



# Carbon Dioxide (CO<sub>2</sub>) Gas Sensor

The TG100 measuring carbon dioxide (chemical formula CO<sub>2</sub>) is a NDIR (Non-Dispersive Infrared) gas sensor. As it is contactless, it has high accuracy and longer life than sensors having a different way. This sensor has been developed with standard gas and is efficiently calibrated using our state of the art gas sensor calibration technology. Furthermore, this sensor comes with Serial Communication (UART), I<sup>2</sup>C interface and Analog Output. So, CO<sub>2</sub> density can be checked using these inter faces easily.

## Features

- NDIR Gas Sensor
- High Precision
- Expected Life Span, 10 years
- Compact Size, 37 x 28 mm
- RoHS Compliance



Model : TG100 Series

## Interfaces

- UART, 38400 Baud Rate
- I<sup>2</sup>C Interface
- Analog Output
- Status LED
- GPIOs for calibration.

## Specifications

Table 1. Electrical Specifications

Parameter	Symbol	Min	Typ.	Max	Unit	Notes
Regulated DC Power Supply is used, Test Condition : $V_{DD} = 5 V$						
Power Supply	$V_{DD}$	4.75	5	5.25	V	
Current Consumption	$I_{DD}$	12	-	21	mA	ready state
	$I_{DD}$	100	-	210	mA	while gas measurement

\* The noise on power supply may cause incorrect measurement.

Table 2. Sensor Specifications

Parameter	Symbol	Min	Typ.	Max	Unit	Notes
Measuring Range		0	-	10k	ppm	
Accuracy			$\pm 5\% \pm 30\text{ppm}$			+degree C
			$\pm 7\% \pm 50\text{ppm}$			-degree C
Detection Limit		-	10	-	ppm	( Resolution @ 0ppm region)
Response Time	$t_{1/e}$	-	-	18	sec	
	$t_{90}$	-	-	30	sec	

Operating Temperature	$T_O$	* $T_{OL}$	-	* $T_{OH}$	°C	
Operating Humidity	$H$	0	-	95	%,RH	Non Condensing

\*  $T_{OL}$  and  $T_{OH}$  are mentioned at ordering guide on Page 17. Refer the ordering guide page.

Storage Temperature	$T_S$	-35	-	70	°C	
Storage Humidity	$H$	0	-	95	%,RH	Non Condensing

Warming-Up Time	$t_w$	30	120	-	sec	for accuracy
Data Sampling Time	$t_s$	-	2	-	sec	Pulse Operation

Table 3. UART Interface Specifications

Parameter	Symbol	Min	Typ.	Max	Unit	Notes
Recommended Request Time	$T_{UR}$	0.5	1	-	sec	
Transmitted Time	$T_{UT}$	-	2	-	sec	
Acceptable TTL Signal High Level	$V_{HU}$	2.31	3.3	5.25	V	TXD, RXD
Acceptable TTL Signal Low Level	$V_{LU}$	-	-	0.99	V	TXD, RXD

Table 4. I<sup>2</sup>C Interface Specifications

Parameter	Symbol	Min	Typ.	Max	Unit	Notes
Operating Frequency	$f_{I2C}$	-	-	200	kHz	
Request Time	$T_{I2C}$	1	-	-	sec	
Acceptable TTL Signal High Level	$V_{HI}$	2.3	3.3	5.25	V	SCL, SDA
Acceptable TTL Signal Low Level	$V_{LI}$	-	-	0.99	V	SCL, SDA

Table 5. Analog Output Specifications

Parameter	Symbol	Min	Typ.	Max	Unit	Notes
Analog Output Range	$V_A$	10	-	4000	mV	10mV $\approx$ 25 ppm
Conversion Time	$T_V$	-	2	-	sec	

\* The range of analog output depend on maximum value of measured ppm.

## UART Interface

This sensor comes with a serial interface for user to read ppm values. Also, several commands are supported. About commands, refer to Table 9. Also, there are examples on next page.

To use UART interface, refer to serial communication configuration in Table 6.

