# SPECIFICATION

**Product Name: Ultrasonic Oxygen Sensor**

**Sensor Item No.: Gasboard-8500FS-L240**

**Gasboard-8500FS-L240H**

**Gasboard-8500FS-L240HL**

**Version: V0.5**

**Date: July 01, 2022**

# Revision

| No. | Version | Content | Date |
|---|---|---|---|
| 1 | V0.1 | First Edition | 2021-11-19 |
| 2 | V0.2 | Changes on specifications and communication protocol. | 2022-04-19 |
| 3 | V0.3 | Modify the calculation of temperature in communication protocol | 2022-04-27 |
| 4 | V0.4 | Add baud rate 460,800 in communication protocol | 2022-05-19 |
| 5 | V0.5 | Add IIC communication protocol. | 2022-07-01 |

# Ultrasonic Oxygen Sensor Gasboard-8500FS Series

## Applications

- ✧ Family and Medical Ventilator
- ✧ High-flow Oxygen Therapy Device
- ✧ Respiratory Device, Anesthetic Machine and Vaporizer
- ✧ Gas Detection in Binary Gas (Including O2)

## Description

Gasboard-8500FS-L240 series are ultrasonic technology 5-in-1 combined sensor solutions to measure flow rate, oxygen concentration, ambient pressure, temperature and humidity simultaneously with both analog and digital outputs. The flow rate range of Gasboard-8500FS-L240 series can be up to 240L/min. Benefit from ultrasonic technology and principle of TOF (time of flight) measurement, Gasboard-8500FS-L240 series have excellent performances with advantages of high accuracy, fast response, no drift, no need for routine calibration, maintenance-free and long life, etc. The interface design is according to ISO5356 with sealing rings to better meet the customers' installation and use requirements. Gasboard-8500FS-L240 series can be widely used in high-flow nasal cannula oxygen therapy ventilation, positive airway pressure ventilation, anesthetic ventilator and other medical equipment related to breath.

## Principle

Flow rate measurement principle: measure the TOF (time of flight) difference between the pulses of ultrasound propagating into and against the direction of the flow to calculate the flow rate.

Concentration measurement principle: when there is a molecular mass difference between the components of binary gas mixture, the sound propagation velocity varies with the composition of the two gases.

## Features

- ✧ Ultrasonic measurement technology, 5-in-1 combined sensor solution to measure flow rate, oxygen concentration, ambient pressure, temperature and humidity simultaneously
- ✧ Flow rate up to 240L/min
- ✧ Ensured accuracy in the full temperature range
- ✧ Continuous monitoring, no drift, no need routine calibration, maintenance-free.
- ✧ Excellent stability, high accuracy, fast response
- ✧ With temperature, humidity and atmosphere pressure compensation
- ✧ No-consuming parts, long lifespan
- ✧ Data update time up to 2ms which meets the requirement of fast response to flow for ventilators
- ✧ Support both analog and serial (UART and IIC) outputs
- ✧ CMC, CE, EMC,ROHS，REACH compatibility
- ✧ Biocompatibility with ISO10993, ISO 18562:2017 and USP graded

## Specification

| Ultrasonic Oxygen Sensor Gasboard 8500FS-L240 Series Specifications | | | |
|---|---|---|---|
| **Model** | **8500FS-L240** | **8500FS-L240H** | **8500FS-L240HL** |
| **Detect Principle** | Ultrasonic Technology | | |
| **Detection Range** 1) | O2 Concentration: 0%~100% vol | | |
| | Flow Rate: 0~240L/min | | |
| **Sampling Interval** 2) | 10ms (100 samples per second) | < 2ms (500 samples per second) | |
| **Detection Accuracy** 3) | O2 Concentration: Typically, ±2.5%FS, Maximum ±3%FS | | |
| | Flow Rate: ±0.2L/min (<10L/min); ±2.0% reading (≥10L/min) | | |
| **Resolution** | O2 Concentration: 0.1% vol | | |
| | Flow Rate: 0.1L/min | Flow Rate: 0.01L/min | |
| **Data Update Time** | O2 Concentration: 10ms | O2 Concentration: < 2ms | |
| | Flow Rate: 10ms | Flow Rate: < 2ms | |
| **Pressure Drop** | <600Pa (2.41in $H_2O$) @240L/min flow rate | | |
| **Working Condition** | 5~60℃; 0~95%RH (Non-condensing) | | -20~60℃; 0~95%RH (Non-condensing) |
| **Storage Condition** | Long term: -20~70℃; 0~95%RH (Non-condensing) | | |
| | Short term 4): -30~70℃; 0~95%RH (Non-condensing) | | |
| **Power Supply** | DC 4.75-5.25V, Ripple Wave ≤100mV | | |
| **Work Current** | Average Current <20mA; Peak Current <50mA | | |
| **Analog output** 5) | O2 Concentration: 200mV~2500mV (0%~100% vol) | | |
| | Flow Rate: 200mV~2500mV (0~240L/min) | | |
| **Communication** | UART_TTL (3.3V) / IIC (available on request) | | |
| **Dimension** 6) | L80*W48*H30mm | | |
| **IP Grade** | IP54 | | |
| **Life Span** | ⩾15 Years (continuous operation) | | |

