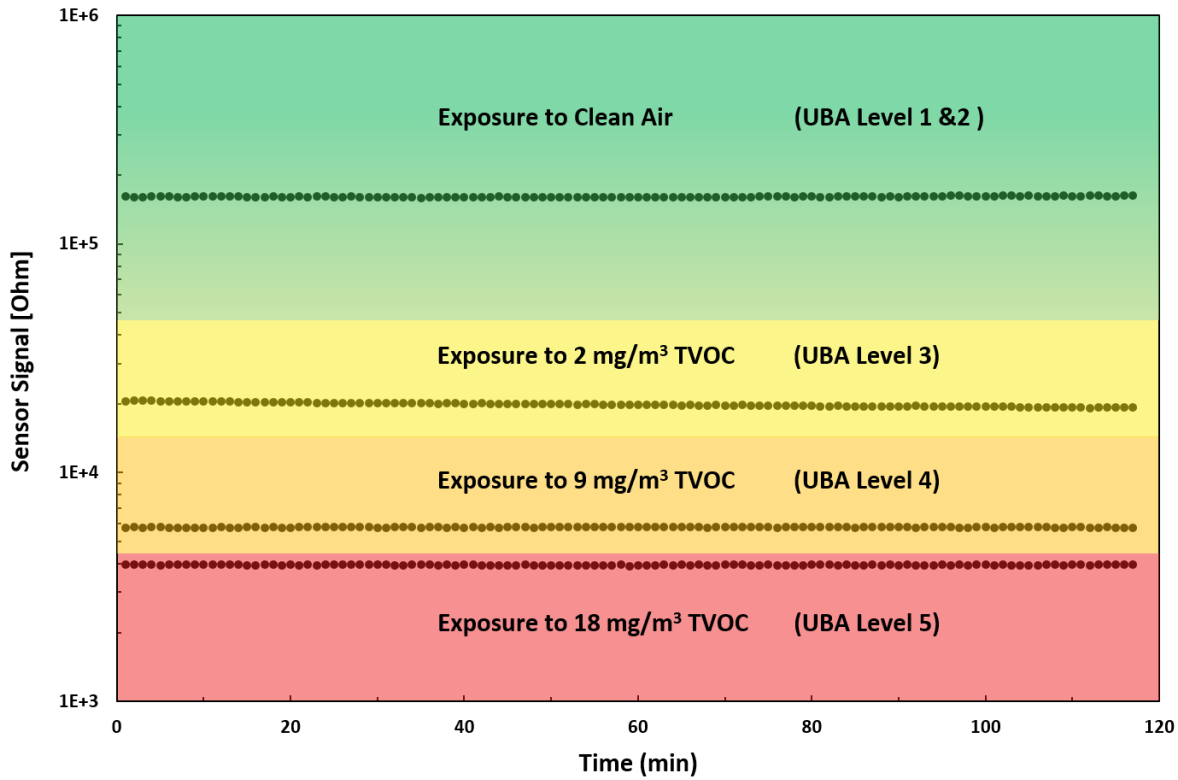
**8.3 Conditioning and Stability**

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. 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 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**

