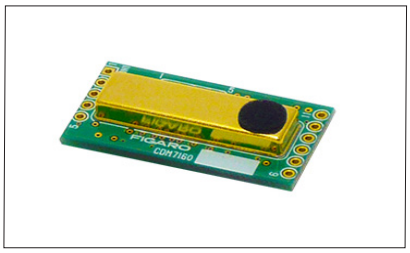
FIGARO

an ISO9001 company

Technical Information for the CDM7160 CO_2 Module



The **CDM7160** CO_2 module uses a nondispersive infrared (NDIR) sensor principle and compact optics to achieve excellent performance characteristics, including high accuracy and low power consumption. Two detector elements inside the module make absolute measurement possible. Every module is individually calibrated and is provided with both a UART and I2C digital interface. The CDM7160 module is designed for simple integration into a user's products. It can be used in a wide range of applications such as ventilation controls for the improvement of energy savings and to assure a good indoor climate.

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IMPORTANT NOTE: OPERATING CONDITIONS IN WHICH FIGARO SENSORS ARE USED WILL VARY WITH EACH CUSTOMER'S SPECIFIC APPLICATIONS. FIGARO STRONGLY RECOMMENDS CONSULTING OUR TECHNICAL STAFF BEFORE DEPLOYING FIGARO SENSORS IN YOUR APPLICATION AND, IN PARTICULAR, WHEN CUSTOMER'S TARGET GASES ARE NOT LISTED HEREIN. FIGARO CANNOT ASSUME ANY RESPONSIBILITY FOR ANY USE OF ITS SENSORS IN A PRODUCT OR APPLICATION FOR WHICH THE SENSOR HAS NOT BEEN SPECIFICALLY TESTED BY FIGARO.

1. Basic Information and Specifications

1-1 *Features*

* Small size
* Low power
* High accuracy
* Absolute measurement via dual sensors

1-2 *Applications:*

* Indoor air quality control
* Fresh air ventilators
* Air conditioners
* Automatic fans and window openers

1-3 *Basic principle and structure*

Fig. 1 shows the basic principle of measuring absolute values. Fig. 2 shows the basic structure of the module's optics.

This sensor is a single light source, dual wavelength system. The sensor employs two detectors with different optical filters in front of each detector. One detector measures the intensity of infrared light passing through the optical filter, transmitting only the infrared wavelength region absorbed by CO_2 (CO_2 absorption wavelength). The other detector measures the intensity of infrared light passing through the optical filter, transmitting only an infrared wavelength (3.8µm) not absorbed by CO_2 (i.e. a reference wavelength), and is thus unaffected by the constant presence of CO_2.

Measuring absolute values of CO_2 concentration by CDM7160 is achieved by the module's microprocessor calculating CO_2 concentration from the difference between light intensity transmitted at the CO_2 absorption wavelength and at the reference wavelength.

The single light source, dual wavelength system employed by the CDM7160 measures light intensities at two different wavelengths after separation by two optical filters, thus compensating drift due to accumulated dust and contamination. This ensures long term stability, minimum maintenance, and cost-effectiveness.

1-4 *Operating conditions & specifications (refer to Table 1)*

1-5 *Absolute maximum ratings (refer to Table 2)*

Products using CDM7160 should be designed so that these maximum ratings are *never* exceeded.

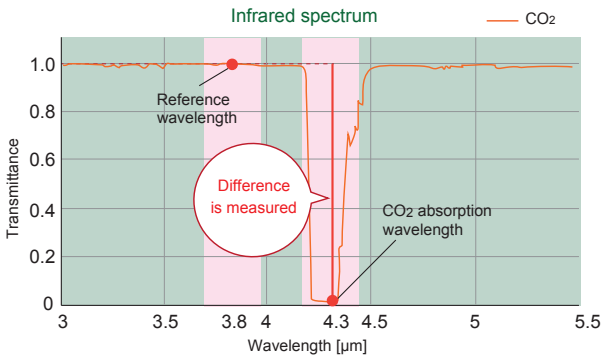


Fig. 1 - Basic principle for measuring absolute values

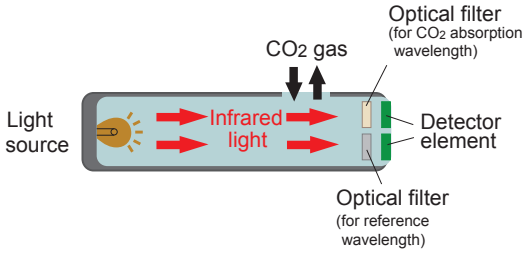


Fig. 2 - Basic structure of CDM7160 optics

Product name	Carbon dioxide (CO2) sensor module
Model No.	CDM7160-B00
Detection range	300~5,000ppm CO2
Operating principle	Non-dispersive infrared (NDIR)
Power supply	4.75~5.25V DC
Current consumption	60mA peak, 10mA avg.
Accuracy (Note 1)	±(50ppm+3% of reading) in the range of 300~5,000ppm CO2
Pressure dependency	approx 1% of reading / kPa
Response time (T90)	2 min. (diffusion)
Operating conditions	0~50˚C/0~85%RH (no condensation)
Storage conditions	-30~70˚C/0~85%RH (no condensation)
Communication port	UART/ I2C (gas conc. output 0~10,000ppm)
Measurement interval	2 sec.
PWM output (1kHz)	0~100% duty cycle for 0~5,000ppm, CMOS output
Alarm output	CMOS output: High>1,000ppm Low<900ppm
Dimensions	32 x 17 x 7.5 (mm)
Weight	approx. 3g

