Technical Information

Optical Dissolved Oxygen, model DO71/DO72
MODBUS Communication

TI 12J06J01-00EN-P

YOKOGAWA
YPA Europe

Yokogawa Process Analyzers Europe B.V.
Euroweg 2, 3825 HD Amersfoort, The Netherlands

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Contents

Introduction

This document describes MODBUS communication by the Optical Dissolved Oxygen (DO) sensor, model DO71 and DO72, for a basic user.

Before communication using the MODBUS protocol, refer to the User's Manual of the Optical Dissolved Oxygen sensors, model DO71 and model DO72 (IM 12J06J01-00EN-P) for details of the parameters and connections.

Latest revision of the User's Manual can be downloaded from the website:

https://www.yokogawa.com/solutions/products-platforms/process-analyzers/liquid-analyzers/#Downloads

You can use the QR-code for quick-access.

NOTE

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1. General

Optical Dissolved Oxygen sensors are slave devices which can be configured or are sending process data using Bi-directional digital communication (RS485, half-duplex) with full MODBUS (RTU) support. The power for the Optical Dissolved Oxygen sensors must be supplied by a HOST or by a separate power supply in the range +7VDC up to +30VDC. Maximum power of the Optical Dissolved Oxygen sensors is 1W in active mode, and 150mW in stand-by mode.

1.1 MODBUS setup

The following list shows the required setting by HOST to establish communication between the HOST as master device and the Optical Dissolved Oxygen sensor as slave device. The procedure for changing list items is explained in the following chapters in this document.

Slave address : 1
Serial Profile : 19200 bps, 8 data bits, No parity, 2 stop bits

NOTE

Slave address and Serial Profile are configurable as explained in this document.
In case of using multiple Optical Dissolved Oxygen sensors in a bus system, connected to one HOST, the Slave addresses of all the Optical Dissolved Oxygen sensors must be unique. Because initial setting of address is 1 it is recommended to change the initial address value to prevent communication conflicts in case a new purchased Optical Dissolved Oxygen sensor is added to the bus.
Serial profile of the slave device(s) must be the same as the HOST.

1.2 Function code / Exception code

MODBUS Function codes used for DO71 and DO72:

Function	Function code (hex)
Read Hold Register	03
Write Single Register	06
Write Multiple Registers	10

Exception codes used for DO71 and DO72:

Name	Exception code	Meaning
Illegal Function	0x01	The Function code received is not an allowable action for the slave
Illegal Data Address	0x02	The Data Address received is not an allowable address for the slave

1.3 MODBUS communication

If the Optical Dissolved Oxygen sensor is used with a HOST, the following must be considered.

- **MODBUS response timing**

The Optical Dissolved Oxygen sensor's HR (HOLD Register) response to a HOST HR Read request is within 100ms. The timing in between a response and a new request must be at least 10ms.

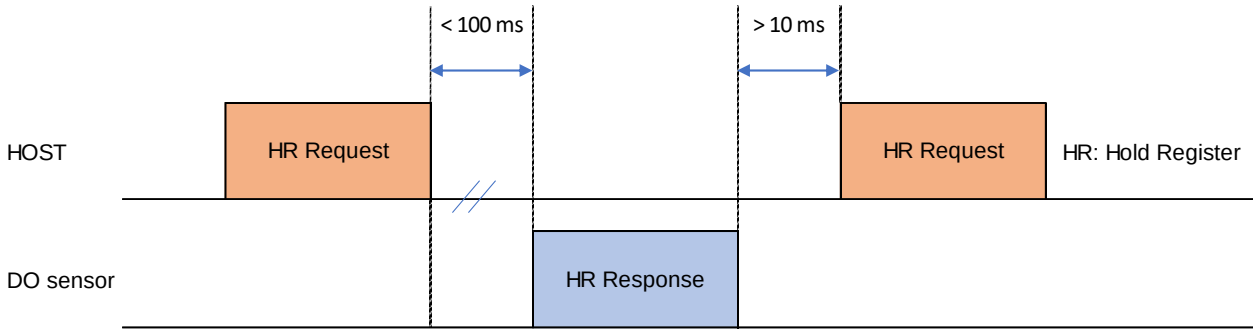

Figure 1.3: Timing diagram

- **HOLD Register renewal cycle**

Process value sent in HOLD Register is configurable, initial value is 1 s.