Table 6. Serial Communication Configuration

<b>Baud Rate</b>	38,400 bps
<b>Stop Bits</b>	1 bit
<b>Parity Check</b>	None
<b>Data Length</b>	8 bits
<b>TTL Level</b>	3.3V or 5V

If the communication configuration is set correctly, user will get the protocol message as mentioned below.

Table 7. Protocol Format

<b>Byte</b>	1	1	1	1	1	1	1	1	1	1	1	1
<b>Value</b>	D6	D5	D4	D3	D2	D1	<SP>	'p'	'p'	'm'	<CR>	<LF>

Table 8. Protocol Format Explanation

Value	Description
D6 ~ D1	Gas density is indicated as string, Maximum length is 6 bytes.
<SP>	Space : 0x20
'ppm'	'ppm' : 0x70 0x70 0x6D
<CR>	Carriage Return : 0x0D
<LF>	Line Feed : 0x0A

The number of <SP> between D6 and D1 will be different for different gas densities. So, user will get 'ppm' values in ASCII format, shown below.

To write commands, Follow the important points below to keep in mind while sending serial commands and refer to the examples given on pages 5 to 7.

- ① This protocol format conforms to ASCII format.
- ② Before send command, Enter command mode.
- ③ To enter in command mode, Send **ATTN<CR><LF>** and to exit, Send **RUN<CR><LF>**.
- ④ All commands should be delimited by<CR><LF>.

Table 9. UART Command Table

Code	Description
<b>ACAL</b>	Period of automatic calibration can be changed.
<b>MCAL</b>	Manual Calibration is requested.

## Getting Started with UART Commands

User can communicate with sensor using PC software / terminal program or another device. Which supports serial communication on same baud rate as mentioned in serial interface specification. If user has connected their serial device correctly, they will receive string message from sensor. The message will be transmitted at intervals of about two seconds.

### Example

```
RX> <SP>643<SP>ppm<CR><LF>
```

Example 1. ASCII Code Message

### Example

```
RX> 20 36 34 33 20 70 70 6D 0D 0A
```

Example 2. HEX Code Message

## Entry Command Mode

To use any command, sensor should be entered in command mode.

To enter in command mode, user should send **ATTN<CR><LF>**. Otherwise, the commands will not recognized by the sensor.

### Example

```
TX> ATTN<CR><LF>  
RX> ATTN<CR><LF>  
RX> <ACK>
```

Example 3. ATTN Message

## Exit Command Mode

To exit from the command mode, user should send **RUN<CR><LF>**. When user is not using serial interface, to continue with normal running mode.

### Example

```
TX> RUN<CR><LF>  
RX> RUN<CR><LF>  
RX> <ACK>
```

Example 4. RUN Message

## ACAL Command Mode

About automatic calibration, The information is on Page 13. Read the page before use this command

The period of automatic calibration can be changed using this command.

### ACAL07<CR><LR>

If the user wants to run ACAL for 7 days, user should send **ACAL07<CR><LF>**. Refer to Example 5

#### Example

```
TX> ACAL07<CR><LF>
RX> ACAL07<CR><LF>
RX> <ACK>
RX> ACAL<SP>Period<SP>is<SP>7<SP>Days<CR><LF>
```

Example 5. ACAL 7 days Message

### ACAL30<CR><LR>

If the user wants to run ACAL for 30 days, user should send **ACAL30<CR><LF>**. Refer to Example 6

#### Example

```
TX> ACAL30<CR><LF>
RX> ACAL30<CR><LF>
RX> <ACK>
RX> ACAL<SP>Period<SP>is<SP>30<SP>Days<CR><LF>
```

Example 6. ACAL 30 days Message

## MCAL Command Mode

At Page 14, There are instructions about manual calibration. Read the instructions before use this command.

**MCAL=<Value><CR><LR>**

When ppm value is put that user wants, Sensor will response like Example 7 message mentioned below. It means that manual calibration is started. And then when manual calibration is finished, sensor will response like Example 8 message.

### Example

```
TX> MCAL=500<CR><LF>
RX> MCAL=500<CR><LF>
RX> <ACK>
RX> MCAL<SP>ON<SP> :<SP>500<SP><CR><LF>
```

Example 7. Starting MCAL Message

### Example

```
RX> MCAL<SP>is<SP>activated<CR><LF>
```

Example 8. Finishing MCAL Message



## I<sup>2</sup>C Interface

This sensor communicates with the host controller, over a digital I<sup>2</sup>C interface. The 7-Bit base slave address is **0x31**.