Table 1 - Specifications of CDM7160

Note 1: Represents accuracy at the time of factory test. For long term accuracy, please refer to *Fig. 5 - Long term stability of CDM7160*.

1-6 Dimensions (Fig. 3)

1-7 *Functions*
CDM7160 has the following 4 major functions:

1-7-1 *CO_2 concentration output*
CDM7160 has two CO_2 concentration outputs. One is PWM output (*please refer to Sec. 1-8-3 - Pin No.4)*, the other is digital output through the communication port (*please refer to Sec. 3 - Communication*).

1-7-2 *Alarm signal output*
CDM7160 has an alarm signal output. Please refer to *Sec 1-8-3. Pin No.3 (Alarm)* for further information about this signal.

1-7-3 *Calibration function*
CDM7160 has two calibration functions. One is background calibration, the other is zero calibration. With background calibration, CO_2 concentration output is set at 400ppm, assuming the sensor is exposed to 400ppm CO_2 (*normal CO2 levels in clean air are approx. 400ppm*). With zero calibration, CO_2 concentration output is set at 0ppm, assuming the sensor is exposed to 0ppm CO_2. For further details, please refer to *Sec 1-8-6. Pin No.7 (CAL)*.

1-7-4 *Atmospheric pressure and altitude compensation*
The factory default setting of CDM7160 for atmospheric pressure and altitude is fixed at 1013.25 hPa and 0m. Since CDM7160 has pressure and altitude dependency, compensation for atmospheric pressure and altitude is needed to obtain high accuracy under different pressures/altitudes. To compensate, please refer to the document *CDM7160 Communication Specifications*.

1-8 *Pin configurations and functions (Table 3)*

1-8-1 *Pin No.1 (VDD)*
Since a voltage regulator is included in the sensor, input voltage variation within the range of 4.75~5.25V does not affect output voltage of the sensor.

1-8-2 *Pin No.3 (ALARM)*
The factory settings of the alarm threshold are 1000ppm for alarm trigger and 900ppm for alarm reset. The thresholds are user-changable. Please refer to the document *CDM7160 Communication Specifications*.

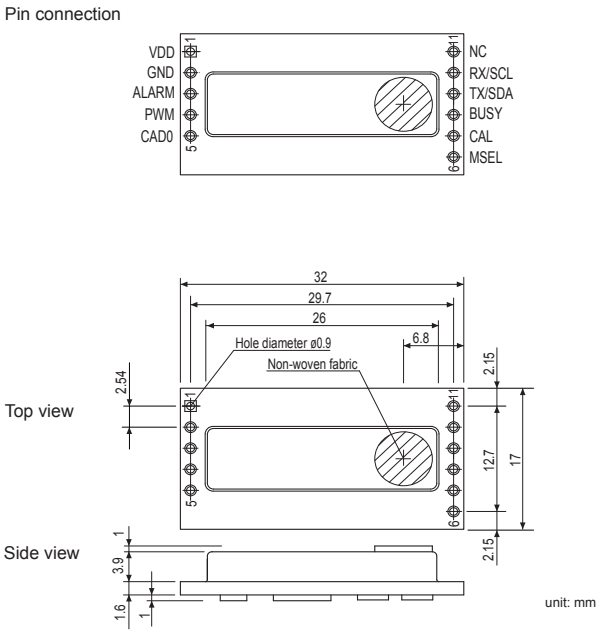


Fig. 3 - Dimensions of CDM7160

Item	Min.	Max.	u/m
Ambient temperature	-40	85	˚C
Input voltage	-0.3	5.5	V
Maximum input voltage (MSEL in, CAD in, CAL in, Rx/SCL)	-0.3	VDD+0.2 and 5.5	V
Maximum output current (Alarm, PWM, Busy, Tx/SDA)	-	50	mA

Table 2 - Absolute maximum ratings for CDM7160

Pin No	Name	Description
1	VDD	Input voltage
2	GND	Common ground
3	ALARM	Alarm output
4	PWM	PWM output
5	CAD0	I2C slave address selection input (internal pull up)
6	MSEL	Communication mode signal input I2C/UART (internal pull up)
7	CAL	Background/zero calibration input (internal pull up)
8	BUSY	BUSY signal output
9	Tx/SDA	UART Tx output/ I2C SDA input/output
10	Rx/SCL	UART Rx input/ I2C SCL input
11	NC	not connected

Table 3 - Pin configurations and functions of CDM7160

1-8-3 *Pin No.4 (PWM)*
A pulse of 1kHz that corresponds to 0~5,000ppm CO_2 is output from Pin No.4. A PWM signal can be easily converted to analog voltage. Please refer to Fig.4 for an example circuit.