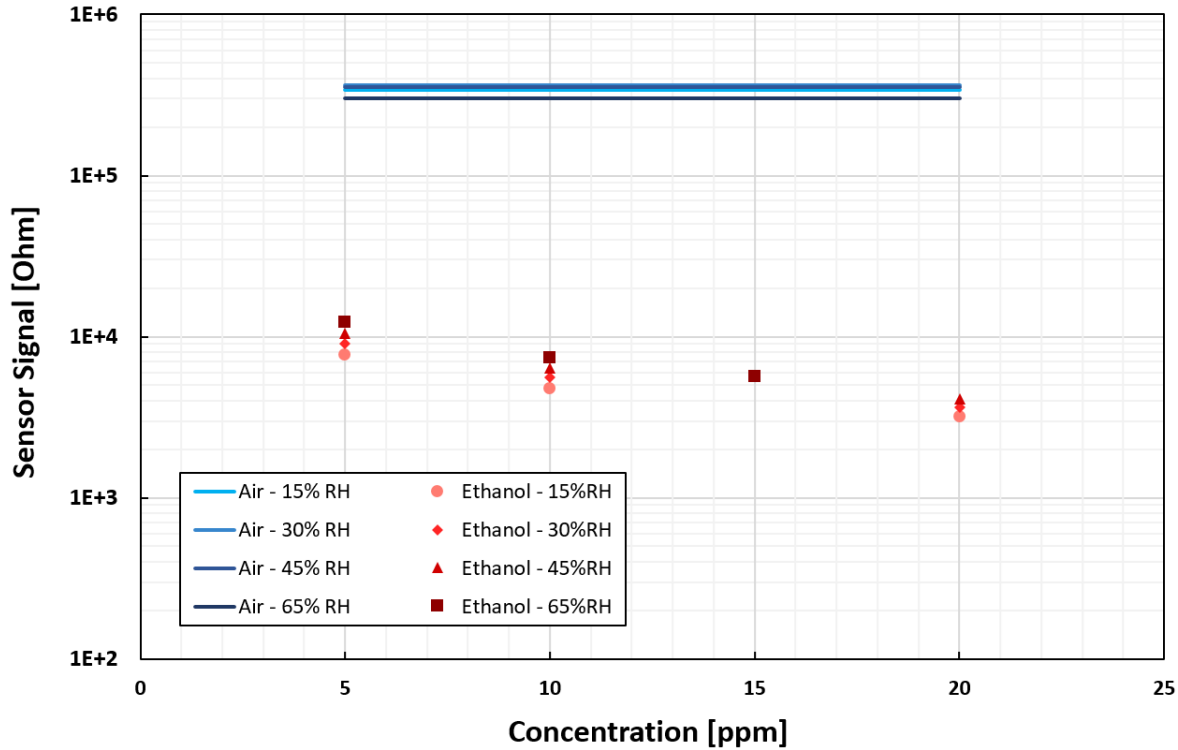


**Figure 5. Sensor Module Response to Exposures at Different TVOC Concentrations for 2 Hours Each**

### 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 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 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% (see Table 9). For some environments, an interference response to siloxanes is of concern; however, IDT’s ZMOD4410 has proven to be resistant against siloxanes. To simulate a maximum potential life-time exposure to D4 (octamethylcyclotetrasiloxane), the concentration of 50ppm has been applied for 330 hours. For more information on test conditions, refer to IDT’s *ZMOD4410 Application Note – TVOC Sensing*.

**Table 9. 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.

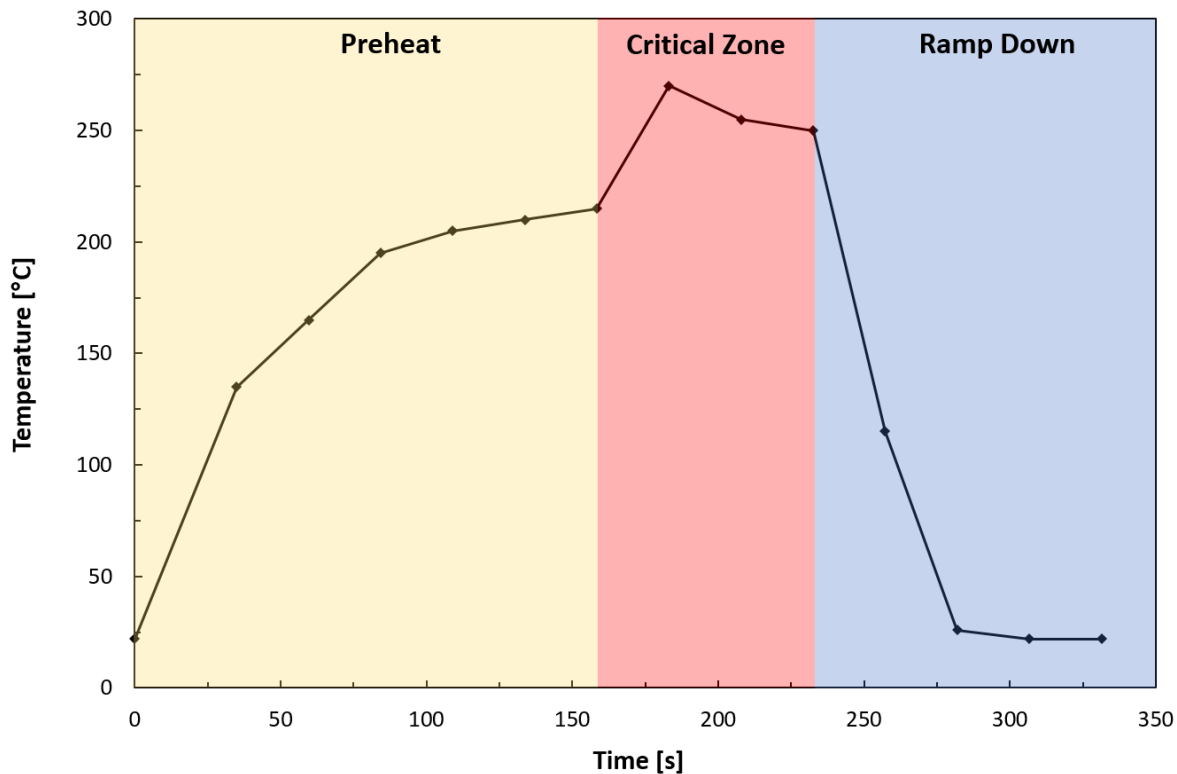
<https://www.idt.com/document/psc/12-lga-package-outline-drawing-30-x-30-x-07-mm-body-05-x-10-mm-pitch-lgg12d1>

## 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, such as the *ZMOD44xx Functional Description for Indoor Air Quality Measurements*. The *ZMOD44xx Programming Manual with ZMOD4410 Example* gives 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 10 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 the JEDEC standard (JESD47).

**Table 10. Final Test Parameters**

Test	Test Object	Parameters	Test Results Saved in NVM?
Electrical	ASIC	Voltages, current consumption, frequencies, scan pattern	No
Electrical	MOx Element	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

### 13. Ordering Information

Orderable Part Number	Description and Package	MSL Rating	Carrier Type	Temperature
ZMOD4410AI1V	ZMOD4410 Sensor Module, 12-LGA	1	Tray	-40°C to +65°C
ZMOD4410AI1R	ZMOD4410 Sensor Module, 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 <a href="http://www.IDT.com/ZMOD4410-EVK">www.IDT.com/ZMOD4410-EVK</a> .)			

### 14. Document Revision History

Revision Date	Description of Change
May 22, 2018	Initial release.



#### Corporate Headquarters

6024 Silver Creek Valley Road  
 San Jose, CA 95138  
[www.IDT.com](http://www.IDT.com)

#### Sales

1-800-345-7015 or 408-284-8200  
 Fax: 408-284-2775  
[www.IDT.com/go/sales](http://www.IDT.com/go/sales)

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