Table 10. I<sup>2</sup>C Slave Address Byte

Bit	7	6	5	4	3	2	1	0
Data	0	1	1	0	0	0	1	R/W
* R/W : Read = 1, Write = 0								

Master I<sup>2</sup>C device communicates with our sensor, using a command structure. The commands are listed in, Table 11. Commands, other than those documented below are undefined and should not be sent to the device.

Table 11. I<sup>2</sup>C Command Table

COMMAND	DATA n	Description
0x52	7 Byte	Read PPM and state of configuration
0x53	2 Byte	Request a manual calibration

In the I<sup>2</sup>C sequence diagrams in the following sections, bits produced by the master and slave are color coded as shown :



Table 12. I<sup>2</sup>C Bit Descriptions

Value	Symbol	Description
START	S	SDA goes low while SCL high
STOP	P	SDA goes high while SCL high
Repeated START	Sr	SDA goes low while SCL high. It is allowable to generate a STOP before the repeated start. SDA can transition to high before or after SCL goes high in preparation for generating the START
READ	R	Read bit = 1
WRITE	W	Write bit = 0
ACK	A	Acknowledge
NACK	NA	No acknowledge

Inside sensor, there are pullup resistors on each I<sup>2</sup>C line. Refer to the circuit below.

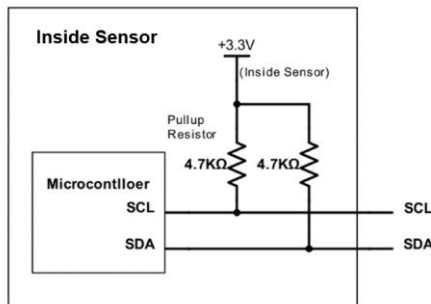


Figure 1. I<sup>2</sup>C Circuit Inside Sensor

### I<sup>2</sup>C Sequence to perform a ppm measurement and read manual calibration state

The master device should request to slave device. The slave device means this sensor.

