

# CO2 Sensor Module CDM7160

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## **Communication Specifications**

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## 1. Overview

The CDM7160 can control communication with the external controller and the I2C bus or the UART interface and obtain the CO2 concentration. Use the MSEL pin to select the I2C bus or the UART.

(1) MSEL = L: I2C specifications

The I2C bus interface is used for communication with the controller.

(2) MSEL = H: UART specifications

The UART interface is used for communication with the controller.

\*The MSEL pin is pull-up input. If this pin is not connected, the UART interface is used.

## 2. Specifications

### 2-1 Absolute maximum ratings

V<sub>SS</sub> = 0 V

Item	Sign	Min.	Max.	Unit
Source voltage (V <sub>dd</sub> )	V <sub>I</sub> +	-0.3	+6.5	V
Input voltage	V <sub>IN</sub>	-0.3	(V <sub>I</sub> )+0.3	V
Input current	I <sub>IN</sub>	-	±10	mA
Storage temperature	T <sub>ST</sub>	-30	+70	°C

(Note 1) If one or more of these values are exceeded during use, the module could be damaged.

In such a case, normal operation is not guaranteed.

### 2-2 Recommended operating conditions

V<sub>SS</sub> = 0 V

Item	Remark	Sign	Min.	Typ.	Max.	Unit
Operation temperature		T <sub>a</sub>	0		+50	°C
Source voltage		V <sub>dd</sub>	4.75	5.0	5.25	V

### 2-3 Electrical characteristics

Unless otherwise specified, the following conditions are used:

V<sub>dd</sub> = 4.75 V to 5.25 V, Temperature range = 0°C to 50°C

DC characteristics

Item	Sign	Pin	Condition	Min.	Typ.	Max.	Unit
High-level input voltage 1	V <sub>IH1</sub>	MSEL CAL CAD0 CAD1 RX		80%V <sub>dd</sub>			V
Low-level input voltage 1	V <sub>IL1</sub>					20%V <sub>dd</sub>	V
Input current	I <sub>IN</sub>			-125		+125	nA
High-level input voltage 2	V <sub>IH2</sub>	SDA SCL		70%V <sub>dd</sub>			V
Low-level input voltage 2	V <sub>IL2</sub>					30%V <sub>dd</sub>	V
Low-level output voltage 1	V <sub>OL1</sub>	UART_R/T ALARM PWM TX	(Note 2)			0.6	V
High-level output voltage	V <sub>OH</sub>		(Note 3)	V <sub>dd</sub> -0.7			V
Low-level output voltage 2	V <sub>OL2</sub>	SDA	(Note 2)			0.6	V
Power consumption	IDD1	VDD	Power down mode		-	-	μA
	IDD2		Continuous operation mode 1		8	60	mA

