VisiFerm RS485 Arc Sensors

Modbus RTU Programmer’s Manual

Firmware version:

ODOUM104

Rev.	Revision Date	Author	Change Description
00	29.06.2022	CS	Initial version Modbus
01	10.08.2022	CS	Update to ODOUM102
02	27.06.2023	JJ	Update Current Value PA9: Moving Average
03	16.08.2023	RI	Update to ODOUM103
04	08.01.2024	JJ	Update to ODOUM104

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1 Modbus RTU General Information

1.1 Introduction

This document describes in detail the VisiFerm RS485 (Arc) Modbus RTU interface. It is addressed to software programmers.
The general information about Modbus command structures and its implementation in the Hamilton Arc Sensor family is described in detail in chapter 1.

1.2 Hamilton Arc Sensors: Modbus Command Structure

In the present manual, only the specific command structure for the VisiFerm RS485 Sensor is described. It is valid for the firmware:

ODOUM104

Please check by reading register 1032 (see chapter 2.12.1).

This present definition of the command structure is an additional document to the Operating Instructions of the specific VisiFerm RS485 sensors. Before reading this manual, the operating instructions of the sensors should be read and understood.

1.2.1 Modbus RTU: Definitions According to Modbus IDA

The definitions in chapter 1.2 are an excerpt from the document:

- "Modbus over serial line - Specification and Implementation Guide V1.02" and
- "Modbus Application Protocol Specification V1.1b"

For more detailed information please consult http://www.modbus.org.

Attention:

- In this manual the register counting starts per definition at address 1. Some Modbus client protocols operate with register-count starting at address 0. Usually, the Modbus client software translates the addressing. Thus, the register address of 2088 will be translated by Modbus client software to 2087 which is sent to the sensor (Modbus server). This must be observed during programming. Please check the specifications of the Modbus client that you are using.
- Representation of data formats in this document:
  - decimal values are displayed as numbers without any prefix, for example 256
  - hexadecimal values are displayed as: 0x2A
  - ASCII-characters or ASCII strings are displayed as: "Text"

1.2.2 Command Structure

The Modbus application protocol defines a simple **P**rotocol **D**ata **U**nit (PDU) independent of the underlying communication layers:

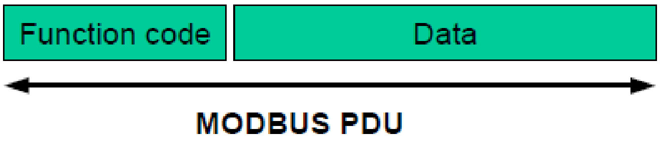


Figure 1 Modbus Protocol Data Unit.

The mapping of Modbus protocol on a specific bus or network introduces some additional fields on the **P**rotocol **D**ata **U**nit. The client that initiates a Modbus transaction builds the Modbus PDU, and then adds fields in order to build the appropriate communication PDU.

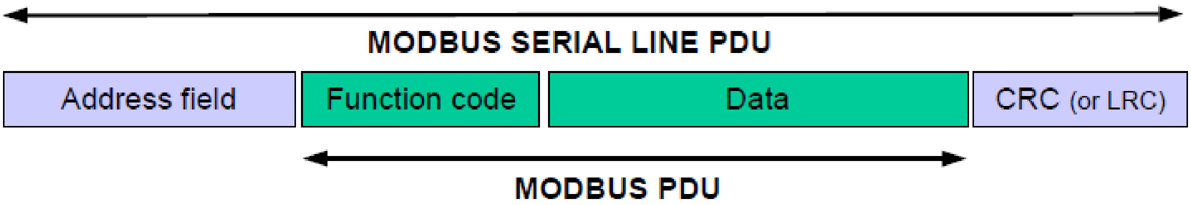


Figure 2 Modbus frame over Serial Line.

- On Modbus Serial Line, the Address field only contains the server address.

Note:
Arc Sensors support only server addresses 1 to 32.

A client addresses a server by placing the server address in the address field of the message. When the server returns its response, it places its own address in the response address field to let the client know which server is responding.

- The function code indicates to the server what kind of action to perform. The function code can be followed by a data field that contains request and response parameters.

- The CRC field is the result of a "Redundancy Checking" calculation that is performed on the message contents.

1.2.3 Modbus RTU Transmission Mode

When devices communicate on a Modbus serial line using the RTU (Remote Terminal Unit) mode, each 8-bit byte in a message contains two 4-bit hexadecimal characters. The main advantage of this mode is that its greater character density allows better data throughput than ASCII mode for the same baud rate. Each message must be transmitted in a continuous stream of characters.

The format (11bits) for each byte in RTU mode is:

Coding System:	8 bit binary
Bits per Byte:	1 start bit 8 data bits, least significant bit sent first 1 bit for parity completion 1 stop bit

Remark: The use of no parity requires 2 stop bits.

How characters are transmitted serially:
Each character or byte is sent in this order (left to right):
Least Significant Bit (LSB)…Most Significant Bit (MSB)

With Parity Checking

Start	1	2	3	4	5	6	7	8	Par	Stop

Figure 3 Bit sequence in RTU mode.

Frame Checking Field:
Cyclical Redundancy Checking (CRC)

Frame description:

Slave Address	Function Code	Data	CRC
1 byte	1 byte	0 up to 252 byte(s)	2 bytes CRC Low / CRC Hi

Figure 4 RTU Message Frame.

=> The maximum size of a Modbus RTU frame is 256 bytes.

1.2.4 Modbus RTU Message Framing

A Modbus message is placed by the transmitting device into a frame that has a known beginning and ending point. This allows devices that receive a new frame to begin at the start of the message, and to know when the message is completed. Partial messages must be detected and errors must be set as a result.

In RTU mode, message frames are separated by a silent interval of at least 3.5 character times.

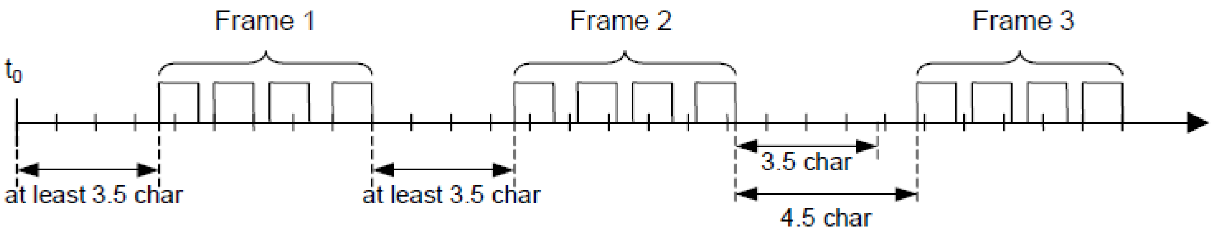


Figure 5 Valid frames with silent intervals.

Start	MODBUS message: Address	Function	Data	CRC Check	End
≥ 3.5 char	8 bits	8 bits	N x 8 bits	16 bits	≥ 3.5 char

Figure 6 RTU Message Frame.

The entire message frame must be transmitted as a continuous stream of characters.

If a silent interval of more than 1.5 character times occurs between two characters, the message frame is declared incomplete and should be discarded by the receiver.

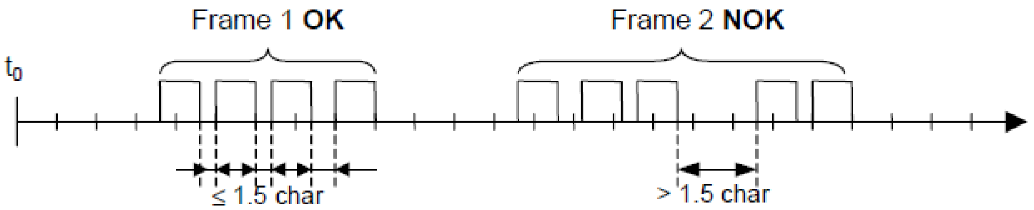


Figure 7 Data transmission of a frame.

1.2.5 Modbus RTU CRC Checking

The RTU mode includes an error-checking field that is based on a Cyclical Redundancy Checking (CRC) method performed on the message contents.

The CRC field checks the contents of the entire message. It is applied regardless of any parity checking method used for the individual characters of the message.

The CRC field contains a 16-bit value implemented as two 8-bit bytes.

The CRC field is appended to the message as the last field in the message. When this is done, the low-order byte of the field is appended first, followed by the high-order byte. The CRC high-order byte is the last byte to be sent in the message.

The CRC value is calculated by the sending device, which appends the CRC to the message. The receiving device recalculates a CRC during receipt of the message and compares the calculated value to the current value it received in the CRC field. If the two values are not equal, an error results.

The CRC calculation is started by first pre-loading a 16-bit register to all 1's. Then a process begins of applying successive 8-bit bytes of the message to the current contents or the register. Only the eight bits of data in each character are used for generating the CRC. Start and stop bits and the parity bit do not apply to the CRC.

During generation of the CRC, each 8-bit character is exclusive OR-ed with the register contents. Then the result is shifted in the direction of the least significant bit (LSB), with a zero filled into the most significant bit (MSB) position. The LSB is extracted and examined. If the LSB was a 1, the register is then exclusive OR-ed with a preset, fixed value. If the LSB was a 0, no exclusive OR takes place.

This process is repeated until eight shifts have been performed. After the last (eight) shift, the next 8-bit byte is exclusive OR-ed with the register's current value, and the process repeats for eight more shifts as described above. The final content of the register, after all the bytes of the message have been applied, is the CRC value.

When the CRC is appended to the message, the low-order byte is appended first, followed by the high-order byte.

A detailed introduction to CRC generation can be found in the manual
"MODBUS over Serial Line, Specification and Implementation Guide, V1.02"
in chapter 6.2 "Appendix B - LRC/CRC Generation" form http://www.modbus.org.

1.3 Implementation of Modbus RTU in Hamilton Arc Sensors

According to the official Modbus definition, the start of a command is initiated with a pause of ≥ 3.5 characters. Also, the end of a command is indicated with a pause of ≥ 3.5 char.
The device address and the Modbus function code have 8 bits.
The data string consists of n*8 bits. The data string contains the starting address of the register and the number of registers to read/write.
The checksum CRC is 16 bits long.

Table 1 Modbus definition for data transmission

	start	**device address**	**function**	**data**	**Checksum**		**end**
value	no signal during ≥ 3.5 char	1-32	function code according to Modbus specs	data according to Modbus specs	CRC L	CRC H	No signal during ≥ 3.5 char
bytes	≥ 3.5	1	1	n	1	1	≥ 3.5

The RS485 interface is configured as follows:

Table 2 RS485 definitions for Arc Sensors

Modbus RTU implementation in Hamilton Arc Sensors	
Start Bits	1
Data Bits	8
Parity	none
Stop Bit	2
String length	11 Bits
Baud Rate	19200 (default), other baud rate can be configured

1.4 Modbus RTU Function Codes Used for Arc Sensors

Arc Sensors use only 3 Modbus function codes:

3: Read Holding Registers
4: Read Input Registers
16: Write Multiple Registers

These three function codes are described below in detail using excerpts from "Modbus Application Protocol Specification V1.1b "(http://www.modbus.org).

1.4.1 Modbus function code #3: Read Holding Registers

This function code is used to read the contents of a contiguous block of holding registers in a remote device. The Request PDU specifies the starting register address and the number or registers. The PDU Registers are addressed starting at zero. Therefore, registers numbered 1 – 16 are addressed as 0 – 15.

The register data in the response message are packed as two bytes per register. For each register, the first byte contains the high order bits and the second contains the low order bits.

Request

Function code	1 Byte	**0x03**
Starting Address	2 Bytes	0x0000 to 0xFFFF
Quantity of Registers	2 Bytes	1 to 125 (0x7D)

Response

Function code	1 Byte	**0x03**
Byte count	1 Byte	2 x **N***
Register value	**N*** x 2 Bytes	

*N = Quantity of Registers

Error

Error code	1 Byte	**0x83**
Exception code	1 Byte	01 or 02 or 03 or 04

Figure 8 Definition of Holding Registers.