*Note:*

*1) 8500FS-L240 series are calibrated with pure oxygen source and the concentration output is for pure oxygen. In case of a PSA oxygen source, the concentration should be converted using formula (transfer relationship is: sensor reading = (target concentration*1.142)-3.42%, in which target concentration is for PSA oxygen source). Concentration measuring range for PSA oxygen source is 20.5% to 95.6%.*

*2) Sampling interval and data update time is typically 1.5ms for 8500FS-L240H and 8500FS-L240HL.*

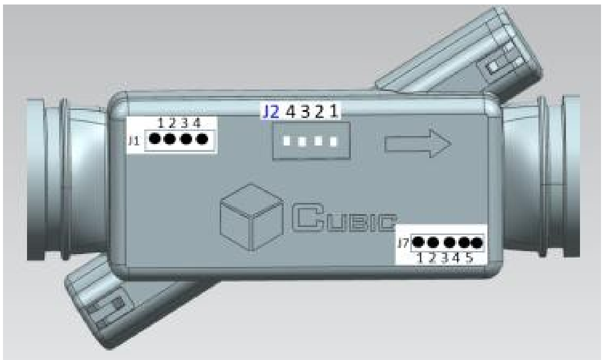
*3) Typical accuracy is define at 10~40) ℃;0~40%RH conditions and maximum accuracy is defined at (5~45) ℃;0~95%RH (non-condensing) conditions. Typical accuracy of O2 concentration meets ISO 80601-2-55 requirements.*

*4) Short term storage refers to temporary conditions for some special scenarios like short distance transportation, no longer than 2 hours.*

*5) Sensor's analog output of concentration is for pure oxygen that 200mV corresponds to concentration 0%, 2500mV corresponds to 100% and 683mV in air by default corresponds to oxygen concentration 21%. In case of a PSA oxygen source, first convert the analog output to pure oxygen concentration in percentage by the linear relationship between the output voltage and concentration, then transfer the pure oxygen concentration to PSA oxygen concentration using formula mentioned in note 1).*

*6) Outside diameter of the connector is 22mm which meets the requirement of ISO 5356.*

# Pin Definition




**Drawing 1 Gasboard-8500FS-L240 Pin Definition**

**Table 2 Connector Pin Definition**

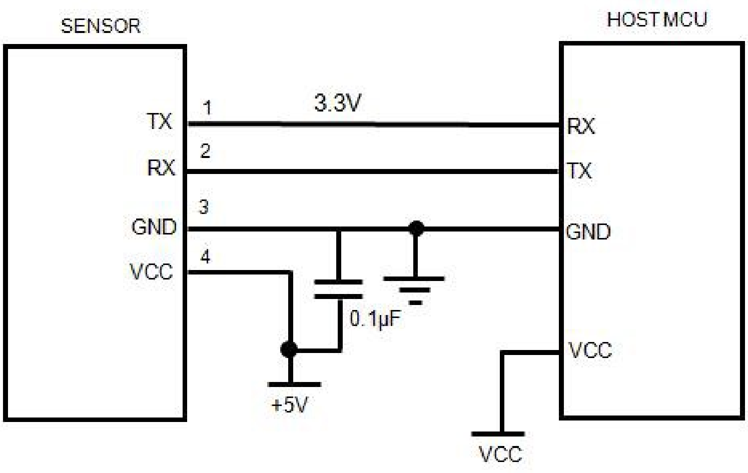
| J2 | | | J1 | | |
|---|---|---|---|---|---|
| **No.** | **Pin** | **Description** | **No.** | **Pin** | **Description** |
| 1 | Vcc | 5V±5%, External Power Supply Input Pin | 1 | GND | Power Ground |
| 2 | Rx / SDA | UART Receive / IIC Data (3.3V) | 2 | O2 | 200mV – 2500mV output pin, 200mV corresponds to 0% Vol 2500mV corresponds to 100% Vol |
| 3 | Tx / SCL | UART Send / IIC Clock (3.3V) | 3 | Flow | 200mV – 2500mV output pin, 200mV corresponds to 0 L/min 2500mV corresponds to 240 L/min |
| 4 | GND | Power Ground | 4 | Vcc | 5V±5%, External Power Supply Input Pin |
| Remark: Sensor enters UART mode if it receives a UART command within 5 seconds after powered on and enters IIC mode otherwise. IIC communication is only available on 8500FS-L240 on request. | | | Remark: The function is customized | | |
| J7 | | | | | |
| **No.** | **Pin** | **Description** | | | |
| 1 | GND | Power Ground | | | |
| 2 | LED1 | Alarm Output 1 | | | |
| 3 | LED2 | Alarm Output 2 | | | |
| 4 | LED3 | Alarm Output 3 | | | |
| 5 | Vcc | Power Output：3.3V | | | |
| Remark: This function is customized | | | | | |

**Table 3 Connector Description**

| Port | Terminal | Connector | Pin Pitch |
|---|---|---|---|
| J1 | PH2.0-4A | PH2.0-4P | 2.00mm |
| J2 | PH2.0-4A | PH2.0-4P | 2.00mm |
| J7 | PH2.0-5A | PH2.0-5P | 2.00mm |