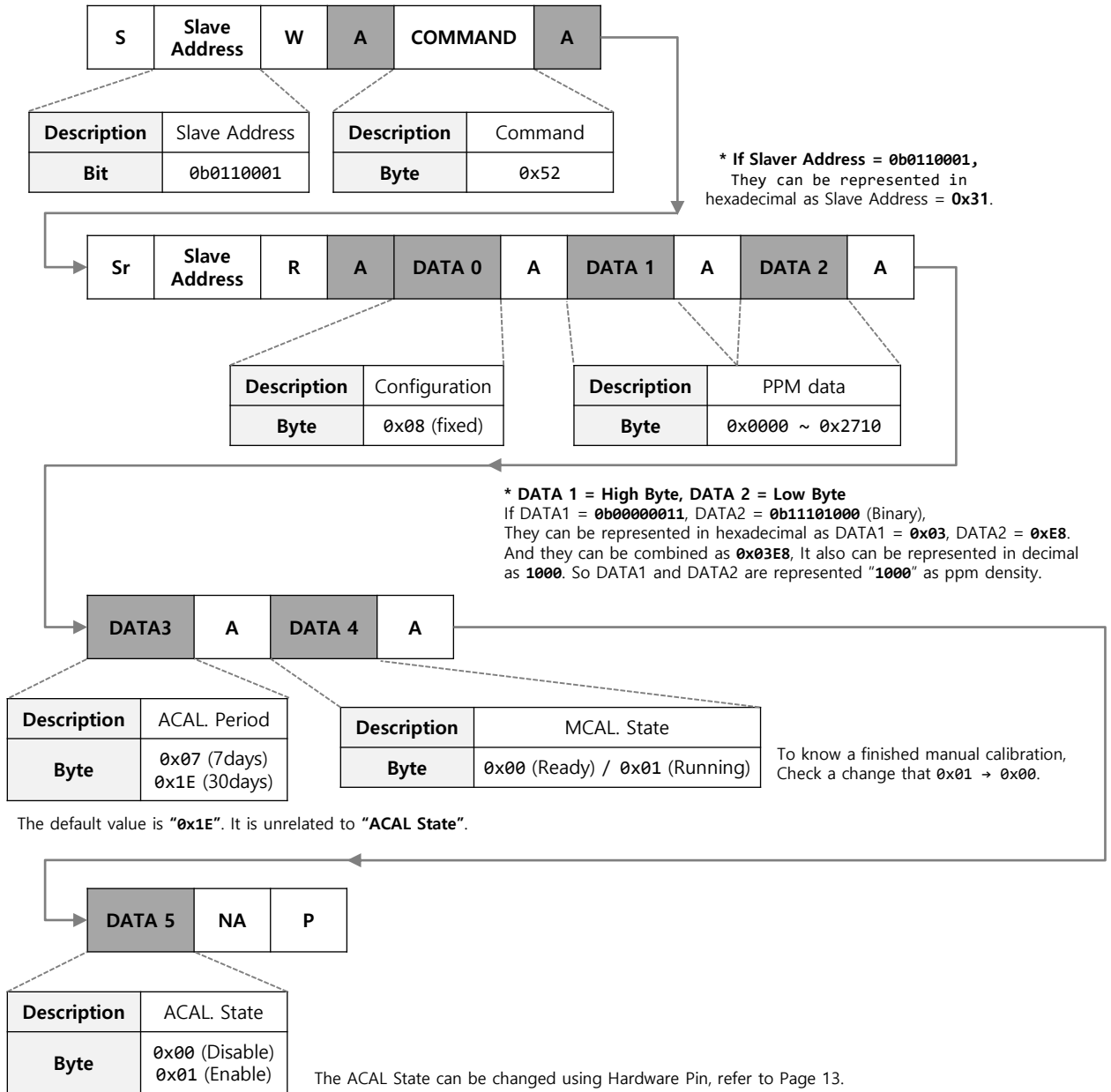


Figure 2. I<sup>2</sup>C Packet while reading data

**I<sup>2</sup>C Sequence to write a value in a manual calibration.**

At Page 14, There are instructions about manual calibration. Read the instructions before use this function.

The master device should request to slave device. After communication using this sequence, User should check the MCAL. State (Refer Figure 2). If the MCAL. State is still 0x00, It means entered data was rejected.

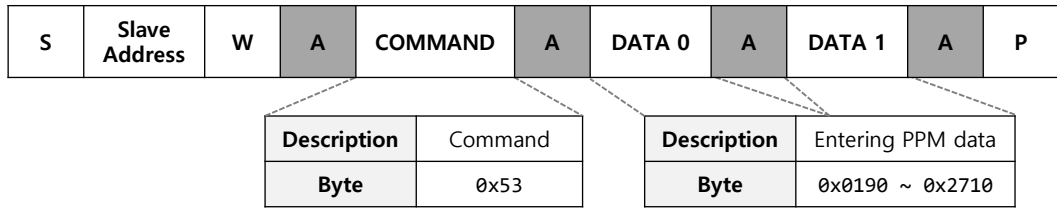


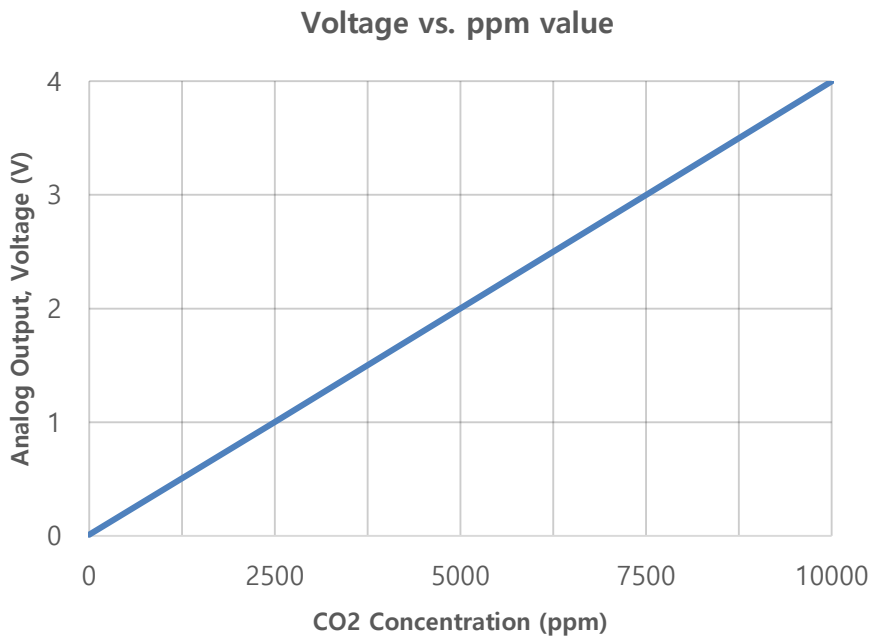
Figure 3. I<sup>2</sup>C manual calibration packet