Request		**Response**	
Field Name	*(Hex)*	*Field Name*	*(Hex)*
Function	03	Function	03
Starting Address Hi	00	Byte Count	06
Starting Address Lo	6B	Register value Hi (108)	02
No. of Registers Hi	00	Register value Lo (108)	2B
No. of Registers Lo	03	Register value Hi (109)	00
		Register value Lo (109)	00
		Register value Hi (110)	00
		Register value Lo (110)	64

Figure 9 Example of reading holding registers 108 – 110. The contents of register 108 are read as the two-byte values 0x022B. The contents of registers 109 – 110 are 0x00 00 and 0x0064.

1.4.2 Modbus function code #4: Read Input Registers

The function code is used to read from 1 to 125 contiguous input registers in a remote device. The Request PDU specifies the starting register address and the number of registers. The PDU Registers are addressed starting at zero. Therefore, input registers numbered 1 – 16 are addressed as 0 – 15.

The register data in the response message are packed as two bytes per register. For each register, the first byte contains the high order bits and the second contains the low order bits.

Request

Function code	1 Byte	**0x04**
Starting Address	2 Bytes	0x0000 to 0xFFFF
Quantity of Input Registers	2 Bytes	0x0001 to 0x007D

Response

Function code	1 Byte	**0x04**
Byte count	1 Byte	2 x **N***
Input Registers	**N*** x 2 Bytes	

*N = Quantity of Input Registers

Error

Error code	1 Byte	**0x84**
Exception code	1 Byte	01 or 02 or 03 or 04

Figure 10 Definition of Input Registers.

Request		Response	
Field Name	*(Hex)*	*Field Name*	*(Hex)*
Function	04	Function	04
Starting Address Hi	00	Byte Count	02
Starting Address Lo	08	Input Reg. 9 Hi	00
Quantity of Input Reg. Hi	00	Input Reg. 9 Lo	0A
Quantity of Input Reg. Lo	01		

Figure 11 Example of reading input register 9. The contents of input register 9 are read as the two-byte value 0x000A.

1.4.3 Modbus Function Code #16: Write Multiple Registers

This function code is used to write a block of contiguous registers (1 to 123 registers) in a remote device. The requested values are specified in the request data field. Data is packed as two bytes per register. The response returns the function code, starting address, and quantity of registers written.

Request

Function code	1 Byte	**0x10**
Starting Address	2 Bytes	0x0000 to 0xFFFF
Quantity of Registers	2 Bytes	0x0001 to 0x007B
Byte Count	1 Byte	2 x **N***
Registers Value	**N*** x 2 Bytes	value

*__N__ = Quantity of Registers

Response

Function code	1 Byte	**0x10**
Starting Address	2 Bytes	0x0000 to 0xFFFF
Quantity of Registers	2 Bytes	1 to 123 (0x7B)

Error

Error code	1 Byte	**0x90**
Exception code	1 Byte	01 or 02 or 03 or 04

Figure 12 Definition of Write Multiple Registers.

Request		Response	
Field Name	*(Hex)*	*Field Name*	*(Hex)*
Function	10	Function	10
Starting Address Hi	00	Starting Address Hi	00
Starting Address Lo	01	Starting Address Lo	01
Quantity of Registers Hi	00	Quantity of Registers Hi	00
Quantity of Registers Lo	02	Quantity of Registers Lo	02
Byte Count	04		
Registers Value Hi	00		
Registers Value Lo	0A		
Registers Value Hi	01		
Registers Value Lo	02		

Figure 13 Example of writing the value 0x000A and 0x0102 to two registers starting at address 2.

1.5 Data Formats Used in Arc Sensors

1.5.1 Float

Definition: Floating point according to IEEE 754 (Single Precision)

Table 3 Definition Floating point Single Precision (4 bytes resp. 2 Modbus registers)

Explanation:	sign	exponent	mantissa	total
Bit:	31	30 to 23	22 to 0	32
Exponent bias	127			

Example: translate the decimal value 62.85 into binary

Step 1: Conversion of the decimal value into binary fixed-point number

62 / 2	= 31	residue 0	LSB
31 / 2	= 15	residue 1	
15 / 2	= 7	residue 1	
7 / 2	= 3	residue 1	
3 / 2	= 1	residue 1	
1 / 2	= 0	residue 1	MSB
	= **111110**		

0.85 * 2	= 1.70	=> 1	MSB
0.70 * 2	= 1.40	=> 1	
0.40 * 2	= 0.80	=> 0	
0.80 * 2	= 1.60	=> 1	
0.60 * 2	= 1.20	=> 1	
0.20 * 2	= 0.40	=> 0	
0.40 * 2	= 0.80	=> 0	LSB
	…		
	= **0.11011001100110011001100**…		

62.85 = 111110.11011001100110011001100…

Step 2: Normalizing (in order to obtain 1 bit on the left side of the fraction point)

111110**.**11011001100110011001100… *2^**0** = 1**.**1111011011001100110011001100… *2^**5**

Sep 3: Calculation of the dual exponent

2^5 => Exponent **5**
Exponent + Exponent bias = **5** + 127 = **132**

132 / 2	= 66	residue 0	LSB
66 / 2	= 33	residue 0	
33 / 2	= 16	residue 1	
16 / 2	= 8	residue 0	
8 / 2	= 4	residue 0	
4 / 2	= 2	residue 0	
2 / 2	= 1	residue 0	
1 / 2	= 0	residue 1	MSB
	= **10000100**		

Sep 4: Definition of the sign bit

Positive = 0
Negative = 1
= **0**

Step 5: conversion into floating-point

1 Bit Sign + 8 Bit Exponent + 23 Bit Mantissa
0 10000100 11110110110011001100110 (corresponds to 0x427B6666)

One important note for the 23 Bit Mantissa: The first bit (so-called hidden bit) is not represented. The hidden bit is the bit to the left of the fraction point. This bit is per definition always 1 and therefore suppressed.

Example: translate the binary float 0100 0010 0111 1011 0110 0110 0110 0110 to a decimal value

Step 1: Separating the binary value into Sign, Exponent and Mantissa

0 10000100 11110110110011001100110
1 Bit Sign + 8 Bit Exponent + 23 Bit Mantissa

S: **0** $_{binary}$ = **0** (positive sign)
E: **10000100** $_{binary}$ $= 1*2^7 + 0*2^6 + 0*2^5 + 0*2^4 + 0*2^3 + 1*2^2 + 0*2^1 + 0*2^0$
$= 128 + 0 + 0 + 0 + 0 + 4 + 0 + 0$
$=$ **132**
M: **11110110110011001100110** $_{binary}$ = **8087142**

Step 2: Calculate the decimal value

$$D = (-1)^S * (1.0 + M/2^{23}) * 2^{E-127}$$
$$= (-1)^0 * (1.0 + 8087142/2^{23}) * 2^{132-127}$$
$$= 1 * 1.964062452316284 * 32$$
$$= \mathbf{62.85}$$

1.5.2 Character

Definition: The numerical representation of characters is defined in 8-Bit ASCII-Code-Table (ANSI X3.4-1986). Accordingly, each Modbus register in Arc Sensors can store two ASCII characters.

Example: translate the ASCII-string “2076” to Hex representation

The following interpretation is made according to the ASCII Codes-Table:

“2” => ASCII code table	=> 0x32	Low Byte
“**0”** => ASCII code table	=> 0x30	
“**7”** => ASCII code table	=> 0x37	
“**6”** => ASCII code table	=> 0x36	High Byte
“2076”	=> **0x36373032**	

1.5.3 Decimal

Example: translate Decimal 2227169 to Hex

2227169 / 16	= 139198	residue 1	Low Byte
139198 / 16	= 8699	residue 14 => E	
8699 / 16	= 543	residue 11 => B	
543 / 16	= 33	residue 15 => F	
33/16	= 2	residue 1	
2 / 16	= 0	residue 2	High Byte
	= **0x21FBE1**		

1.6 Modbus RTU Error Messages

Here are listed the Modbus standard error-codes we have implemented in Arc Sensors.

Table 4 Implemented Error-Codes

Error-Code Hex	**Status-Text**
0x00	OK
0x01	Illegal function
0x02	Illegal data address
0x03	Illegal data value
0X04	Server device failure

See "Modbus_Application_Protocol_V1.1b" (www.modbus.org) for details.

If a server device failure exception occurs, try to repeat the command that has thrown the exception. If the exception remains, check the sensor status.

2 VisiFerm RS485 Commands in Modbus RTU

2.1 General

In order to communicate with a VisiFerm RS485 sensor over Modbus RTU protocol a Modbus client terminal application software is needed. The Modbus RTU is an open standard and a number of free and commercial application toolkits are available.

This manual contains examples and illustrations from WinTECH Modbus client ActiveX Control tool: WinTECH (www.win-tech.com) "Modbus Master OCX for Visual Basic". The Modbus Organization (www.modbus.org/tech.php) provides other links to a wide variety of Modbus terminal software.

In the present manual the addressing of the Modbus registers starts at 1. But the Modbus client protocol operates with register addresses starting at 0. Usually, the Modbus client software translates the addressing. Thus, the register address of 2090 will be translated by the Modbus client software to 2089 which is sent to the sensor (Modbus server).

Attention:
When configuring and calibrating the sensor, please limit write operations to a reasonable number. More than 100'000 write operations will physically damage the memory of the sensor.

2.2 Operator levels and Passwords

2.2.1 Reading / Setting Operator Level

VisiFerm RS485 can be operated in three different operator levels. Each operator level allows a defined access to a specific set of commands.

Table 5 Definition of operator level and default passwords

Abbreviation	Description	Code (hex)	Password (default)	
			(decimal)	(hex)
U	User (lowest level)	0x03	0	0x00000000
A	Administrator	0x0C	18111978	0x01145DEA
S	Specialist	0x30	16021966	0x00F479CE

At each power up or processor reset, the operator level falls back to the default level U.

The active operator level can be read and written in register 4288.
The Password itself can't be read, the information in Reg 3/ Reg 4 is always read as zero.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
4288	4	Operator Level	Password	3, 4, 16	U/A/S	U/A/S

Attention:
If the password is wrong, the operator level falls back to operator level U. To make sure that the operator level switch was successful, read back register 4288.

2.2.2 Changing Passwords for Operator Level

The passwords for accessing the operator levels A and S can be modified by S (Specialist) only. U (User) and A (Administrator) have no right to change any password. If they try anyway, an illegal data address exception (0x02) is returned.
The new password will remain stored after power down.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
4292	4	Level	New password	16	None	S

2.3 Configuration of the serial RS485 Interface

Factory settings for the RS485 interface:

Table 6 RS485 factory settings

Start Bits	1
Data Bits	8
Parity	None
Stop Bits	2
Baud Rate	19200

2.3.1 Device Address

2.3.1.1 Reading and Writing the Device Address

The sensor specific device address can be read and written in register 4096.

Start register	Number of registers	Reg1 / Reg2 (uint)	Modbus function code	Read access	Write access
4096	2	device address	3, 4, 16	U/A/S	S

The device address can be set by S (Specialist), default value is 1. If the address limits are not met when setting a new address, the former address stays active.

Attention:

The device address changes immediately, what means that the next Modbus access must be done using the new address.

2.3.1.2 Reading the Device Address Limits

The device address limits can be read in register 4098.

Start register	Number of registers	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
4098	4	Min. device address	Max. device address	3, 4	U/A/S	none

Device address limits are:
Minimal device address: 1
Maximal device address: 32

2.3.1.3 Broadcast

Independent from the selected device address, the sensor responds to broadcasted Modbus commands (address 0).

2.3.2 Baud Rate

2.3.2.1 Reading and Writing the Baud Rate

The baud rate can be read and written in register 4102.