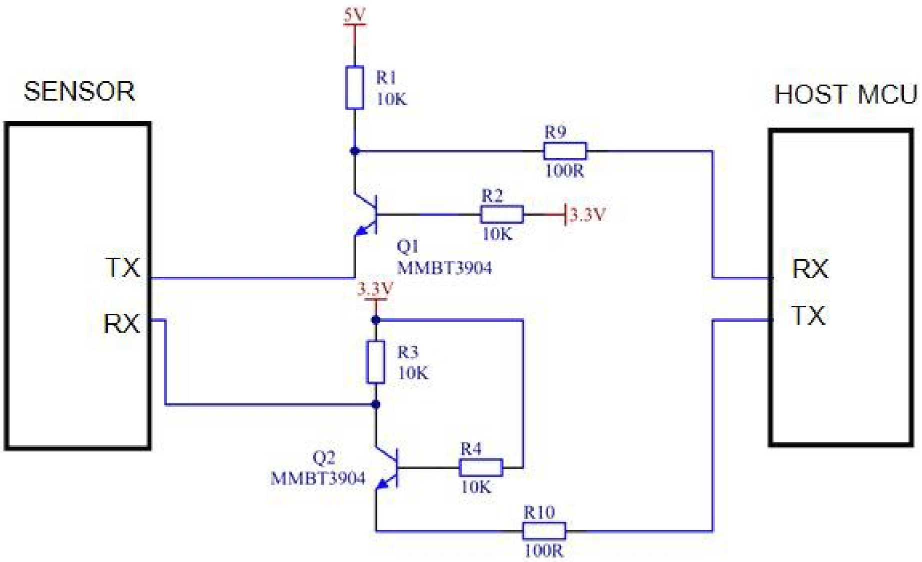
## Reference Circuit

### Application Scenario 1: UART TTL 3.3V Output




**Drawing 2** UART Communication Connection Circuit

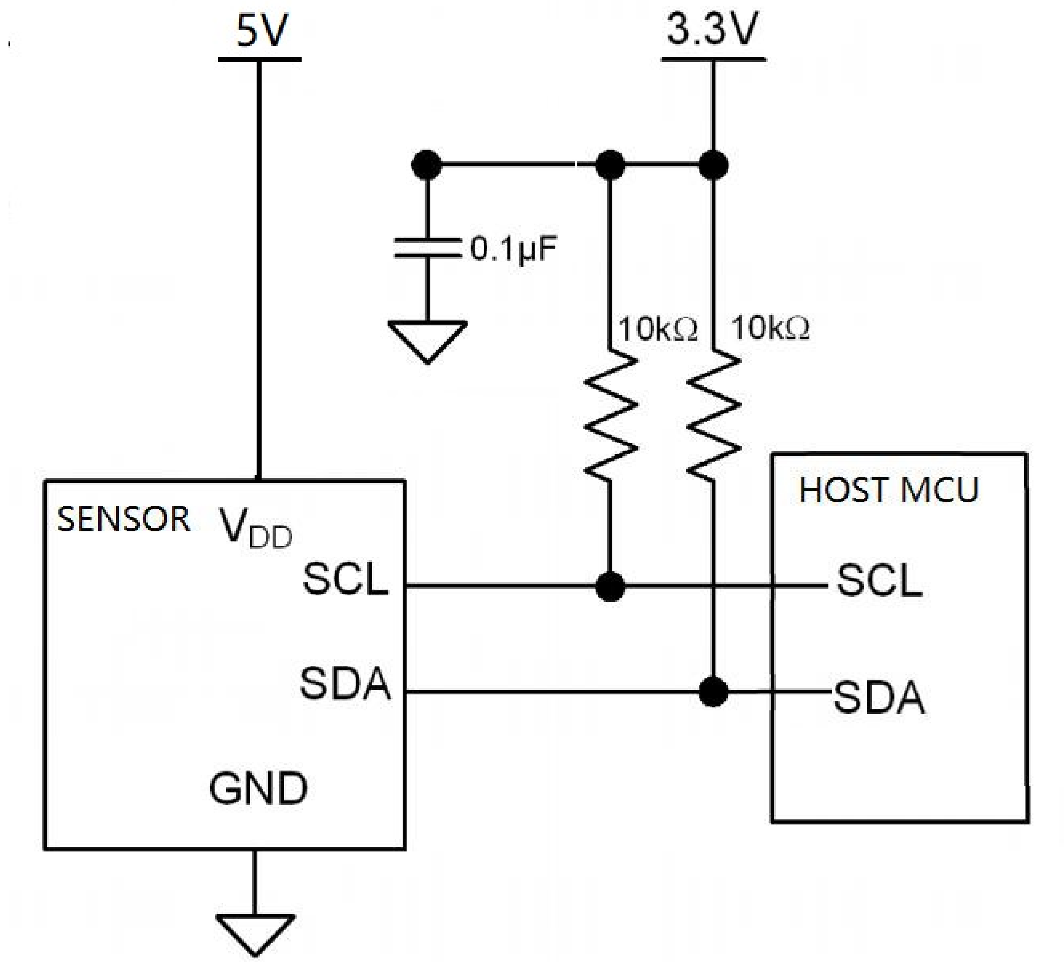
### Application Scenario 2: UART TTL 3.3V to 5V Communication Circuit