1.4 Connection

- **BUS system**

Wired connection:

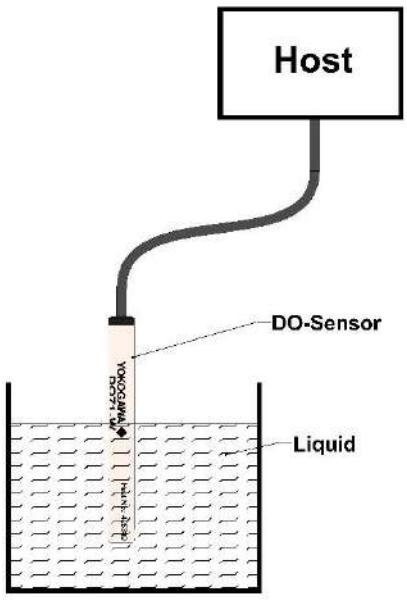

Figure 1.4: DO71 sensor with HOST

Table 1.4.1: DO71 connection definition

Terminal pin no. (Fixed cable)	Wire colour	Description
12	yellow	RS485 Data + (B)
11	green	RS484 Data – (A)
13	white	Power - GND
10	brown	Power - VDC
14	transparent	Cable shield / Probe body

Table 1.4.2: DO72 connection definition

Terminal pin no. (WU10-V-D-xx)	Wire colour	Connector pin (Variopin)	Description
12	green	H	RS485 Data + (B)
11	yellow	G	RS484 Data – (A)
13	white-shield	D	Power - GND
10	white-core	C	Power - VDC
14	black	Shield	Cable shield / Probe body

xx: Cable length in meters

2. MODBUS map

Data type for Optical Dissolved Oxygen sensor MODBUS map:

Data type	Definition
Float	floating point (4byte, little endian byte swap [CDAB]) IEEE754 NaN: 0x7FFFFFFF
Uint32	32 bit unsigned integer, little endian byte swap [CDAB]
ASCII	character set (using one byte per character), multiple registration possible, little endian byte swap [CDAB])

Access (load/import) to multiple data types, such as Float, Uint32, ASCII etc., must be implemented at once. The current version does not support Script yet.

Access		Function	Function Code (hex)
Data Access	16 bits	Read Hold Registers	03
		Write Single Register	06
		Write Multiple Register	10

Hold Registers are Read only (R) or Read/Write (R/W).

NOTE

The content of this Modbus Map is based upon DO71 firmware YPA 1.4.0.xx and DO72 firmware YPA 1.4.0.xx

2.1 Hold Register DO

If applicable, in the Value/description field the Factory Default setting (D), Low limit setting (L) and High limit setting (H) are explained. NaN does mean that there is Not a Number defined.

NOTE

Because no limit checks are implemented, incorrect settings or settings outside the specified range are accepted as is. Please take care that settings are done correctly and within the specified range.

Address	Item name	Data type	Access	Value / description
1031	Firmware version	ASCII	R	Alphanumeric Firmware version code: 16 bytes, 8 addresses
2089	Oxygen unit	Uint32	R/W	0x 0000 0010 % vol O_2 0x 0000 0020 % air saturation 0x 0000 0040 ppb (µg/L) 2) 0x 0000 0080 ppm (mg/L) 2) 0x 0400 0000 µmol/L 2) 0x 0800 0000 % DO saturation 0x 2000 0000 hPa (mbar) 0x 4000 0000 ppm gas 1) 2) 0x 8000 0000 Torr Remark: 1) ppm gas only possible with DO72-T 2) Setting not possible in measurement mode “Dry” (register HR5703)
				D: % DO saturation
2091	Oxygen value	Float	R	Calculated oxygen value in oxygen unit as defined in register HR2089 Remark: 1) The calculated oxygen value is only updated if an interval rate is set (register HR3499) 2) When value is -999 this means there is no calculated output
2093	Error	Uint32	R	For details see Section 3.1
2409	Temperature Unit	Uint32	R/W	0x 0000 0002 K 0x 0000 0004 °C 0x 0000 0008 °F
				D: °C
2411	Temperature Value	Float	R	Measured temperature value used for temperature compensation