(Note 2) IOL = 8 mA, V<sub>dd</sub> = 5 V

(Note 3) IOH = 3.5 mA, V<sub>dd</sub> = 5 V

## 3. Connection Methods

### 3-1 UART communication

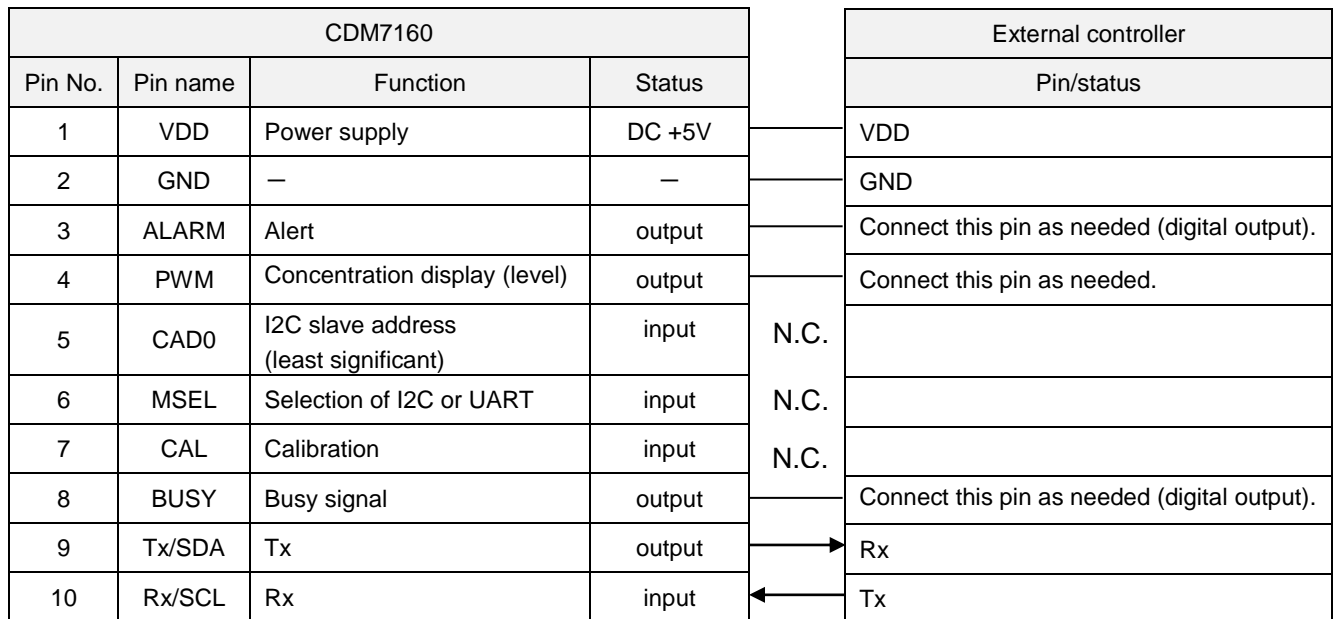


Figure 1 UART Communication Connection

### 3-2 I2C communication

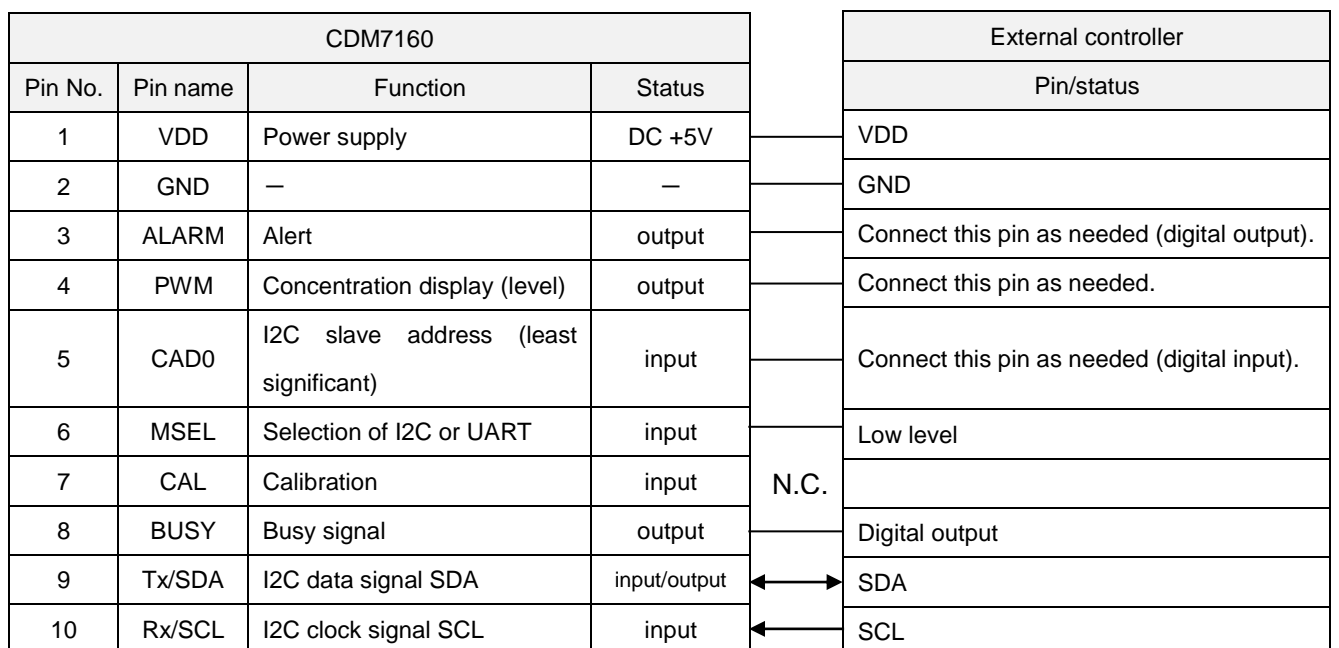


Figure 2 I2C Communication Connection

Operation sequence from the viewpoint of the external controller (master)

- (1) Sends the start condition.
- (2) Sends the slave address.
- (3) Receives acknowledge (abbreviated as Ack.) from the CDM7160.
- (4) Sends the register address to be accessed.
- (5) Receives acknowledge (abbreviated as Ack.) from the CDM7160.
- (6) Repeats steps (4) and (5).
- (7) Sends the stop bit.

## 4. Description of Basic Operations

### 4-1 Reset function (applicable to both UART and I2C)

The CDM7160 is reset when the power is turned on. The CDM7160 also has the soft reset function.

#### Soft reset

The CDM7160 can be reset by writing 1 to the REST bit in the RST register through the UART interface. When reset is complete, the REST bit automatically returns to 0.

### 4-2 Operation modes (applicable to both UART and I2C)

The CDM7160 has the following two operation modes:

- (1) Power down mode
- (2) Continuous operation mode 1

The corresponding operation mode can be activated by setting a value to the CTL register.

#### (1) Power down mode

The master clock stops and all the analog circuits are turned off.

#### (2) Continuous operation mode 1

When the continuous operation mode 1 is set, the analog circuits start operating. Then, the following series of operations start.

- A) First, measurement of CO<sub>2</sub> concentration starts after determined setup time. At this time, 1 is set to the BUSY bit in the ST1 register and H is set to the BUSY pin.
- B) The first measurement of CO<sub>2</sub> concentration ends after about 0.3 sec. At this time, 0 is set to the BUSY bit in the ST1 register and L is set to the BUSY pin. Then, the analog circuits stop and enter into the low power consumption status.
- C) After 1.7 seconds, the analog circuits operate again and automatically start measuring the CO<sub>2</sub> concentration. At this time, 1 is set to the BUSY bit in the ST1 register and H is set to the BUSY pin.
- D) This measurement of CO<sub>2</sub> concentration ends after about 0.3 seconds and 0 is set to the BUSY bit in the ST1 register and L is set to the BUSY pin. The CO<sub>2</sub> concentration data is now ready to be read.

External devices can detect this change and read the concentration data from the DAL and DAH registers.

Then, the analog circuits stop and enter into the low power consumption status.

After that, the status at step C) reappears and measurement is repeated.

Measurement is repeated until the operation mode is changed by overwriting the value in the CTL register.

\*To change alarm and other settings, move to the power down mode, change set conditions, and move back to the continuous operation mode.

The operation sequence is shown in the figure below.

Continuous operation mode 1

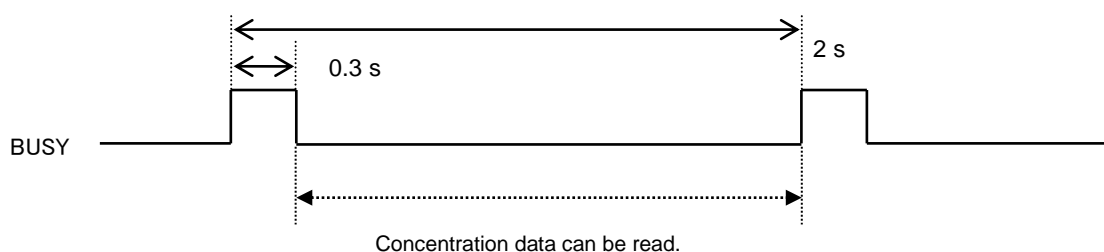


Figure 3 Continuous Operation Mode

## 5. UART Communication - Description of Operation

### 5-1 Overview

When H is set to the MSEL pin, the CDM7160 uses the UART communication mode. As the UART interface is used for communication with the external controller, the TX/SDA pin and the RX/SCL pin operate as TX and RX, respectively, with the communication protocol based on the Modbus protocol. For details on the Modbus specifications, refer to [www.modbus.org](http://www.modbus.org).

### 5-2 Communication conditions

The UART communication by the CDM7160 only supports the following limited specifications:

- (1) Only the RTU mode to send 1-byte (8-bit) data as is supported. The ASCII mode is not supported.
- (2) The supported communication speed is 9600 bps only.
- (3) Both for transmission and reception, no parity bit is used, the start bit is 1 bit, and the stop bit is 1 bit. The logic of the start bit is L while the logic of the stop bit is H.

(Reference) A 10-bit data string used to send 1-byte data is defined as one character. The time to send one character is about 1.04 ms at 9600 bps.

### 5-3 Overview of Modbus protocol

According to the Modbus protocol, the master always sends messages while the slave responds to them.

The controller is the master device while the CDM7160 is the slave device.

The transmission procedure is as follows:

- (1) The master sends the command message to the slave.
- (2) The slave checks if the device address contained in the received message matches its local station.
- (3) When the device address matches, the slave performs processing according to the function code and returns a response message.
- (4) When the device address does not match, the slave discards the received message and waits for the next message.

3.5 or more space characters are required before and after the message.

1.5 or less space characters are required between characters in the message.

### 5-4 Configuration of message

The command message from the master and the response message from the slave consist of four sections: device address, function code, data section, and error check code, which are sent in this order. Each of these sections is described below.