## Analog Output

This sensor has analog output to read ppm value. To read ppm value, the analog voltage value should be converted to ppm value. Refer to Function 1.

$$ppm = \frac{V_{Analog\ Output}}{0.0004}$$

Function 1. Voltage to ppm



Graph 1. Voltage to ppm Graph

In case of analog output, the accuracy of ppm may be different when compared with other interface.

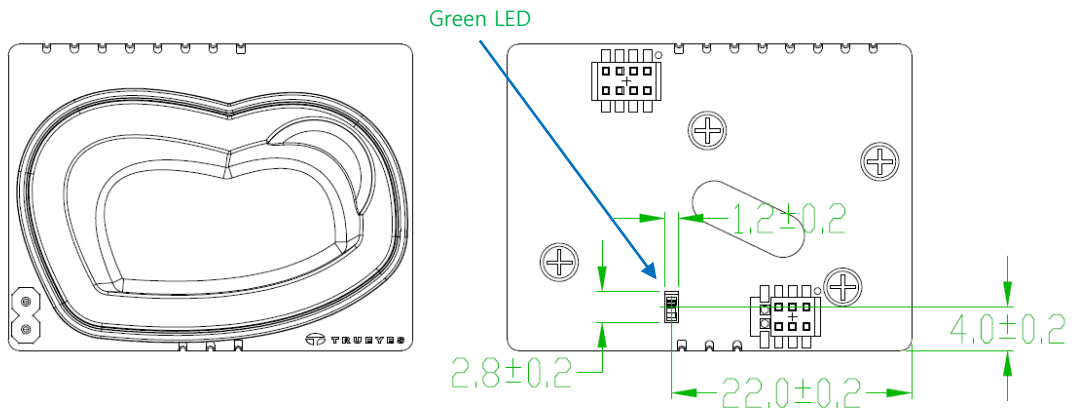
## Check LED

This sensor has one led on the bottom. User can check the state of sensor easily. The led will be light up in mentioned situations below. Refer to the conditions.

### - Conditions when the green led is light up.

- ① When sensor responses after receive any data trough UART, the led will be twinkled.
- ② When manual calibration is running, the led will be light up until finish the calibration.

As see the Dimension 1, user can know the location of green led.



Dimension 1. Green LED Position

## ABC (Automatic Calibration)

This sensor was calibrated in a factory. But, it will be recalibrate monthly to get the accuracy of ppm. It mean if the ABC is enabled, sensor will have these operation. If user wants to disable the ABC, use a hardware pin. As use a hardware pin, the ABC can be disabled easily. Refer to instruction at Table 13 and Figure 4.

If UART or I<sup>2</sup>C is used, the period can be changed. In the initial state, the period is one month. It will be selected as one week or one month.

### How to Enable and Disable the ABC function

Table 13. Hardware State vs ABC State

Hardware State	Description
Open	ABC is Enabled
Short	ABC is Disabled

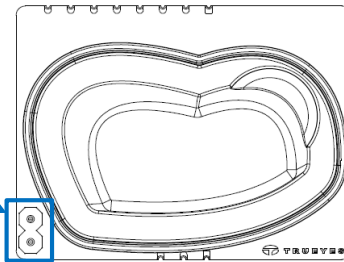


Figure 4. Hardware Pin Location

To change the period of ABC, use a UART or I<sup>2</sup>C at Page 6 (UART), Page 10 (I<sup>2</sup>C), there are instructions that how to use.