Address	Item name	Data type	Access	Value / description
3115	Salinity	Float	R/W	Salinity value used for salinity compensation (unit is g/L) D: 0
3145	Pressure Comp. Unit	Uint32	R	0x 0080 0000 hPa (mbar) Remark: 1) This is a fixed unit D: hPa (mbar)
3147	Volatile Pressure Comp. Value	Float	R/W	Pressure value in hPa (mbar) used for oxygen calculation Remark: 1) If included in a multi register write, no change will take place 2) Value is not written into Flash memory D: By default, this is the Persistent Pressure Comp. value (register HR3153)
3153	Persistent Pressure Comp. Value	Float	R/W	Default setting for compensation pressure value in hPa (mbar) Remark: 1) Do not use this register frequently due to limited number of write cycles into Flash memory. For frequent pressure changes please use register HR3147 2) Value is stored into Flash memory and restored at startup D: Set by manual input
3497	Interval Unit	Uint32	R/W	0x 0000 0001 seconds Remark: 1) This is the time unit for the oxygen measurement interval rate, fixed set to seconds D: seconds
3499	Interval rate	Uint32	R/W	Oxygen measurement interval rate in time unit as set in register HR3497 Remark: 1) Setting the interval rate to 0 deactivates the continuous measurement (see register HR9000) D: 1 L: 0 H: 300

Address	Item name	Data type	Access	Value / description		
4095	Device ID	Uint32	R/W	Modbus address Remark: 1) Setting is effective immediately		
				D: 1	L: 1	H: 247
4097	Reserved	Uint32	R			
4099	Reserved	Uint32	R			
4101	Baud rate	Uint32	R/W	0x 0000 0002 4800 baud 0x 0000 0003 9600 baud 0x 0000 0004 19200 baud 0x 0000 0005 38400 baud 0x 0000 0006 57600 baud 0x 0000 0007 115200 baud Remark: 1) Setting is effective immediately		
				D: 19200	L: 4800	H: 115200
4103	Reserved	Uint32	R			
4105	Reserved	Uint32	R			
4107	Parity	Uint32	R/W	0x 0000 0000 Even parity /1 Stop bit 0x 0000 0001 Odd parity / 1 Stop bit 0x 0000 0002 No parity / 2 Stop bits Remark: 1) Setting is effective immediately		
				D: No parity 2 Stop bits		
4607	Operating Temp. min	Float	R	The minimum operating temperature of the sensor		
				D: -50°C		
4609	Operating Temp. max	Float	R	The maximum operating temperature of the sensor		
				D: +130°C		
4611	Measurement Temp. min	Float	R/W	The minimum measurement temperature of the sensor Remark: 1) Sensor precision is only specified within the range 0…+50°C		
				D: -40°C		

Address	Item name	Data type	Access	Value / description
4613	Measurement Temp. max	Float	R/W	The maximum measurement temperature of the sensor Remark: 1) Sensor precision is only specified within the range 0…+50°C
				D: +100°C
4615	Calibration Temp. min	Float	R	The minimum value of the temperature calibration range
				D: 0°C
4617	Calibration Temp. max	Float	R	The maximum value of the temperature calibration range
				D: +50°C
4677	Hours out of Measurement Temperature Range	Float	R	Accumulated hours in which the sensor was out of the defined measurement temperature range (see registers HR4611 and HR4613)
				D: 0
4679	Hours out of Operating Temperature Range	Float	R	Accumulated hours in which the sensor was out of the defined operating temperature range (see registers HR4607 and HR4609).
				D: 0
4895	Pressure Value Raw	Float	R	Measured pressure value in hPa (mbar)
4897	Reference Amplitude Value Raw	Float	R	Reference amplitude raw value in µV
4899	Oxygen Amplitude Value Raw	Float	R	Measured oxygen amplitude raw value in µV
4901	Oxygen Phase Value Raw	Float	R	Measured oxygen phase shift in degrees
4903	Temperature Value Raw	Float	R	Measured temperature value in the unit defined in HR2409
4905	Calculated Oxygen Value	Float	R	Calculated Oxygen Value in the unit defined in register HR2089
4907	Measurement Error	Uint32	R	For details see Section 3.1