1-8-4 *Pin No.5 (CAD0)*
This port is for the selection of the least significant bit of the I2C slave address. By assigning High or Low to each slave, a maximum of 2 units of CDM7160 can be connected to one I2C bus. Since this pin is internally pulled up, if this port is not connected, High is input.

1-8-5 *Pin No.6 (MSEL)*
For I2C communication, this pin should be connected to Low. The MSEL pin is internally pulled up. If the MSEL pin is not connected, the UART interface is used.

1-8-6 *Pin No.7 (CAL)*
When Low voltage is applied to this port, calibration mode is activated. During normal operation (i.e. when calibration is not being performed), please connect to High or do not connect (open). (This pin is internally pulled up.)

When this pin is connected to Low for 4~10 sec., background calibration is carried out assuming 400ppm exposure to the sensor.

When connected to Low for 12 sec. or longer, zero calibration is carried out assuming 0ppm exposure to the sensor.

1-8-7 *Pin No.8 (BUSY)*
The sensor may not communicate for a short period (about 0.3 sec.) due to the internal processing. During the BUSY state, High signal is output. For more detail, please refer to the document *CDM7160 Communication Specifications*.

1-8-8 *Pin No. 9 (Tx/SDA)*
This port works as a Tx port for UART communication and as a SDA (data) port for I2C communication.

1-8-9 *Pin No. 10 (Rx/SCL)*
This port works as an Rx port for UART communication and as a SCL (clock) port for I2C communication.

1-9 *Installation and soldering conditions*
CDM7160 can be mounted on a mother printed circuit board by soldering the 0.9mmφ terminal holes of the sensor to pin strips of a 2.54mm pitch.

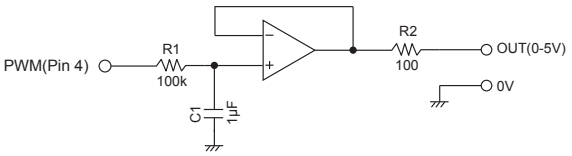


Fig. 4 - PWM signal conversion circuit

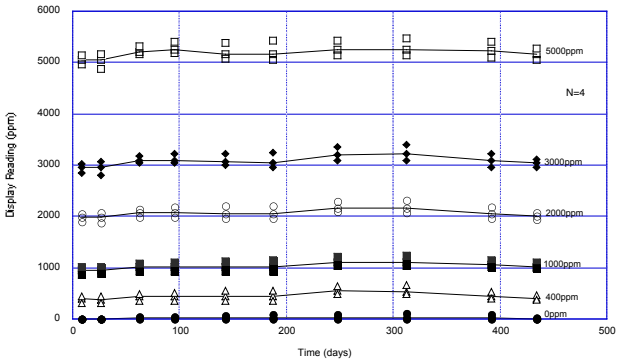


Fig. 5 - Long term stability of CDM7160

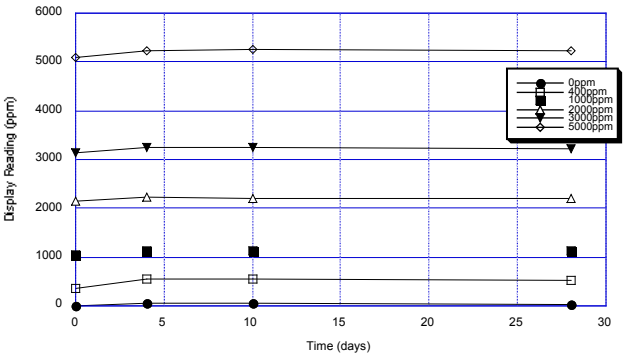


Fig. 6-1 - Durability of CDM7160 against H_2S

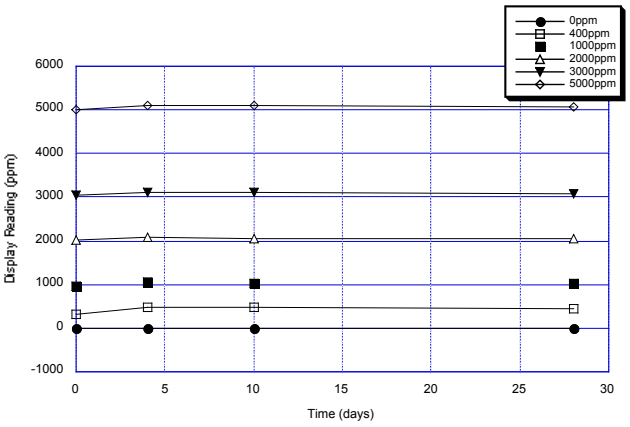


Fig. 6-2 - Durability of CDM7160 against SO_2

2. Reliability

2-1 *Long term stability*

Fig. 5 shows the long term stability of the sensor. The Y-axis shows CO_2 concentration output at various concentrations of CO_2. The CO_2 concentration output is stable during the test period.

