Digital fluorescent dissolved oxygen sensor DO-Sx User Manual

[Revision Record]

Time	Modify the content	Remark
20210107	Preliminary decision	
20210118	Supplementary revision	
20210323	Address adjustment and acquisition mode adjustment	
20210330	Add dimension information	
20210727	Increase the parameters of general type and breeding type	
20210816	S3 Finishing	
20211215	Add commands to enter handheld mode and calibration model	
20220101	Modify modbus register to continuous address version	
20220410	Adjust the parameters	
20220607	Added register description	
20220916	Add S5 sensor	
20221013	Modify the wiring diagram	
20221216	Increase S2 motor control interval to 5 minutes Add S2 motor starting current description	
20230601	Adjust some pictures and text	
20240102	Added sensor parameter description Trim register description Precautions for use of adjustment sensor	
20240401	Add Recovery Factory Mode	
20240701	Add PH correction function Add fishpond mode	
20240717	Refine the communication frame example	
20240826	Add status bit for dissolved oxygen calibration failure	
20250524	Add ORP content	
20250611	Add S21 information	
20250726	Calculation method of adde dissolved oxygen Add operating instructions for PH calibration	

目录

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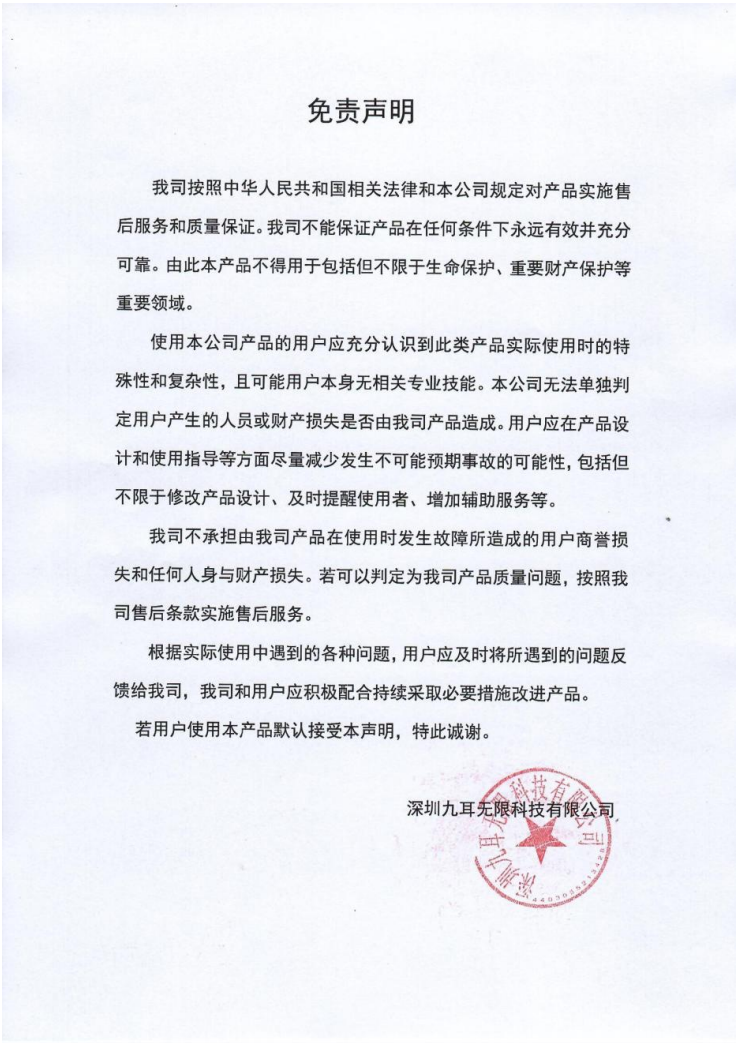

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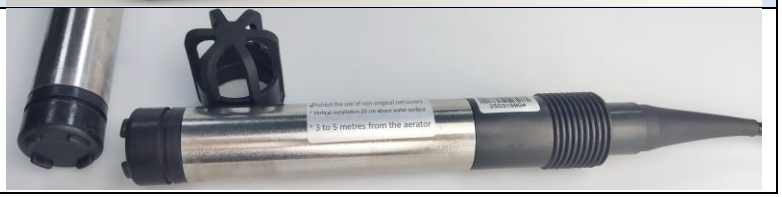
1. Product Introduction

DO-Sx is a sensor specially used for measuring dissolved oxygen in water, which can be used in food, pharmacy, experiment, aquaculture, environmental monitoring and other fields, and can be used for both seawater and freshwater. The sensor uses the fluorescence measurement method to measure the dissolved oxygen in water through the principle of fluorescence quenching of special materials by oxygen atoms. The measuring method is stable and reliable, has long service life, is not affected by water quality, is not interfered by ions, usually does not need calibration, and is the best method for measuring dissolved oxygen at present.

Some models have a variety of water quality parameter measurement functions to provide customers with more convenient and flexible use.

2. List of Sensor Products

Sensor model	Measuring Unit	Measurement mode	Characteristic	In kind
DO_S2	Dual-channel dissolved oxygen + temperature	Long-term online measurement	Dual-channel data self-comparison to improve data security Motor brush head self-cleaning, easy to cope with sewage environment	
DO_S4 (halt production)	Dissolved oxygen + temperature	Long-term online measurement	Good value for money	
DO_S5	Dissolved oxygen + temperature	Hand-held measurement	Quick response of measurement data, can be used as handheld device	
DO_S6A	Dissolved oxygen + temperature	Long-term online measurement	Stainless steel housing Install the tail thread	

DO_S6B	Dissolved oxygen + temperature	Long-term online measurement	All plastic shell Install the tail thread	
DO_S6C	Dissolved oxygen + temperature	Long-term online measurement	All plastic shell Middle thread mounting	
DO_S20B (S20)	Dissolved oxygen + PH value + temperature	Long-term online measurement	All plastic shell Middle thread mounting	
DO_S21	PH + temperature	Long-term online measurement	All plastic shell Install the tail thread	

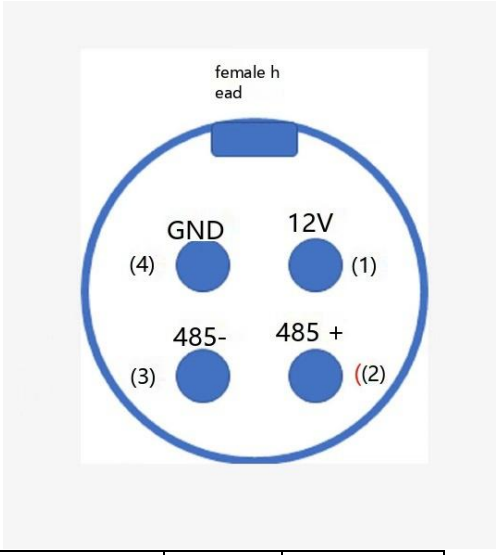
3. Technical Indicators

Project	S2 parameter	S4 parameters	S5 parameters	S6 parameters	S20 parameter	S21
Measuring range (dissolved oxygen)	0-20mg/L (ppm)					–
	0-200% saturation					–
Measurement accuracy (dissolved oxygen)	Less than 5ppm: ± 0.2 ppm (0.2mg/L)					–
	Above 5ppm: ± 0.3ppm (0.3mg/L)					–
Repeatability (dissolved oxygen)	0.2ppm (0.2mg/L)					–
Response time (dissolved oxygen)	T90 < 60sec	T90 < 30sec	T90 < 10sec	T90 < 30sec	T90 < 60sec	–
Isothermal dissolved oxygen return < 0.1mg/L condition	300s	200S	100 S	200S	300s	–
Temperature shock regression < 0.1mg/L condition	2 hours	1 hour	0.5 hour	1 hour	2 hours	–
Measuring range (temperature)	0-40℃					
Measurement accuracy (temperature)	±0.1℃					
Response time (temperature)	T80 < 600 sec	T80 < 300s	T80 < 30s	T80 < 300s	T80 < 600 sec	–
PH measuring range	–				4-11	4-11
PH value accuracy	–				0.1	0.1
Storage temperature	-5-50 ℃ (pay attention to moisturizing)					
Communication interface	RS485 (baud rate 9600)					
Communication protocol	ModbusRTU					
DC power supply requirements	12V(≥1A)	12V-18V	12V-18V	Before2025:12V-18V After 2025:12V-24V	Before2025:12V-18V After 2025:12V-24V	12V-24V
Power consumption	20mA@12V Motor current: Startup 1000mA @ 12V Operating 300mA @ 12V	20mA@12V	20mA@12V	20mA@12V	20mA@12V	20mA@12V
Reliable life	Dissolved oxygen 2 years				PH 1 year Dissolved oxygen 2 years	PH 1 year
Waterproof depth	10 meters					