Address	Item name	Data type	Access	Value / description		
4911	Sensor Constant f1	Float	R/W	Sensor constant f1 Remark: 1) The default value is printed on the Quality Inspection Certificate (Q.I.C.)		
					L: 0.001	H: 0.999
4913	Sensor Constant dPhi1	Float	R/W	Sensor constant dPhi1 Remark: 1) The default value is printed on the Quality Inspection Certificate (Q.I.C.)		
					L: -0.19999	H: 0.19999
4915	Reserved	Uint32	R			
				D: NaN		
4917	Sensor Constant dPhi2	Float	R/W	Sensor constant dPhi2 Remark: 1) The default value is printed on the Quality Inspection Certificate (Q.I.C.)		
					L: -0.19999	H: 0.19999
4919	Sensor Constant dKSV1	Float	R/W	Sensor constant dKSV1 Remark: 1) The default value is printed on the Quality Inspection Certificate (Q.I.C.)		
					L: -0.199999	H: 0.199999
4921	Sensor Constant dKSV2	Float	R/W	Sensor constant dKSV2 Remark: 1) The default value is printed on the Quality Inspection Certificate (Q.I.C.)		
					L: -0.199999	H: 0.199999
4923	Sensor Constant m	Float	R/W	Sensor constant m Remark: 1) The default value is printed on the Quality Inspection Certificate (Q.I.C.)		
					L: 0.01	H: 999.99

Address	Item name	Data type	Access	Value / description
5157	Oxygen Calibration Low Point Status	Uint32	R	For details see Section 4
5159	Oxygen Unit for Oxygen Calibration Low Point	Uint32	R	0x 0800 0000 % DO saturation Remark: 1) Shows the oxygen unit for the oxygen calibration low point. D: % DO saturation
5161	Activate Oxygen Calibration Low Point	Float	R/W	Write any value to trigger a calibration for the low oxygen calibration point. If no calibration error regarding the low point (bits 2 to 7, see Table 4.1) occurred, the measured phase and temperature values (or the manually set temperature value) will be written in the registers for Cal0 (register HR5521) and T0 (register HR5523)
5181	Low Calibration Point Timestamp	Uint32	R	The timestamp the last low point calibration point was performed
5189	Oxygen Calibration High Point Status	Uint32	R	For details see Section 4
5193	Activate Oxygen Calibration High Point	Float	R/W	Write the desired O_2-2nd value to trigger a calibration for the high oxygen calibration point. The unit is set in HR5535. If no calibration error regarding the high point (bits 10 to 15, see Table 4.1) occurred, the measured phase, pressure, and temperature values (or the manually set temperature value) will be written in the registers for Cal-2nd (register HR5529), T2nd (register HR5531) and pATM (register HR5533)
5213	High Calibration Point Timestamp	Uint32	R	The timestamp the last high point calibration point was performed

Address	Item name	Data type	Access	Value / description		
5517	Calibration Mode	Uint32	R/W	Measurement mode during calibration: 0: Humid 1: Dry		
				D: 0 (for wide range sensors) D: 1 (for trace range sensors)		
5521	Cal0	Float	R/W	Calibration value of Phase shift at the low oxygen calibration point		
					L: 30.01	H: 79.99
5523	T0	Float	R/W	Calibration value of Temperature at the low oxygen calibration point		
					L: 10.01	H: 29.99
5525	Reserved	Uint32	R			
5527	O_2-2nd	Float	R/W	Calibration value of Oxygen concentration (unit defined in HR5535) at the high oxygen calibration point		
					L: 0.001	H: 299.999
5529	Cal-2nd	Float	R/W	Calibration value of Phase shift at the high oxygen calibration point		
					L: 10.01	H: 49.99
5531	T2nd	Float	R/W	Calibration value of Temperature at the high oxygen calibration point		
					L: 10.01	H: 29.99
5533	pATM	Float	R/W	Calibration value of Pressure (in hPa) at the high oxygen calibration point		
					L: 901	H: 1099
5535	O_2-2nd Unit	Uint32	R/W	0x 0800 0000 % DO saturation Remark: 1) The unit for the O_2-2nd value, for set values see HR2089		
				D: % DO saturation		
5703	Measurement Mode	Uint32	R/W	Measurement mode: 0: Humid 1: Dry		
				D: 0		
6437	Calibration counter	Uint32	R/W	Counts the number of Low/High Point Calibrations		
				D: 0		
6457	Serial Number YPA	ASCII	R	Alphanumeric Serial Number code: 16 bytes, 8 addresses		