Table 14. ABC Period

Period
7 days
30 days (Default)

## Manual Calibration

If user wants recalibrated data manually, this sensor can be calibrated as use a manual calibration function. To use manual calibration, Please, Read all comments and cautions very carefully.

### CAUTIONS

※ Please, Make sure that air conditions should be stabilized. It means that the CO<sub>2</sub> density and temperature should be stabled in vicinity of sensor.

If manual calibration is run with unstable air conditions, calibration run time will be increased. Furthermore, the sensor data after finishing such manual calibration may be incorrect.

### Manual Calibration Sequence

- ① Request a manual calibration command using Hardware Pin (Page 14) or UART (Page 7) or I<sup>2</sup>C (Page 10) interface.
- ② When sensor receives requested command, the manual calibration will be started. User can check it by watching Green LED glowing up during calibration process. Also, it can be checked through UART or I<sup>2</sup>C communication.

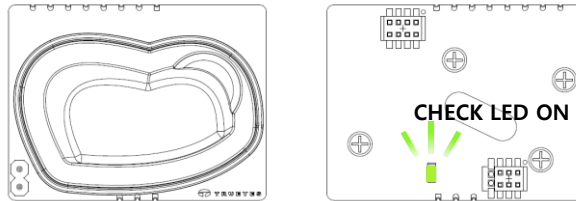


Figure 5. Green LED glowing up while manual calibration.

### How to use Hardware Pin

At the moment, when the MCAL pin is connected to GND (at least 2 seconds), this sensor will start the manual calibration with set default value (**default value = 400 ppm**) and it will be ended automatically after calibration time. Which is dependent on surrounding conditions.

So, in Figure 6, it is shown when the switch (SW) is pressed, the manual calibration will be started.

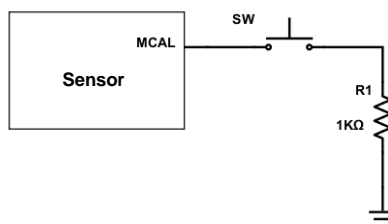
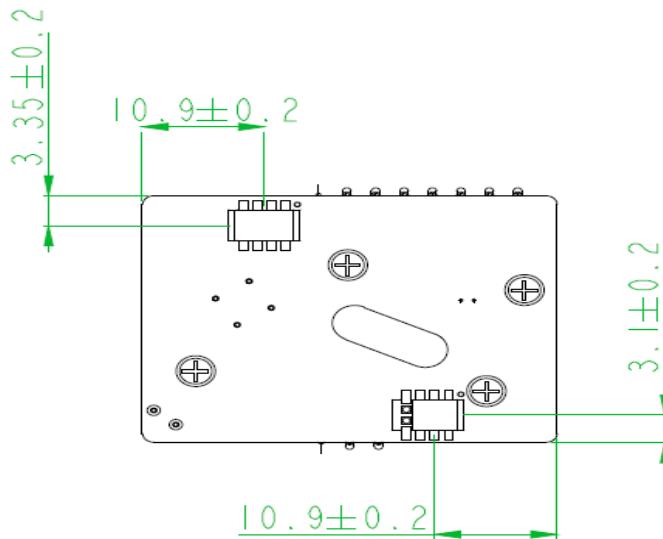
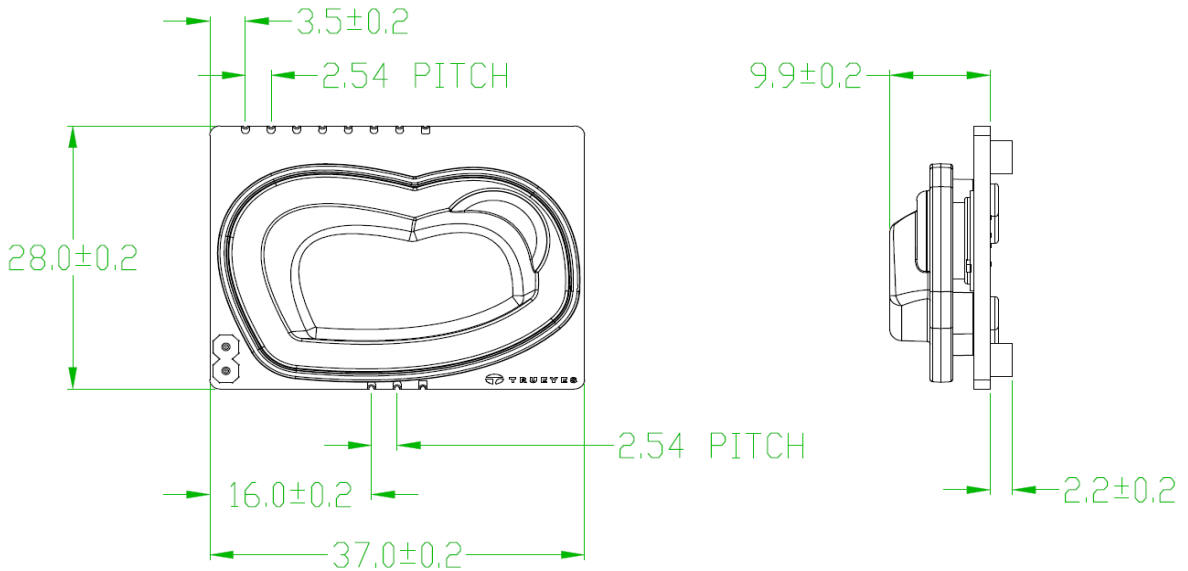