2-2 *Corrosion test*

The influence of corrosive gases on the sensor was evaluated. Test samples were stored at 40˚C/82%RH. Under this condition, two different tests were carried out:

1) exposure to 3ppm H_2S for 28 days
2) exposure to 10ppm SO_2 for 28 days

After gas exposure was concluded, CO_2 concentration output was measured.

Fig. 6-1 and Fig. 6-2 show the durability test results for H_2S and SO_2 respectively. The test results demonstrate that there is no significant influence on the sensor from this corrosive gas exposure test.

2-3 *Dust test*

Durability against dust exposure was tested. Five different types of dust as specified by JIS Z 8901 were dropped onto the sensor continuously for 15 minutes under conditions of 22˚C/41%RH. Fig. 7 shows CO_2 concentration output before and after the dust test. This demonstrates that there is no significant influence from this dust exposure test on sensor performance.

2-4 *Temperature cycle test*

Durability to temperature cycling was tested. Test samples were exposed to 500 cycles of -30˚C/30 minutes and 70˚C/30 minutes. The test results shown in Fig. 8 demonstrate that there is no significant influence on the sensor from the extreme conditions of this temperature cycle.

2-5 *High/Low temperature test*

Fig.9-1 shows the test result when the samples were operated at 60˚C with a maximum input voltage 5.25V. Before measuring the CO_2 concentration output, sensors were conditioned at room temperature for 1 hour. The test result demonstrates that there is no significant influence from high temperature.

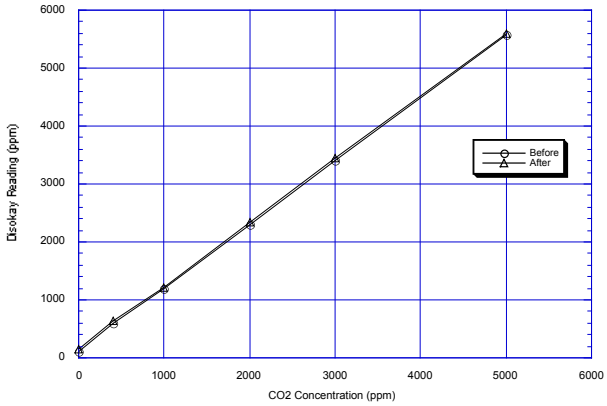


Fig. 7 - Durability of CDM7160 against dust

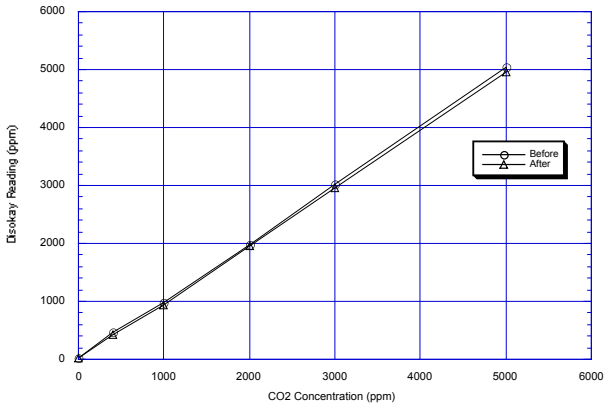


Fig. 8 - Durability of CDM7160 to temperature cycling

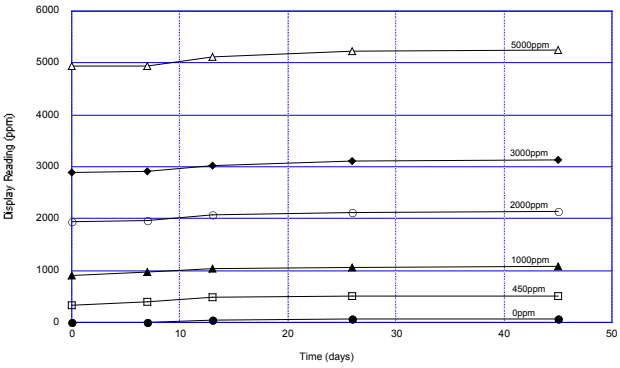


Fig. 9-1 - Durability of CDM7160 to high temperature (60˚C)

Fig.9-2 shows the test result when the samples were operated at -10˚C with a minimum input voltage 4.75V. Before measuring the CO_2 concentration output, sensors were conditioned at room temperature for 1 hour. The test result demonstrates that there is no significant influence from low temperature.