#### 1. Device address (1 byte)

Number to identify the slave. For the time being, only FEH, which corresponds to all the addresses, is supported.

#### 2. Function code (1 byte)

Code to specify the function to be executed by the slave.

For details, refer to "5-5 Function codes."

#### 3. Data section (2 to 17 bytes)

Data required to complete the function code. The configuration of the data section differs depending on the function code. For details, refer to "5-6 Details of messages."

## 4. Error check code (2 bytes)

Code to detect errors in the message during signal transmission.

CRC16-IBM (Rightward transmission, Initial value: 0xFFFF, Generating polynomial value: 0xA001) is used in the RTU mode for Modbus protocol. The calculation range is from the start of the message (device address) to the end of the data section.

The slave calculates the CRC of the received message and does not respond if it does not match the received CRC code.

Device address	Function code	Data section	Error check code (CRC-16)
1 byte	1 byte	2 to 17 bytes	2 bytes

Configuration of Message

## 5-5 Function codes

The CDM7160 only supports the six types of function codes shown in the table below. The length of the data section differs depending on the function code.

Param. No.			Length of data section		
Function code	Function	Target	Command	Response (at normal time)	
03H	Read	Holding register	4 bytes	3 to 17 bytes	Checks the CAL execution status with UART.
04H	Read	Input register	4 bytes	3 to 17 bytes	Reads CO2 concentration data with UART.
06H	Write	Holding register	4 bytes	4 bytes	Executes CAL with UART.
44H	Read	CO2 concentration data	3 bytes	2 to 17 bytes	Dedicated to reading CO2 concentration data with UART.
64H	Write	Register for CDM7160	2 bytes	2 bytes	Writes the register value with UART.
65H	Read	Register for CDM7160	2 bytes	2 to 17 bytes	Reads the register value with UART.

Function Codes



## 5-6 Details of messages

This section individually describes each function code.

### Reading from the holding register [Function code: 03H]

#### Structure of command message

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		03H	
Read start address	High-order	00H	
	Low-order	00H	
Number of read words	High-order	00H	Up to 8 words (16 bytes)
	Low-order	01H	
CRC data	High-order	90H	
	Low-order	05H	

#### Structure of response message

##### At normal time

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		03H	
Number of read bytes		02H	Number of words ×2
First read data	High-order	00H	Contents at address 0
	Low-order	20H	Acknowledgment register
CRC data	Low-order	ADH	
	High-order	88H	

##### When read start address > 001FH or (Read start address + Number of read words) > 0020H

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		83H	
Exception code		02H	Illegal Data Address
CRC data	Low-order	F0H	
	High-order	C1H	

##### When the message length excluding CRC is not six bytes or when the number of read words is zero or larger than eight

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		83H	
Exception code		03H	Illegal Data Value
CRC data	Low-order	31H	
	High-order	01H	

## Reading from the input register [Function code: 04H]

### Structure of command message

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		04H	
Read start address	High-order	00H	
	Low-order	00H	
Number of read words	High-order	00H	Up to 8 words (16 bytes)
	Low-order	04H	
CRC data	Low-order	E5H	
	High-order	C6H	

### Structure of response message

#### At normal time

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		04H	
Number of read bytes		08H	Number of words x2
First read data	High-order	00H	Contents ad address 0
	Low-order	00H	Meter Status
Second read data	High-order	00H	Contents ad address 1
	Low-order	00H	Alarm Status
Third read data	High-order	00H	Contents ad address 2
	Low-order	00H	Output Status
Fourth read data	High-order	01H	Contents ad address 3
	Low-order	90H	CO2concentration
CRC data	Low-order	16H	
	High-order	E6H	

#### When read start address > 001FH or (Read start address + Number of read words) > 0020H

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		84H	
Exception code		02H	Illegal Data Address
CRC data	Low-order	F2H	
	High-order	F1H	

#### When the message length excluding CRC is not six bytes or when the number of read words is zero or larger than eight

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		84H	
Exception code		03H	Illegal Data Value
CRC data	Low-order	33H	
	High-order	31H	

## Writing to the holding register [Function code: 06H]

### Structure of command message

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		06H	
Write start address	High-order	00H	Writes 0000H to address 0
	Low-order	00H	
Write data	High-order	00H	
	Low-order	00H	
CRC data	Low-order	9DH	
	High-order	C5H	

### Structure of response message

#### At normal time

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		06H	
Write address	High-order	00H	Returns written data
	Low-order	00H	
Write data	High-order	00H	
	Low-order	00H	
CRC data	Low-order	9DH	
	High-order	C5H	

#### When write address > 1FH

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		86H	
Exception code		02H	Illegal Data Address
CRC data	Low-order	F3H	
	High-order	91H	

#### When the message length excluding CRC is not six bytes

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		86H	
Exception code		03H	Illegal Data Value
CRC data	Low-order	32H	
	High-order	51H	

## Reading CO2 concentration data [Function code: 44H]

### Structure of command message

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		44H	
Read start address	High-order	00H	
	Low-order	08H	
Number of read bytes		02H	
CRC data	Low-order	9FH	
	High-order	25H	

\*Only the message in the above command message example can be used.

### Structure of response message

#### At normal time

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		44H	
Number of read bytes		02H	
CO2 concentration data	High-order	01H	Contents at address 3 (CO2 concentration) is indirectly read.
	Low-order	90H	
CRC data	Low-order	B9H	
	High-order	18H	

When read start address > 03FFH or (Read start address + Number of read words) > 0400H

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		A4H	
Exception code		02H	Illegal Data Address
CRC data	Low-order	EBH	
	High-order	31H	

When the message length excluding CRC is not five bytes or when the number of read bytes is 0

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		A4H	
Exception code		03H	Illegal Data Value
CRC data	Low-order	2AH	
	High-order	F1H	

## Writing to the register for CDM7160 [Function code: 64H]

### Structure of command message

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		64H	CDM7160 unique code
Write address		01H	
Write data		06H	Writes to address 1 CTL: Control
CRC data	Low-order	F1H	
	High-order	81H	

### Structure of response message

#### At normal time

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		64H	CDM7160 unique code
Write address		01H	
Write data		06H	Returns written data
CRC data	Low-order	F1H	
	High-order	81H	

#### When write address > 0FH

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		E4H	
Exception code		02H	Illegal Data Address
CRC data	Low-order	DAH	
	High-order	F1H	

#### When the message length excluding CRC is not four bytes

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		E4H	
Exception code		03H	Illegal Data Value
CRC data	Low-order	1BH	
	High-order	31H	

The writable address range is from 00H to 0FH.