**Drawing 3** UART 3.3V to 5V Communication Connection Circuit

# Reference Circuit

**Application Scenario 3: IIC communication Circuit**




**<u>Drawing 4</u> IIC 3.3V Communication Connection Circuit**

# Communication Protocol

## UART Communication Protocol

### 1. Protocol Overview

(1) Baud Rate: For 8500FS-L240: 9600 bps by default, Data Bits: 8, Stop Bits: 1, Parity: No, Flow Control: No; For 8500FS-L240H/HL: 460,800 bps by default, Data Bits: 8, Stop Bits: 1, Parity: No, Flow Control: No
Note: Some device may lose data when receiving data, in this case, the user can send change baud rate command to switch to low-speed mode: baud rate 9600 bps;

(2) The protocol data are hexadecimal data. For example, “46” is [70] in decimal;

(3) [xx] is single- byte data (unsigned,0-255); For double- byte data, the higher byte is ahead of lower byte;

(4) The sensor will send data actively by default.

### 2. Serial Communication Protocol Format

**Host Send Format**

| Start Symbol | Length | Command No | Data 1 | …… | Data n | Check Sum |
|---|---|---|---|---|---|---|
| **HEAD** | **LEN** | **CMD** | **DATA1** | **……** | **DATAn** | **CS** |
| **11H** | XXH | XXH | XXH | …… | XXH | XXH |

**Protocol Format Description**

| Protocol Format | Description |
|---|---|
| **Start Symbol** | PC sending is fixed to [11H], module response is fixed to[16H] |
| **Length** | Byte length of the frame, =data length+1 (include CMD+DATA) |
| **Command No** | Command number |
| **Data** | Read or written data, the length is variable |
| **Check Sum** | The sum of data accumulation, =256-(HEAD+LEN+CMD+DATA) |

### 3. Serial Protocol Command List

| No | Functions | Command |
|---|---|---|
| 1 | Actively send data by default | / |
| 2 | Read the measurement result | 0x01 |
| 3 | Read the software version number | 0x1E |
| 4 | Inquiry instrument serial number | 0x1F |
| 5 | Change baud rate | 0x08 |
| 6 | Read temperature, humidity and ambient pressure | 0x03 |

### 4. Detailed Description

#### 4.1 Default Active Data

The sensor will send data actively by default.

**Response:** 16 09 01 DF1 DF2 DF3 DF4 DF5 DF6 DF7 DF8 [CS]

**Function:** Read the measurement results

**Description:**

O2 Concentration = (DF1*256 + DF2) /10 (Vol %)

Gas Flow Value = (DF3*256 + DF4) /10 (L/min) (For 8500FS-L240)

Gas Flow Value = (DF3*256 + DF4) /100 (L/min) (For 8500FS-L240H and 8500FS-L240HL)

Gas Temperature Value = (DF5*256 + DF6) /10 – 50 (℃) (Temperature in the sensor’s gas chamber)

Humidity value = (DF7*4)/10 (RH%) (Humidity in the sensor's gas chamber)

Ambient Pressure value = (DF8*5) / 10 (KPa) (The ambient pressure outside of the chamber)

**Response Example：**

Response：16 09 01 00 CD 00 FF 02 EE 4B CA 0F

**Remark:**

Hexadecimal Convert into Decimal: CD is 205; EE is 238; 4B is 75; CA is 202

O2 Concentration = (0*256 + 205)/10 = 20.5 (20.5%)

O2 Flow Value = (0*0+0)/10 = 0 (L/min)

O2 Temperature Value = (2*256+238)/10-50 = 25.0 (25.0℃)

O2 Humidity Value = (75*4) / 10 = 30 (30%RH)

Ambient Pressure value = (202*5) / 10 = 101 (101Kpa)

### 4.2 Read the Measurement Result

**Send:** 11 01 01 ED

**Response:** 16 09 01 DF1 DF2 DF3 DF4 DF5 DF6 DF7 DF8 [CS]

**Function:** Read the measurement results

**Description:**

O2 Concentration = (DF1*256 + DF2) /10 (Vol %)

Gas Flow Value = (DF3*256 + DF4) /10 (L/min) (For 8500FS-L240)

Gas Flow Value = (DF3*256 + DF4) /100 (L/min) (For 8500FS-L240H and 8500FS-L240HL)

Gas Temperature Value = (DF5*256 + DF6) /10 – 50 (℃) (Temperature in the sensor's gas chamber)

Humidity value = (DF7*4)/10 (RH%) (Relative humidity in the sensor's gas chamber)

Ambient Pressure value = (DF8*5) / 10 (KPa) (The ambient pressure outside of the sensor chamber)

**Remark:**

The O2 concentration here is for pure oxygen source, for PSA oxygen source, then the transfer relationship is:

Sensor reading = (target concentration*1.142)-3.42%, in which target concentration is for PSA oxygen source.

