

Description

The ZMOD4510 Gas Sensor Platform detects outdoor air quality in a variety of indoor and outdoor applications. The module 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 a heater element on a silicon-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 device is ideal for monitoring and reporting Total Outdoor Air Quality. The Air Quality Index (AQI) output is based on a combination of outdoor gases present, including nitrogen oxides (NOx) and ozone (O₃).

The measurement results can be read via an I2C interface with the user's microprocessor, which processes the data to determine the levels of gases present and to indicate the AQI based on international standards. With its low operating current, the ZMOD4510 is an excellent choice for low-voltage and low-power battery applications. Built-in nonvolatile memory (NVM) stores the module configuration and calibration data.

Typical Applications

- Outdoor air monitoring
- Detect unhealthy conditions in outdoor air
- Personal air quality monitors
- Automation based on AQI (HVAC systems, building air purification systems)

Physical Characteristics

- Target operation temperature: -40°C to 65°C
- Supply voltage: 1.7V to 3.6V
- Package: 12-LGA
- Assembly size: $3.0 \times 3.0 \times 0.7$ mm

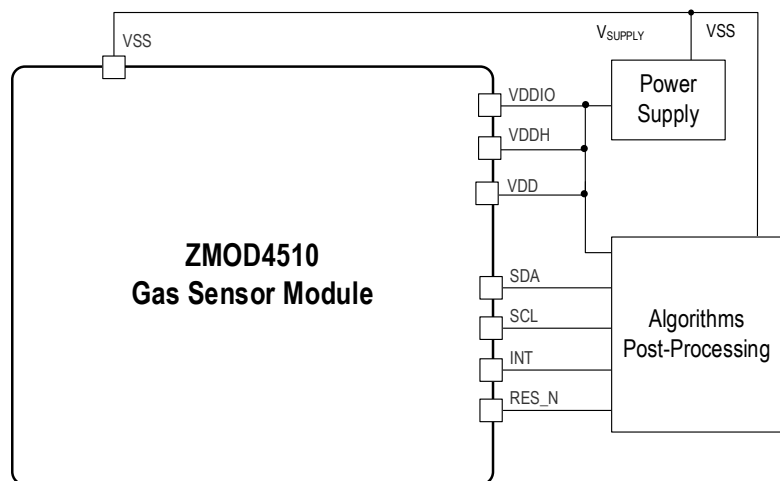
Available Support

- ZMOD4510 Evaluation Kit
- Manuals, application notes, blog, and white papers
- Instructional videos
- Programming libraries, example codes, and algorithm support to optimize performance

Features

- Measurement of outdoor air quality, including ppb trace gas concentrations of nitrogen oxides (NO_x) and ozone (O₃)
- Supports international standards for total outdoor air quality, such as the US Environmental Protection Agency (EPA)
- Heater driver and regulation loop for constant resistance, minimizing effect of environmental temperature on signal
- Internal auto-compensated temperature sensor; not stress sensitive
- I2C interface: up to 400kHz
- Configurable alarm/interrupt output with static and adaptive levels
- Built-in nonvolatile memory (NVM) for module-specific data
- Low average power consumption in low mW range
- Supports low-voltage and low-power battery applications
- No external trimming components required
- External reset pin (active-LOW)
- Customization for mobile, industrial, and consumer applications
- Siloxane resistant
- RoHS compliant

ZMOD4510 Application Circuit



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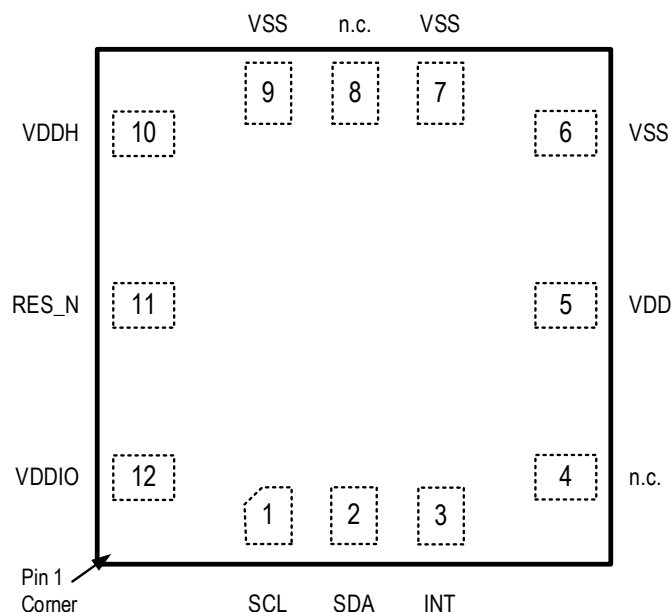
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1. Pin Assignments