## Reading from the register for CDM7160 [Function code: 65H]

### Structure of command message

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		65H	CDM7160 unique code
Read start address		00H	
Number of read bytes		05H	Up to 16 bytes
CRC data	Low-order	E1H	
	High-order	D0H	

### Structure of response message

#### At normal time

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		65H	CDM7160 unique code
Number of read bytes		05H	
First read data		00H	RST: Software reset
Second read data		06H	CTL: Control
Third read data		01H	ST1: Status 1
Fourth read data		90H	DAL: Low-order CO2 concentration data
Fifth read data		01H	DAH: High-order CO2 concentration data
CRC data	Low-order	07H	
	High-order	18H	

#### When write address > 0FH

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		E5H	
Exception code		02H	Illegal Data Address
CRC data	Low-order	DBH	
	High-order	61H	

#### When the message length excluding CRC is not four bytes or when (Read start address + Number of read bytes) > 0FH

Message structure (byte)		Example	Remark
Device address		FEH	All the devices
Function code		E5H	
Exception code		03H	Illegal Data Value
CRC data	Low-order	1AH	
	High-order	A1H	

The readable address range is from 00H to 0FH.

## 6. I<sup>2</sup>C Communication - Description of Operation

### 6-1 Overview

When L is set to the MSEL pin, the CDM7160 operates with I2C communication. As the I2C bus interface is used for communication with the external controller, the TX/SDA pin and the RX/SCL pin operate as SDA and SCL, respectively. The UART\_R/T/BUSY pin operates as the BUSY signal output pin.

For the I2C bus interface in the CDM7160, the standard mode (up to 100 kHz) or the high-speed mode (up to 400 kHz) can be selected. (For details on the I2C bus interface, refer to Appendix 2, "Specifications of I2C Bus Interface" at the end of this document.)

### 6-2 Data transfer

The start condition must be first input to access the CDM7160 via the bus.

Then, the 1-byte slave address containing the device address is sent. At this time, the CDM7160 compares the received slave address with its own slave address. When these addresses match, the CDM7160 generates acknowledge and executes the read or write instruction. To end the instruction, input the stop condition.

### 6-3 Data change

Change data on the SDA line while the clock on the SCL line is Low. While the clock signal on the SCL line is High, the status of the SDA line must be constant. (Data on the SDA line can be changed only while the clock signal on the SCL line is Low.)

While the SCL line is High, the status of data on the SDA line is changed only when the start or stop condition is input.

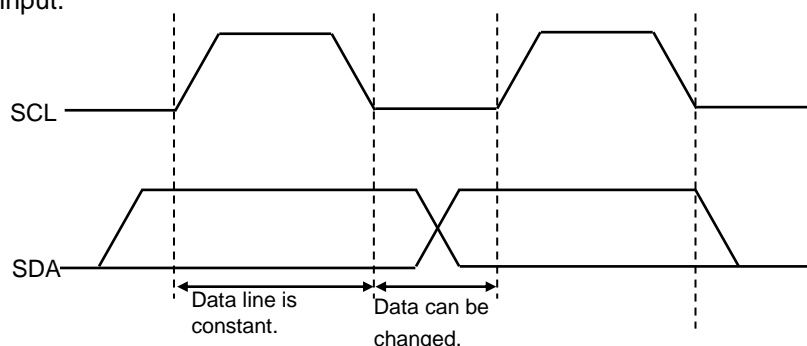


Figure 4 Data Change

### 6-4 Start and stop conditions

If the SDA line is changed from High to Low while the SCL line is High, the start condition is generated.

All data transfer starts with the start condition.

If the SDA line is changed from Low to High while the SCL line is High, the stop condition is generated.

All data transfer ends with the stop condition.

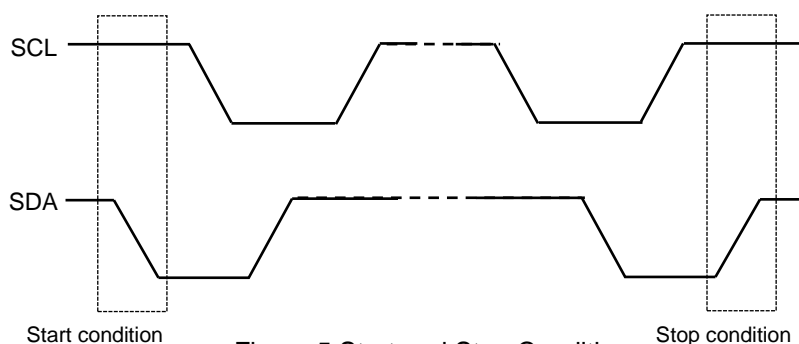


Figure 5 Start and Stop Conditions

## 6-5 Acknowledge

The device that sends data opens the SDA line after sending 1-byte data (High status). The device that receives the data sets Low to the SDA line at the next clock. This operation is called acknowledge. Acknowledge allows you to check if data transfer has been successfully completed.

The CDM7160 generates acknowledge after receiving the start condition and the slave address.

When executing the WRITE instruction, the CDM7160 generates acknowledge when receiving each byte.

When executing the READ instruction, the CDM7160 generates acknowledge and sends data stored at the specified address. The CDM7160 then opens the SDA line and monitors it. If the master device generates acknowledge instead of the stop condition, the CDM7160 sends the 8-bit data stored at the next address. If acknowledge is not generated, the CDM7160 stops sending data.

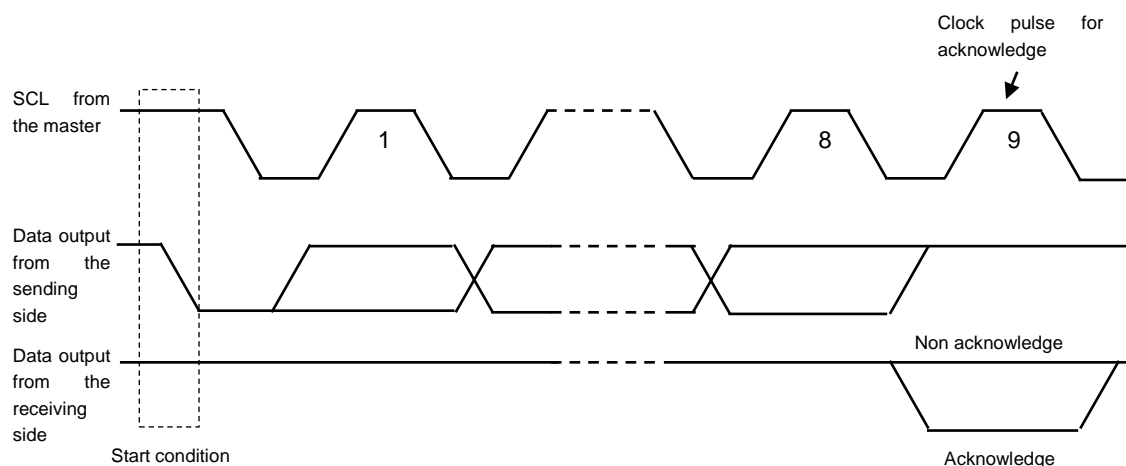


Figure 6 Generation of Acknowledge

## 6-6 Slave address

The first byte containing the slave address is input after the start condition. The slave address is used to select the device to be accessed from the devices on the bus.