Figure 6. Manual Calibration Application Circuit, in case of using external hardware

### Package Dimension



Dimension 2. Product Dimension

※ Caution : Do not attempt to reassemble or give physical stress while handling.



## Pin Description - TOP

Table 15. Upper Pin Description

No.	Pin Assigned
1	Analog Output
2	GND
3	UART TXD →
4	UART RXD ←
5	I <sup>2</sup> C SDA
6	I <sup>2</sup> C SCL
7	GND
8	V <sub>DD</sub>

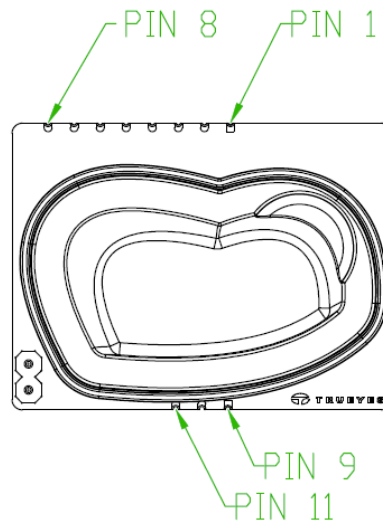


Figure 7. Assigned Pin on Top

Table 16. Lower Pin Description

No.	Pin Assigned
9	GND
10	GND
11	GND

### Pin Description - BOTTOM

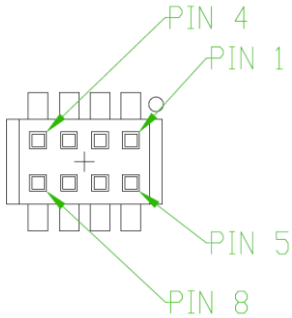


Table 17. Upper Connector-1

No.	Pin Assigned
1	I <sup>2</sup> C SDA
2	I <sup>2</sup> C SCL
3	GND
4	V <sub>DD</sub>