4. Materials and Textures

Component	Material
Shell	ABS/PC 304 316 Stainless Steel
Tail line	TPU/PVC

5. Wiring Mode



Serial number	Color	Definition
1	Red	Power +
2	Green	A (485+)
3	Yellow	B (485–)
4	Black	Power -

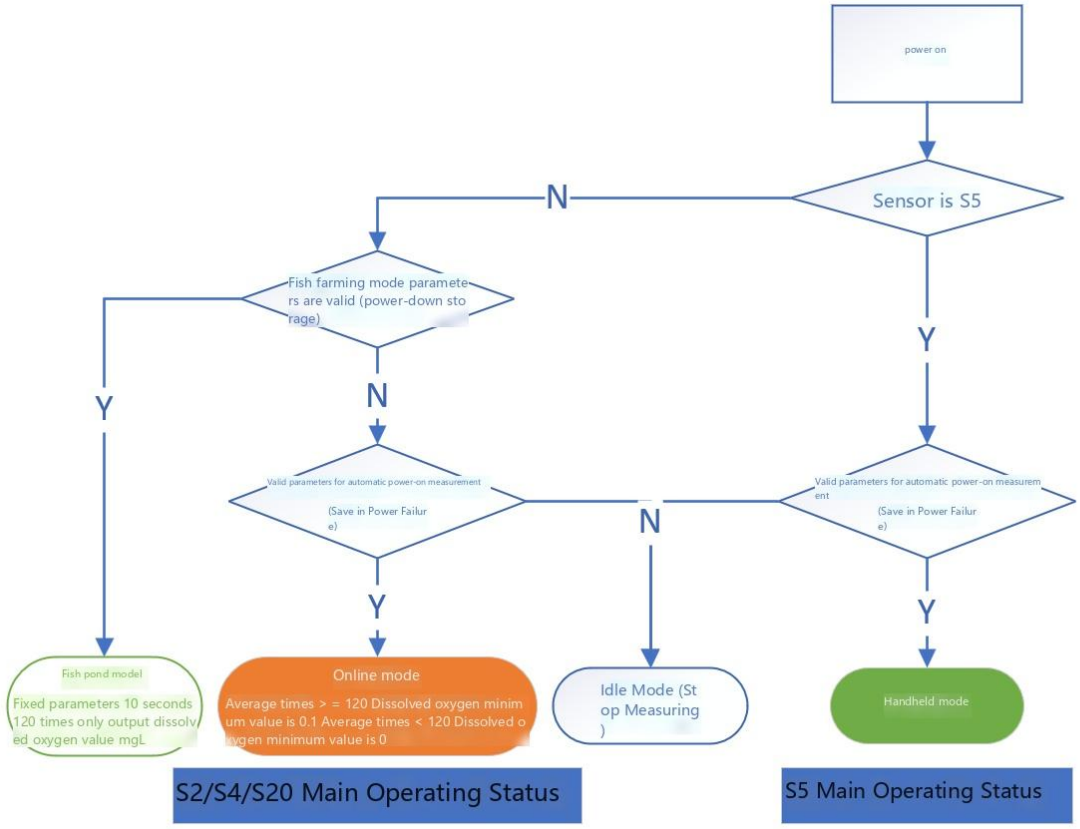
6. Installation Considerations

Note: Please read this item carefully.

- The waterproof connector shall be kept above the water surface as far as possible and shall not be immersed in the water for a long time.
- The default measurement depth is about 20cm.
- Make sure that the sensitive film is clean and intact (if it is contaminated, please wipe it gently with soft cloth and clean water. It is forbidden to use benzene and alcohol substances to clean film surface). It is forbidden to scratch.

7. Sensor Operating Mode Description

- Online mode: applicable to long-term online measurement equipment scenario (controller)
- Handheld mode: applicable to scenes such as handset (handset)
- Fishpond mode: applicable to professional breeding scene (fishpond environment). This mode only outputs dissolved oxygen value mgL
- Idle mode: the sensor stops measuring



8. Modbus Communication Content

8.1. Hardware Conditions

The universal RS485 Modbus protocol is used to operate the sensor and access the registers.

- Communication baud rate 9600
- Format 8 data bits without parity, 1stop bit
- Refer to relevant MODBUS documents for verification and calculation of

CRC16/MODBUS.

Online calculation tools: http://www.ip33.com/crc.html

8.2. Common Communication Protocol Standard

Note: refer to the specific contents of the protocol standard

1. National standard Modbus file - 《Modbus 协议国标规范 GBT_19582-1_2008.pdf》
2. Streamlined Commercial Modbus Documentation - 《MODBUS 通讯协议(RTU 传输模式).pdf》

Quick overview of the agreement

MODBUS definition of data transmission

	Device address	Function Code	Data	Sum check	
Numerical value	1-119	Function Code	Data	CRCL	CRCH
Byte	1	1	n	1	1

The dissolved oxygen sensor transmission unit uses two MODBUS function codes:

0x03: Read holding register

0x10: write multiple register

Read register content distribution

	Address	Function Code	Number of bytes	Byte0	Byte1	Byte2	Byte3	Register.	CRC_H	CRC_L
				Register 0		Register 1				
Byte		0x03	4N	0x12	0x34	0x56	0x78	...		
Word				0x1234		0x5678				
Double word				0x12345678						

Error Code

The abnormal response message has two domains different from the normal response:

- Function code field: In the normal response, the function code of the reply is consistent with the function code of the request. In the exception response, the replied function code MSB is set to 1

  For the read holding register instruction 0x03, the corresponding error response function code is 0x 83;

  For the write multiple register instruction 0x10, the corresponding error response function code is 0x90.

Error response data field definition:

Code	Name	Meaning
1	Illegal function code	The slave receives a code that cannot perform the function. This code indicates no program function after a query command is issued.
2	Illegal data address	The address of the received data is not allowed by the slave.
3	Illegal data	The value of the query data area is not allowed by the slave.
4	Slave device failure	An unrecoverable error occurred while the slave was performing an action requested by the master.
5	Confirm	The slave has received a request to process the data, but it takes a long time to process. This acknowledgement response is sent to avoid a timeout error from the master. The master thus sends another "inquiry procedure complete" without determining whether the slave has completed processing.
6	Slave device is busy	The slave is busy processing a long program command requesting the master to send information while the slave is idle.
7	Negative	This code returns an "unsuccessful programming request" message to the master using a decimal 13 or 14 code when the slave is unable to perform the program function requested by the query. The master should request an error message to diagnose the slave.
8	Memory parity error	When the slave reads data in the extended memory, a parity error is detected, and the master resends the data request at the request of the slave

Query:

Addr	Fun	DO start reg hi	DO start reg lo	DO #of regs hi	DO #of regs lo	CRC16 Hi	CRC16 Lo
0AH	01H	04H	A1H	00H	01H	XXH	XXH

Response(not normal or exception):

Addr	Fun	Exception Code	CRC16 Hi	CRC16 Lo
0AH	**81H**	02H	XXH	XXH

8.3. Dissolved Oxygen Sensor Custom Protocol

Address of broadcast inquiry

Obtain the current sensor device address through the broadcast address (0xFF)

Host sends:

Definition	Address field	Function Code	Start address		Number of registers		CRC	
Byte	0	1	2	3	4	5	6	7
Content	0xFF	0x03	0x00	0x0A	0x00	0x02	0xF1	0xD7

Device response:

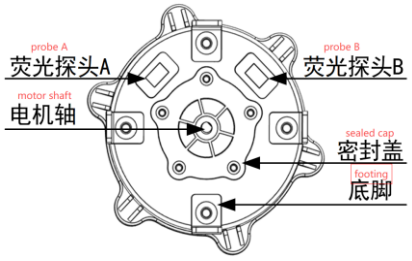
Definition	Address field	Function Code	Number of bytes	Register value				CRC	
Byte	0	1	2	3	4	5	6	7	8
Content	0xFF	0x03	0x04	0x00	0x02	0x00	0x04	0x44	0x3C
				Reg0: Current device address 2		Reg1: Sensor Type S4			

Explai:

- The host send address field is 0xFF
- Byte 4 is the device address, sensor address 2 in the example
- Byte 6 is the device type, in the example the sensor type is S4
- If you do not know the sensor address, you can use this command to obtain the address.
- This command is only applicable when one sensor is connected to the 485 bus. Multiple sensors reporting at the same time will interfere with the 485 data.

※ S2 Description (DO-S2 only)

DO-S2 contains two fluorescent dissolved oxygen probes in one shell. In actual use, you can choose to access different probes, and you can judge whether the measurement data is reliable by comparing the values of the two probes.