Figure 1. Pin Assignments – Top View



2. Pin Descriptions

Table 1. 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: 33 _{HEX} .
3	INT	Output	Interrupt signal (push-pull): ▪ HIGH when a measurement is running ▪ LOW when a measurement has finished
4	n.c.	–	Do not connect.
5	VDD	Supply	Voltage supply for the ZMOD4510.
6	VSS	Ground	Ground reference for the ZMOD4510.
7	VSS	Ground	Ground reference for the ZMOD4510.
8	n.c.	–	Do not connect.
9	VSS	Ground	Ground reference for the ZMOD4510.
10	VDDH	Supply	Voltage supply for the integrated heater in the ZMOD4510.
11	RES_N	Input	ZMOD4510 reset; active low.
12	VDDIO	Supply	Voltage supply for I/O-interface in ZMOD4510.

3. Absolute Maximum Ratings

The absolute maximum ratings are stress ratings only. The ZMOD4510 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. Renesas does not recommend designing to the “Absolute Maximum Ratings.”

Table 2. Absolute Maximum Ratings

Symbol	Parameter	Minimum	Typical	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	–		1500	V
$T_{OPERATION}$	Operation Temperature Sequence of Sense Element [a]	220		320	°C
T_{STOR}	Storage Temperature	-50		125	°C

[a] Controlled via API in firmware and EVK software.

4. Operating Conditions

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

Table 3. Operating Conditions

Symbol	Parameter	Minimum	Typical	Maximum	Unit
V_{DD}	Supply Voltage for ZMOD4510 Sensor Module	1.7	–	3.6	V
T_{AMB}	Ambient Temperature Range for Sensor Operation	-40	–	65	°C