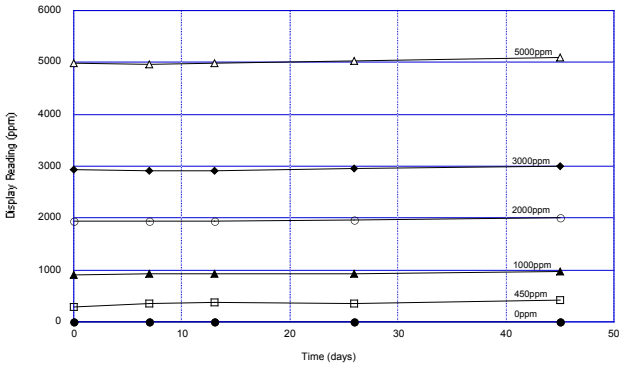


Fig. 9-2 - Durability of CDM7160 to low temperature (-10˚C)

3. Communication

The sensor is provided with both UART and I2C digital interfaces. There are two operating modes:

1) continuous operating mode
2) power down mode.

To change register value in I2C communication, it is necessary to write the register value after switching to power down mode.

3-1 *UART communication*

3-1-1 *Connection*

Please connect the system (Master) and CDM7160 (Slave) as shown in Fig.10.

3-1-2 *Basic operation*

When CDM7160 is reset with the MSEL pin being set to High, the sensor starts operation in the UART communication mode. When the sensor is unable to communicate during internal processing, the BUSY terminal will output a High signal. The external controller (Master) should monitor the terminal output to check for the status of communication.

Communication speed	9600bps
Parity	No
Start bit	1 bit
Stop bit	1 bit
Bit length	8
Flow control	No

Table 4- UART communication parameters

3-1-2-1 *Communication parameters (Table 4)*

3-1-2-2 *Protocol*

The communication protocol of CDM7160 is similar to but not fully compatible with Modbus protocol. With Modbus protocol, the master always sends

CDM7160					System
Pin No	Terminal	Function	Condition		Terminal/State
1	VDD	Power	5V DC		VDD
2	GND	-	-		GND
3	ALARM	Alarm	output		Connect when needed (digital input)
4	PWM	Concentration display (level)	output		Connect when needed
5	CAD0	I2C slave address (least significant bit)	input	N.C.	
6	MSEL	UART selection	input	N.C.	
7	CAL	Calibration	input	N.C.	
8	BUSY	Busy signal	output		Connect when needed (digital input)
9	Tx/SDA	Tx	output	→	Rx
10	Rx/SCL	Rx	input	←	Tx

Fig. 10 - UART connections

messages and the slave responds to them. The external controller serves as the master device (Master) and the CDM7160 serves as the slave device (Slave).

The transmission procedure is as follows:

1) The master sends a command message to the slave.
2) The slave checks if the device address in the received message matches its own address.

When the addresses match, the slave performs processing according to the function code and sends back a response message. When the addresses do not match, the slave discards the received message and waits for the next message.

Note:
Please insert a space corresponding to 3.5 bytes or more before and after messages. Please do not include space characters of 1.5 bytes or more between bytes within a message.

3-1-2-3 *Structure of message (Table 5)*
The command message from Master and the response message from Slave consist of four parts: Device address, Function code, Data section, and Error check code. They are sent in this order.

There are two kinds of function commands:

1) similar to Modbus (Modbus common command)
2) a specially designed command for CDM7160 (CDM7160 unique command). (*see Table 6*)

Notes:
1) For both kinds of commands, the Master always sends messages and the Slave responds to them.
2) The CDM7160 unique command can access the CO_2 concentration readout-only area the same as the Modbus common command. In addition, CDM7160 unique command can access the registered memory area which is shown in *Sec. 3-2-5*.

No.	Name	Byte
1	Device address *1	1
2	Function code	1
3	Data section	2~17
4	Error check code *2	2

*1 Please fix "FEH" for device address
*2 Please calculate error check code using CRC-16 method. Please refer to document *CDM7160 Communication Specifications*

Table 5 - UART message structure

Command Group	Function
Modbus common command	CO_2 concentration readout Zero offset calibration
CDM7160 unique command	CO_2 concentration readout Alarm threshold change Altitude pressure compensation Zero offset calibration

Table 6 - UART function commands

Message from Master

	Device code	Function code	Data part (1)	Data part (2)	Data part (3)	Data part (4)	Error check (1)	Error check (2)
CO_2 concentration readout	FE	04	00	03	00	01	D5	C5

Readout start address — Number of readout words

Response from Slave

	Device code	Function code	Data part (1)	Data part (2)	Data part (3)	Error check (1)	Error check (2)
CO_2 concentration readout	FE	04	02	06	5B	EF	7F

Number of readout bytes — CO2 concentration (hexidecimal number)

Table 7 - Modbus common command for CO_2 concentration readout (example)

Message from Master

	Device code	Function code	Data part (1)	Data part (2)	Data part (3)	Error check (1)	Error check (2)
CO_2 concentration readout	FE	44	00	08	02	9F	25

Response from Slave

	Device code	Function code	Data part (1)	Data part (2)	Data part (3)	Error check (1)	Error check (2)
CO_2 concentration readout	FE	44	02	06	59	7B	7E

Number of readout bytes — CO2 concentration (0659H=1625ppm)

Table 8 - CDM7160 unique command for CO_2 concentration readout (example)

3-1-2-4 *Message example*

3-1-2-4-1 *Example of Modbus common command for CO_2 concentration readout (Table 7)*

3-1-2-4-2 *Example of CDM7160 unique command for CO_2 concentration readout (Table 8)*

Note:
Please refer to the document *CDM7160 Communication Specifications* for how to make an error check code (CRC-16 calculation method).