Start register	Number of registers	Reg1 / Reg2 (uint)	Modbus function code	Read access	Write access
4102	2	Baud rate code (definition see below)	3, 4, 16	U/A/S	S

The code for the baud rate is defined as follows:

Table 7 Code for the baud rates.

Baud rate	4800	9600	19200	38400	57600	115200
Code	2	3	4	5	6	7

Attention:

If the baud rate limits are not met when setting a new baud rate, the former baud rate stays active.
If the baud rate is valid, it will change immediately, which means that the next Modbus access must be done using the new baud rate.

2.3.2.2 Reading the Baud Rate Limits

The baud rate limits can be read in register 4104.

Start register	Number of registers	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
4104	4	Min. Baud rate code	Max. Baud rate code	3, 4	U/A/S	none

The baud rate limits are:
Minimal baud rate code: 2
Maximal baud rate code: 7

2.3.3 Parity and Stop Bits

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
4108	2	Interface parameter	3, 4, 16	U/A/S	S

The interface parameter is coded as following:
0xAABBCCDD where
AA = no meaning (reading: 0x00)
BB = Parity (0x00: no parity, 0x01: even, 0x02: odd)
CC = Stop bits (0x00: 1 stop bit, 0x04: 2 stop bits)
DD = no meaning (reading 0x00)

The interface parameters do not change before the next power up!
When writing to register 4108 set Bytes AA and DD to 0x00.

Attention:

If one of the parameter limits is not met, the old configuration stays active! Parity option (even or odd) is only available with one stop bit (max. string length of 11 bits).
The configuration changes immediately, what means that the next Modbus access must be done using the new baud rate.

2.4 Configuration of the Analog Interfaces (4-20 mA and ECS)

Note:

VisiFerm RS485 has one single physical analog output interface (AO1) that can only be used as an ECS - electrochemical sensor interface (Hamilton proprietary). The 4-20mA analog interface is only provided by an Arc Wi 2G Adapter BT, but the registers to configure these interfaces are available on the sensor. That means, that these registers can be read and written with or without Arc Wi 2G Adapter BT. Therefore, the sensor has no error or warning information if the measurement values is below or above the limit of the analog interface.

2.4.1 Available Analog Interfaces

Equipped with an Arc Wi 2G Adapter BT, the VisiFerm RS485 Sensor has two individual physical analog interfaces that have identical functionalities, but can be configured independently from each other.

- Analog Output Interface 1 (AO1)
- Analog Output Interface 2 (AO2)

The number of analog interfaces is defined in register 4320.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
4320	2	Available analog outputs	3, 4	U/A/S	none

The answer always is “0x03” meaning that there exists an Analog Interface 1 (AO1) and an Analog Interface 2 (AO2).

2.4.2 Available Analog Interface Modes

With register 4322, the available analog interface modes for AO1 and AO2 are defined

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
4322	8	Available Analog Interface Modes for AO1	Available Analog Interface Modes for AO2	reserved	reserved	3,4	U/A/S	none

Register 4322 defines the analog interface modes available for AO1 and AO2. The analog interface modes are described in Table 8.

Table 8 Definition of the analog interface modes

Code (Hex)	Analog Interface Mode	Description
0x0000	4-20 mA inactive	Analog interface is deactivated
0x0001	4-20 mA fixed	Set to a constant output value for current loop testing See 2.4.5.7
0x0002	4-20 mA linear	Linear output of measurement (PMC1 / 6)
0x0004	4-20 mA bilinear	Bilinear output of measurement (PMC1 / 6)
0x0100	ECS fixed	Set to a constant output value for current loop testing
0x0200	ECS linear	nA output linked to oxygen reading (PMC1)

The answer is a bitwise combination (OR) of the available modes defined in Table 8.
Reg1/Reg2 return "0x0307" meaning that 4-20 mA fixed, 4-20 mA linear, 4-20 mA bilinear, ECS fixed and ECS linear mode are available.
Reg3/Reg4 return "0x0007" meaning that 4-20 mA fixed, 4-20 mA linear and 4-20 mA bilinear mode are available.
Reg5 to Reg8 return always zero.
How to select or change the analog interface mode, see 2.4.4.

2.4.3 Description of the Analog Interface

Register 4352 / 4480 contain the descriptions of AO1 / AO2 as plain text ASCII. AO1 for VisiFerm RS485 is called "mA/ECS interface". AO2 for VisiFerm RS485 is called "mA interface".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
4352	8	Description of the analog interface AO1	3, 4	U/A/S	none
4480	8	Description of the analog interface AO2	3, 4	U/A/S	none

2.4.4 Selection of an Analog Interface Mode

The analog interface mode of AO1 / AO2 is selected by programming the analog interface mode in register 4360 / 4488.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
4360	2	Analog interface mode for AO1	3, 4, 16	U/A/S	S
4488	2	Analog interface mode for AO2	3, 4, 16	U/A/S	S

For available analog interface modes are see register 4322.

Only one bit can be set. Using not allowed interface mode codes will leave the selection unchanged.

⚠ Attention:
VisiFerm RS485 has one single physical analog output interface (AO1) that can only be used as an ECS - electrochemical sensor interface (Hamilton proprietary).
When the sensor is programmed to ECS mode (0x0100/0x0200) and an Arc Wi 2G Adapter BT is attached at the same time, the ECS interface is not available.
When the sensor is programmed to ECS mode (0x0100/0x0200) and an Arc Wi 1G Adapter BT is attached at the same time, the ECS interface will be disturbed by RS485 communication. Therefore, it is recommended by using the ECS interface, not use an Arc Wi xG Adapter at any time.
In general, the ECS interface will be disturbed by RS485 communication.

2.4.5 Configuration of the 4-20 mA Interface

Note:

The configuration of the 4-20 mA interface is only effective if register 4360 (analog interface mode) is set to the value 0x01, 0x02 or 0x04 (see chapter 2.4.4).

2.4.5.1 Reading the Available Primary Measurement Channels to be Mapped to the Analog Output

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
4362	2	Available Primary Measurement Channels for AO1	3, 4	U/A/S	none
4490	2	Available Primary Measurement Channels for AO2	3, 4	U/A/S	none

Table 9 Code for selection of the primary measurement channel

Code (Hex)	Primary Measurement Channel (PMC)
0x01	PMC1
0x20	PMC6

Reading the available Primary Measurement Channels (PMC) always return the hexadecimal value of "0x21" meaning that PMC1 or PMC6 can be mapped to AO1 respectively AO2.

2.4.5.2 Selecting the Primary Measurement Channel to be Mapped to the Analog Interface

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
4364	2	Selected PMC for AO1	3, 4, 16	U/A/S	S
4492	2	Selected PMC for AO2	3, 4, 16	U/A/S	S

Write this register to change the mapped measurement channel to AO1 respectively AO2. Make sure that only one bit is set, according to Table 9. Writing 0 or an illegal code will leave the selection unchanged. Only one bit can be set!
Reading this register returns the selected PMC for AO1 respectively AO2 according to Table 9.

The factory setting for register 4364 is "0x01" mapping PMC1 to AO1.
The factory setting for register 4492 is "0x20" mapping PMC6 to AO2.

2.4.5.3 Reading the Minimal and Maximal Possible Physical Output Current

Register 4366/4494 delivers the limits of the physical output current for AO1/AO2.

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
4366	4	Min physical output current for AO1 [mA]	Max physical output current for AO1 [mA]	3, 4	U/A/S	none
4494	4	Min physical output current for AO2 [mA]	Max physical output current for AO2 [mA]	3, 4	U/A/S	none

The limits are fixed to:
Minimum is 3.5mA
Maximum is 22 mA

Note:

Currents above 20 and below 4 mA indicate erroneous measurements or errors.

2.4.5.4 Reading the Minimum, Maximum and Mid Current for Measurement Value Output

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Modbus function code	Read access	Write access
4370	6	Min output for measurement value for AO1 [mA]	Max output for measurement values for AO1 [mA]	Mid output for measurement values for AO1 [mA]	3, 4	U/A/S	none
4498	6	Min output for measurement value for AO2 [mA]	Max output for measurement values for AO2 [mA]	Mid output for measurement values for AO2 [mA]	3, 4	U/A/S	none

These registers deliver the minimal, maximal and middle output current for AO1 respectively AO2 in mA during normal operation. They are fixed to 4, 20 and 12 mA.

Note:

Mid current must always be defined. However, in linear output mode, the mid current value has no physical meaning and will not affect the 4-20 mA output.

2.4.5.5 Reading the Selected Physical Unit for Analog Interface

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
4376	2	Selected physical unit of AO1 (see Table 15)	3, 4	U/A/S	none
4504	2	Selected physical unit of AO2 (see Table 15)	3, 4	U/A/S	none

Read the selected unit of the selected PMC of AO1 respectively AO2. The value returned has to be interpreted as a hex value that represents the unit according to Table 15.
The physical unit for the PMC is defined in Reg. 2090 or 2410 and applies automatically for 4-20 mA output.

2.4.5.6 Defining the Measurement Values for 4, 12 and 20 mA Output

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Modbus function code	Read access	Write access
4378	6	Measurement value at Min Output Current (4 mA) for AO1	Measurement value at Max Output Current (20 mA) for AO1	Measurement value at Mid Output Current (12 mA) for AO1	3, 4, 16	U/A/S	S
4506	6	Measurement value at Min Output Current (4 mA) for AO2	Measurement value at Max Output Current (20 mA) for AO2	Measurement value at Mid Output Current (12 mA) for AO2	3, 4, 16	U/A/S	S

These registers define the relation between measurement value and output current in linear mode. Reg1/Reg2 define the measurement value at 4mA and Reg3/Reg4 define the measurement value at 20mA. Reg5/Reg6 do not affect the 4-20mA output. When writing, write 0 or any random value. When reading, Reg5/Reg6 return half of Min + Max.
The corresponding physical unit can be read in register 4376 / 4504 respectively in the corresponding PMC register (2090 for PMC1 and 2410 for PMC6).

Attention:

When assigning measurement values to 4-20 mA analog output by using register 4378 / 4506, you need to consider the following:

- The PMC you have mapped to AO1 / AO2 (register 4364 / 4492)
- The physical unit currently in use for the selected PMC (register 2090 for PMC1and register 2410 for PMC6.
- The measurement parameter 2 Air Pressure when %-vol or %-sat is selected as physical unit and PMC1 is mapped to AO1 or AO2.
- The measurement parameter 3 Humidity when %-vol is selected as physical unit and PMC1 is mapped to AO1 or AO2.

Therefore, when the operator redefines any of the above-mentioned register, the definitions of the register 4378 / 4506 should be reviewed. If not, the current output at the 4-20 mA interfaces may suddenly be unexpected!

Note:

Mid current must always be defined. However, in linear output mode, the mid current value has no physical meaning and will not affect the 4-20 mA output.

Example 1:
Register 4364 is set to 1 (PMC1 is mapped to AO1).
Register 2090 is set to 0x00000010 (the unit "%-vol" is assigned to PMC1).
Register 4360 is set to 0x00000002 (linear analog output of PMC1).
Register 4378 is set to 0 and 62.85 (4 mA = 0 %-vol, 20 mA = 62.85 %-vol) as shown in Figure 14.
The measurement parameter 2 Air Pressure is set to 1000 mbar.
The sensor is placed in air and currently reads a value of 20.95 %-vol oxygen, the output at the 4-20 mA accordingly is 9.33 mA (20.95 %-vol).
The operator now re-assigns register 2090 to the value of 0x00000020 (%-sat) but does not modify all other registers. The sensor reads now 100 %-sat. At the analog output, as 20 mA is programmed to a value of 62.85 by register 4378, the current will go to the maximum value of 20 mA. This will not generate an interface warning.