The slave address consists of the upper 7 bits. The upper 6 bits of the slave address are fixed to 110100 in the CDM7160. The 7th bit is the address bit to select the device to be accessed and is set by the CAD0 pin.

When the slave address is input, the device whose address matches generates acknowledge and then executes the instruction. The eighth bit (the least significant bit) in the first byte is the R/W bit.

When the R/W bit is 1, the READ instruction is executed. When the R/W bit is 0, the WRITE instruction is executed.

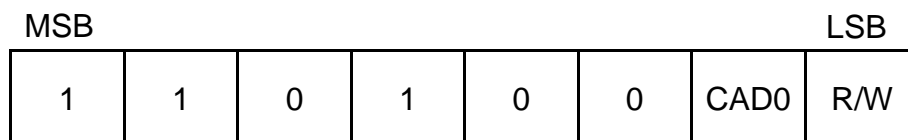


Figure 7 Slave Address



## 6-7 WRITE instruction <applicable to the register and EEPROM>

When 0 is set to the R/W bit, the CDM7160 executes the write operation.

During the write operation, the CDM7160 receives the start condition and the first byte (slave address), generates acknowledge, and then receives the second byte. The second byte specifies the address of the internal control register in the MSB first format.

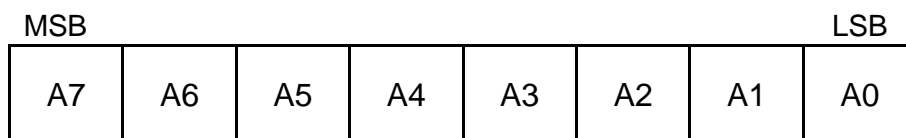


Figure 8 Register Address

After receiving the second byte (register address), the CDM7160 generates acknowledge and then receives the third byte.

The third byte represents control data. Control data consists of 8 bits in the MSB first format.

After receiving control data, the CDM7160 generates acknowledge. Data transfer always ends with the stop condition generated by the master.

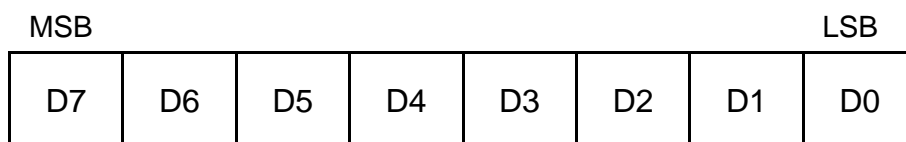


Figure 9 Control Data

The CDM7160 does not support sequential write to write multibyte data at once. The CDM7160 writes data under the stop condition.

If the specified address is write-only, data is not written.

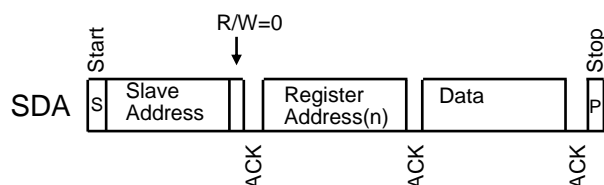


Figure 10 Write

If the specified address points to EEPROM, the CDM7160 generates acknowledge after the slave address is sent and after the address is sent.

If the CDM7160 receives data afterward, clock stretch occurs to ensure the EEPROM write time. Note 1)

When clock stretch ends and SCL is released, the master device generates the stop condition and the write operation ends.

Note 1) The CDM7160 delays the processing at the master device to ensure the EEPROM write time by forcibly setting L to SCL.

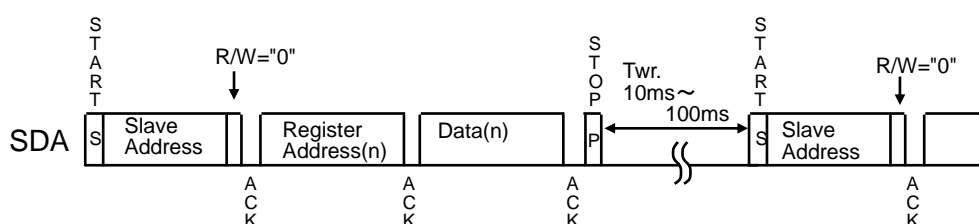


Figure 11 Write (EEPROM)

## 6-8 READ instruction <applicable to the register and EEPROM>

When 1 is set to the R/W bit, the CDM7160 executes the read operation.

If the master device generates acknowledge instead of the stop condition after the CDM7160 sends the data from the specified address, data can be read from the next address.

Once the address is counted up to 0FH in the range between 00H and 0FH, the next address returns to 00H.

### (1) Reading data from the current address

The CDM7160 has the internal address counter. During the operation to read data from the current address, data is read from the address specified at this counter.

The internal address counter retains the address next to the last accessed address.

For example, if the last accessed address for the READ instruction is n, data is read from address n+1 when the instruction to read data from the current address is executed.

When reading data from the current address, the CDM7160 receives the slave address for the READ instruction (R/W bit = 1) and generates acknowledge. Then, the CDM7160 starts transferring data specified at the internal address counter at the next clock and increments the internal address counter by 1. If the master device generates the stop condition instead of acknowledge after the CDM7160 sends 1-byte data, the read operation ends.

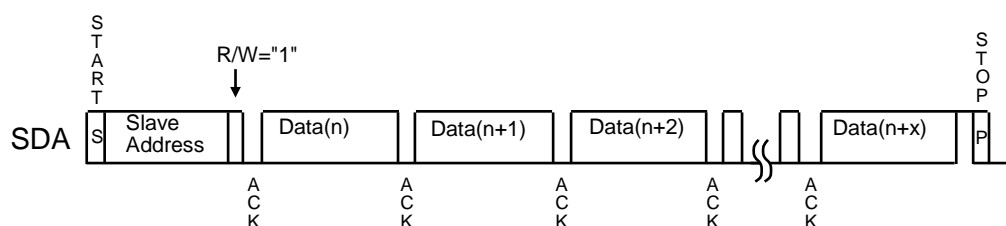


Figure 12 Reading Data from the Current Address

### (2) Random read

The random read operation reads data from an arbitrary address.

For random read, the WRITE instruction must be executed as dummy before the slave address for the READ instruction (R/W bit = 1) is sent. During the random read operation, the start condition is first generated and then the slave address for the WRITE instruction and the read address are sent. In response to this address transmission, the CDM7160 generates acknowledge and then the master device sends the start condition and the slave address for the READ instruction (R/W bit = 1) again. The CDM7160 generates acknowledge in response to this transmission of slave address. After that, the CDM7160 sends data from the specified address and increments the internal address counter by 1.

If the master device generates the stop condition instead of acknowledge after sending data, the read operation ends.