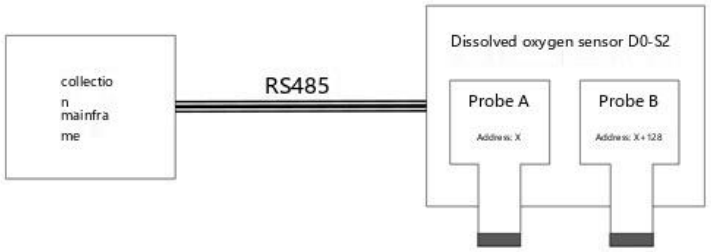


- The measuring structures of the two probes are completely independent, and only the communication part is common.
- The 2 probes are logically completely independent and the Modbus access addresses differ by 128 decimal

  When the second probe is used, the first channel address add1 is read each time,

and 128 is added on the basis of addr1, that is, the second channel address. For example, when the read address command reads the address 2, the address of the second channel is 130.

- The Modbus address setting can only be set for probe A, the address for probe B follows + 128



With the exception of the address register, each parameter needs to be set and read separately.

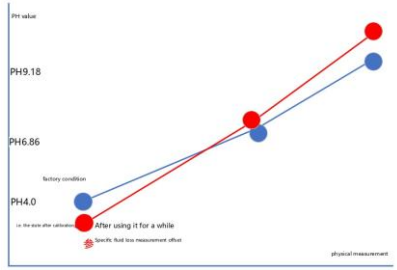
- During normal use, the water environment is constantly changing. When the dissolved oxygen is not particularly high, it is normal if the difference between the two probes is within 1mg/L (10%). If the difference is too large, please contact our company for support.

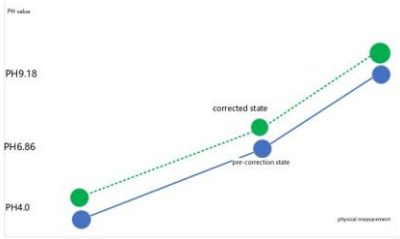
8.4. Register Table

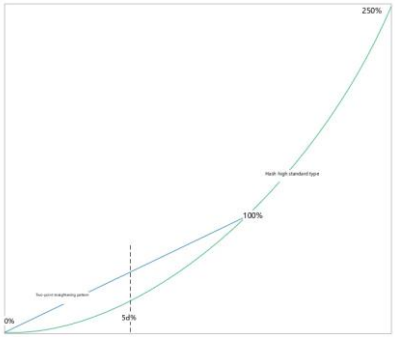
	Register name	Address (Decimal)	Number of registers	Read/write	Read content description (4 bytes) / Write content description (4 bytes)	Explain
Run parameter setting class	**Online mode** (Not supported by S5) (Not saved in case of power failure)	0	2	R/W	Reg0: Measurement interval X (5~10s) Reg 1: average frequency n (10~180 times) Stop the measurement when both Reg0 and Reg1 are 0	**Measurement interval X:** measure and update data every X[5-10] seconds. Recommend 5 seconds. **Number of averages n:** The data is averaged, and the larger the number, the smoother the data. Recommend 120 times, that is, average 120 times of data collected in history. The factory default is 5 seconds & 120 times, which means that the current data is the average value of the historical 5 * 120 = 10 minutes. Updates every 5 seconds. **Notic:** **1. The contents of this register are not saved in case of power-down, and are restored to the parameter of "Power-up Automatic Measurement" in case of power-up.** **2. The online/handheld working mode settings are mutually exclusive, and the last setting shall prevail.** **3. S5 does not support the current mode, and writing non-zero will report an error** **4. When the number of calculation is more than 120, the lowest value of dissolved oxygen ratio & dissolved oxygen value is 0.1.**
	Handheld mode (Not supported by S2) (Not saved in case of power failure)	2	2	R/W	Reg0: Measurement duration T (5 ~ 60 minutes) Reg 1: average number n (1 ~ 180) Stop the measurement when both Reg0 and Reg 1 are 0	Enter the "Hand-held Mode" command, the sensor will measure at the speed of 1 time per second, and exit the measurement after working for the specified time. **Measurement duration T:** exit the measurement after 5 ~ 60 minutes. Rewrite the command to retime. **Number of averages n:** The data is averaged, and the larger the number, the smoother the data. Recommended 30 times. **Notic:** **1. This register will not be saved in case of power-down, and the parameter will be restored to "Power-on Automatic Measurement" when S5 is powered on.** **2. The online/handheld working mode settings are mutually exclusive, and the last setting shall prevail.** **3. S2 does not support the current mode, and writing non-zero will report an error** **4. S5 Reg0 measurement duration does not take effect, and S5 can measure all the time without exiting.**
	Altitude	4	2	R/W	Reg0: Range 0 ~ 8848m Reg 1: Reserved	The annual average air pressure of the area is indirectly calculated through the altitude, which is used to compensate the dissolved oxygen value (mg/L).
	Salinity (PSU)	6	2	R/W	Reg0: range 0 ~ 100 Reg 1: Reserved	Obtain the salinity value by looking up the table, which is used to compensate the dissolved oxygen (mg/L)
	The motor works (Not saved in case of power failure)	8	2	R/W	Reg0: Motor operating mode [0: stop working] [1: Timed automatic cleaning] [2: Rotate once]{ At least 10min interval is required for continuous control }	**Only S2 is supported** S2 After setting the parameter of "power-on automatic measurement", the motor mode is automatically 1. The timing period is 15 minutes. [Avoid rotating current overload when multiple S2s are powered on at the same time, and start to

					Reg 1: Timed Automatic Cleaning Cycle (It is valid when the motor working mode is " [1: Timed automatic cleaning]", and 0 is written for other invalid modes). Range: 10 ~ 240 minutes		work after random delay (0 ~ 10 seconds) during startup]
Configure the class	Device address	10	2	R/W	**Prior to 2023.4.1** ~~Reg0: address [range 1 ~ 119]~~ ~~Reg 1: Reserved~~ **Version after 2023.4.1** Reg0: address [range 1 ~ 119] Reg1: Sensor Type [Range: 0/2/4/5/6/20/21/30] [Read Only]		When you do not know the address, first use the broadcast to query the address, and then set the address. S2 Second channel address, 128 plus the first channel value Sensor Type: [0: Reserved] [2: S2] [4: S4] [5: S5] [6: S6] [20: S20] [21: S21] [30: S30]
	Power-on automatic measurement (Power-down save)	12	2	R/W	Not S5 (online mode parameter) Reg0: Measurement duration (5 ~ 10 seconds) Reg 1: Number of calculations (10 ~ 180) S5 (Hand-held mode parameter) Reg0: Measurement duration (60 minutes) Reg 1: Number of calculations (1 ~ 180) When Reg0 and Reg1 are both 0, the power-on automatic measurement function is turned off.		AfterS2/S4/S6/S20 are configured with this parameter, the automatic measurement can be realized in the online mode after power-on. S5 After the parameter is configured, the automatic measurement can be realized in the handheld mode when the power is turned on. **Note that the contents of this register are saved** **After S4/S6/S2/S20 are powered on, the online mode measurement is automatically performed according to this parameter [the recommended parameter of aquaculture pond is 5 seconds/120 times].** **After version S5 is powered on in January 2024, the handheld mode measurement will be automatically started according to this parameter [recommended 60 minutes/30 times].**
Action class	Dissolved oxygen calibration operation	14	2	R/W	Byte0: calibration flag bit [0: Calibration finished] [1: Calibration in progress] Byte1: Zero oxygen calibration valid flag bit (Valid when the measurement has ended) [0: Zero oxygen calibration invalid] [1: Zero oxygen calibration is valid] Byte2: Saturated oxygen calibration valid flag bit (Valid when calibration has ended) [0: invalid saturated oxygen calibration] [1: Saturated oxygen calibration is valid] Byte3: (valid when calibration is in progress) Calibration in progress countdown (minutes)	1 Start zero oxygen calibration 2 Start Saturated Oxygen Calibration 3 Exit calibration (used in calibration) 4 Empty Saturated Oxygen Calibration 5 Empty Zero Oxygen Calibration **Version support after 20250614** 6 Start Fast Zero Oxygen Calibration 7 Start Fast Saturation Oxygen Calibratio	Read First《Test method and calibration instructions for sensor accuracy》 In actual use, only the saturated oxygen point can be calibrated (single-point calibration), or the saturated oxygen point and the zero oxygen point can be calibrated (two-point calibration). Calibration speed description: **The normal speed calibration is completed in 100 seconds, and the fast speed calibration is completed in 30 seconds.** Normal speed calibration is recommended after the operating environment has stabilized.
Read data class	Temperature	16	2	R	Temperature Unit:℃ Range:-10 ℃ ~ 50 ℃ Reg0: unsigned short format Temp = ((uint16_t) reg0)/100.0f-50.0f Reg1: signed short format Temp =((int16_t)reg1)/100.0f	Not supported	Example of reg0 conversion: 4000：-10˚C 7521:25.21˚C 9001:40.01˚C Example of reg1 conversion: -10000：-10˚C 2521:25.21˚C 4001:40.01˚C