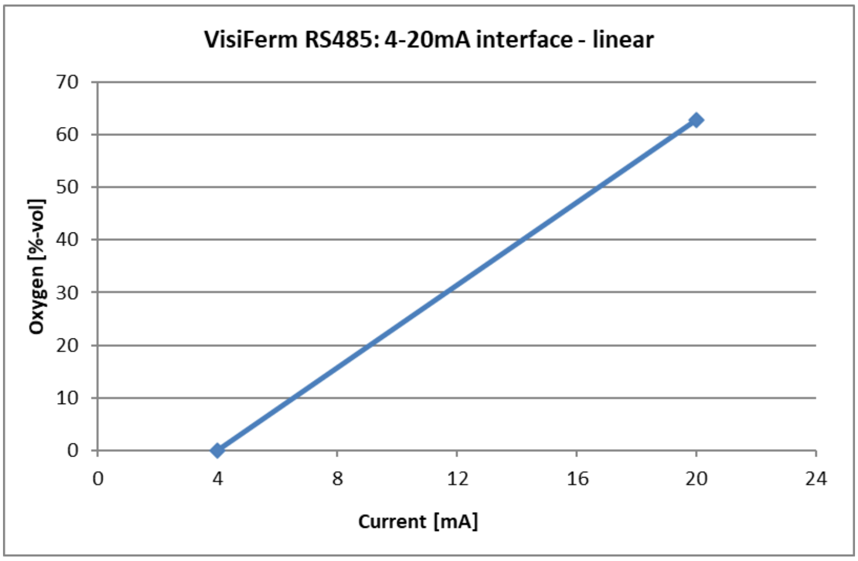


Figure 14 Example of linear 4-20mA output characteristics

Example 2:
Register 4364 is set to 1 (PMC1 is mapped to AO1).
Register 2090 is set to 0x00000010 (the unit "%-vol" is assigned to PMC1).
Register 4360 is set to 0x00000004 (bilinear analog output of PMC1).
Register 4378 is set to 0, 62.85 and 10.0 (4 mA = 0 %-vol, 20 mA = 62.85 %-vol, 12 mA = 10.0 %-vol) as shown in Figure 15.
The measurement parameter 2 Air Pressure is set to 1000 mbar.
The sensor is placed in air and currently reads a value of 20.95 %-vol oxygen, the output at the 4-20 mA accordingly is 13.66 mA (20.95 %-vol).

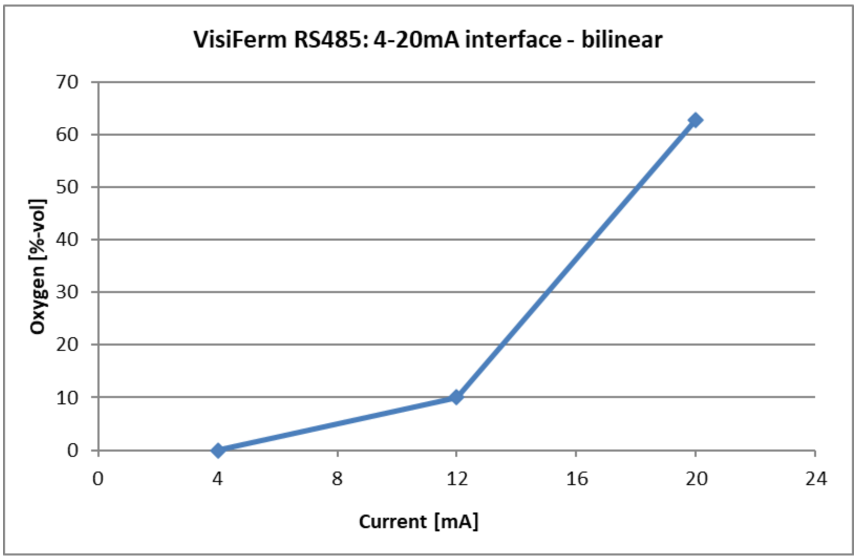


Figure 15 Example of bilinear 4-20mA output characteristics

Attention:
When assigning measurement values to 4-20 mA analog output by using register 4378, you need to consider the following:

- The PMC you have mapped to 4-20 mA analog output (register 4364)
- The unit currently in use for the selected PMC (register 2090 for PMC1 (oxygen) and register 2410 for PMC6 (temperature).

Therefore, when the operator redefines one of the registers 4364, 2090 or 2410, the definitions of the register 4378 should be reviewed. If not, the current output at the 4-20 mA interface may be wrong.

The 4-20 mA analog output freezes if

- the measure mode is in Hold Mode, see chapter 2.6
  or
- the current temperature is outside the user defined measurement temperature range (reg. 4624).

Note:
The physical unit of the analog output corresponds always to the unit that is set for the selected PMC (register 2090 for PMC1 or register 2410 for PMC6). Accordingly, not only oxygen partial pressure (mbar, %-vol, %-sat) is selectable at the 4-20 mA interface, but also oxygen concentration (mg/l, µg/l, ppb, ppm, ppm gas).

2.4.5.7 Defining a Constant Current Output for Testing

Note:

For constant current output, the AO1 / AO2 must be set to analogue interface mode 4-20 mA fixed (0x01) (see Table 8):

Start register	Number of registers	Reg1 / Reg2 (float)	Modbus function code	Read access	Write access
4384	2	Constant current output value for AO1 [mA]	3, 4, 16	U/A/S	S
4512	2	Constant current output value for AO2 [mA]	3, 4, 16	U/A/S	S

Values lower than 4mA respectively higher than 20mA will automatically be set within the limits.

2.4.5.8 Defining the Error and Warning Output of the 4-20 mA Interface

Errors and warnings can be mapped to the AO1 / AO2.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Reg7 / Reg8 (float)	Modbus function code	Read access	Write access
4386	8	Code of warnings and errors for AO1	Current in case of "warning" for AO1 [mA]	Current in case of "error" for AO1 [mA]	Current in case of "T exceed" for AO1 [mA]	3, 4, 16	U/A/S	S
4514	8	Code of warnings and errors for AO2	Current in case of "warning" for AO2 [mA]	Current in case of "error" for AO2 [mA]	Current in case of "T exceed" for AO2 [mA]	3, 4, 16	U/A/S	S

Table 10 Code for the 4-20 mA interface in case of errors and warnings.

Code (Hex)	Behavior of the 4-20 mA interface in case of errors and warnings
0x000001	Error continuous output
0x010000	Warning continuous output

If the corresponding bits for the errors and warnings are not set (=0), the respective options are inactive.
"T exceed" is always active. What means that in case of a measurement temperature limit violation, the output current will be as the specified value. "T exceed" values lower than 3.5mA respectively higher than 4mA will automatically be set within the limits.

The "T exceeds" limits are:
Minimal current value: 3.5 mA
Maximal current value: 4 mA

The default settings are:

- Code 0x01
- current in case of warnings: 3.5 mA
- current in case of errors: 3.5 mA
- current in case of measurement temperature limits violation: 3.5 mA

Table 11 Example: Read the settings for AO1 in case of warnings and errors

Command: ErrorWarnings AO1		Modbus address: **4386**	Length: **8**	Type: **3** Read
Parameter:	Warning code	Current in case of warning [mA]	Current in case of error [mA]	Current in case of temperature exceed [mA]
Format:	Hex	Float	Float	Float
Value:	**0x010001**	**3.5**	**3.5**	**3.5**

Warning code 0x010001 corresponds to the continuous output current in case of warning (0x010000) and continuous output current in case of error (0x01) of 3.5 mA. The output current in case of temperature exceed is 3.5 mA.

For more information about warnings, errors and temperature limits, see chapter 2.10.5.

2.4.6 Reading the Internally Calculated Output Current

Reg. 4414 / 4542 provides internal calculated output current of AO1 / AO2. These values are helpful to compare against the externally measured electrical current.

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
4414	4	Set point [mA] AO1	Internally measured [mA] AO1	3, 4	U/A/S	none
4542	4	Set point [mA] AO2	Internally measured [mA] AO2	3, 4	U/A/S	none

⚠ Attention:

The current outputs are provided by the Arc Wi 2G Adapter BT. Therefore, the sensor cannot internally measure any output currents. Reg3/Reg4 always deliver the same value as Reg1/Reg2 even though there is no Arc Wi 2G Adapter BT connected. This is due to compatibility to other Arc Sensors.

2.4.7 Configuration of the ECS Interface

The ECS interface is used to emulate a classical electrochemical DO sensor, having a cathode and an anode, and a 22 kOhm NTC (temperature sensor). The 22 kOhm NTC is realized in the VisiFerm RS485 hardware and cannot be modified by software settings. The current on the cathode, however, can be modified by using the registers described below.

⚠ Attention

- The configuration of the ECS interface is only effective if register 4360 (analog interface mode) is set to the value of 0x0100 or 0x0200 (see chapter 2.4.4).
- Please note that – unlike to the 4-20 mA analog output – only PMC1 ("oxygen") can be mapped to the ECS output.

The ECS interface freezes if

- the measure mode is in Hold Mode, see chapter 2.6
  or
- the current temperature is outside the user defined measurement temperature range (reg. 4624).

2.4.7.1 Reading the Minimum and Maximum Possible Output Current at the ECS Interface

Register 4394 delivers the limits of the physical output current for the ECS interface.

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
4394	4	Min physical output current [nA]	Max physical output current [nA]	3, 4	U/A/S	none

The limits are fixed to:
Minimum is 0.0nA
Maximum is 500.0 nA

Note:
A current at 499 nA indicates, that the temperature is outside the sensor operating area.

2.4.7.2 Defining the Characteristics of the Emulated Electrochemical Sensor

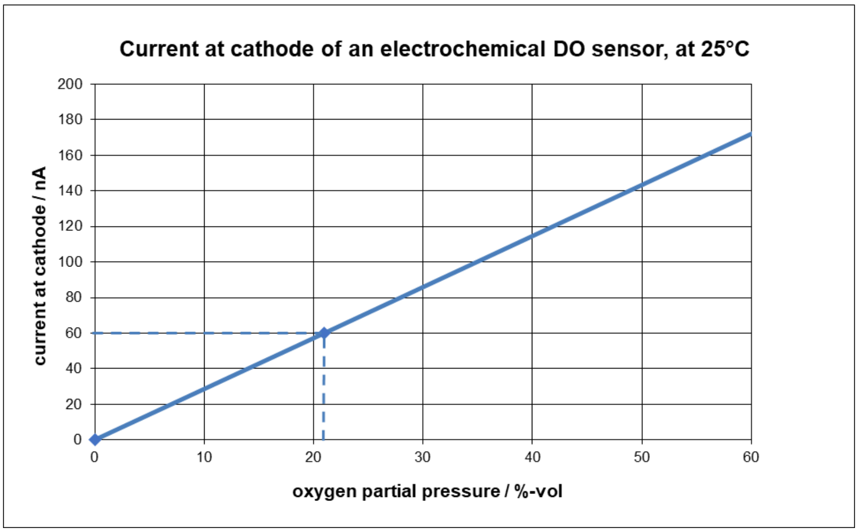


Figure 16 Typical characteristic of an electrochemical dissolved oxygen sensor at fixed temperature

In Figure 16 a typical characteristic of an electrochemical dissolved oxygen sensor at fixed temperature (here 25 °C) the current generated at the cathode by the reduction of oxygen is proportional to the oxygen partial pressure, here expressed as %-vol in a gas mixture. If no oxygen is present, the current is zero. The linear curve is defined by the current at zero oxygen and the current in air (20.95 %-vol). For a typical sensor, these values are 0 and 60 nA at 25 °C.