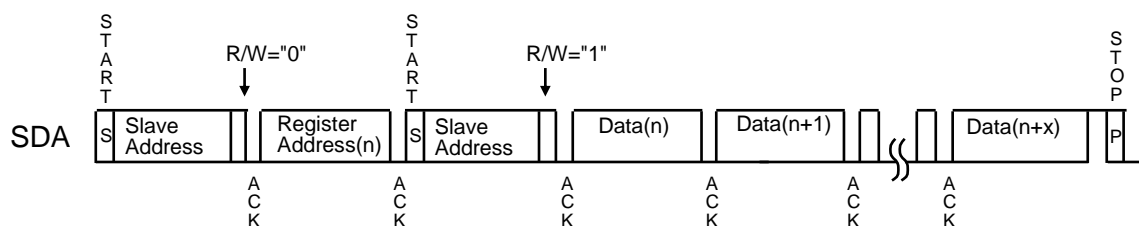


Figure 13 Random Read

## 7. List of Registers (Applicable to Both UART and I2C)

### 7-1 Register memory map

The CDM7160 has the registers and EEPROM with the addresses shown in Table 1. Each address consists of 8-bit data.

Address	Name	REG/EEP*	Brief description	Description
00H	RST	REG	Soft reset	Resets the module.
01H	CTL	EEP	Operation mode	Sets the operation mode.
02H	ST1	REG	Status register	Monitors the operation state. Read-only
03H	DAL	REG	Lower CO2 concentration data	Read-only
04H	DAH	REG	Upper CO2 concentration data	Read-only
05H	—		Reserved	Read/write not allowed
06H	—		Reserved	Read/write not allowed
07H	—		Reserved	Read/write not allowed
08H	—		Reserved	Read/write not allowed
09H	HPA	EEP	Atmospheric pressure data	Sets the atmospheric pressure value (hPa).
0AH	HIT	EEP	Altitude data	Sets the altitude value (m).
0BH	—		Reserved	Read/write not allowed
0CH	ALHI	EEP	Upper limit concentration for the alarm signal	Sets the upper limit concentration for the alarm signal.
0DH	ALLO	EEP	Lower limit concentration for the alarm signal	Sets the lower limit concentration for the alarm signal.
0EH	CAL	REG	User calibration	User calibration with I2C
0FH	FUNC	EEP	Control of each type of function	Sets correction for PWM output, atmospheric pressure and altitude.
10H	ERROR	REG	Self-diagnosis (error output)	Read-only
11H	—		Reserved	Read/write not allowed
12H	AJCON	EEP	CO2 concentration for user calibration	Sets the CO2 concentration. (400 ppm is set by default.)

Table 1 Register Table

\*REG: The data in the register is initialized when the power is turned off.

EEP: The data in the register is retained even when the power is turned off.

## Register map

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
05H	—	-	-	-	-	-	-	-	-
06H	—	-	-	-	-	-	-	-	-
07H	—	-	-	-	-	-	-	-	-
08H	—	-	-	-	-	-	-	-	-
09H	HPA	Hpa7	Hpa6	Hpa5	Hpa4	Hpa3	Hpa2	Hpa1	Hpa0
0AH	HIT	Hit7	Hit6	Hit5	Hit4	Hit3	Hit2	Hit1	Hit0
0BH	—	-	-	-	-	-	-	-	-
0CH	ALHI	Alhi7	Alhi6	Alhi5	Alhi4	Alhi3	Alhi2	Alhi1	Alhi0
0DH	ALLO	Allo7	Allo6	Allo5	Allo4	Allo3	Allo2	Allo1	Allo0
0EH	CAL	-	-	-	-	-	-	Zero-A	Air-A
0FH	FUNC	-	-	-	-	PWMR	HPAE	-	PWME
10H	ERROR	-	-	-	-	-	-	-	Error0
12H	AJCON	Ajcon7	Ajcon6	Ajcon5	Ajcon4	Ajcon3	Ajcon2	Ajcon1	Ajcon0

Table 2 Register Map

Note) Do not write or read data to or from an address other than the above ones.

## 7-2 Detailed description of each register

### RST: Soft reset

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Write/read									
00H	RST	-	-	-	-	-	-	-	REST

#### REST: Reset

0: Normal status

1: Reset

The CDM7160 is reset when 1 is written to this bit. When reset ends, this bit automatically returns to 0.

### CTL: Control

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Write/read EEPROM									
01H	CTL	-	-	-	-	-	CTL2	CTL1	CTL0
Reset		0	0	0	0	0	1	1	0

#### CTL<2:0>: Specification of operation mode

Set value			Operation mode
D2	D1	D0	
0	0	0	Power down mode
1	1	0	Continuous operation mode

**\*Note: Do not write a value other than 00H or 06H to the CTL register.**

### ST1: Status 1

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read-only register									
02H	ST1	BUSY	ALARM	-	-	-	-	CAD0	MSEL
Reset		0	0	0	0	0	0	0	0

#### BUSY: Busy

0: Data can be read.

1: Busy status

The BUSY bit becomes 1 if data cannot be read for example during ADC conversion or operation of read data. The controller reads data after confirming that this bit changed from 1 to 0.

The status of this bit is output to the BUSY pin as well.

#### ALARM: Alarm

0: The CO2 concentration is below 10 times the CO2LO value.

1: The CO2 concentration is above 10 times the CO2HI value.

The ALARM bit notifies that the CO2 concentration exceeds the preset value.

The status of this bit is output to the ALARM pin as well.

#### CAD0, MSEL:

Can monitor the statuses of the CAD0 and MSEL pins.

\*If there is no connection to the CAD0 pin, CAD0 is internally pulled up to the High status.

## DAL to DAH: CO2 concentration data

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read-only register									
03H	DAL	D7	D6	D5	D4	D3	D2	D1	D0
04H	DAH	-	D14	D13	D12	D11	D10	D9	D8
Reset		0	0	0	0	0	0	0	0

CO2 concentration data is output to D0 to D14. Concentration data is stored in little endian.  
The data range is from 0 to 10000 in decimal notation.

CO2 concentration data			CO2 concentration data
Binary	Hexadecimal	Decimal	
X010 0111 0001 0000	2710	10000	10000ppm
X000 0000 0000 0000	0000	0	0ppm

If the concentration is 400 ppm, DAL = 90H and DAH = 01H.

## ALHI: ALARM high threshold data

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Write/read EEPROM									
0CH	ALHI	Alhi7	Alhi6	Alhi5	Alhi4	Alhi3	Alhi2	Alhi1	Alhi0
At shipment		0	1	1	0	0	1	0	0

This register sets the CO2 concentration at which the ALARM bit changes from 0 to 1. When the CO2 concentration data exceeds 10 times the value written to this register, the ALARM bit changes to 1. If ALHI = 64H, the ALARM bit changes to 1 when the CO2 concentration exceeds 1000 ppm.