3-2 *I2C communication*

3-2-1 *Connection*

Please connect the system (Master) and CDM7160 (Slave) as shown in Fig. 11.
When Low voltage is applied to the MSEL pin, CDM7160 starts operation in I2C communication mode.

3-2-2 *Basic operation*

Operating sequence from the Master side

1. Transmit "Start Condition" to Slave
2. Transmit Slave address
3. Acknowledge (Ack.) is transmitted from Slave (CDM7160) back to the Master
4. Transmit Register address to Slave
5. Acknowledge (Ack.) is transmitted from Slave (CDM7160) back to Master
6. Repeat steps 4 and 5
7. Send "Stop Condition" to Slave

3-2-3 *Address and register*

Address and register consist of 1 byte (=8 bits). Data with 2 bytes or longer will be transmitted from the highest-order bit (big endian).

3-2-3-1 *Bit configuration of Slave address (1 byte) (Table9)*

Within one byte, the highest 7 bits are used for the

CDM7160					System
Pin No	Terminal	Function	Condition		Terminal/State
1	VDD	Power	5V DC	→	VDD
2	GND	-	-	→	GND
3	ALARM	Alarm	output	→	Connect when needed (digital input)
4	PWM	Concentration display (level)	output	→	Connect when needed
5	CAD0	I2C slave address (least significant bit)	input	→	Connect when needed (digital input)
6	MSEL	UART selection	input	→	Low level
7	CAL	Calibaration	input	N.C.	
8	BUSY	Busy signal	output	→	Digital input
9	Tx/SDA	I2C data signal SDA	input/output	↔	SDA
10	Rx/SCL	I2C clock signal SCL	input	←	SCL

Fig. 11 - I2C connections

slave address, and the least significant bit is used to select Read or Write.

b7~b1: Slave address

where:

b1 corresponds to H/L of CAD0 port (5 pin)

b1 = 0 for CAD0 = Low,

b1 = 1 for CAD0 = High

b0=1 for Read

b0=0 for Write

examples:

Slave address to Write with CAD0=Low

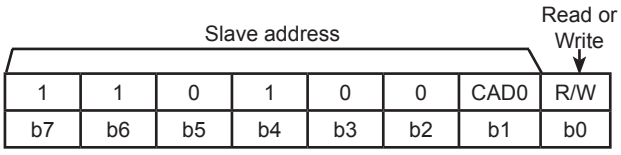
11010000

Slave address to Read with CAD0=High

11010011

3-2-3-2 *Bit configuration of Register address (1 byte) (Table 10)*

3-2-3-3 *Bit configuration of Data (1 byte) (Table 11)*



1	1	0	1	0	0	CAD0	R/W
b7	b6	b5	b4	b3	b2	b1	b0

(MSB) **(LSB)**

Table 9 - Bit configuration of slave address

A7	A6	A5	A4	A3	A2	A1	A0
b7	b6	b5	b4	b3	b2	b1	b0

(MSB) **(LSB)**

Table 10 - Bit configuration of register address (1byte)

D7	D6	D5	D4	D3	D2	D1	D0
b7	b6	b5	b4	b3	b2	b1	b0

(MSB) **(LSB)**

Table 11 - Bit configuration of data (1byte)

3-2-4-1 *Write command*

Fig.12 shows the data transfer sequence for the Write command. In this sequence, "06H" is written at register address "01H" for setting continuous operating mode. When CAD0=Low, the Slave address is 110100.

For details about the Start bit, Stop bit, ACK, and NACK, please refer to the document *CDM7160 Communication Specifications*.

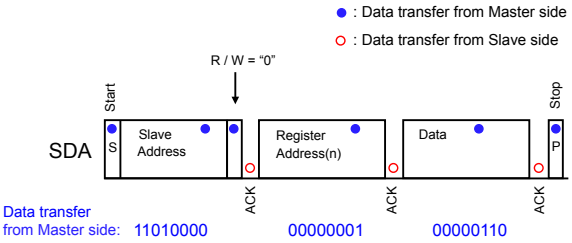


Fig. 12 - Data transfer sequence for Write command

3-2-4-2 *Read command*

There are two Read commands:

1) current address read command
2) random read command.

Fig.13 shows the random read command. The data transmission sequence shows how CO_2 concentration is read from CDM7160. The random Read comand assigns "03H" as the register address and reads 2 bytes from the address.

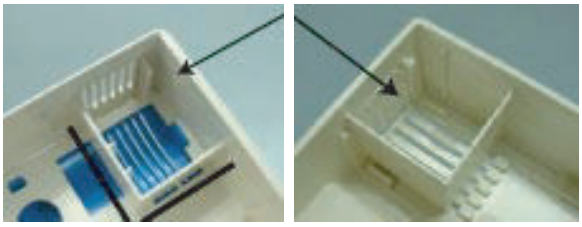
3-2-5 *Register memory map (Table 12, 13)*

Please refer to the document *CDM7160 Communication Specifications* for information about each register value, functions, and factory default setting.