5. Electrical Characteristics

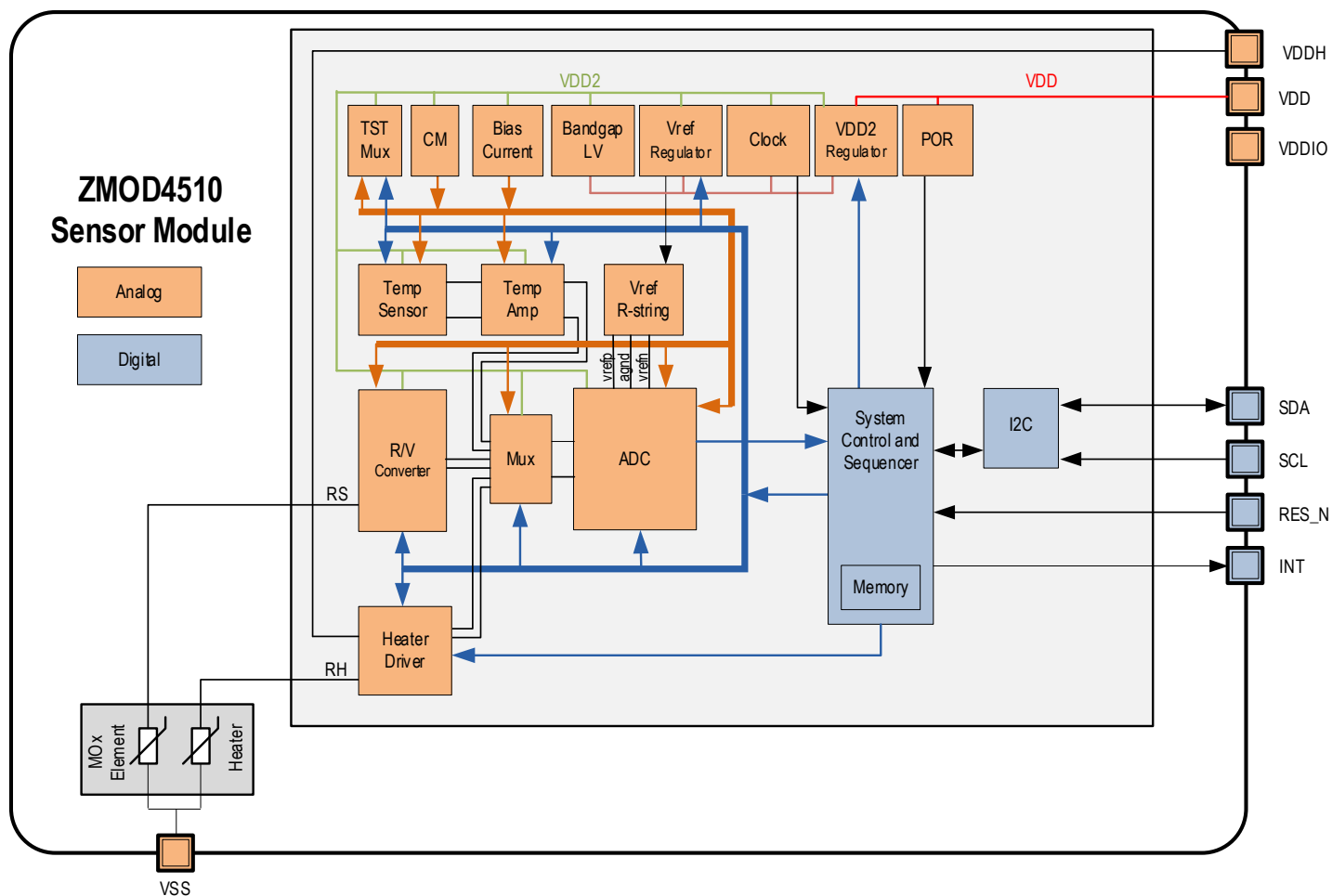
The following values are valid at operating conditions unless noted otherwise.

Table 4. Electrical Characteristics

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
	Average Power ZMOD4510	Continuous operation	–	21	–	mW
I_{ACTIVE}	Supply Current, Active Mode including Heater Current.	At VDD = 1.8V		11		mA
		At VDD = 3.3V		8		mA
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	VDD ≥ 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: VDD Ramp up to Interface Communication		–	–	1	ms
t_{STA2}	Start-up Time: VDD 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
	NVM Programming Cycles		1000	–	–	cycles
	Default Communication Address	7-bit slave address	–	33 _{HEX}	–	–
	Blocking Capacitor for Power Supply	Ceramic type; recommended to be placed close to gas sensor module	100	–	–	nF

6. Block Diagram

Note: See section 11 for definitions of abbreviations.



7. Sensor Module Characteristics

The ZMOD4510 Gas Sensor Module detects typical outdoor gases based on studies and international standards for outdoor air quality. Characteristic module parameters are shown in Table 5. The ZMOD4510 uses a sequence of applied temperatures in order to sample the air and report a combined Air Quality Index based on the EPA standard. The sample rate to execute the sequence and detect outdoor air is 60 seconds. The sensor does not require an active or direct airflow onto the sensor module since diffusion of ambient gas does not limit the sensor response time.

Important: The ZMOD4510 can also detect safety-relevant gases; 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 Renesas disclaims all liability for any such use.

Table 5. Gas Sensor Module Characteristics

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit ^[a]
	Measurement Range	Ozone	20		500	ppb
	Measurement Range	Nitrogen dioxide	20		500	ppb
	Humidity Range	Non-condensing	0		90	% RH
	Temperature Range		-40		65	°C
	Repeatability	Variation in sensor signal for consecutive exposures		±25		%
T-90	Response Time	Limited by sample rate		±60		sec

[a] The abbreviation ppb stands for “parts per billion” and is a molar ratio with the exponent of 10⁻⁹.

8. Gas Sensor Module Characteristics

Additional information about sensitivity 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 ZMOD4510 Gas Sensor Module upon exposure to a variety of test conditions. For additional information, including application notes, white papers, blog, and manuals, visit www.idt.com/ZMOD4510.