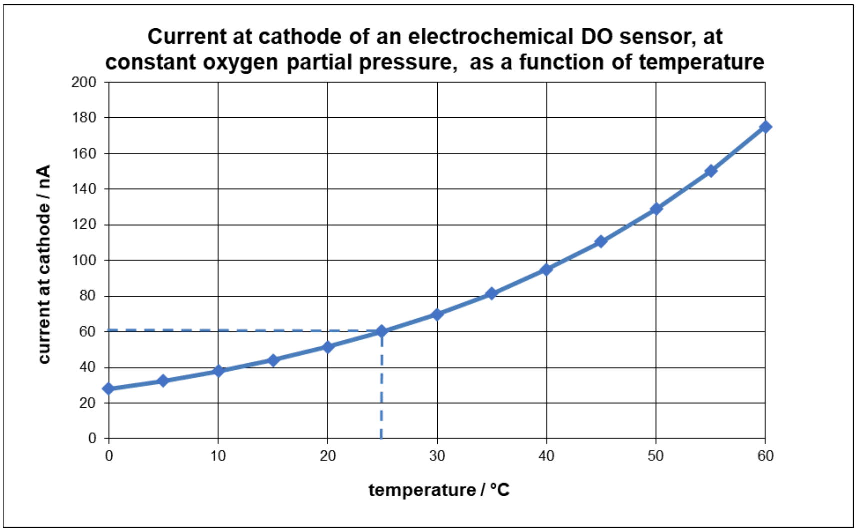


Figure 17 Measurement current of a typical electrochemical DO sensor as a function of temperature

In Figure 17 the measurement current of a typical electrochemical DO sensor as a function of temperature, at fixed oxygen partial pressure (here 20.95 %-vol). The current generated at the cathode is an exponential function of temperature. At 25 °C, the current is typically 60 nA.

The exponential function is defined as:

$I_{Teff} = I_{25°C} * EXP(0.031*(T_{eff} - 25))$

with:
$I_{25°C}$: electrical current at 25 °C
I_{Teff} : electrical current at effective temperature
T_{eff} : effective temperature in °C

The value of 3.1 (unit %/°C) is the temperature coefficient for Hamilton DO sensors (Oxyferm, OxyGold, Oxysens). It can be different for sensors of other manufacturers.

Register 4398 defines the characteristics of the electrochemical sensor to be simulated with the ECS interface.

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Modbus function code	Read access	Write access
4398	6	Electrical Current in zero oxygen at 25°C [nA]	Electrical Current in air at 25°C [nA]	Temperature coefficient [%/°C]	3, 4, 16	U/A/S	S

The factory setting for register 4398 is:
- the current in zero oxygen: 0 nA
- the current in air: 60 nA
- the temperature coefficient: 3.1 %/°C.

The ECS output current is calculated by VisiFerm RS485 sensor as follows:

$$I_{ECS} = I_{Reg.4398/99} + I_{Reg.4400/01} * \{(PMC1 / 20.95) * EXP(TC_{Reg.4402/03} *(PMC6 -25))\}$$

$I_{Reg.4398/99}$:	current defined in register 4398/99
$I_{Reg.4400/01}$:	current defined in register 4400/01
$TC_{Reg.4402/03}$:	temperature coefficient defined in register 4402/03
PMC1 :	value of PMC1 in %-vol
PMC6 :	value of PMC6 in °C

Note:

- It is not mandatory to program a temperature coefficient above 0. If set to 0, the current at the ECS output will be directly proportional to PMC1. No temperature compensation.
- The current at zero oxygen can be higher than 0.
- Changing the physical units for PMC1 (register 2090) has no effect on the current output at the ECS.

2.4.7.3 Defining a Constant Current Output for Testing

Note:

For constant ECS output current, VisiFerm RS485 must be set to the analog interface mode 0x0100 (see Table 8).
The constant output current is a test value and completely independent from oxygen reading and temperature.

Start register	Number of registers	Reg1 / Reg2 (float)	Modbus function code	Read access	Write access
4404	2	Constant current ECS [nA]	3, 4, 16	U/A/S	S

2.4.7.4 Defining Error and Warning Output of ECS

Errors and warnings can be mapped to the ECS.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Reg7 / Reg8 (float)	Modbus function code	Read access	Write access
4406	8	Code of warnings and errors (Table 12)	Current in case of "warning" [nA]	Current in case of "error" [nA]	Current in case of "T exceed" [nA]	3, 4, 16	U/A/S	S

Table 12 Code for the ECS interface in case of errors and warnings.

Code (Hex)	4-20 mA interface in case of errors and warnings
0x000001	Error continuous output
0x010000	Warning continuous output

Note:

If the corresponding bit for the errors and warnings is not set (0), the respective Option is not active.

The default settings are:

- code 0x00
- current in case of "warnings": 433 nA
- current in case of "errors": 466 nA
- current in case of "T exceed": 499 nA

2.4.8 Reading the Internally Measured Output Current

Reg. 4414 provides internal parameters of the ECS output interface AO1:

- the setpoint to which the current is regulated in a closed loop control
- the electrical current the sensor is measuring to feed the closed loop control

These values are helpful to compare against the externally measured electrical current.

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
4414	4	Set point AO1 [nA]	Internally measured current AO1 [nA]	3, 4	U/A/S	none

To know which current loop is active, please refer to chapter 2.4.4.

2.5 Measurement

2.5.1 Definition of Measurement Channels and Physical Units

The Arc Modbus register structure allows the definition of 6 individual Primary Measurement Channels (PMC), and 16 individual Secondary Measurement Channels (SMC).

Table 13 Definition of PMC1 to 6 and SMC1 to 16

Code (Hex)	Description	Definition
0x000001	PMC1	Oxygen
0x000020	PMC6	Temperature

In Register 2048, the available PMC and SMC are defined for a specific sensor and a specific operator level.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
2048	2	Available measurement channels PMC and SMC (bitwise set)	3, 4	U/A/S	none

Table 14 Example to read Reg. 2048

Command: Avail. meas. channels	Modbus address: **2048**	Length: **2**	Type: **3**	Read
Parameter:	Avail. meas. ch. PMC and SMC			
Format:	Hex			
Value:	**0x21**			

In case of operator level U, A or S, the value 0x21 is returned. In other words: PMC1 and PMC6 are available to the operator U, A or S.

The VisiFerm RS485 Modbus register structure uses the following physical units used for Primary or Secondary Measurement Channels.

Table 15 Definition of physical units

Code (Hex)	Physical unit	Start register. (8 ASCII characters, length 4 registers, Type 3, read for U/A/S)
0x00000001	none	1920
0x00000002	K	1924
0x00000004	°C	1928
0x00000008	°F	1932
0x00000010	%-vol	1936
0x00000020	%-sat	1940
0x00000040	ug/l ppb	1944
0x00000080	mg/l ppm	1948
0x00000100	g/l	1952
0x00000200	uS/cm	1956
0x00000400	mS/cm	1960
0x00000800	1/cm	1964
0x00001000	pH	1968
0x00002000	mV/pH	1972
0x00004000	kOhm	1976
0x00008000	MOhm	1980
0x00010000	pA	1984
0x00020000	nA	1988
0x00040000	uA	1992
0x00080000	mA	1996
0x00100000	uV	2000
0x00200000	mV	2004
0x00400000	V	2008
0x00800000	mbar	2012
0x01000000	Pa	2016
0x02000000	Ohm	2020
0x04000000	%/°C	2024
0x08000000	°	2028
0x10000000	not used	2032
0x20000000	not used	2036
0x40000000	not used	2040
0x80000000	SPECIAL	2044

Table 16 Example to read the physical unit in plain text ASCII in register 1952

Command: Unit text		Modbus address: **1952**	Length: **4**	Type: **3** Read
Parameter:	Text			
Format:	8 ASCII characters			
Value:	**“g/l”**			

2.5.2 Primary Measurement Channel 1 (Oxygen)

2.5.2.1 Definition of PMC1

Start register	Data size (registers)	Function	Data type	Modbus function code	Read access	Write access
2080	8	Description of PMC1	ASCII chars	3, 4	U/A/S	none
2088	2	Available physical units of PMC1	uint	3, 4	U/A/S	none
2090	2	Selected physical unit for PMC1	uint	16	none	S

In register 2080, a plain text ASCII description of PMC1 is given. PMC1 for VisiFerm RS485 is called "DO".

In register 2088, the available physical units for this channel are defined. The available physical units for Calibration: 0x108000F0 → ppm gas, mbar, mg/l ppm, ug/l ppb, %-sat and %-vol

In register 2090, the active physical unit for this channel can be selected, by choosing one of the physical units that are defined in register 2088.
Selecting an invalid unit code will leave the current unit unchanged.

Table 17 Example to set the physical unit of PMC1 to %-vol (0x00000010)

Command: PMC1 set unit		Modbus address: **2090**	Length: **2**	Type: **16** Write
Parameter:	Unit			
Format:	Hex			
Value:	**0x00000010**			

Note:
A change of the PMC1 unit will also automatically change the calibration unit, see chapter 2.10.2.1.

Attention:
Changing the physical unit of PMC1 has also an influence on the output of the 4-20 mA analog output, as the same physical unit is active for 4-20 mA. All limits of the 4-20 mA analog output must be redefined after changing the physical unit! See chapter 2.4.5 for more details.

Example 1: Reading the available physical units of PMC1 (Oxygen)

Read the available physical units of PMC1 at register 2088 with length 2 and function-code 3.

Request:

The command in HEX-format sent to the sensor:
0x 01 03 08 27 00 02 76 60

0x 01 Server address (decimal "01")
0x 03 Function code "Read Holding Registers"
0x 08 27 Starting address (decimal "2087")
0x 00 02 Number of registers (decimal "02")
0x 76 60 CRC

Response:

The answer received in HEX-format from the sensor:
0x 01 03 04 00 F0 00 80 FB A0

0x 01	Server address (decimal "01")	
0x 03	Function code "Read Holding Registers"	
0x 04	Data-Byte count (decimal "04")	
0x 00 F0	Register 1 (decimal "240")	Available physical unit – low register
0x 00 80	Register 2 (decimal "128")	Available physical unit – high register
0x FB A0	CRC	

Registers 2 and 1 together result in 0x 008000F0 which represents the available physical units %-vol (0x00000010), %-sat (0x00000020), ug/l ppb (0x00000040), mg/l ppm (0x00000080) and mbar (0x00800000), see chapter 2.5.1

Example 2: Writing the physical unit of PMC1 (Oxygen)

Writing to register 2090 with length 2 and function-code 16:

Request:

The command in HEX-format sent to the sensor:
0x 01 10 08 29 00 02 04 00 20 00 00 57 D7

0x 01	Server address (decimal "01")	
0x 10	Function code "Write Multiple Registers"	
0x 08 29	Starting address (decimal "2089")	
0x 00 02	Quantity of registers (decimal "2")	
0x 04	Byte count (decimal "4")	
0x 00 20	Register 1 (hex)	Physical unit – low register
0x 00 00	Register 2 (hex)	Physical unit – high register
0x 57 D7	CRC	

Response:

The answer received in HEX-format from the sensor:
0x 01 10 08 29 00 02 92 60

0x 01	Server address (decimal "01")
0x 10	Function code "Write Multiple Registers"
0x 08 29	Starting address (decimal "2089")
0x 00 02	Quantity of registers (decimal "2")
0x 92 60	CRC

2.5.2.2 Reading the measurement value of PMC1

Register 2090 is also used to read the measurement values of PMC1.

Start reg.	Num-ber of reg.	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Reg5 / Reg6 (bitwise defined)	Reg7 / Reg8 (float)	Reg9 / Reg10 (float)	Modbus function code	Read access	Write access
2090	10	Selected physical unit	Measure-ment value of PMC1 (1)	Measure-ment status (2)	Min allowed value (1)	Max allowed value (1)	3, 4	U/A/S	none

(1) Value is always in the physical unit defined in register 2090.
(2) Definition of the status see chapter 2.5.4. All bits set to zero means: no problem.

Attention:

You cannot read selectively the registers 3 and 4 for the measurement value only. You must read the entire length of the command (10 registers) and extract the desired information.
For the definition of the Measurement Status see chapter 2.5.4.