### 4.3 Read the Software Version Number

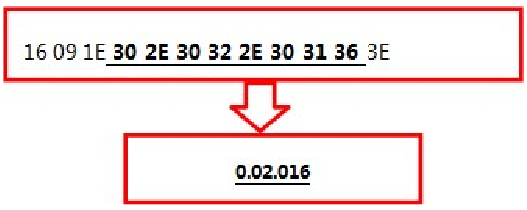
**Send:** 11 01 1E D0

**Response:** 16 09 01 DF1 DF2 DF3 DF4 DF5 DF6 DF7 DF8 [CS]

**Function:** Read the module's firmware version

**Description:** DF1-DF8 refers to the ASCII code of particular version number

**For example**： When module's firmware version number is 0.02.016, response data:



**4.4 Inquiry Instrument Serial Number**

**Send:** 11 01 1F CF

**Response:** 16 0B 1F (SN1) (SN2) (SN3) (SN4) (SN5) [CS]

**Function:** Read the module's serial number

**Description:** Outputs the module's serial number. SNn range is 0~9999, 5 integers constitute a 20-bit serial number.

**4.5 Change Baud Rate**

**Send:** 11 02 08 0X [CS]

**Response:** [ACK] 02 08 0X [CS]

**Function:** Change baud rate of the serial output

**Description:**

**For 8500FS-L240:**

When 0X=02, change baud rate from 9,600 bps to 115,200 bps;

When 0X=03, change baud rate from 115,200 bps to 9,600 bps;

**For 8500FS-L240H and 8500FS-L240HL:**

When 0X=00, change baud rate from 460,800 bps or 1,000,000 bps to 9,600 bps;

When 0X=01, change baud rate from 9,600 bps or 1,000,000 bps to 460,800 bps;

When 0X=02, change baud rate from 9,600 bps or 460,800 bps to 1,000,000 bps;

Command will take effective after a power off and on operation.

**4.6 Read Temperature, Humidity, Ambient Pressure**

**Send:** 11 01 03 EB

**Response:** 16 07 03 DF1 DF2 DF3 DF4 DF5 DF6 [CS]

**Function:** Read temperature, humidity and ambient pressure results

**Description:**

Temperature value = (DF1*256 + DF2) / 10 (℃)

Humidity value = (DF3*256 + DF4) / 10 (%)

Ambient pressure value = (DF5*256 + DF6) / 10 (kPa)

**Response Example:**

**Response:** 16 07 03 00 C8 01 67 03 FD B0

Remark: Hexadecimal Convert into Decimal: C8 is 200, [67] is 103, FD is 253;

Temperature = (0*256 + 200) / 10 = 20 (20 ℃)

Humidity = (1*256 + 103) / 10 = 35.9 (35.9%RH)

Ambient Pressure = (3*256 + 253) / 10 = 102.1 (102.1kPa)

# Communication Protocol

## IIC Communication Protocol

### 1. Timing Sequence

#### 1.1 IIC Protocol Overview

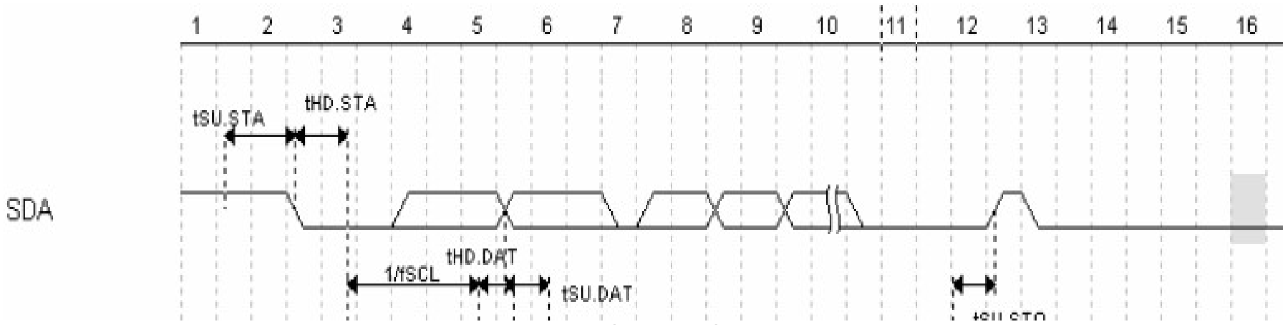
a. Utilize standard IIC timing sequence, clock frequency is 10khz～400khz

b. Utilize Big-Endian system, MSB first.

#### 1.2 IIC Timing Characteristics

| Symbol | Parameter | | | Unit |
|---|---|---|---|---|
| | Min | Typ. | Max | |
| **fSCL (SCL clock frequency)** | 10 | 100 | 400 | KHZ |
| **tHD.STA (Start condition Hold Time)** | | 0.6 | | us |
| **tSU.STA (Start condition Setup Time)** | | 0.6 | | us |
| **tHD.DAT (Data Hold Time)** | | 0 | | ns |
| **tSU.DAT (Data Setup Time)** | | 250 | | ns |
| **tSU.STO (Stop condition Setup Time)** | | 4 | | us |

*Note: SCL clock frequency generates from master with range 10khz～400khz*




**Drawing 5** IIC Timing Sequence

### 2. IIC Protocol Commands

#### 2.1 Command Format

**Send:** [CMD][DF0] …… [DFn]

[CMD] Command, used to distinguish from different commands

[DF0] ……[DFn] Parameters of the command, optional.