Table 18. Upper Connector-2

No.	Pin Assigned
5	UART RXD ←
6	UART TXD →
7	GND
8	Analog Output

Figure 8. 4x2 Pin Header, 1.27mm SMD Type

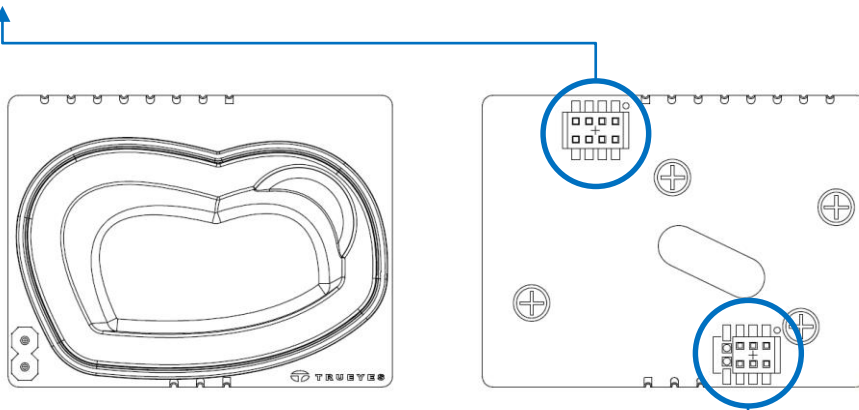


Figure 9. Assigned Pin on Bottom

Table 19. Lower Connector-1

No.	Pin Assigned
9	GND
10	*MCAL Pin
11	Reserved
12	NC

\*MCAL : Manual Calibration

Table 20. Lower Connector-2

No.	Pin Assigned
13	Reserved
14	*ABC Pin
15	Reserved
16	NC

\*ABC : Manual Calibration

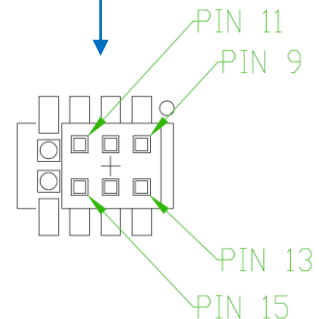


Figure 10. 3x2 Pin Header, 1.27mm SMD Type

※ Caution : Reserved pins should not be connected to anything.

## Ordering Guide

Table 21. Ordering Guide

Model	Description	Supply Voltage ( $V_{DD}$ )	Operating Range (°C)	
			$T_{OL}$	$T_{OH}$
TG100	NDIR Type CO <sub>2</sub> Gas Sensor Module	5 V	0 °C	50 °C
TG100-R2	NDIR Type CO <sub>2</sub> Gas Sensor Module	5 V	-25 °C	50 °C
TG100-R3	NDIR Type CO <sub>2</sub> Gas Sensor Module	5 V	-35 °C	50 °C

\* The "R" denotes what product can operate in temperatures below zero like a refrigeration system.

## Revision History

Table 22. Revision History

Revision	Description	Date	Author
2.3	Last Version	-	-
2.4	The previous version is destroyed because modified template and major parameters.  Major changed contents : - Electrical Spec. was changed. - Details about interface, dimensions were added	5 Jan 2018	JH Yi
2.5	The pitch value at the dimension section was modified. - Changed : 2.5±0.2 ⇒ 2.54 PITCH Specific define for resolution ( @0ppm)	8 Jan 2018	JH Yi
2.6	I2C section was modified with details.	15 Jan 2018	JH Yi
2.7	The page 2, on specifications - The range of power supply was modified. - Thus, current consumption were modified. - Location of Operating Humidity just is moved. The table 4, I2C frequency was changed according to mater I2C. On I2C sequence, the slave address was added. On Analog Output page, The equation was modified. On Page 13, Release time was added. read the contents. Dimension was changed to old version.	29 Jan 2018	JH Yi
2.8	- Add sensor gross weight at dimension drawing page - Correct operating temp -20~50 → -25 to 50 - Remove slave frequency description on I2C spec - Add mechanical tolerance on dimension	31 Jan 2018	JH Choi
2.9	- Dimension was changed to new version On page 15, Pin Description was added. On Page 17, Ordering Guide was added.	3 July 2018	DH Jeong
2.91	- On Page 3, Correct Request Time unit ( ms → sec ).	12 July 2018	DH Jeong
2.92	- On Page 6, ACAL Mode example was modified. - The Table 11, Set a period of automatic calibration command is removed. - On page 9, Correct ACAL Period unit ( 0x30 (30days) → 0x1E (30days) ). - On page 10, I <sup>2</sup> C automatic calibration packet is removed.	1 August 2018	DH Jeong
2.93	- On page 11, Correct Graph description.. - On Page 15, Bottom dimension was added.	3 August 2018	DH Jeong
2.94	- Remove TG100-R model in ordering guide	13 November 2018	JH Choi
2.95	- Modify Lower Storage temperate from -30 to -35	18 December 2018	JH Choi



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