							The output of -25 ℃ indicates that the reading has been made before the thermometry is started. Please set the power-on automatic measurement.
	Dissolved oxygen ratio	18	2	R	Reg0: dissolved oxygen ratio, unit%, output range 0 ~ 25000 [0% ~ 250%] Reg 1: Reserved		Numeric magnification 100 times **The status bit bit0 of the measurement flag bits (Bit0-Bit15) can be used only when it is valid** **When the value is the 65535, it indicates that the measurement is faulty. Please troubleshoot the film surface damage/power supply undervoltage/signal interference before sale.** **The membrane surface is damaged artificially and cannot be protected**
	Dissolved oxygen value	20	2	R	Reg0: dissolved oxygen value mg/L, output range 0 ~ 10000 [0 ~ 100mgL] Reg 1: Reserved		Numeric magnification 100 times **The status bit bit0 of the measurement flag bits (Bit0-Bit15) can be used only when it is valid** **When the value is the 65535, it indicates that the measurement is faulty. Please troubleshoot the film surface damage/power supply undervoltage/signal interference before sale.** **The membrane surface is damaged artificially and cannot be protected**
	Status bit	22	2	R	Reg0: Countdown to measurement **Reg 1: Measurement flag bit**		**Countdown to measurement:** This register value is valid when the Bit0 data valid flag in the measurement flag bit is 0 The value is the time in seconds until the next time the data is valid. **Measurement flag bits (Bit0-Bit15):** ----------Software Status Class---------- **Bit0: Data Valid Flag Bit** 1: Indicates that the dissolved oxygen data has been updated 0: indicates that the dissolved oxygen data is not updated and is the last measured data. This bit automatically returns to 0 when the valid do data is read During operation, the host can periodically query the bit to determine whether to read the dissolved oxygen data. Note: The temperature information is valid in real time, and the temperature read each time is the real-time temperature. ----------Warning Class---------- Bit1: Measurement Exception Warning Power supply interference or film peeling warning sign position. When this bit is 1, check whether the power supply and film surface are normal. If the problem still exists after maintenance, please return to the factory. Bit2: motor overload exception flag bit [only supported by S2] When this bit is 1, check whether the brush is stuck by foreign objects. If the problem still exists after maintenance, please return to the factory. Bit 3: Membrane Life Warning When this bit is 1, it indicates that the service life of the membrane is about to expire, and it is recommended to replace the sensor within 1 week. Bit 4: Real-time clock exception [only S27 supports] If activation is involved, it is recommended to return to the factory. Bit5: Abnormal calibration parameter When this bit is 1, return to the factory immediately.

							Bit 6: Temperature measurement unit is abnormal. Bit 7: The dissolved oxygen calibration fails. Please check the calibration environment and contact the after-sales service after confirmation. ---------- Not used ---------- Bit 8 ~ Bit15: Not used
Read information class	Software version	24	2	R	Byte0: year (example: 21 is 2021) Byte1: month Byte2: Day Byte3: hour	Not supported	Example: The four bytes are { 21, 12, 15, 11 } Means 2021/12/15 11:00
	Hardware version	26	2	R			
	Calibration date	28	2	R			
	Working time of sensor	30	2	R	Reg0: Used time (unit: hour) Reg 1: Reserved		
	SN	32	6	R	12-byte SN, high-order bit first		Example: 0x20303556414E5004004B001D
Read data class	Measure the PH value	38	2	R	Reg0:PH value magnified by 1000 times Value range 0~14000 [PH: 0~14.0] Reg 1: valid status [1 valid/0 invalid]	**Only S20/S21 support**	The software version is supported after 20240301 When S20/S21 starts the dissolved oxygen measurement, the PH starts the measurement synchronously. Register is an integer amplified by 1000 times PH For example, reading 7100 actually represents a PH value of 7.100 (PH value precision is 0.1)
Action class	PH calibration operation	40	2	R/W	Byte0: Calibration proces [0:Calibration finished] [1:PH4.00 calibration in progress] [2:PH6.86 calibration in progress] [3:PH9.18 calibration in progress] Byte1: PH4.00 Calibration Valid Flag Byte2: PH6.86 Calibration Valid Flag Byte3: PH 9.18 Calibration Valid Flag 0: No calibration data 1: Calibration data available	Only S20/S21 support Calibration operation 1Start PH4.00 calibration 2 Clear PH4.00 calibration 3 Start calibration at PH6.86 4 Clear PH6.86 Calibration 5 Start calibration of PH9.18 6 Clear PH 9.18 Calibration Version support after 20251209 7 Exit the current calibration operation(used in calibration)	Operating Instructions for PH Multi-point Calibration Due to the physical characteristics, the electrode slope and zero potential of the PH electrode will drift slightly after soaking. Reference document < PH calibration method> Operation, calibrate the red status in the figure below to the blue factory status.  **When PH needs after-sales service, please clear the three-point calibration value and correction value and then measure it under the standard liquid. If the error is large, then after-sales service is required.**
Action class	Restore factory settings	42	2	R/W	Key	Key	The software version is supported after 20240401. Restore factory settings: Execute after writing the key (0x23456789) Recovery parameters: The address is 1 The altitude and salinity are 0 Power-on automatic measurement parameter (10 * 120 for non-S5) (60 * 10 for S5)

							The motor rotates for 15 minutes (only supported by S2) Empty Zero Oxygen & Saturated Oxygen Calibration Clear PH4.00/PH 6.86/PH9.18 calibration (S20/S21 support only) Close the fishpond mode Empty PH correction operation
Action class	Fishpond model (Not supported by S5)	44	2	R/W	Reg0: fishpond mode control command 0: single start [no save in case of power failure] 1: Single shutdown [no save in case of power failure] 2.Always on [Power-Down Save] 3.Always turn off [Power-down Save] [Factory Default] Reg 1: empty (0)		The software version is supported after 20240701 Used only for fishpond farming scenario This parameter is saved in case of power failure. If the parameter is valid, the non-S5 sensor enters this mode first after being powered on. **If the fishpond mode is started, the fishpond mode will be turned off once when the online mode and handheld mode are entered.** **Note:** After the fishpond mode is enabled, start measuring 120 times in 10 seconds according to the fixed parameters. In this mode, the value of dissolved oxygen ratio (%) is always 0, and the value of dissolved oxygen value (mgL) is output normally.
Read information class	Product serial number information	46	2	R	Reg0: batch (year and month of production) Reg 1: production serial number (production serial number)	Not supported	The software version is supported after 20240701 The bar code on the outer label of the sensor is the 240603456. Batch: 2406 Sensor ID: 03456.
OTP Region	Start working time	48	2	R/W	Byte0: Year H8 Byte 1: Year L8 Byte2: Month Byte3: Day The content of the example is { 7,229,12,28 }: it means 20211228.		The software version is supported after 20240701 It is used to record the time when the current sensor is used for the first time, which is written by the controller on the fish pond. **You can only write once when you read all zeros.** Note: There is no limit to the size of the four-byte value, and the user can write a custom content format, such as writing a product activation key for authentication.
Action class	PH correction operation **Only S20/S21 support**	50	2	R/W	Byte 0: Fix flag bit [0: Uncorrected] [1: Corrected] Byte 1:0 (reserved) Byte2: 0 (Reserved) Byte3: 0 (reserved)	Corrective action [Range: 0 ~ 141] 0 corrected to 0.0 1 corrected to 0.1 2 corrected to 0.2 .... 40 corrected to 4.0 ... 68 Amend to 6.8 ... 92 Amend to 9.2 .... 140 corrected to 14.0 141Clear correction value	The software version is supported after 20240701  The correction is performed by adding a correction value to the current measurement result to obtain the value of the current correction fluid **Note:** The correction value is superimposed on the whole measurement range, and it is necessary to work stably in the correction fluid for more than 1 minute before starting. **Precise correction in standard solution (recommended), or fuzzy correction with PH test**

							paper For example, a liquid that is currently PH7, after writing 70, reads a PH of 7.0 For example, a liquid that is currently PH8, after writing 80, reads a PH of 8.0 **When PH needs after-sales service, please clear the three-point calibration value and correction value and then measure it under the standard liquid. If the error is large, then after-sales service is required.**
Action class	Dissolved oxygen calculation type	52	2	R/W	Reg0: calculation type [0: Hach High Standard] [1: Two-point straight line] (factory default)] [2: Reserved] [3: Reserved] Reg 1:0 (Reserved)		The software version is supported after 20240728 **Hach High Standard:** Dissolved Oxygen Measurement Accuracy Benchmarking International Brand Hach Optical Dissolved Oxygen Sensor **Draw a straight line at two points:** draw a straight line at the saturated oxygen point and the zero oxygen point of the synchronous market electrode sensor. [The middle point of dissolved oxygen of the straight line method will be higher than that of the Hach sensor as a whole, which is 18% higher than that of the 50% point of dissolved oxygen.] 
Read data class	Measure ORP value [TBD]	54	2	R	Reg0: ORP measured value (int16 _ t), value range: -1650 ~ 1650 Actual ORP = (int16 _ t) (reg0) mV Reg 1: valid status [1 valid/0 invalid]	**Only supported on Sxx** 1: ORP starts calibration ORP calibration starts after writing a 1 and ends when the ORP active status bit 1 is read	Example of reg0: Read the value 0x003E and the corresponding result is 63mV Example of reg0: Read the value 0xFFC2 and the corresponding result is -62mV Case reg1: The ORP value corresponding to 1 is valid. Example reg1: The ORP value measurement corresponding to 0 is invalid and cannot be used.
Action class	ORP CALIBRATION [TBD]	56	2	R/W			
Read data class	Measure TDS value [TBD]	58	2	R			
Action class	TDS Calibration [TBD]	60	2	R/W			

Note: All registers are unsigned except the Reg1 register for temperature (uint8 _ t uint16 _ t uint32 _ t)

Register length reference table

Firmware Version Register Value	Register length
Value < 2024030100	38
Value < 2024040100	42
Value < 2024070100	44
Value < 2025072800	52
Value > 2025072800.	54

Salinity description

PSU (Practical Salinity Units) is a standard for expressing salinity in oceanography, which has no unit dimension and is generally expressed in ‰. The average salinity in seawater is 34.7 ‰, which translates into the actual salinity standard or the practical salinity standard.