**Response:** [DF0]……[DFn][CS]

[DF0]……[DFn] Valid data

[CRC8] CRC8 check

#### 2.2 Command Description

The IIC slave address is represented by a 7-digit binary value. By default, the IIC slave address is set to 64 (0x40 or 1000000b). The address is always followed by a write bit (0) or read bit (1). Therefore, the hexadecimal IIC header for read access to the sensor is 0x81 and write access to the sensor is 0x80.

There are various commands as shown below to get different results from the sensor.

# Communication Protocol

| No. | Function | CMD | Description |
|---|---|---|---|
| **1.** | Inquiry flow result | 0x1000 | Read flow rate |
| **2.** | Inquiry O2 concentration result | 0x2000 | Read O2 concentration |
| **3.** | Inquiry atmosphere results | 0x3000 | Read temperature, humidity, ambient pressure |

### 2.2.1 Inquiry flow result

IIC master writes command 0x1000 to sensor with salve address 0x40(1000000b) + write bit(0b) = 0x80:

| | | | | | | |
|---|---|---|---|---|---|---|
| **START** | **0x80** | **ACK** | **0x10** | **ACK** | **0x00** | **ACK** |

IIC master reads results from sensor with slave address 0x40(1000000b) + read bit(1b) = 0x81:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **START** | **0x81** | **ACK** | **DF0** | **ACK** | **DF1** | **ACK** | **CRC8** | **NACK** | **STOP** |

Command description:

1. Upon receiving command 0x1000, sensor enter flow rate inquiry mode after which IIC master will read the same format data until the sensor receives a new command or reset.
2. Data interpretation is shown as below:

| Identifier | Data | Decimal range | Corresponding value | Multiple |
|---|---|---|---|---|
| Flowrate value | [DF0] [DF1] | 0~2400 | 0~240L/min | 10 |

Flow rate = ([DF0] * 256 + [ DF1]) / 10;

### 2.2.2 Inquiry O2 concentration result

IIC master writes command 0x2000 to sensor with salve address 0x40(1000000b) + write bit(0b) = 0x80:

| | | | | | | |
|---|---|---|---|---|---|---|
| **START** | **0x80** | **ACK** | **0x20** | **ACK** | **0x00** | **ACK** |

IIC master reads results from sensor with slave address 0x40(1000000b) + read bit(1b) = 0x81:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **START** | **0x81** | **ACK** | **DF0** | **ACK** | **DF1** | **ACK** | **CRC8** | **NACK** | **STOP** |

Command description:

1. Upon receiving command 0x2000, sensor enter O2 concentration inquiry mode after which IIC master will read the same format data until the sensor receives a new command or reset.
2. Data interpretation is shown as below:

| Identifier | Data | Decimal range | Corresponding value | Multiple |
|---|---|---|---|---|
| O2 conc. value | [DF0] [DF1] | 0~1000 | 0~100% | 10 |

O2 conc. = ([DF0] * 256 + [ DF1]) / 10;

# Communication Protocol

### 2.2.3 Inquiry atmosphere results

IIC master writes command 0x3000 to sensor with salve address 0x40(1000000b) + write bit(0b) = 0x80:

| | | | | | | |
|---|---|---|---|---|---|---|
| **START** | **0x80** | **ACK** | **0x30** | **ACK** | **0x00** | **ACK** |

IIC master reads results from sensor with slave address 0x40(1000000b) + read bit(1b) = 0x81:

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **S** | **0x81** | **A** | **DF0** | **A** | **DF1** | **A** | **DF2** | **A** | **DF3** | **A** | **CRC** | **NA** | **P** |

*Note: S: Start A: ACK NA: NACK P: STOP*

Command description:

1. Upon receiving command 0x3000, sensor enter atmosphere results inquiry mode after which IIC master will read the same format data until the sensor receives a new command or reset.

2. Data interpretation is shown as below:

| Identifier | Data | Decimal range | Corresponding value | Multiple |
|---|---|---|---|---|
| **Temperature value** | [DF0] [DF1] | 1000~19000 | -40~140℃ | 10 |
| **Humidity value** | DF2 | 0~250 | 0-100% | 10 |
| **Atm. pressure value** | DF3 | 0-1700 | 0-850Kpa | 10 |

Temperature = ([DF0] * 256 + [ DF1]) / 10 - 50;

Humidity = (DF2 / 10) * 4;

Atmospheric pressure = (DF3 / 10) * 5;

### 2.2.4 CRC-8 redundant data transmission

CRC (Cyclic Redundancy Check) is a data transmission error detection function, which performs polynomial calculation on data (using polynomial, modulo 2 division of data), and attaches the obtained result to the back of the frame for transmission and reception. The device also performs a similar algorithm after receiving it (it still uses the same polynomial to divide the received data modulo 2, but there is no remainder to be considered as correct transmission) to ensure the correctness and integrity of data transmission. CRC uses the principle of division and remainder to realize the function of error detection which is clear in principle and simple in implementation. The 8500FS-L240 sensor implements the CRC-8 standard based on the generator polynomial x8 + x5 + x4 +1.