8.1 Typical Gas Stimulation

The algorithm provided by Renesas for the user's microprocessor uses the output from the ZMOD4510 to determine the relative level of outdoor gases present (see Renesas' *ZMOD4510 Programming Manual – Read Me*; see section 12). The algorithm features an automated baseline correction function, ensuring that the module can learn from its environment and distinguish elevated levels of outdoor gases under all conditions. The proprietary metal oxide (MOx) used in the sensor ensures that the sensor module can respond effectively to changing Ozone and Nitrogen Oxide levels during long-term operation.

There are many sources of poor outdoor air that can elevate the Air Quality Index (AQI). Renesas has adopted the definition of Outdoor Air Quality and its impact on user health and comfort proposed by the US Environmental Protection Agency (EPA); see Table 6*. The ZMOD4510 Gas Sensor Module can detect the presence of elevated Ozone (O₃) and Nitrogen Oxides (NO₂) levels as described by the EPA. Each concentration is considered from a 1-hour class; however, in case the 1-hour value is not available a linear approach was assumed to calculate the AQI value. AQI values above 500 are considered beyond the AQI.

The reported AQI from the ZMOD4510 sensor is derived from the calculated combination of NO₂ and O₃ present.

Additional information on this topic, chemical background information, and measurement technologies is available in Renesas' *ZMOD4510 White Paper – Overview Outdoor Air Quality*.

Table 6. Air Quality Index Levels Described by the EPA*

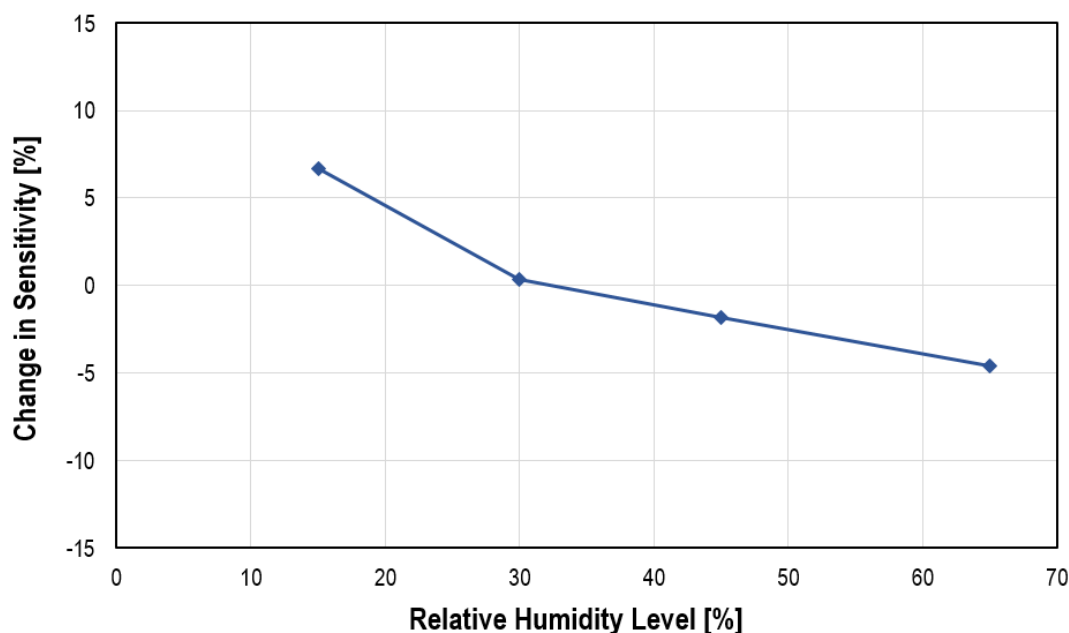
Air Quality Index (AQI)	Level of Concern and Air Quality Condition	NO ₂ Concentration [ppb]	O ₃ Concentration [ppb]	Color Code
0 to 50	Good	0 to 53	0 to 62	Green
51 to 100	Moderate	54 to 100	63 to 124	Yellow
101 to 150	Unhealthy for Sensitive Groups	101 to 360	125 to 164	Orange
151 to 200	Unhealthy	361 to 649	165 to 204	Red
201 to 300	Very unhealthy	650 to 1249	205 to 404	Purple
301 to 500	Hazardous	1250 to 2050	405 to 604	Maroon