## ALLO: ALARM low threshold data

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Write/read EEPROM									
0DH	ALLO	Allo7	Allo6	Allo5	Allo4	Allo3	Allo2	Allo1	Allo0
At shipment		0	1	0	1	1	1	0	0

This register sets the CO2 concentration at which the ALARM bit changes from 1 to 0. When the CO2 concentration data drops below 10 times the value written to this register, the ALARM bit changes to 0. If ALLO = 5AH, the ALARM bit changes to 0 when the CO2 concentration drops below 900 ppm.

You can add hysteresis by setting a value larger than ALLO to ALHI.

Set a value equal to or larger than ALLO to ALHI.

## HPA: hPa (atmospheric pressure)

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Write/read EEPROM									
09H	HPA	Hpa7	Hpa6	Hpa5	Hpa4	Hpa3	Hpa2	Hpa1	Hpa0
At shipment		1	1	0	1	0	1	0	1

Write the atmospheric pressure data to correct the atmospheric pressure when calculating the CO<sub>2</sub> concentration.

The atmospheric pressure data is expressed as follows.

Atmospheric pressure (hPa) = HPA + 800

When HPA = D5H, the atmospheric pressure is 1013 hPa.

HPA data			Atmospheric pressure
Binary	Hexadecimal	Decimal	
1111 1111	FF	255	1055 hPa
0000 0000	00	0	800 hPa

## HIT: Height (altitude)

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Write/read EEPROM									
0AH	HIT	Hit7	Hit6	Hit5	Hit4	Hit3	Hit2	Hit1	Hit0
At shipment		0	0	0	0	0	0	0	0

Write the altitude data to correct the atmospheric pressure when calculating the CO<sub>2</sub> concentration.

The altitude data is expressed as follows.

Altitude (m) = HIT×10

HIT data			Altitude
Binary	Hexadecimal	Decimal	
1111 1111	FF	255	2550 m
0000 0000	00	0	0 m

Note: When writing altitude data, HIT

- When writing the actual altitude (m) value: Write the atmospheric pressure at 0 m above sea level to the atmospheric pressure data, HPA.

- When the actual atmospheric pressure (hPa) value has been written to HPA: 0 (m) \*At the time of shipment

(Reference): The atmospheric pressure correction value by altitude is simplified to be -1.1 hPa per 10 m.

When using the atmospheric pressure and altitude correction functions, set 1 (enabled) to the HAPE bit in the FUNC register (address: 0FH).

## CAL: User calibration

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Write-only register									
0EH	CAL	-	-	-	-	-	-	Zero-A	Air-A
Reset		0	0	0	0	0	0	0	0

**Air-A:** Air Adjustment is executed when the Air-A bit is set to 1 under normal clean atmosphere or the CO<sub>2</sub> concentration that is pre-set at the register address (12H). After execution of the Air Adjustment, measured concentration value is reset to the pre-set CO<sub>2</sub> value at the register address (12H).

**Zero-A:** Zero Adjustment is executed when the Zero-A bit is set to 1 while sensor is placed in zero gas. Measured concentration value is reset to 0ppm.

## FUNC: Function setting

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Write/read EEPROM									
0FH	FUNC	-	-	-	-	PWMR	HPAE	-	PWME
At shipment		0	0	0	0	0	0	0	1

This register enables/disables each type of function and sets other conditions.  
This register is not initialized even when the CDM7160 is reset.

**PWME:** Enables/disables the PWM pin.

0: Disable

1: Enable

When 1 is set to the PWME bit, 1-kHz square wave with the pulse width that is proportional to the CO<sub>2</sub> concentration is output from the PWM pin.

When 0 is set, the PWM pin is always high impedance. You can reduce power consumption by setting 0 when not using the PWM pin.

**PWMR:** Sets the concentration range represented by the pulse width output to the PWM pin.

0: High concentration

1: Low concentration

The relationship between the concentration and the pulse width (PW) is expressed by the following expressions:

High concentration: Concentration (ppm) = PW (μs) × 5

Low concentration: Concentration (ppm) = PW (μs) × 2

**HPAE:** Enables/disables atmospheric pressure correction.

0: Disable

1: Enable

When 1 is set to the HPAE bit, the CO<sub>2</sub> concentration is calculated after correcting the atmospheric pressure based on the data written to the HPA and HIT registers. When 0 is set, the CO<sub>2</sub> concentration is calculated assuming an atmospheric pressure of 1013 hPa and altitude of 0 m.



## ERROR: Self-diagnosis

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Read-only register									
10H	ERROR	-	-	-	-	-	-	-	Error0
Reset		0	0	0	0	0	0	0	0

### Error0: Self-diagnosis error

0: No self-diagnosis error

1: Self-diagnosis error was generated.

The error bit outputs whether an error occurred as a result of self-diagnosis. If there is no error, the error bit is 0. If an error occurred, the error bit is 1.

## AJCON: User calibration adjustment concentration

Address	Register name	D7	D6	D5	D4	D3	D2	D1	D0
Write/read EEPROM									
12H	AJCON	Ajcon7	Ajcon6	Ajcon5	Ajcon4	Ajcon3	Ajcon2	Ajcon1	Ajcon0
At shipment		0	1	1	0	0	1	0	0

This register sets the adjustment concentration (target concentration) when executing user calibration.

The default value at the time of shipment is 400 ppm.

The adjustment concentration is expressed as follows:

Adjustment concentration (ppm) = AJCON × 10 + 300

AJCON data			Adjustment concentration
Binary	Hexadecimal	Decimal	
1111 1111	FF	255	2850ppm
0000 0000	00	0	300ppm

## Appendix 1 (Configuration of Modbus Registers)

The Modbus registers in the CDM7160 consist of two independent register groups, which are input registers and holding registers.

The tables below show their configuration.

Both types of registers are defined by 32 16-bit addresses. Though accessing the reserved section does not cause an error, no operation is performed.

Although the input register supports continuous read, data can be read from up to eight addresses at once.

The address number is the value calculating by subtracting 1 from the register number.

### Input registers

Input registers are read-only registers.

Only IR4 is actually enabled.

IR4 stores the measured CO<sub>2</sub> concentration in ppm.

Register No.	Address	Register Name	
IR1~3	0 to 2		Reserved
IR4	3	CO <sub>2</sub> concentration	CO <sub>2</sub> concentration/ppm
IR5~21	4 to 20		Reserved, returns "illegal data address" exception
IR22	21		Reserved
IR23~32	22 to 31		Reserved, returns "illegal data address" exception

## Holding registers

Register No.	Address	Register Name																
HR1	0	Acknowledgment register	DI 16	DI 15	DI 14	DI 13	DI 12	DI 11	DI 10	DI 9	DI 8	DI 7	DI 6	DI 5	DI 4	DI 3	DI 2	DI 1
			DI1 DI2 DI3 DI4 DI5 DI6 - CO2 air adjustment has been performed DI6 DI7 - CO2 zero adjustment has been performed DI7 DI8 DI9 DI10 DI11 DI12 DI13 DI14 DI15 DI16															
HR2	1	Special Command Register *	Command									Parameter						
			7CH									06H - CO2 air adjustment 07H - CO2 zero adjustment						
HR3~32	2~31		Reserved, returns “illegal data address” exception															

Only HR1 and HR2 are actually enabled.