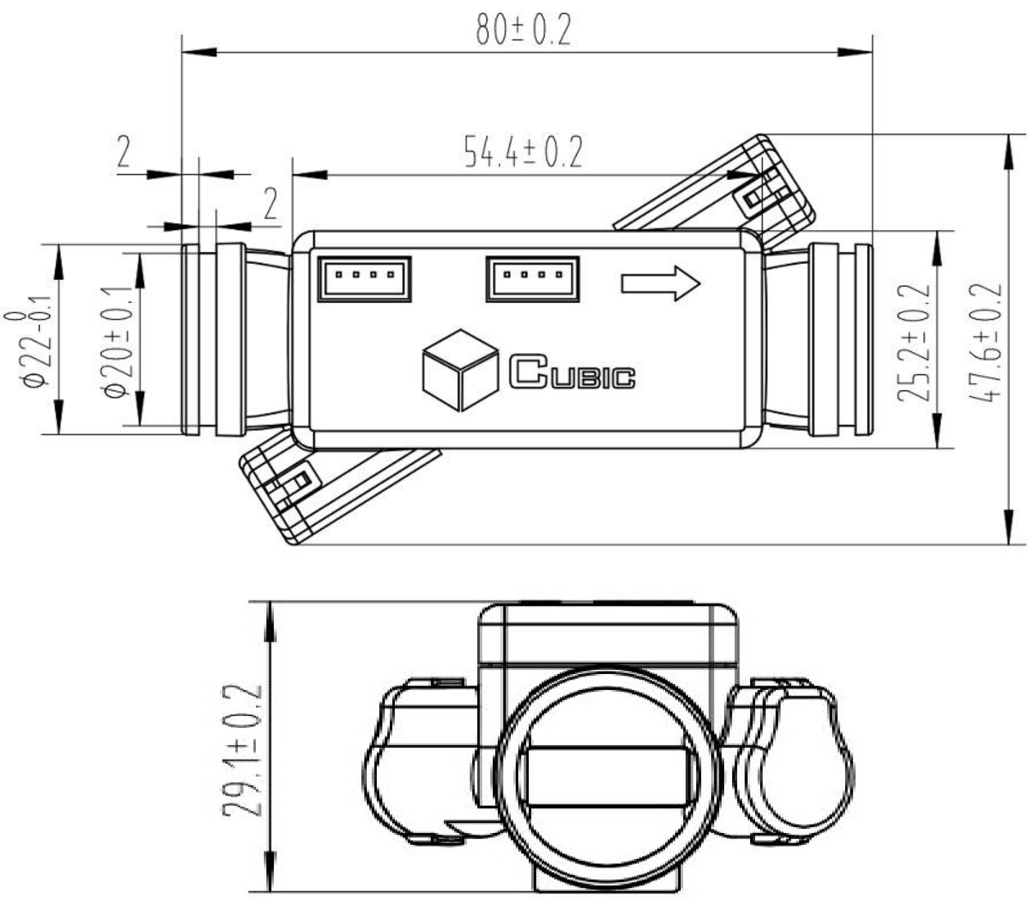
Example C codes:

```
unsigned char crc8(unsigned char *ptr, unsigned char len)
{
    unsigned char i;
    unsigned char crc=0xFF;

    while(len--)
    {
        crc ^= *ptr++;
        for (i=8; i>0; --i)
        {
            if (crc & 0x80)
                crc = (crc << 1) ^ 0x31;
            else
                crc = (crc << 1);
        }
    }
    return (crc);
}
```

## Dimensions and Installation

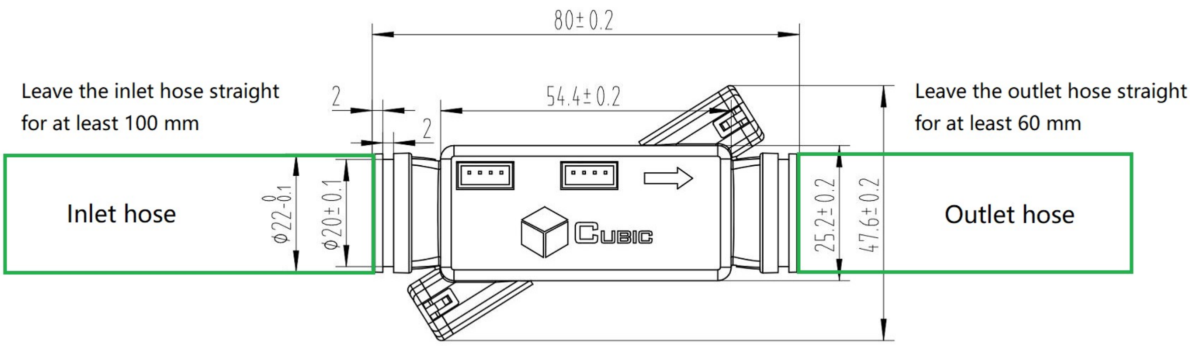
### Dimensions




**Drawing 5** Product Dimensions of 8500FS Series

### Installation

1. Leave the hose straight at least 100 mm from sensor's inlet and 60 mm from the sensor outlet side.
2. Make sure that there is no leakage.
3. Oxygen source should be input from the correct direction as indicated on the housing of the sensor (an arrow sign).