* AirNow, United States Environmental Protection Agency, Office of Air Quality Planning and Standards (OAQPS), 2019

8.2 Environmental Temperature and Humidity

The sensor module is tested, qualified, and functional in the operation range of -40°C to +65°C. Figure 2 shows the module's sensitivity during operation to variations in relative humidity while stimulated with 100ppb Nitrogen Dioxide (NO₂). Due to the low influence of humidity, there is additional humidity measurement and no algorithmic compensation necessary.

Figure 2. Humidity Influence on the Sensitivity for 100ppb NO₂



8.3 Accuracy and Conditioning

All Renesas 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 Renesas and the calibration coefficients in the NVM will result in stable measurements of the AQI levels discussed in section 8.1. The ZMOD4510 will respond reliably to typical outdoor gases after a warm-up time of 60 min, consisting of 20 min for stabilization and 40 min for baseline finding; however, a conditioning period of 48 hours in an outdoor environment is recommended to improve stability and achieve maximum performance.

Users who require an absolute measurement with the maximum achievable accuracy are advised to re-calibrate the sensor with a known outdoor air compound. This enables an absolute accuracy of $\pm 15\%$ (see Table 7). For some environments, an interference response to siloxanes is of concern; however, Renesas' ZMOD4510 gas sensors have been proven to be resistant against siloxanes. A maximum potential life-time exposure has been simulated in all ZMOD4510 operation modes by applying the chemicals D4 (Octamethylcyclotetrasiloxane) and D5 (Decamethylcyclopentasiloxane) in high concentration for several hundred hours.

Table 7. Typical ZMOD4510 Sensor Module Accuracy Achievable with Calibration

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
	Accuracy	With additional calibration		± 15		%
	Durability to Siloxanes	Change in sensitivity		± 8		%

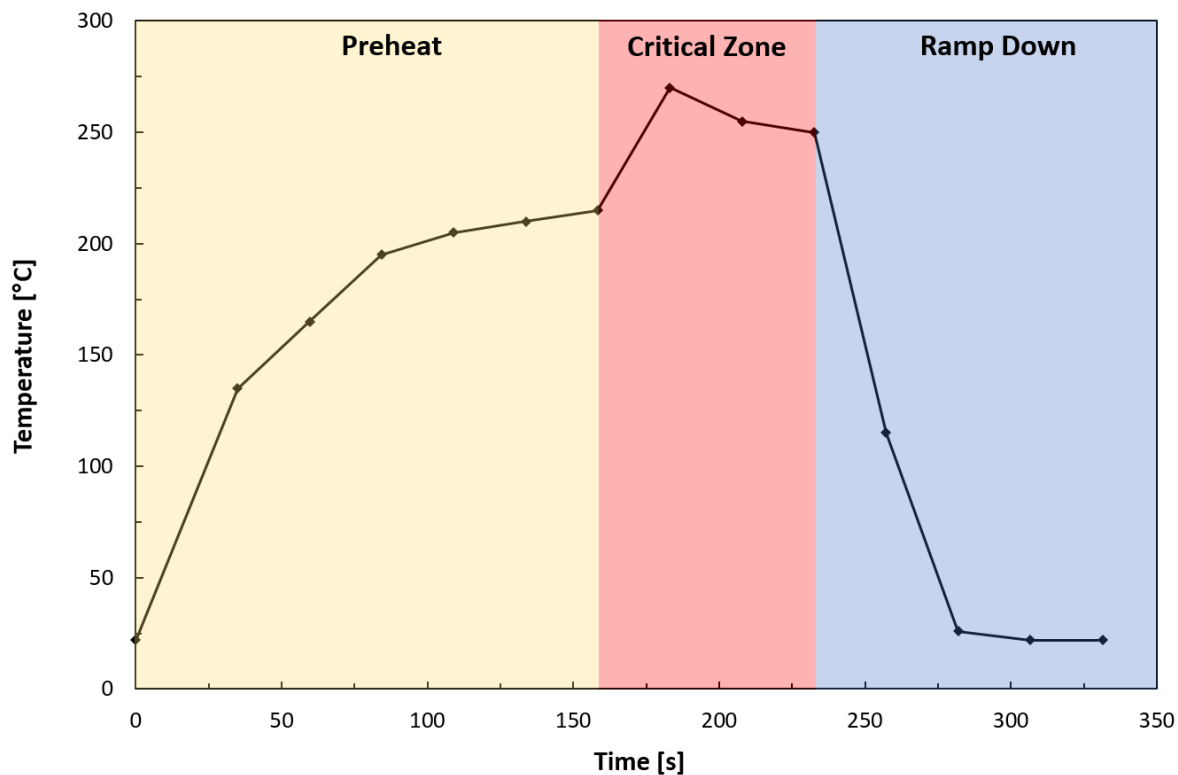
9. Assembly Restrictions, Operation, Integration Notes, and Storage