PSS (Practical salinity scales) also indicates the standard of salinity. The basic definition of salinity is grams of dissolved matter per kilogram of water.

Pure drinking water: EC = 1 ~ 10 uS/cm (national standard), seawater conductivity = 40 ~ 48 mS/cm

Salinity (PSU) measured from conductivity values (mS/cm)

mS/cm	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
PSU	0	3	4	4	5	6	6	7	8	8	9	10	10	11	12	13	13	14	15	15	17	17
mS/cm	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	42	44	46	48	50	52	54
PSU	18	18	19	20	21	22	22	23	24	25	25	26	27	28	29	30	32	33	35	37	38	40

9. Examples of Communication Frames

- Read the device address

Send : FF 03 00 0A 00 02 F1 D7
Receive: FF 03 04 00 01 00 02 35 FD [read address 1 type S2]

- Set the online mode [120 times in 10 seconds] [Recommended parameters for fishpond culture scene]

Send : 01 10 00 02 04 00 0A 00 78 D3 8F [[Measurement interval 10 seconds, average times 120 times]
Receive: 01 10 00 00 00 02 41 C8 [Write Register Response]

- Set the online mode [set to 30 times in 5 seconds] [request to quickly measure the recommended parameters of the scene]

Send : 01 10 00 00 00 02 04 00 05 00 1E 63 A6 [Measurement interval 5 seconds, average times 30 times]
Receive: 01 10 00 00 00 02 41 C8 [Write Register Response]

- **Set the handheld mode [recommended operating mode for the handset scene]**

Send : 01 10 00 02 00 02 04 00 3C 00 0A 32 7D [Measurement time 60 minutes, Average times 10 times]
Receive: 01 10 00 02 00 02 E0 08 [Write Register Response]

- Set the power-on automatic measurement [automatically write the parameter into the online mode after power-on]

Send : 01 10 00 0C 00 02 04 00 0A 00 78 D3 DA [Measurement interval 10 seconds, average times 120 times]
Receive: 01 10 00 0C 00 02 81 CB [Write Register Response]

- Read the dissolved oxygen measurement results separately (temperature + dissolved oxygen ratio + dissolved oxygen value + status bit)

Send : 01 03 00 10 00 08 45 C9
Receive: 01 03 10 1F 4D 0B C5 2B 70 00 00 03 43 00 00 00 00 00 01 1B 2F [uint16 Temperature 30.13 ℃ int16 Temperature 30.13 ℃ dissolved oxygen ratio 111.20% dissolved oxygen value 8.35 mgL Countdown 0 status bit 1]

Before calibration, please refer to the 《Sensor_accuracy_testing_method_and_calibration_operation_instructions》 to prepare the calibration environment. Do not calibrate randomly.

- Oxygen concentration calibration operation

Send :01 10 00 0E 00 02 04 00 00 00 01 B3 E3【Start zero-oxygen calibration】
Send :01 10 00 0E 00 02 04 00 00 00 02 F3 E2【Start oxygen saturation calibration】

Send :01 10 00 0E 00 02 04 00 00 00 04 73 E0【Empty saturated oxygen calibration】
Send :01 10 00 0E 00 02 04 00 00 00 05 B2 20【Empty zero oxygen calibration】
Receive:01 10 00 0E 00 02 20 0B

- Read oxygen calibration status

Send :01 03 00 0E 00 02 A5 C8
Receive:01 03 04 01 00 00 02 7A 0E [Calibration in progress, zero oxygen not calibrated, saturated oxygen not calibrated, remaining 2 minutes]

- PH calibration operation

Send :01 10 00 28 00 02 04 00 00 00 01 31 D1 [Start PH 4.00 calibration]
Send :01 10 00 28 00 02 04 00 00 00 02 71 D0 [Clear PH 4.00 calibration]
Send :01 10 00 28 00 02 04 00 00 00 03 B0 10 [Start PH 6.86 calibration]
Send :01 10 00 28 00 02 04 00 00 00 04 F1 D2 [Clear PH 6.86 calibration]
Send :01 10 00 28 00 02 04 00 00 00 05 30 12 [Start PH 9.18 calibration]
Send :01 10 00 28 00 02 04 00 00 00 06 70 13 [Clear PH 9.18 calibration]
Receive:01 10 00 28 00 02 C1 C0

- Read PH calibration status

Send :01 03 00 28 00 02 44 03
Receive:01 03 04 01 00 00 00 FB CF [PH calibration in progress, PH4.00 not calibrated, PH6.86 not calibrated, PH9.18 not calibrated]

- **All registers read**

Software version	Supports Max **Number of register reads**	Send	Receive (original frame)	Frame parsing
<230301	38	01 03 00 00 00 26 C4 10 Read 38 registers	01 03 4C 00 0A 00 78 00 00 00 00 00 64 00 00 00 20 00 00 00 01 00 00 00 01 00 14 00 0A 00 78 00 00 00 00 1E 36 0A AE 61 A8 00 00 06 5D 00 00 00 00 00 01 18 07 11 0E 16 05 1B 00 18 07 11 00 00 00 00 00 20 32 35 39 41 30 50 06	01 (Address) 03 (Read) 4C (Bytes) 00 0A (Time Interval) 00 78 (Average Times) 00 (Measurement Time) 00 (Average Times) 00 64 (Altitude) 00 (Reserved) 00 20 (Salinity) 00 00(Reserved) 00 01 (motor mode) 00 00 (motor cycle) 00 01 (address) 00 14 (type) 00 0A (power-on automatic time interval) 00 78 (power-on automatic average times) 00 (calibration flag bit) 00 (zero oxygen calibration) 00 (saturated oxygen calibration) 00 (calibration countdown) 1E 36 (uint16 temperature) 0A AE (int16 temperature) 61 A8 00 00 (dissolved oxygen ratio) 06 5D 00 00(dissolved oxygen value) 00 00(countdown) 00 01 (flag bit) 18 07 11 0E (software version) 16 05 1B 00 (hardware version) 18 07 11 00 (factory version) 00 00 (measurement duration) 00 00 (reserved) 20 32 35 39 41 30 50 06 00 3B 00 28 (SN) 5A D2 (CRC)