Example: Reading PMC1 (Oxygen)

Reading register 2090 with length 10 and function-code 3 the five different values at once:

- Physical unit (registers 1 and 2) interpret as hex value
- Measurement value PMC1 (registers 3 and 4) transform to a floating-point value
- Status (registers 5 and 6) interpret as hex value
- Min allowed value (registers 7 and 8) transform to a floating-point value
- Max allowed value (registers 9 and 10) transform to a floating-point value

Request:

The command in HEX-format send to the sensor:
0x 01 03 08 29 00 0A 16 65

0x 01	Server address (decimal "01")
0x 03	Function code "Read Holding Registers"
0x 08 29	Starting address (decimal "2089")
0x 00 0A	Number of registers (decimal "10")
0x 16 65	CRC

Response:

The answer received in HEX-format from the sensor:
0x 01 03 14 00 10 00 00 7B C4 41 A8 00 00 00 00 00 00 00 00 CF 8D 42 7B C0 30

0x 01	Server address (decimal "01")	
0x 03	Function code "Read Holding Registers"	
0x 14	Data-Byte count (decimal "20")	
0x 00 10	Register 1 (hex)	Physical unit – low register
0x 00 00	Register 2 (hex)	Physical unit – high register
0x 7B C4	Register 3 (floating point)	Measurement value PMC1 – low register
0x 41 A8	Register 4 (floating point)	Measurement value PMC1 – high register
0x 00 00	Register 5 (hex)	Status – low register
0x 00 00	Register 6 (hex)	Status – high register
0x 00 00	Register 7 (floating point)	Min allowed value – low register
0x 00 00	Register 8 (floating point)	Min allowed value – high register
0x CF 8D	Register 9 (floating point)	Max allowed value – low register
0x 42 7B	Register 10 (floating point)	Max allowed value – high register
0x C0 30	CRC	

Now extract the desired information:

- The physical unit 0x00000010 of registers 2 and 1 represents %-vol, see chapter 2.5.1.
- The measurement value 0x41A87BC4 of registers 4 and 3 transformed to a floating-point figure results in the decimal value 21.06043.
- The status 0x00000000 of registers 6 and 5 indicate that there is no error or warning.
- The min allowed value 0x00000000 in registers 8 and 7 transformed to a floating-point figure results in the decimal value 0.
- The max allowed value 0x427BCF8D in registers 10 and 9 transformed to a floating-point figure results in the decimal value 62.95269.

2.5.3 Primary Measurement Channel 6 (Temperature)

The VisiFerm RS485 sensor has a built-in temperature sensor (NTC22kΩ). This temperature sensor is to be used only for monitoring the sensor conditions, not for controlling the process temperature.

2.5.3.1 Definition of PMC6

Start register	Data size (registers)	Function	Data type	Modbus function code	Read access	Write access
2400	8	Description of PMC6	ASCII chars	3, 4	U/A/S	none
2408	2	Available physical units of PMC6	uint	3, 4	U/A/S	none
2410	2	Selected physical unit for PMC6	uint	16	none	S

In register 2400, a plain text ASCII description of PMC6 is given. PMC6 is called "T".

In register 2408, the available physical units for this channel are defined. The available physical units for PMC6: 0x0000000E => K, °C and °F

In register 2410, the active physical unit for this channel can be selected, by choosing one of the physical units that are defined in register 2408.
Selecting an invalid unit code will leave the current unit unchanged.

Attention:
Changing the physical unit of PMC6 has also an influence on the output of AO1 / AO2, as the same physical unit is active for the analog outputs. All limits of the 4-20 mA analog output must be redefined after changing the physical unit! See chapter 2.4.5 for more details.

2.5.3.2 Reading the measurement value of PMC6

Register 2410 is also used to read the measurement values of PMC6.

Start reg.	Number of reg.	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Reg5 / Reg6 (bitwise defined)	Reg7 / Reg8 (float)	Reg9 / Reg10 (float)	Modbus function code	Read access	Write access
2410	10	Selected physical unit	Measurement value of PMC6 (1)	Measurement status (2)	Min allowed value (1)	Max allowed value (1)	3, 4	U/A/S	none

(1) Value is always in the physical unit defined in register 2410, length 2.
(2) For definition of the status see chapter 2.5.4. All bits set to zero means: no problem.

Table 18 Example to read register 2410

Command: PMC6 read			Modbus address: **2410**	Length: **10**	Type: **3** Read
Parameter:	Unit	Value	Status	Min limit	Max limit
Format:	Hex	Float	Hex	Float	Float
Value:	**0x04**	**27.42447**	**0x00**	**-20**	**140**

Physical unit is set to °C, PMC6 is 27.42 (°C), Status is 0x00, Min allowed value is -20 °C, Max allowed value is 140 °C.

Attention:

You cannot read selectively the registers 3 and 4 for the measurement value only. You must read the entire length of the command (10 registers) and extract the desired information.

Example: Reading PMC6 (Temperature)

Reading register 2410 with length 10 and function-code 3:

- Physical unit (registers 1 and 2) interpret as hex value
- Measurement value PMC6 (registers 3 and 4) transform to a floating-point value
- Status (registers 5 and 6) interpret as hex value
- Min allowed value (registers 7 and 8) transform to a floating-point value
- Max allowed value (registers 9 and 10) transform to a floating-point value

Request:

The command in HEX-format send to the sensor:
0x 01 03 09 69 00 0A 16 4D

0x 01 Server address (decimal "01")
0x 03 Function code "Read Holding Registers"
0x 09 69 Starting address (decimal "2409")
0x 00 0A Number of registers (decimal "10")
0x 16 4D CRC

Response:

The answer received in HEX-format from the sensor:
0x 01 03 14 00 04 00 00 2A E0 41 D1 00 00 00 00 00 00 C2 20 00 00 43 02 70 E5

0x 01 Server address (decimal "01")
0x 03 Function code "Read Holding Registers"
0x 14 Data-Byte count (decimal "20")
0x 00 04 Register 1 (hex) Physical unit – low register
0x 00 00 Register 2 (hex) Physical unit – high register
0x 2A E0 Register 3 (floating point) Measurement value PMC6 – low register
0x 41 D1 Register 4 (floating point) Measurement value PMC6 – high register
0x 00 00 Register 5 (hex) Status – low register
0x 00 00 Register 6 (hex) Status – high register
0x 00 00 Register 7 (floating point) Min allowed value – low register
0x C2 20 Register 8 (floating point) Min allowed value – high register
0x 00 00 Register 9 (floating point) Max allowed value – low register
0x 43 02 Register 10 (floating point) Max allowed value – high register
0x 70 E5 CRC

Now extract the desired information:

- The physical unit 0x00000004 of registers 2 and 1 represents °C, see chapter 2.5.1.
- The measurement value 0x41D12AE0 in registers 4 and 3 transformed to a floating-point figure represents the decimal value 26.14594.
- The status 0x00000000 of registers 6 and 5 indicates that there is no error or warning
- The min allowed value 0xC2200000 in registers 8 and 7 transformed to a floating-point figure represents the decimal value -40.
- The max allowed value 0x43020000 in registers 10 and 9 transformed into a floating-point figure represents the decimal value 130.

2.5.3.3 Input of an Externally Measured Temperature

The VisiFerm RS485 sensor offers the possibility to preset the temperature value PMC6 externally for the sensor.

External temperature data can be written into register 2410. The value must be within the range of "measurement temperature min" and "measurement temperature max", see chapter 2.8.1 (register 4612). External temperature data will then be used for the internal calculations instead of the internally measured temperature. If the external reading exceeds the min-max measurement temperature range, the sensor will automatically fall back to the internal measurement. The same switch to internal temperature measurement will happen after sensor power on!
As soon as Reg. 2410 is written, the external temperature data is used for all calculation, interface and calibration procedures, except for warnings and errors.

Start register	Number of Register	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
2410	4	Physical unit (bitwise defined)	External temperature	16	none	S

Table 19 Example to set the physical unit to °C (0x04) and the value of the external temperature

Command: PMC6 set		Modbus address: **2410**	Length: **4**	Type: **16** Write
Parameter:	Unit	Value		
Format:	Hex	Float		
Value:	**0x04**	**25**		

<u>Attention:</u>

The operator needs to guarantee regular data update, once external temperature data has been written to register 2410.

2.5.4 Definition of the Measurement Status for PMC1 / PMC6

This is the definition of the status registers read in registers 2090 (PMC1) and 2410 (PMC6):

Table 20 Definition of measurement status for Primary Measurement Channels

Code (Hex)	Description
0x01	Temperature out of user defined measurement temperature range (see chapter 2.11.1)
0x02	Temperature out of operating range (see chapter 2.11.1)
0x04	Not available
0x08	Warning not zero (see chapter 2.11.3)
0x10	Error not zero (see chapter 2.11.4)

2.6 Measurement Hold Mode

The measurement hold mode is not persistently stored in the VisiFerm RS485, therefore on every sensor start up, the measurement hold mode is in the "on" mode (default mode).
A detailed description of the measurement hold mode is described in Figure 18.

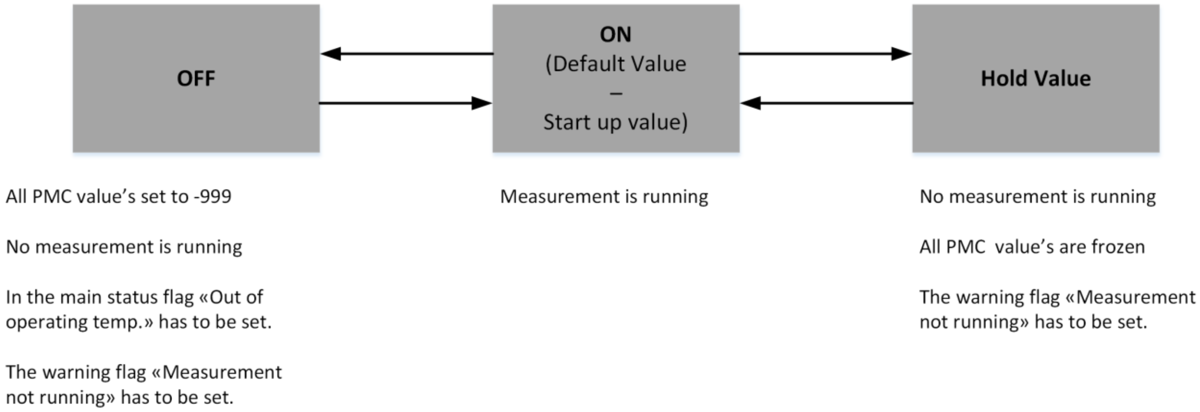


Figure 18: Description of the measurement hold mode functionality

The measurement hold mode for PMC1 and PMC6 is selected by programming the mode in register 2064.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
2064	2	Measurement Hold Mode, see Table 21	3, 4, 16	S	S

Table 21 Code for selection of the measurement hold mode

Code (Hex)	Description
0x00	Off • PMC1 and PMC6 values set to -999 • Measurement status "Temperature out of operating range" is set, see chapter 2.5.4 • Measurement warning "Measurement not running" is set, see chapter 2.11.3
0x01	On • current measured value output of PMC1 and PMC6
0x02	Hold Value • PMC1 and PMC6 values are frozen • Measurement warning "Measurement not running" is set, see chapter 2.11.3

2.7 Configuration of the Measurement

This chapter describes the configuration of PMC1 and PMC6 by means of measurement parameters (PA).

2.7.1 Available Parameters

In register 3072, all available parameters (PA) are given.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3072	2	Available parameters (see Table 22)	3, 4	U/A/S	none

Table 22 Bitwise definition of all parameters PA1 to PA16

Code (Hex)	Description	Definition in VisiFerm RS485
0x0001	PA1	Salinity
0x0002	PA2	Atmospheric pressure
0x0004	PA3	Humidity
0x0100	PA9	Moving average
0x0200	PA10	Number of sub-measurements
0x1000	PA13	Measurement interval
0x2000	PA14	Sensor cap part number

Table 23 Example to read the available Parameters with operator level S

Command: Available parameters		Modbus address: **3072**	Length: **2**	Type: **3** Read
Parameter:	Measurement parameters			
Format:	Hex			
Value:	**0x3307**			

The hex value 0x3307 corresponds to 0x01 (PA1) + 0x02 (PA2) + 0x04 (PA3) + 0x0100 (PA9) + 0x0200 (PA10) + 0x1000 (PA13) + 0x2000 (PA14).