When implementing the ZMOD4510 in electrical circuit boards, a gas sensor module 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 ZMOD4510 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 3. 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 accuracy of the Air Quality Index (AQI). A PCB heat treatment before assembling the ZMOD4510 is recommended. After the gas sensor module assembly, no coating, cleaning, or ultrasonic bath should be applied to the PCB.

Store the sensor in an antistatic metallic bag with a low VOC background after the sensor module is removed from its original packaging or the assembled PCB is populated. The optimal storage conditions are <1 ppm TVOC, <100 ppb O₃, <100 ppb NO₂, 10°C to 50°C, and humidity levels within 20% to 80%RH. If the sensor is stored outside of these conditions for extended periods of time, the sensor readings can exhibit a temporary offset. The sensor can be reconditioned and brought back to its calibration state by operation for 24 hours to 48 hours in clean air.

To operate the ZMOD4510, the software and libraries provided by Renesas can be used. For implementing the sensor module in a customer-specific application, detailed information on the programming is available. The *ZMOD4510 Programming Manual - Read Me* explains documentation, libraries for supported controllers and compilers, code examples in C, and the minimum requirements for the host MCU for an easy integration (see section 12).

Figure 3. Typical Solder Profile



10. Test and Calibration

As a unique feature, all sampled gas sensor modules are fully tested during Renesas' final test. The final test parameters in Table 8 are applied for each ZMOD4510. 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.); it has been tested for a lifetime of 5 years. Renesas has proven a MOx lifetime of over 15+ years in actual continuous operation in conditions without exposures to stressful environments.

Table 8. 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 and intercept) at stimulation with different gas concentrations	Yes
Gas	Module	Pre-stabilization	No

11. I2C Interface and Data Transmission Protocol

The I2C slave device interface supports various bus speeds: Standard Mode ($\leq 100\text{kHz}$) and Fast Mode ($\leq 400\text{kHz}$).

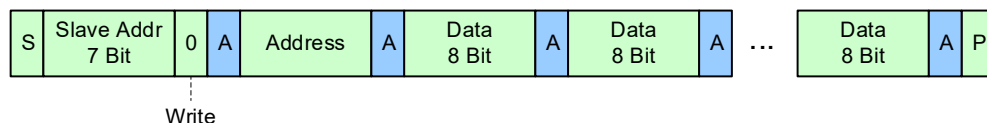
By default, the 7-bit slave address for the serial I2C data interface is set to 33_{HEX}. The implemented data transmission protocol is similar to the one used for conventional EEPROM devices. The register to read/write is selected by a register address pointer. This address pointer must be set during an I2C write operation. After transmission of a register, the address pointer is automatically incremented. An increment from the address FF_{HEX} rolls over to 00_{HEX}.

For an example of the I2C data transmission protocol, see Figure 4. For information on I2C bus timing, see Figure 5. For I2C bus characteristics, see Table 9, which explains how to set up the interface. Although the ZMOD4510 has an I2C interface, the user is not intended to modify any registers because a configuration change will affect the 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 read/write access it is possible to write random values to registers 0x88 to 0x8B, and then read them afterwards. After register testing, reset the device by disconnecting the power support; otherwise, the device may not operate properly.