Address	Item name	Data type	Access	Value / description
8231	Timestamp	Uint32	R/W	The timestamp set by the user application. Remark: 1) During reboot this timestamp is reset to 0 and must be set (again) to a value representing local time 2) Register is automatically incremented every second 3) Timestamp will be saved to the applicable calibration timestamp (register HR5181 or HR5213) on the event of a calibration process
9000	Measurement Status	Uint32	R	Triggers a single scan using the following code table: Bit 0 Continuous measurement Off (0) / On (1) Setting is a result of the interval rate setting in register HR3499

3. Failures and Warnings DO

Device failures and Measurement warnings are checked and identified by bit content (0 or 1) in specific Hold Registers (HR2093 and HR2094). The definition of each bit, the root cause and possible remedy are explained in table 3.1.

Table 3.1: Bit assignment for DO71/DO72 failures/warnings

Bit#		Bit definition	Root cause & *Remedy*
0:	0x00000000	Reference channel overflow	Reference amplitude too high. *Decrease reference current.*
1:	0x00000002	Temperature too high	The temperature is too high for performing a measurement.
2:	0x00000004	Reference photo detector overflow A	Reference amplitude is too low/high; Sensor cap is not attached; Too much ambient light. *Adjust reference current;* *Attach sensor cap;* *Reduce ambient light.*
3:	0x00000008	Signal channel overflow	Signal amplitude too high. *Decrease signal current.*
4:	0x00000010	Reserved	
5:	0x00000020	Reserved	
6:	0x00000040	No sensor calculation / Amplitude too low	Signal amplitude is too low; Sensor cap is not attached. *Decrease signal current;* *Attach sensor cap.*
7:	0x00000080	Pulse counter overflow	Pulse counter reached its maximum value.
8:	0x00000100	Reference amplitude out of range	Reference amplitude is too low/high; Sensor cap is not attached. *Adjust reference current;* *Attach sensor cap.*
9:	0x00000200	Signal photo detector overflow	Signal amplitude is too high; Sensor cap is not attached; Too much ambient light. *Adjust signal current;* *Attach sensor cap;* *Reduce ambient light.*
10:	0x00000400	Reference photo detector overflow B	Reference amplitude is too low/high; Sensor cap is not attached; Too much ambient light. *Adjust reference current;* *Attach sensor cap;* *Reduce ambient light.*
11:	0x00000800	Memory Write error detected	Memory errors occurred. *Contact the relevant YOKOGAWA sales office.*
12:	0x00001000	PME timeout	Internal error. *Contact the relevant YOKOGAWA sales office.*

4. Low/High Point Calibration DO

Low/High Point Calibration status register explains if calibration process is executed successfully. If any error regarding the low/high point was present this is identified by bit content change (0 to 1) in specific Hold Registers (low point: HR5157 and high point: HR5189). The definition of each bit is explained in table 4.1.

Table 4.1: Bit assignment for DO71/DO72 calibration failures

Bit#		Bit definition
0:	0x00000000	Reserved
1:	0x00000002	Reserved
2:	0x00000004	Temperature value too low while calibrating the low point
3:	0x00000008	Temperature value too high while calibrating the low point
4:	0x00000010	Temperature value not stable while calibrating the low point
5:	0x00000020	Reserved
6:	0x00000040	Reserved
7:	0x00000080	Phase value not stable while calibrating the low point
8:	0x00000100	Reserved
9:	0x00000200	Reserved
10:	0x00000400	Temperature value too low while calibrating the high point
11:	0x00000800	Temperature value too high while calibrating the high point
12:	0x00001000	Temperature value not stable while calibrating the high point
13:	0x00002000	Reserved
14:	0x00004000	Reserved
15:	0x00008000	Phase value not stable while calibrating the high point

5. Revision History

October 2022 1st Edition