Note:

- PA1 to PA8 use FLOAT as data format for its values
- PA9 to PA16 use UNSIGNED INT as data format for its values

2.7.2 PA1: Salinity

The physical measurement of VisiFerm RS485 is responding to the partial pressure of oxygen. For a given partial pressure of oxygen in air, the concentration of dissolved oxygen in saturated water is strongly dependent on temperature, as well as on its salinity. By measuring the partial pressure of oxygen and correcting for temperature and salinity, VisiFerm RS485 can determine the concentration of oxygen in a sample.
At 25°C and in air saturated, pure water, the concentration of dissolved oxygen is 8.2 mg/l. The more salt, the lower the solubility.

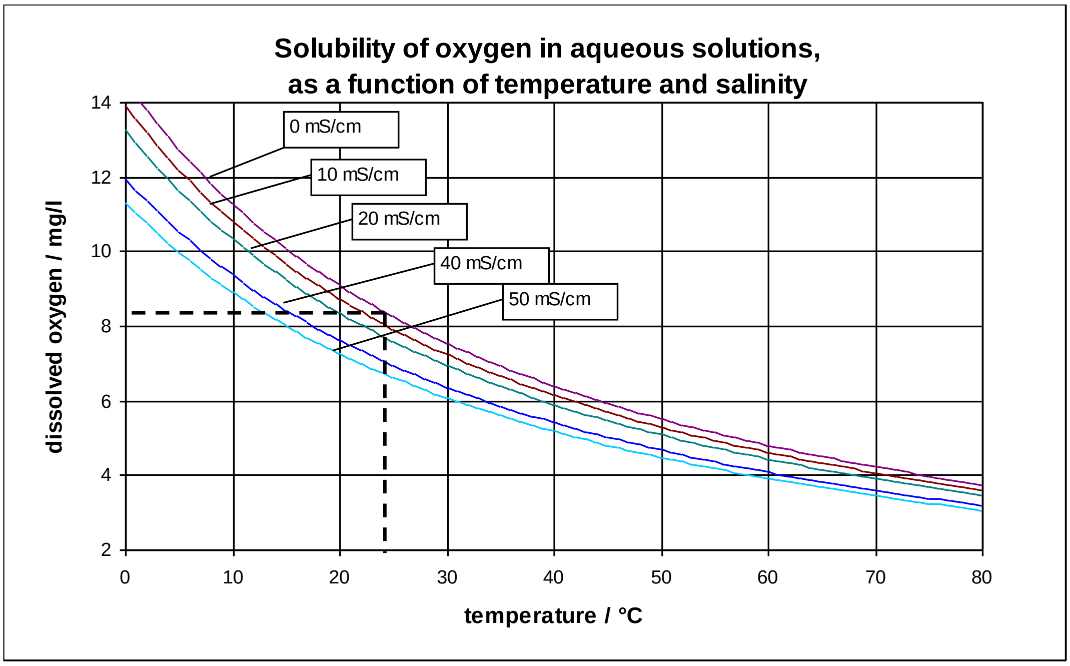


Figure 19 Solubility of oxygen as a function of temperature and salinity, in air saturated aqueous solution. Temperature range is from 0-85 °C.

2.7.2.1 Description of PA1 (Salinity)

In register 3104, a plain text ASCII description of PA1 is given. It returns "Salinity".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3104	8	Description of PA1	3, 4	U/A/S	none

2.7.2.2 Selecting the Physical Unit and Writing the Value for PA1

In register 3112, the available physical units for PA1 are defined. The only one available unit here is mS/cm (0x400). For the definition of the physical units see Table 15.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3112	2	Available physical units for PA1	3, 4	U/A/S	none

By writing to register 3114, the active physical unit for PA1 can be selected, by choosing one of the physical units that are defined in register 3112. According to register 3112 only one bit for the physical unit can be set. The value of the parameter can be set as well.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
3114	4	Select physical unit for PA1	Value for PA1 (0-50mS/cm)	16	none	S

2.7.2.3 Reading all Values for PA1

By reading register 3114, the active physical unit, the selected value, and the min and max allowed values can be read.
The unit is always mS/cm (0x400), the min is 0 (mS/cm) and the max is 50 (mS/cm).

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Reg7 / Reg8 (float)	Modbus function code	Read access	Write access
3114	8	Physical unit	Current value	Min value	Max value	3, 4	U/A/S	none

The default settings are:

- Physical unit of PA1: 0x400 (mS/cm)
- Current value of PA1: 0.0 (mS/cm)
- Min value of PA1: 0.0 (mS/cm)
- Max value of PA1: 50.0 (mS/cm)

2.7.3 PA2: Pressure

The VisiFerm RS485 sensor measures the partial pressure of oxygen. The partial pressure of oxygen is proportional to the atmospheric pressure or the pressure of the air supply to the process. To compensate for changes in atmospheric pressure or pressure of air supply in the process, one can use parameter PA2.

PA2 defines the current air pressure, the value of which is used for internal calculation.

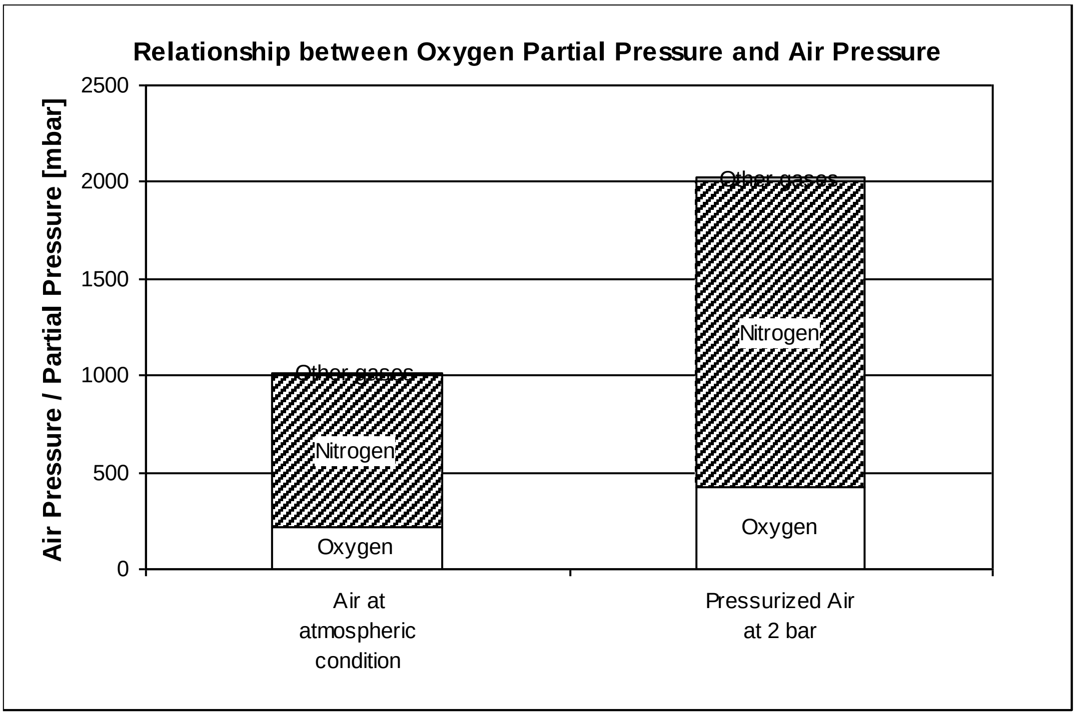


Figure 20 Influence of air pressure on the partial pressure of oxygen. Doubling the air pressure also doubles the oxygen partial pressure.

2.7.3.1 Description of PA2 (Air Pressure)

In register 3136, a plain text ASCII description of PA2 is given. It returns "Pressure".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3136	8	Description of PA2	3, 4	U/A/S	none

2.7.3.2 Selecting the Physical Unit and Writing the Value for PA2

In register 3144, the available physical units for PA2 are defined. The only available unit here is mbar (0x800000). For the definition of the physical units see Table 15.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3144	2	Available physical units for PA2	3, 4	U/A/S	none

By writing to register 3146, the active physical unit for parameter 2 can be selected, by choosing one of the physical units that are defined in register 3144. According to register 3144 only one bit for the physical unit can be set. The value of the parameter can be set as well.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
3146	4	Select physical unit for PA2	Value for PA2 (10-12000 mbar)	16	none	S

2.7.3.3 Reading All Values for PA2

By reading register 3146/8 the active physical unit, the current value, and the min and max allowed values can be read.
The unit is always mbar (0x800000), the min is 10 (mbar) and the max is 12000 (mbar).

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Reg7 / Reg8 (float)	Modbus function code	Read access	Write access
3146	8	Physical unit	Current value	Min value	Max value	3, 4	U/A/S	none

The default settings are:

- Physical unit of PA2: 0x800000 (mbar)
- Current value of PA2: 1013.0 (mbar)
- Min value of PA2: 10.0 (mbar)
- Max value of PA2: 12000.0 (mbar)

2.7.4 PA3: Humidity

The measuring parameter 3 (PA3) Humidity defines the current humidity and is used to calculate the volume fraction in %-vol of dissolved oxygen in gas phase.
The physical unit's mbar, µg/l ppb, mg/l ppm and ppm gas should not be used for liquid media. The measuring parameter 3 Humidity has no influence on these units.

2.7.4.1 Description of PA3 (Humidity)

In register 3168, a plain text ASCII description of PA3 is given. It returns "Humidity".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3168	8	Description of PA3	3, 4	U/A/S	none

2.7.4.2 Selecting the Physical Unit and Writing the Value for PA3

In register 3176, the available physical units for PA3 are defined. The only one available here is % (0x20000000). For the definition of the physical units see Table 15.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3176	2	Available physical units for PA3	3, 4	U/A/S	none

By writing to register 3178/4, the active physical unit for parameter 3 can be selected, by choosing one of the physical units that are defined in register 3176. According to register 3176 only one bit for the physical unit can be set. The value of the parameter can be set as well.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
3178	4	Select physical unit for PA3	Value for PA3 (0-100)	16	none	S

2.7.4.3 Reading all Values for PA3

By reading register 3178/8, the active physical unit, the current value, and the min and max allowed values can be read.
The unit is always % (0x20000000), the min is 0 (%) and the max is 100 (%).