Figure 4. I2C Data Transmission Protocol

WRITE Access RAM



READ Access NVM and RAM

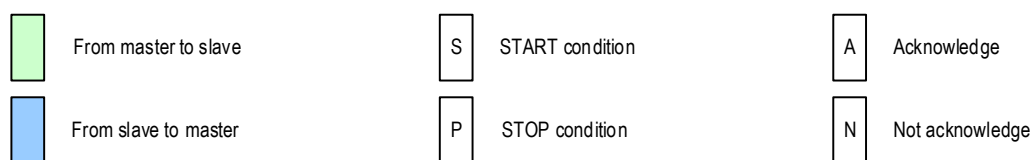


Figure 5. Bus Timing

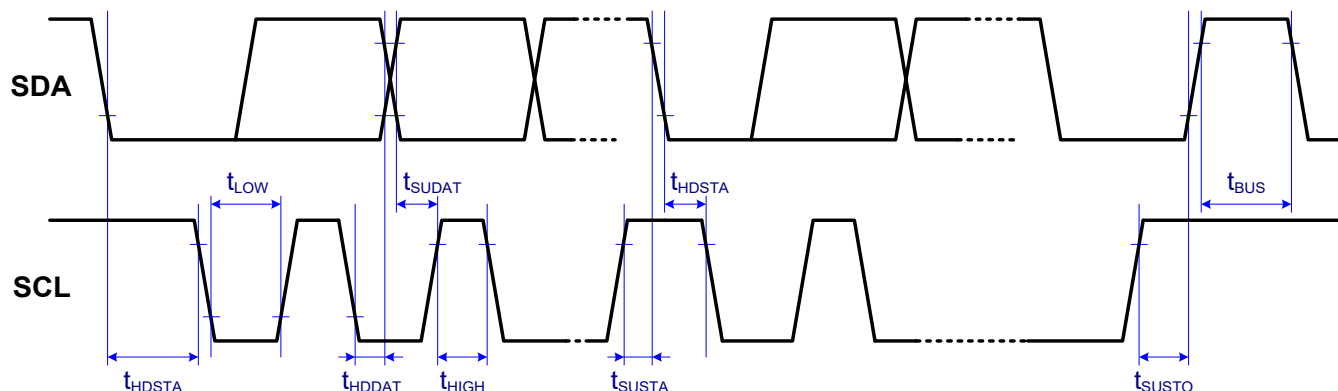


Table 9. Bus Timing Characteristics

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

12. Related Websites and Software

Visit the ZMOD4510 and ZMOD4510 Evaluation Kit (ZMOD4510-EVK) product pages on Renesas' website to download software and the latest version of related documents, such as application notes, white papers, product briefs, and third-party reports.

Note that some documents require logging in with a free customer account, which can be set up under the "LOG IN" button on www.IDT.com. Some downloads require an additional step to complete a request form that appears when the link is clicked.

Product	Web Page
ZMOD4510	www.IDT.com/ZMOD4510
ZMOD4510-EVK	www.IDT.com/ZMOD4510-EVK

If further support is needed for downloading, contact Renesas via the contact information on the last page.

13. Glossary

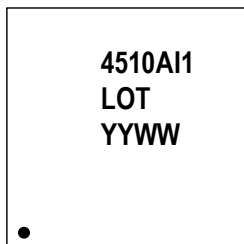
Term	Description
ADC	Analog-to-Digital Converter
CDM	Charged Device Model
CM	Common Mode Generator
EPA	Environmental Protection Agency (USA)
HBM	Human Body Model
LGA	Land Grid Array
LV	Low Voltage
MOx	Metal Oxide
MSL	Moisture Sensitivity Level
Mux	Multiplexer
n.a.	Not Applicable
NVM	Nonvolatile Memory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

14. 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.