4. Housing Design

CO_2 gas enters the chamber of CDM7160 through a pin hole under the non-woven fabric as shown in Fig. 3. For gas diffusion, it is recommended to separate the device housing from the top of the non-woven fabric by 5mm or more. If quicker response is required, it is recommended that the gas inlet of the sensor be located at the device's slits/opening. It is also recommended to make a small compartment with slits in at least two sides as shown in Fig. 14.

1) Sensor compartment



2) Slits

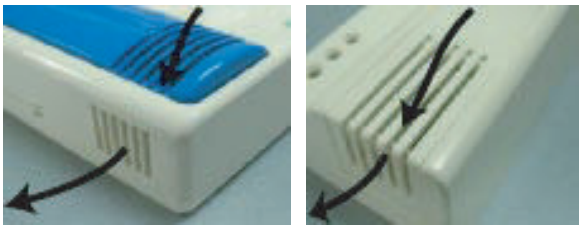


Fig. 14 - Example housing design

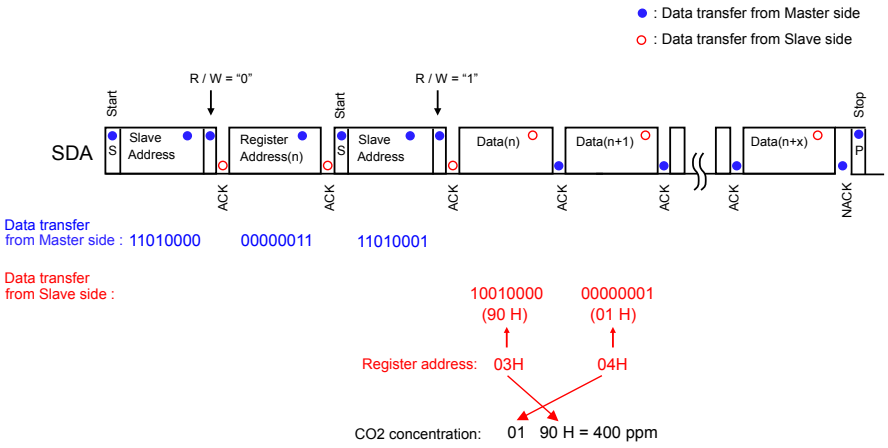


Fig. 13 - Data transfer sequence for random Read command

Address	Name	REG/EEP	Function	Description
00H	RST	REG	Sofware reset	Resets the module
01H	CTL	EEP	Operating mode	Specifies operating mode
02H	ST1	REG	Status register	Monitors the operating status--read-only
03H	DAL	REG	Low-order CO2 concentration data	Read-only
04H	DAH	REG	High-order CO2 concentration data	Read-only
09H	HAP	EEP	Atmospheric pressure	Specifies atmospheric pressure
0AH	HIT	EEP	Altitude	Specifies altitude
0CH	ALHI	EEP	Upper limit concentration for alarm signal	Specifies upper limit cocentration for alarm signal
0DH	ALLO	EEP	Lower limit concentration for alarm signal	Specifies lower limit concentration for alarm signal
0FH	FUNC	EEP	PWM output	Specifies properties of PWM function, enables/ disables PWM, compensates atmospehric pressure and altitude

Table 12 - Register table

Heat is generated at the internal optical source of CDM7160. If a temperature sensor is located near the gas sensor, the temperature sensor may not show the correct ambient temperature. In this case, it is recommended to locate a temperature sensor where there is no thermal influence by CDM7160. Maintain enough distance from the CO_2 sensor or separate the temperature sensor from the CO_2 sensor (e.g. by using a thermal insulator).

5. Packing ***(Fig. 15--see p. 12)***

50pcs. (25pcs. x 2 layers) of the individually wrapped CDM7160 with antistatic bubble sheet is packed in an inner box. 10 inner boxes (CDM7160: 50pcs. x 10boxes) are packed in a carton box.

6. Maintenance

The single light source, dual wavelength system employed by the CDM7160 measures light intensities at two different wavelengths after separation by two optical filters, thus compensating drift due to accumulated dust and contamination. As a result, there is no need for maintenance.

However, for customers who would like to calibrate periodically, the sensor has a function for Background calibration and Zero calibration. For more detail, please refer to *Sec. 1-8-6. Pin No.7 (CAL)*.

7. Handling Precautions

7-1 CDM7160 is an ESD-sensitive product. No ESD protection components such as zener diodes or varistors are used in this product. It is recommended that ESD protection equipment be used for handling the module during assembly of application products. ESD protection components and/or an ESD protection enclosure should be used as required for the intended application when this module is embedded into finished products.

7-2 If sensors are dropped, please do not use them. Sensors may be damaged by mechanical shock.