			00 3B 00 28 5A D2	
<240401	42	01 03 00 00 00 2A C4 15 Read 42 registers	01 03 54 00 0A 00 78 00 00 00 00 00 64 00 00 00 20 00 00 00 01 00 00 00 01 00 14 00 0A 00 78 00 00 00 00 1E 36 0A AE 61 A8 00 00 06 5D 00 00 00 00 00 01 18 07 11 0E 16 05 1B 00 18 07 11 00 00 00 00 00 20 32 35 39 41 30 50 06 00 3B 00 28 17 D4 00 01 00 00 00 00 85 6E	01 (Address) 03 (Read) 54 (Bytes) 00 0A (Time Interval) 00 78 (Average Times) 00 00(Measurement Time) 00 00(Average Times) 00 64 (Altitude) 00 00(Reserved) 00 20 (Salinity) 00 00(Reserved) 00 01 (motor mode) 00 00 (motor cycle) 00 01 (address) 00 14 (type) 00 0A(power-on automatic time interval) 00 78 (power-on automatic average times) 00 (calibration flag bit) 00 (zero oxygen calibration) 00 (saturated oxygen calibration) 00 (calibration countdown) 1E 36 (uint16 temperature) 0A AE (int16 temperature) 61 A8 00 00(dissolved oxygen ratio) 06 5D 00 00(dissolved oxygen value) 00 00(countdown) 00 01 (flag bit) 18 07 11 0E (software version) 16 05 1B 00 (hardware version) 18 07 11 00 (factory version) 00 00 (measurement duration) 00 00 (reserved) 20 32 35 39 41 30 50 06 00 3B 00 28 (SN) 17 D4 (pH) 00 01 (pH valid) 00 (pH calibration flag) 00(PH4) 00(PH6.86) 00(PH9.18) 85 6E(CRC)
<240701	44	01 03 00 00 00 2C 44 17 Read 44 registers	01 03 58 00 0A 00 78 00 00 00 00 00 64 00 00 00 20 00 00 00 01 00 00 00 01 00 14 00 0A 00 78 00 00 00 00 1E 36 0A AE 61 A8 00 00 06 5D 00 00 00 00 00 01 18 07 11 0E 16 05 1B 00 18 07 11 00 00 00 00 00 20 32 35 39 41 30 50 06 00 3B 00 28 17 D4 00 01 00 00 00 00 23 45 67 89 69 1D	01 (address) 03 (read) 58 (number of bytes) 00 A (time interval) 00 78 (average times) 00 (measurement time) 00 (average times) 00 64 (altitude) 00 (reservation) 00 20 (salinity) 00 (reservation) 00 01 (motor mode) 00 00 (motor cycle) 00 01 (address) 00 14 (type) 00 0A (power-on automatic time interval) 00 78 (power-on automatic average times) 00 (calibration flag bit) 00 (zero oxygen calibration) 00 (saturated oxygen calibration) 00 (calibration countdown) 1E 36 (uint16 temperature) 0A AE (int16 temperature) 61 A8 00 00(dissolved oxygen ratio) 06 5D 00 00(dissolved oxygen value) 00 00(countdown) 00 01 (flag bit) 18 07 11 0E (software version) 16 05 1B 00 (hardware version) 18 07 11 00 (factory version) 00 00 (measurement duration) 00 00 (reserved) 20 32 35 39 41 30 50 06 00 3B 00 28 (SN) 17 D4 (pH) 00 01 (pH valid) 00 (pH calibration flag) 00 (PH4) 00 (PH6.86) 00 (PH9.18) 23 45 67 89 (key) 69 1D (CRC)
<250728	52	01 03 00 00 00 34 44 1D Read 52 registers	01 03 68 00 0A 00 78 00 00 00 00 00 64 00 00 00 20 00 00 00 01 00 00 00 01 00 14 00 0A 00 78 00 00 00 00 1E 36 0A AE 61 A8 00 00 06 5D 00 00 00 00 00 01 18 07 11 0E 16 05 1B 00 18 07 11 00 00 00 00 00 20 32 35 39 41 30 50 06 00 3B 00 28 17 D4 00 01 00 00 00 00 23 45 67 89 00 03 00 00 09 65 00 01 00 00 00 00 00 00 00 00 12 ED	01 (address) 03 (read) 68 (number of bytes) 00 A (time interval) 00 78 (average times) 00 (measurement time) 00 (average times) 00 64 (altitude) 00 (reservation) 00 20 (salinity) 00 (reservation) 00 01 (motor mode) 00 00 (motor cycle) 00 01 (address) 00 14 (type) 00 0 A (power-on automatic time interval) 00 78 (power-on automatic average times) 00 (calibration flag bit) 00 (zero oxygen calibration) 00 (saturated oxygen calibration) 00 (calibration countdown) 1E 36 (uint16 temperature) 0A AE (int16 temperature) 61 A8 00 00(dissolved oxygen ratio) 06 5D 00 00(dissolved oxygen value) 00 00(countdown) 00 01 (flag bit) 18 07 11 0E (software version) 16 05 1B 00(hardware version) 18 07 11 00 (factory version) 00 00 (measurement duration) 00 00 (reserved) 20 32 35 39 41 30 50 06 00 3B 00 28 (SN) 17 D4 (pH) 00 01 (pH valid) 00 (pH calibration flag) 00 (PH4) 00 (PH6.86) 00 (PH9.18) 23 45 67 89 (key) 00 03 (fishpond mode) 00 00 (reserve) 09 65 (batch) 00 01 (production serial number) 00 00 00 00(start working time) 00 (PH correction) 00 00 00 (Reserved) 12 ED (CRC)
>250728	54	01 03 00 00 00 36 C5 DC Read 54 registers	01 03 6C 00 0A 00 78 00 00 00 00 00 64 00 00 00 20 00 00 00 01 00 00 00 01 00 14 00 0A 00 78 00 00 00 00 1E 36 0A AE 61 A8 00 00 06 5D 00 00 00 00 00 01 18 07 11 0E 16 05 1B 00 18 07 11 00 00 00 00 00 20 32 35 39 41 30 50 06 00 3B 00 28 17 D4 00 01 00 00 00 00 23 45 67 89 00 03 00 00 09 65 00 01 00 00 00 00 00 00 00 00 00 00 01 00 00 16 2F	01 (address) 03 (read) 6C (number of bytes) 00 A (time interval) 00 78 (average times) 00 (measurement time) 00 (average times) 00 64 (altitude) 00 (reservation) 00 20 (salinity) 00 (reservation) 00 01 (motor mode) 00 00 (motor cycle) 00 01 (address) 00 14 (type) 00 0 A (power-on automatic time interval) 00 78 (power-on automatic average times) 00 (calibration flag bit) 00 (zero oxygen calibration) 00 (saturated oxygen calibration) 00 (calibration countdown) 1E 36 (uint16 temperature) 0A AE (int16 temperature) 61 A8 00 00(dissolved oxygen ratio) 06 5D 00 00(dissolved oxygen value) 00 00(countdown) 00 01 (flag bit) 18 07 11 0E (software version) 16 05 1B 00(hardware version) 18 07 11 00 (factory version) 00 00 (measurement duration) 00 00 (reserved) 20 32 35 39 41 30 50 06 00 3B 00 28 (SN) 17 D4 (pH) 00 01 (pH valid) 00 (pH calibration flag) 00 (PH4) 00 (PH6.86) 00 (PH9.18) 23 45 67 89 (key) 00 03 (fishpond mode) 00 00 (reserve) 09 65 (batch) 00 01 (production serial number) 00 00 00 00(start working time) 00 (PH correction) 00 00 00 (Reserved) 00 (PH correction) 00 00 00 (Reserved) 00 01 (ParamType) 00 00 (Reserved) 16 2F (CRC)

10. Sequence of Operations

It is suggested to use USB to RS485 to connect to the computer first, and then use the debugging tool to get familiar with the operation of the sensor.

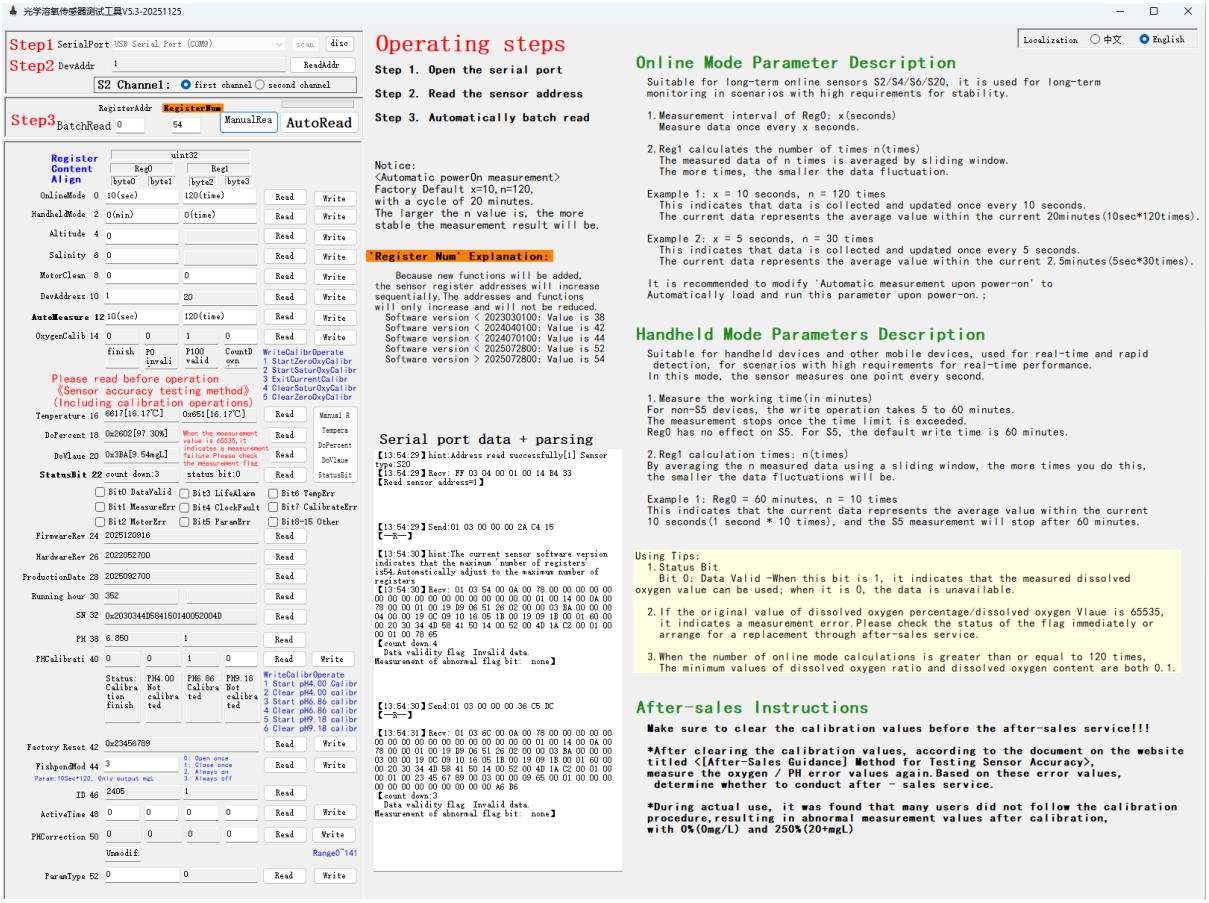
Power-on automatic measurement is the factory default, which can directly read the dissolved oxygen data and the flag bit, and adopt the data according to the data effective bit and the status bit.