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

15. Marking Diagram



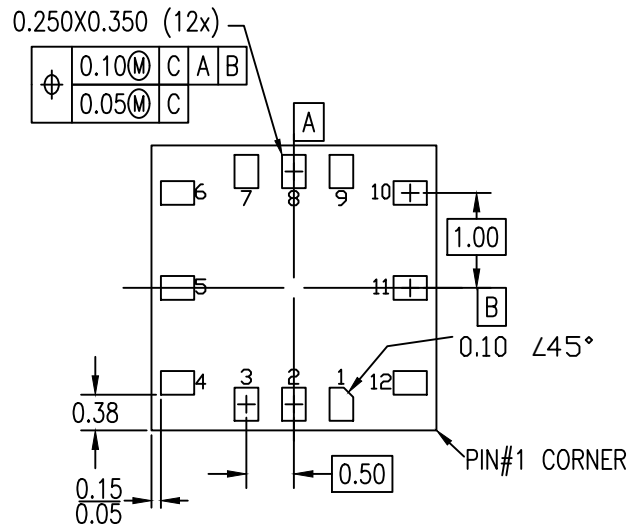
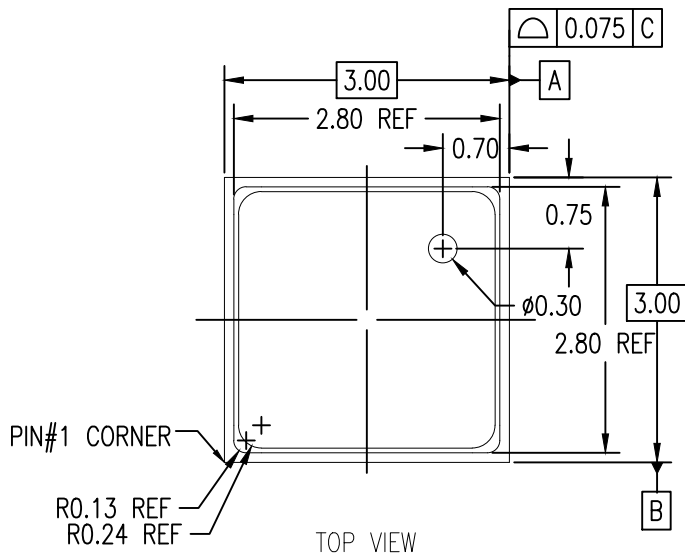
1. Line 1 is the truncated part number.
2. Line 2 – “LOT” denotes the assembly lot number.
3. Line 2 – “YYWW” are the last two digit of the year and week that the part was assembled.

16. Ordering Information

Orderable Part Number	Description and Package	MSL Rating	Carrier Type	Temperature
ZMOD4510AI1V	ZMOD4510 Sensor Module, 3.0 × 3.0 × 0.7 mm 12-LGA	3	Tray	-40°C to +65°C
ZMOD4510AI1R	ZMOD4510 Sensor Module, 3.0 × 3.0 × 0.7 mm 12-LGA	3	Reel	-40°C to +65°C
ZMOD4510-EVK-HC	ZMOD4510 Evaluation Kit including the ZMOD4510 Sensor Board, HiCom Communication Board (USB Interface) and Micro-USB Cable. The Gas Sensor Evaluation Software is available for download free of charge on www.IDT.com/ZMOD4510-EVK			

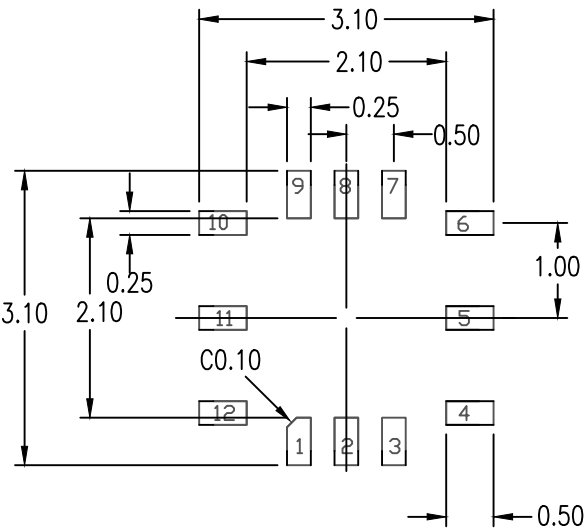
17. Revision History

Revision Date	Description of Change
February 7, 2020	- Added ROHS compliance - Updated NVM data space - Updated on temperature measurements
September 9, 2019	Initial release.



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 12, 2019	Rev 01.	Add Dimension on Gal Inlet Hole
Dec 17, 2019	Rev 02	Add Location Dimension Gal Inlet

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