Address	Name	D7	D6	D5	D4	D3	D2	D1	D0
00H	RST	-	-	-	-	-	-	-	REST
01H	CTL	-	-	-	-	-	CTL2	CTL1	CTL0
02H	ST1	BUSY	ALARM	-	-	-	-	CAD0	MSEL
03H	DAL	D7	D6	D5	D4	D3	D2	D1	D0
04H	DAH	-	D14	D13	D12	D11	D10	D9	D8
09H	HPA	Hpa7	Hpa6	Hpa5	Hpa4	Hpa3	Hpa2	Hpa1	Hpa0
0AH	HIT	Hit7	Hit6	Hit5	Hit4	Hit3	Hit2	Hit1	Hit0
0CH	ALHI	Alhi7	Alhi6	Alhi5	Alhi4	Alhi3	Alhi2	Alhi1	Alhi0
0DH	ALLO	Allo7	Allo6	Allo5	Allo4	Allo3	Allo2	Allo1	Allo0
0FH	-	-	-	-	-	PWMR	HPAE	-	PWME

Table 13 - Register map

8. Frequently Asked Questions

Q1: *Is it possible to measure up to 10,000ppm? Can 400ppm or less concentration be measured?*
A: The measurable CO_2 concentration output range through communication is from 0~10,000ppm. However, accuracy may be less than specifications at less than 300ppm or higher than 5,000ppm. The maximum PWM output range is 5,000ppm.

Q2: *What kind of component is used for the optical source and detector element?*
A: A incandescent lamp is used as an optical source and a photodiode is used for the detector element.

Q3: *There is a hysteresis by 100ppm between the high and low alarm thresholds. Is it possible to change the hysteresis?*
A: Yes, hysteresis can be changed. Please refer to "ALHI and ALLO" register of *Register and EEPROM* in the document *CDM7160 Communication Specifications*.

Q4: *Can the sensor be operated by 3V?*
A: No.

Q5: *Can analog output be obtained?*
A: By converting the PWM output signal, an analog output voltage can be easily made. Please refer to Fig. 4 in *Sec. 1-8-3 Pin No.4 (PWM).*

Q6: *What is the sensor's life expectancy?*
A: Expected sensor life of CDM7160 is 10 years or more.

IMPORTANT NOTICE

This product is designed for use in indoor air quality control systems, including variable air volume systems and demand controlled ventilation systems. Please consult Figaro prior to use of this product in other applications. This product is not designed and authorized for use as a critical component in life support applications wherein a failure or malfunction of the products may result in injury or threat to life.

Figaro Engineering Inc. reserves the right to make changes without notice to this product to improve reliability, functioning or design.

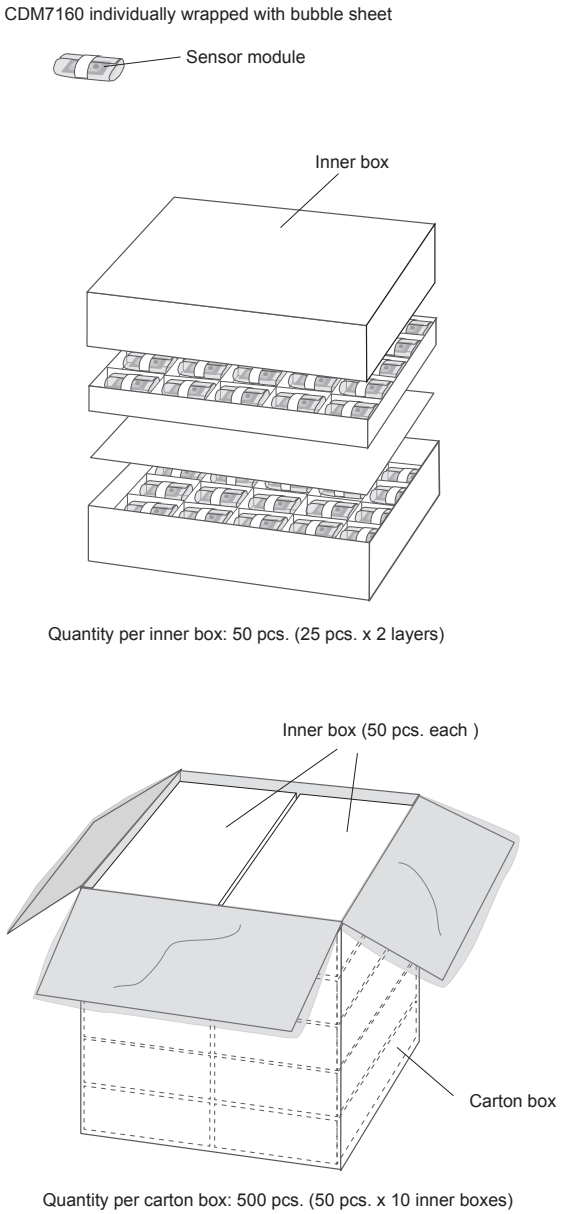


Fig. 15 - Packing of CDM7160

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