**Drawing 6** Installation Guide for 8500FS Series

# Product Code Instruction

**Gasboard** | **8500** | **FS** | **L240** | **XX**

※ Version

H: 2ms response, standard version (5 to 60℃)

HL: 2ms response, low temperature(-20 to 60℃)

※ Flow rate range

L240: flow rate range 240 L/min

※ Measurement Type

FS： Measurement type code

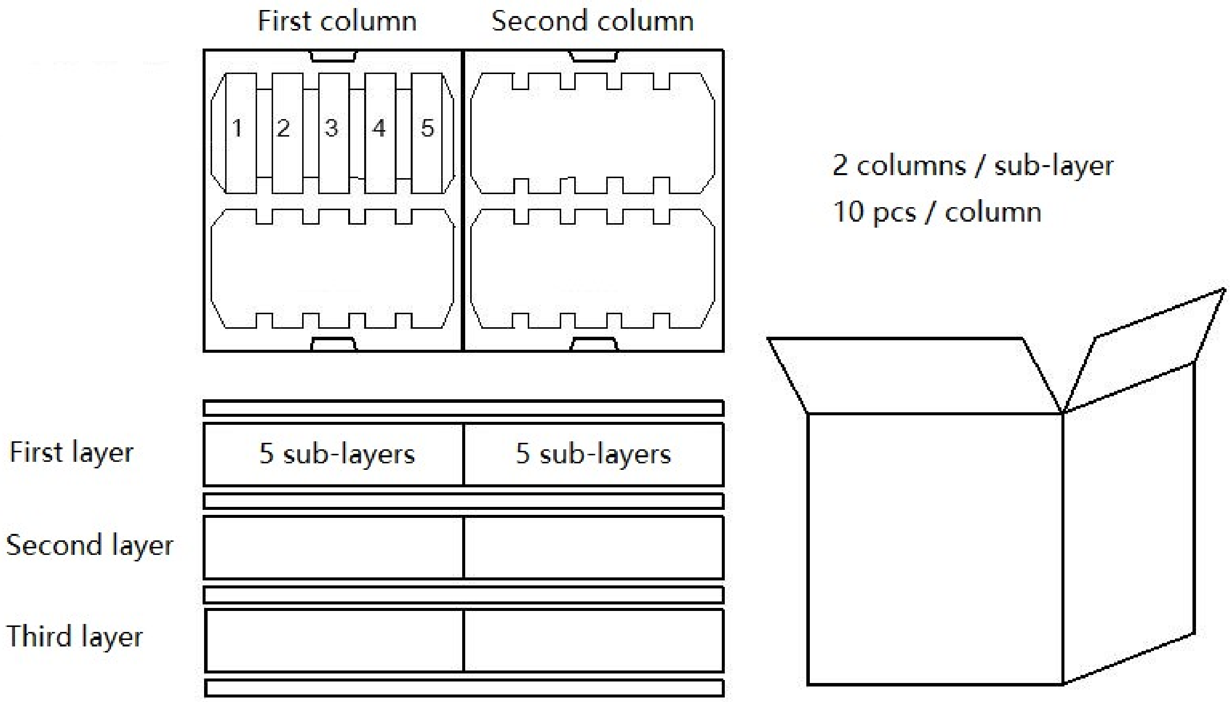
※ Product Application

8500: Civil application

※ Product Category

Gasboard： Ultrasonic Oxygen Sensor

## Packing Information




**Drawing 6 Packing information**

| Qty/Layer | Small Tray Qty | Big Tray Qty | Sensor per Carton | Carton Dimension | Packing Material |
|---|---|---|---|---|---|
| 20pcs | 5 sub-layers | 3 layers | 150pcs | W395 * L320 * H470mm | Anti-static Plastic Tray |

Remark:

Packing specification might be updated without prior notice.

# User Attention

Please pay attention to below:

(1) Install the sensor as far away as possible from the heat source and heat dissipation outlet of the compressor, and install the sensor as close as possible to the oxygen outlet, and install a one-way valve to prevent the water from humidifying glass from entering sensor.

(2) In order to ensure reliability and long service life, do not use or store the sensor in a place where the temperature is higher than the rated temperature, and do not use the sensor in an environment where the voltage is higher than the rated voltage of the sensor.

(3) Without necessary compensations, please do not use the sensor in the environments of high humidity water steam, abnormal pressure, and low temperature.

(4) The product shall not be used or stored in a place with corrosive gas, especially hydrogen sulfide gas, acid, alkali, salt or similar. The products stored in the warehouse should be stored in normal temperature and humidity, and avoid direct sunlight.

(5) When there is a problem with the Cubic's products, please contact Cubic team in time; the sensor must not be disassembled privately, and Cubic will not bear any consequences if it is damaged by disassembled privately.

# Consultancy & After-sales Service

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