11. Debugging Tools

For specific operation, please refer to Dissolved Oxygen Sensor Software Quick Use.pdf.

After the sensor is powered on, it is connected to the computer through the RS485 serial port, and the dissolved oxygen value measured by the sensor can be read by reading the sensor address and setting the measurement parameters.

After the first measurement is completed, start reading the data normally.



12. Frequently Asked Questions

1) Do not immerse the sensor connector in water during installation
2) It is necessary to wear a net cover when using it.
3) On-line long-term measurement equipment, when first used, the value will be low, it needs to be soaked for at least 1 hour, and the measurement data will be more accurate after the fluorescent film is fully hydrated.
4) Usually, the dissolved oxygen in tap water with aeration for more than 1 hour is about 100%.
5) For manual cleaning, if not necessary, just rinse gently with clean water. Do not scratch the fluorescent film with your fingernails.
6) For the sensor with PH function, the glass surface is very fragile. Pay attention to bump and impact.

13. Knowledge of Dissolved Oxygen Data

Dissolved oxygen data is the amount of dissolved oxygen in water, which is the core parameter reflecting water quality. It is the first important data in water environment monitoring and aquaculture industry. Sufficient dissolved oxygen in water can fully oxidize and decompose most pollutants, which can meet the survival needs of aquaculture animals. High dissolved oxygen is a necessary condition for high-density aquaculture and healthy aquaculture.

Oxygen dissolved in water is "permeated" into water by oxygen in the air under the action of atmospheric pressure, and gas molecules fill the gaps between water molecules. Therefore, the oxygen that can be contained in water is directly related to temperature, air pressure (altitude) and salinity. The value of dissolved oxygen content percentage (%) can be read in DO-Sx, and the value of mg/L can be converted by itself (the conversion formula is provided in Appendix 1), or the value of mg/L can be read directly from the sensor. When reading the value of mg/L directly from the probe, it is necessary to configure the altitude and salinity data through the RS485 interface in advance. By default, the altitude and salinity are both 0.

Usually, the temperature has the greatest impact on the dissolved oxygen in fresh water at low altitude. The higher the temperature, the lower the dissolved oxygen, and the lower the temperature, the higher the dissolved oxygen in water. Please refer to Appendix 2 for specific values.

14. Dissolved Oxygen Data and Aquaculture

- The dissolved oxygen in the upper layer of the natural water body is much higher than that in the lower layer, so the dissolved oxygen value measured

within the water depth of 0. 3m can not fully reflect the dissolved oxygen level of the whole fish pond. It is necessary to maintain a certain flow of water to ensure reasonable dissolved oxygen, and the water truck or oxygenation equipment needs to be turned on continuously.

- In summer, when the temperature is high and the air pressure is low (cloudy day), the dissolved oxygen capacity of water is low, the consumption is fast and the replenishment is slow. It is recommended not to start the oxygenation equipment when the dissolved oxygen is very low.
- In high density culture in deep pond, attention should be paid to the dissolved oxygen in deep water, and it is suggested that multi-probe measurement should be used to measure the dissolved oxygen in different depths. One probe measures the dissolved oxygen in surface water within 1 meter, and one probe measures the dissolved oxygen below 2-3 meters to obtain accurate dissolved oxygen. When the dissolved oxygen at the bottom is difficult to meet the requirements, devices such as bottom oxygenation, impeller oxygenator with water turning function, and undershot oxygenation ship can be used to increase the oxygen content at the bottom.
- High dissolved oxygen content in the whole pond can bring many benefits, such as improving the bottom of the pond, reducing diseases, improving vitality and so on. Good dissolved oxygen management is a necessary condition for successful aquaculture.
- Usually, it is recommended to turn on the oxygenation equipment when the dissolved oxygen is too low at night. No matter what the value of dissolved oxygen is, it is necessary to consider turning off the oxygenation equipment until the next day when the temperature rises.
- Fish, shrimps and crabs have different requirements for dissolved oxygen. Keeping a reasonable amount of dissolved oxygen in the whole pond or even at the bottom can prevent many problems such as floating head, stealing death, poor shelling and so on.

Note: Only simple knowledge is provided here. For more information about dissolved oxygen and aquaculture, please refer to relevant materials.

15. Appendix 1: Algorithm for Conversion of Dissolved Oxygen% to Mg/L

Calculate DO (mg/L), i.e. convert DO (%) to DO (mg/L)
According to the formula:

DO (mg/L) = DO (%) * X1 * X2 * 1.4276 **(Note: 1 ml/L = 1.4276 mg/L)**

lnX1= A1 + A2 100/T + A3 ln T/100 + A4 T/100 + S* [B1 + B2 T/100 + B3 (T/100)^2]

A1 = -173.4292 B1 = - 0.033096,
A2 = 249.6339 B2 = 0.014259,
A3 = 143.3483 B3 = - 0.001700;
A4 = -21.8492
T = 273.15 + t (T is absolute temperature, t is Celsius temperature)
S = 0 (for salinity, purified water, S = 0)

X2= (Phmg - u) / (760 - u)

Phmg = pressure * 760/101.325 (pressure is air pressure in kPa)
Logu = 8. 10765- (1750.286/ (235 + t)) (t is Centigrade)

```
//*************************************************************************************
        /* The following is the reference C code */
        #include <math.h>
        float pressure = 101.325; //Standard atmospheric pressure (fill in according to the actual situation)
        float Phmg= 0.0;
        float t = 25.0;              //Fill in according to the actual situation
        float T = 0.0;
        float S = 0.0;               //Fill in according to the actual situation
        T = 273.15 + t;              //t is the current temperature
        X1 '= -173.4292              //x1' = ln x1 according to the classical formula above
             + 249.6339*(100/ T)
             + 143.3483 * log (T/100)                    //log () The function is ln (X)
             + -21.8492*( T /100)
             +S*(-0.033096 + (0.014259* T)/100
             -0.001700*( T /100)*( T /100));
       X1 = exp(X1');                 //natural logarithm log u = 8. 10765- (1750.286/ (235 + t))
        u' = 8.10765 - (1750.286/ (235 + t));    // u' = log u
        u = pow(10, u' );                        //u=10^u'

        Phmg = pressure*760/101.325;
        X2 = ((Phmg - u)/(760 - u));
        DO(mg/L)= DO(%)*X1*X2*1.4276;
//*************************************************************************************
```

16. Appendix 2: Reference Table of Dissolved Oxygen Value

[Salinity 0, Altitude 0, Dissolved Oxygen Value (mg/L) Corresponding to Dissolved Oxygen Ratio (%) at Different Temperatures]