HR1 supports read/write while HR2 is write-only.

Calibration starts when a value is written to HR2. When calibration is complete, the relevant bit in HR1 becomes 1.

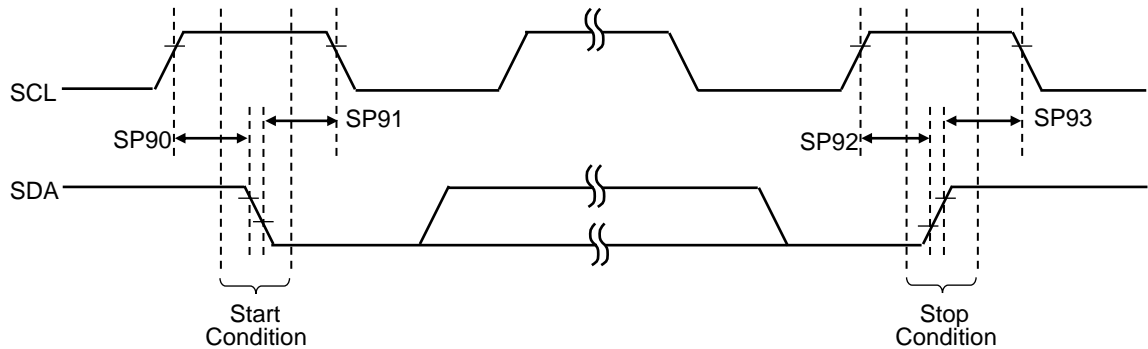
When performing calibration using HR1 and HR2, the following procedure is recommended.

- (1) Write 0 to HR1.
- (2) Write 7C06H (air adjustment) or 7C07H (zero adjustment) to HR2.
- (3) Read HR1 and check that DI6 or DI7 is 1.

## Appendix 2 (Specifications of I<sup>2</sup>C Bus Interface)

The I<sup>2</sup>C bus interface supports the standard mode and the high-speed mode.

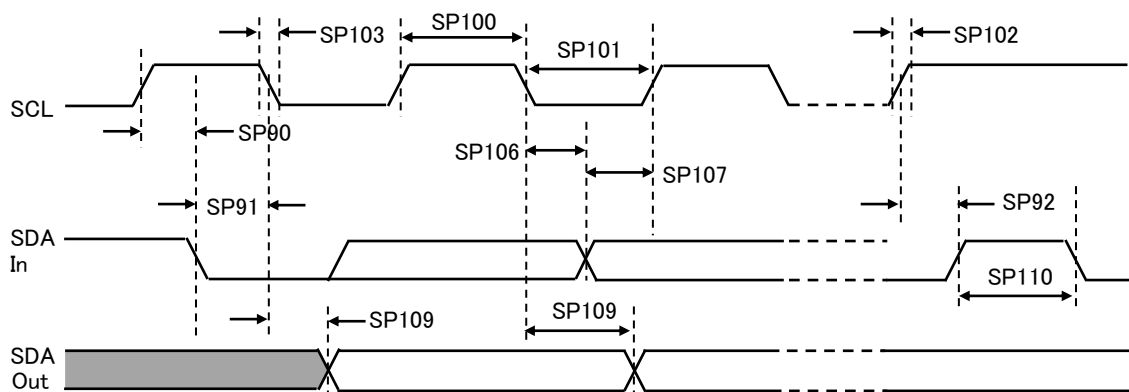
### (1) I<sup>2</sup>C BUS START/STOP BITS TIMING



### (2) I<sup>2</sup>C BUS START/STOP BITS REQUIREMENTS

Param. No.	Sign	Item		Min.	Typ.	Max.	Unit	Condition
SP90	TSU:STA	Start Condition Setup time	100kHz mode	4700	-	-	ns	Only relevant for Repeated Start condition
			400kHz mode	600	-	-		
SP91	THD:STA	Start Condition Hold time	100kHz mode	4000	-	-	ns	After this period, the first clock pulse is generated
			400kHz mode	600	-	-		
SP92	TSU:STO	Stop Condition Setup time	100kHz mode	4700	-	-	ns	
			400kHz mode	600	-	-		
SP93	THD:STO	Stop Condition Hold time	100kHz mode	4000	-	-	ns	
			400kHz mode	600	-	-		

### (3) I<sup>2</sup>C DATA TIMING



## (4) I<sup>2</sup>C BUS DATA REQUIREMENTS

Param. No.	Sign	Item		Min.	Max.	Unit	Condition
SP100	THIGH	Clock high time	100kHz mode	4.0	-	μs	Device must operate at a minimum of 1.5MHz
			400kHz mode	0.6	-	μs	Device must operate at a minimum of 10MHz
			SSP module	1.5Tcy	-		
SP101	TLOW	Clock low time	100kHz mode	4.7	-	μs	Device must operate at a minimum of 1.5MHz
			400kHz mode	1.3	-	μs	Device must operate at a minimum of 10MHz
			SSP module	1.5Tcy	-		
SP102	TR	SDA and SCL rise time	100kHz mode	-	1000	ns	
			400kHz mode	20+0.1C <sub>B</sub>	300	ns	CB is specified to be from 10-400pF
SP103	TF	SDA and SCL fall time	100kHz mode	-	250	ns	
			400kHz mode	20+0.1C <sub>B</sub>	250		CB is specified to be from 10-400pF
SP106	THD:DAT	Data input hold time	100kHz mode	0	-		
			400kHz mode	0	0.9		
SP107	TSU:DAT	Data input setup time	100kHz mode	250	-	ns	(Note2)
			400kHz mode	100	-	ns	
SP109	TAA	Output valid from clock	100kHz mode	-	3500	ns	(Note1)
			400kHz mode	-	-	ns	
SP110	TBUF	Bus free time	100kHz mode	4.7	-		Time the bus must be free before a new transmission can start
			400kHz mode	1.3	-		
SP111	CB	Bus capacitive loading		-	-	400	

Note1: As a transmitter, the device must provide this internal minimum delay time to bridge the undefined region(min. 300 ns) of the falling edge of SCL to avoid unintended generation of Start or Stop conditions

Note2: A Fast mode (400 kHz) I<sup>2</sup>C™ bus device can be used in a Standard mode (100 kHz) I<sup>2</sup>C bus system, but the requirement TSU:DAT ≥ 250 ns must then be met. This will automatically be the case if the device does not stretch the low period of the SCL signal. If such a device does stretch the low period of the SCL signal, it must output the next data bit to the SDA line TR max. + TSU:DAT=1000 + 250 = 1250 ns (according to the Standard mode I<sup>2</sup>C bus specification), before the SCL line is released.