	Oxygen solubility ratio																				
degree centigrade	0.00%	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	90.00%	100.00%	110.00%	120.00%	130.00%	140.00%	150.00%	160.00%	170.00%	180.00%	190.00%	200.00%
-5	0.00	1.69	3.38	5.08	6.77	8.46	10.15	11.84	13.53	15.23	16.92	18.61	20.30	21.99	23.69	25.38	27.07	28.76	30.45	32.15	33.84
-4	0.00	1.64	3.28	4.92	6.56	8.20	9.84	11.48	13.12	14.77	16.41	18.05	19.69	21.33	22.97	24.61	26.25	27.89	29.53	31.17	32.81
-3	0.00	1.59	3.18	4.78	6.37	7.96	9.55	11.14	12.73	14.33	15.92	17.51	19.10	20.69	22.28	23.88	25.47	27.06	28.65	30.24	31.83
-2	0.00	1.55	3.09	4.64	6.18	7.73	9.27	10.82	12.36	13.91	15.45	17.00	18.54	20.09	21.63	23.18	24.72	26.27	27.81	29.36	30.91
-1	0.00	1.50	3.00	4.50	6.00	7.50	9.01	10.51	12.01	13.51	15.01	16.51	18.01	19.51	21.01	22.51	24.02	25.52	27.02	28.52	30.02
0	0.00	1.46	2.92	4.38	5.83	7.29	8.75	10.21	11.67	13.13	14.59	16.05	17.50	18.96	20.42	21.88	23.34	24.80	26.26	27.72	29.17
1	0.00	1.42	2.84	4.26	5.67	7.09	8.51	9.93	11.35	12.77	14.18	15.60	17.02	18.44	19.86	21.28	22.69	24.11	25.53	26.95	28.37
2	0.00	1.38	2.76	4.14	5.52	6.90	8.28	9.66	11.04	12.42	13.80	15.18	16.56	17.94	19.32	20.70	22.08	23.46	24.84	26.22	27.60
3	0.00	1.34	2.69	4.03	5.37	6.72	8.06	9.40	10.75	12.09	13.43	14.78	16.12	17.46	18.80	20.15	21.49	22.83	24.18	25.52	26.86
4	0.00	1.31	2.62	3.92	5.23	6.54	7.85	9.16	10.46	11.77	13.08	14.39	15.70	17.00	18.31	19.62	20.93	22.24	23.55	24.85	26.16
5	0.00	1.27	2.55	3.82	5.10	6.37	7.65	8.92	10.20	11.47	12.74	14.02	15.29	16.57	17.84	19.12	20.39	21.67	22.94	24.21	25.49
6	0.00	1.24	2.48	3.73	4.97	6.21	7.45	8.70	9.94	11.18	12.42	13.67	14.91	16.15	17.39	18.63	19.88	21.12	22.36	23.60	24.85
7	0.00	1.21	2.42	3.63	4.85	6.06	7.27	8.48	9.69	10.90	12.12	13.33	14.54	15.75	16.96	18.17	19.38	20.60	21.81	23.02	24.23
8	0.00	1.18	2.36	3.55	4.73	5.91	7.09	8.27	9.46	10.64	11.82	13.00	14.18	15.37	16.55	17.73	18.91	20.09	21.28	22.46	23.64
9	0.00	1.15	2.31	3.46	4.61	5.77	6.92	8.08	9.23	10.38	11.54	12.69	13.84	15.00	16.15	17.31	18.46	19.61	20.77	21.92	23.07
10	0.00	1.13	2.25	3.38	4.51	5.63	6.76	7.89	9.01	10.14	11.27	12.39	13.52	14.65	15.77	16.90	18.03	19.15	20.28	21.41	22.53
11	0.00	1.10	2.20	3.30	4.40	5.50	6.60	7.70	8.80	9.90	11.01	12.11	13.21	14.31	15.41	16.51	17.61	18.71	19.81	20.91	22.01
12	0.00	1.08	2.15	3.23	4.30	5.38	6.45	7.53	8.60	9.68	10.76	11.83	12.91	13.98	15.06	16.13	17.21	18.28	19.36	20.43	21.51
13	0.00	1.05	2.10	3.15	4.21	5.26	6.31	7.36	8.41	9.46	10.51	11.57	12.62	13.67	14.72	15.77	16.82	17.88	18.93	19.98	21.03
14	0.00	1.03	2.06	3.09	4.11	5.14	6.17	7.20	8.23	9.26	10.28	11.31	12.34	13.37	14.40	15.43	16.45	17.48	18.51	19.54	20.57
15	0.00	1.01	2.01	3.02	4.02	5.03	6.04	7.04	8.05	9.06	10.06	11.07	12.07	13.08	14.09	15.09	16.10	17.10	18.11	19.12	20.12
16	0.00	0.98	1.97	2.95	3.94	4.92	5.91	6.89	7.88	8.86	9.85	10.83	11.82	12.80	13.79	14.77	15.76	16.74	17.73	18.71	19.70
17	0.00	0.96	1.93	2.89	3.86	4.82	5.79	6.75	7.71	8.68	9.64	10.61	11.57	12.53	13.50	14.46	15.43	16.39	17.36	18.32	19.28
18	0.00	0.94	1.89	2.83	3.78	4.72	5.67	6.61	7.55	8.50	9.44	10.39	11.33	12.28	13.22	14.16	15.11	16.05	17.00	17.94	18.89
19	0.00	0.93	1.85	2.78	3.70	4.63	5.55	6.48	7.40	8.33	9.25	10.18	11.10	12.03	12.95	13.88	14.80	15.73	16.65	17.58	18.50
20	0.00	0.91	1.81	2.72	3.63	4.53	5.44	6.35	7.25	8.16	9.07	9.97	10.88	11.79	12.69	13.60	14.51	15.41	16.32	17.23	18.13
21	0.00	0.89	1.78	2.67	3.56	4.44	5.33	6.22	7.11	8.00	8.89	9.78	10.67	11.56	12.45	13.33	14.22	15.11	16.00	16.89	17.78
22	0.00	0.87	1.74	2.62	3.49	4.36	5.23	6.10	6.97	7.85	8.72	9.59	10.46	11.33	12.20	13.08	13.95	14.82	15.69	16.56	17.44
23	0.00	0.86	1.71	2.57	3.42	4.28	5.13	5.99	6.84	7.70	8.55	9.41	10.26	11.12	11.97	12.83	13.68	14.54	15.39	16.25	17.10
24	0.00	0.84	1.68	2.52	3.36	4.20	5.03	5.87	6.71	7.55	8.39	9.23	10.07	10.91	11.75	12.59	13.43	14.26	15.10	15.94	16.78
25	0.00	0.82	1.65	2.47	3.29	4.12	4.94	5.77	6.59	7.41	8.24	9.06	9.88	10.71	11.53	12.35	13.18	14.00	14.82	15.65	16.47
26	0.00	0.81	1.62	2.43	3.23	4.04	4.85	5.66	6.47	7.28	8.09	8.89	9.70	10.51	11.32	12.13	12.94	13.75	14.55	15.36	16.17
27	0.00	0.79	1.59	2.38	3.18	3.97	4.76	5.56	6.35	7.15	7.94	8.73	9.53	10.32	11.12	11.91	12.71	13.50	14.29	15.09	15.88
28	0.00	0.78	1.56	2.34	3.12	3.90	4.68	5.46	6.24	7.02	7.80	8.58	9.36	10.14	10.92	11.70	12.48	13.26	14.04	14.82	15.60
29	0.00	0.77	1.53	2.30	3.07	3.83	4.60	5.36	6.13	6.90	7.66	8.43	9.20	9.96	10.73	11.50	12.26	13.03	13.79	14.56	15.33
30	0.00	0.75	1.51	2.26	3.01	3.77	4.52	5.27	6.03	6.78	7.53	8.28	9.04	9.79	10.54	11.30	12.05	12.80	13.56	14.31	15.06
31	0.00	0.74	1.48	2.22	2.96	3.70	4.44	5.18	5.92	6.66	7.40	8.14	8.88	9.62	10.37	11.11	11.85	12.59	13.33	14.07	14.81
32	0.00	0.73	1.46	2.18	2.91	3.64	4.37	5.10	5.82	6.55	7.28	8.01	8.74	9.46	10.19	10.92	11.65	12.37	13.10	13.83	14.56
33	0.00	0.72	1.43	2.15	2.86	3.58	4.30	5.01	5.73	6.44	7.16	7.87	8.59	9.31	10.02	10.74	11.45	12.17	12.89	13.60	14.32
34	0.00	0.70	1.41	2.11	2.82	3.52	4.22	4.93	5.63	6.34	7.04	7.75	8.45	9.15	9.86	10.56	11.27	11.97	12.67	13.38	14.08
35	0.00	0.69	1.39	2.08	2.77	3.46	4.16	4.85	5.54	6.24	6.93	7.62	8.31	9.01	9.70	10.39	11.08	11.78	12.47	13.16	13.86
36	0.00	0.68	1.36	2.05	2.73	3.41	4.09	4.77	5.45	6.14	6.82	7.50	8.18	8.86	9.54	10.23	10.91	11.59	12.27	12.95	13.63
37	0.00	0.67	1.34	2.01	2.68	3.35	4.03	4.70	5.37	6.04	6.71	7.38	8.05	8.72	9.39	10.06	10.74	11.41	12.08	12.75	13.42
38	0.00	0.66	1.32	1.98	2.64	3.30	3.96	4.62	5.28	5.94	6.60	7.27	7.93	8.59	9.25	9.91	10.57	11.23	11.89	12.55	13.21
39	0.00	0.65	1.30	1.95	2.60	3.25	3.90	4.55	5.20	5.85	6.50	7.15	7.80	8.45	9.10	9.75	10.40	11.06	11.71	12.36	13.01
40	0.00	0.64	1.28	1.92	2.56	3.20	3.84	4.48	5.12	5.76	6.40	7.04	7.68	8.32	8.97	9.61	10.25	10.89	11.53	12.17	12.81