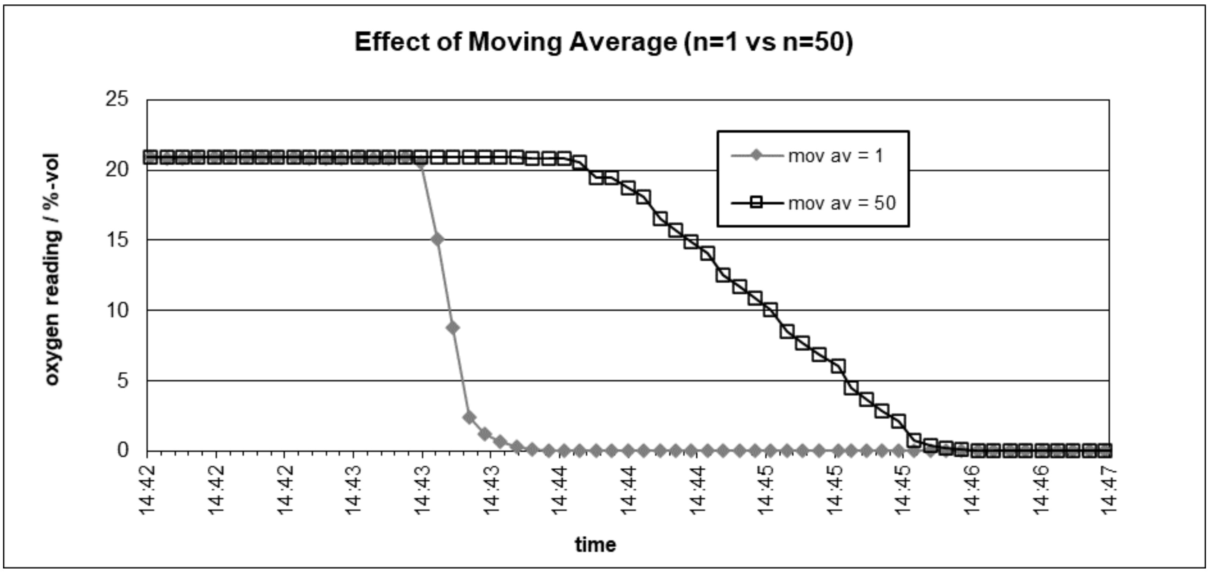
Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Reg7 / Reg8 (float)	Modbus function code	Read access	Write access
3178	8	Physical unit	Current value	Min value	Max value	3, 4	U/A/S	none

The default settings are:

- Physical unit of PA3: 0x20000000 (%)
- Current value of PA3: 0.0 (%)
- Min value of PA3: 0.0 (%)
- Max value of PA3: 100.0 (%)

2.7.5 PA9: Moving Average

VisiFerm RS485 calculates new oxygen readings with a measurement interval defined in PA13. One has the possibility to smoothen the oxygen and temperature reading (PMC1 and PMC6) by means of a moving average.
Figure 21 shows a comparison between no moving average (n=1) and a moving average over 50 readings at a measurement interval of 3 second.



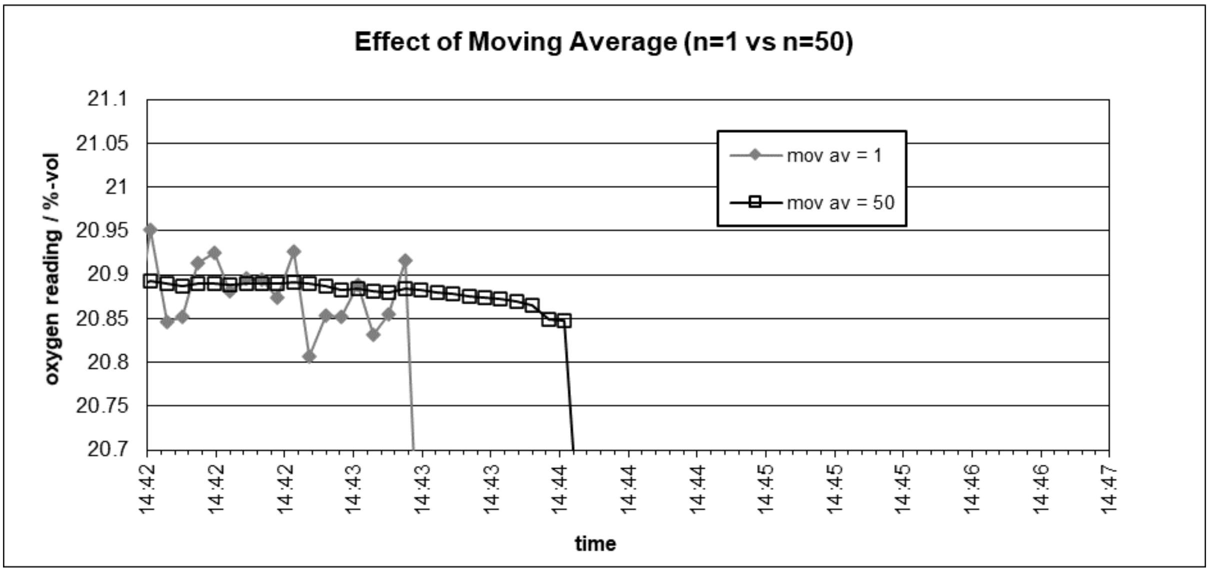


Figure 21 Comparison of the response of VisiFerm RS485 to a change from air to zero oxygen

Using moving average, the short-term signal stability can be improved; on the other hand, the response time of the sensor increases with increasing moving average. A moving average over 50 samples results in a response time of at least 50 times the measurement interval defined in PA13.

Note:

The moving average defined by PA9 is applied to both PMC1 and PMC6

2.7.5.1 Description of PA9 (Moving Average)

In register 3360, a plain text ASCII description of PA9 is given. It returns "Moving average".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3360	8	Description of PA9	3, 4	U/A/S	none

2.7.5.2 Selecting the Physical Unit and Writing the Value for PA9

In register 3368, the available physical units for PA9 are defined. The only one available here is "none" (0x01). For the definition of the physical units see Table 15.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3368	2	Available physical units for PA9	3, 4	U/A/S	none

By writing to register 3370/4, the active physical unit for PA9 can be selected, by choosing one of the physical units that are defined in register 3368. According to register 3368 only one bit for the physical unit can be set. The value of the parameter can be set as well.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
3370	4	Select physical unit for PA9	Value for PA9 (1-150, default: 10)	16	none	S

PA9 can take values between 1 and 150. The value of 1 does not influence the response time of the sensor, the value of 10 increases the response time 10 times the value of the measurement interval.

2.7.5.3 Reading all Values for PA9

By reading register 3370/8, the active physical unit of measurement, the current value, and the min and max values can be read.
The unit is always none (0x01), the min is 1 and the max is 150.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
3370	8	Physical unit	Current value	Min value	Max value	3, 4	U/A/S	none

The default settings are:

- Physical unit of PA9: 0x00000001 (none)
- Current value of PA9: 10
- Min value of PA9: 1
- Max value of PA9: 150

2.7.6 PA10: Number of Sub-Measurements (Resolution)

The measurement value of VisiFerm RS485 in each measurement interval is on itself an average over 16 (or less) individual sub-measurements. With PA10, the number of sub-measurements can be set between 1 and 16. The advantage of using a smaller amount of sub-measurements is a shorter exposure of the luminophore to the excitation light. Photo bleaching of the luminophore will be reduced. The disadvantage is a reduced signal quality.
In case of a measurement interval (PA13) of 1 or 2 seconds, the resolution has a maximum of 3 sub-measurements. The number of sub-measurements will be automatically set if the measurement interval is set to 1 or 2 seconds and the resolution was greater than 3.

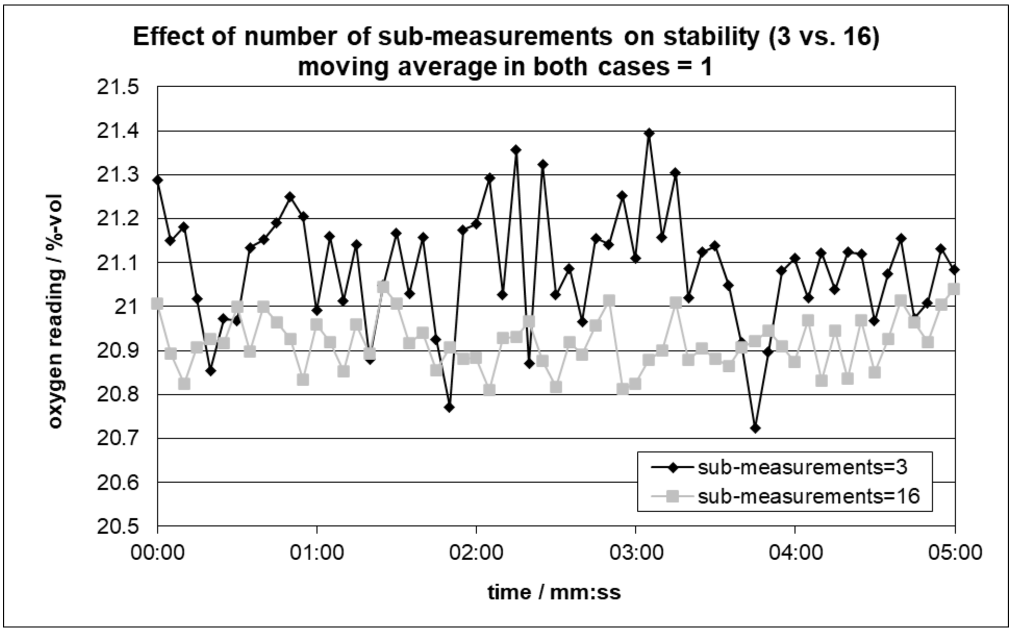


Figure 22 Comparison of the signal stability of VisiFerm RS485

2.7.6.1 Description of PA10 (Number of Sub-Measurements)

In register 3392, a plain text ASCII description of PA10 is given. It returns "Resolution".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3392	8	Description of PA10	3, 4	U/A/S	none

2.7.6.2 Selecting the Physical Unit and Writing the Value for PA10

In register 3400, the available physical units for PA10 are defined. The only one available here is "none" (0x01). For the definition of the physical units see Table 15.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3400	2	Available physical units for PA10	3, 4	U/A/S	none

By writing to register 3402/4, the active physical unit of PA10 can be selected, by choosing one of the physical units that are defined in register 3400. According to register 3400 only one bit for the physical unit can be set. The value of the parameter can be set as well.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
3402	4	Select physical unit for PA10	Value for PA10 (1-16, default: 8)	16	none	S

PA10 can take values between 1 and 16.

2.7.6.3 Reading all Values for PA10

By reading register 3402/8, the active physical unit, the current value, and the min and max values can be read.
The unit is always none (0x01), the min is 1 and the max is 16.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
3402	8	Physical unit	Current value	Min value	Max value	3, 4	U/A/S	none

The default settings are:

- Physical unit of PA10: 0x00000001 (none)
- Current value of PA10: 8
- Min value of PA10: 1
- Max value of PA10: 16

⚠ Attention:

If PA13 (Measurement Interval) is set to one or two, PA10 (Number of sub-measurements) will be limited from one to three.

Table 24 The limits for the minimum number of sub-measurements in dependency of the measurement interval

	PA13 (Measurement Interval) < 3	PA13 (Measurement Interval) ≥ 3
PA10 (Number of sub-measurements)	1 to 3	1 to 16

2.7.7 PA13: Measurement Interval

The measurement interval for the VisiFerm RS485 can be set between 1s and 300s (5min). The dissolved oxygen measurement cannot be deactivated by writing a 0 to the measurement interval register. When increasing the interval, the sensor cap respectively the luminophore is preserved better, but the reaction time for an oxygen change is slower.

Note:

1) When a CP1/CP2 calibration is initiated and the current measurement interval is greater than 3s or equals 0s, the measurement interval is temporarily set to 3s. The measurement interval is automatically reset to the original value 10 min after the last calibration command, or after power up. See chapter 2.10.3 for more details.
2) When a CP6 calibration is performed, the measurement interval is not changed by the sensor.

2.7.7.1 Description of PA13 (Measurement Interval)

In register 3488, a plain text ASCII description of PA13 is given. It returns "Meas. interval".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3488	8	Description of PA13	3, 4	U/A/S	none

2.7.7.2 Selecting the Physical Unit and Writing the Value for PA13

In register 3496, the available physical units for PA13 are defined. The only one available here is "none" (0x01). For the definition of the physical units see Table 15.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3496	2	Available physical units for PA13	3, 4	U/A/S	none

By writing to register 3498/4, the active physical unit of PA13 can be selected, by choosing one of the physical units that are defined in register 3496. According to register 3496 only one bit for the physical unit can be set. The value of the parameter can be set as well.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
3498	4	Select physical unit for PA13	Value for PA13 (1-300; default: 3)	16	none	S

PA13 can take values between 1 and 300.

2.7.7.3 Reading all Values for PA13

By reading register 3498/8, the active physical unit of measurement, the current value, and the min and max values can be read.
The unit is always none (0x01), the min is 1 and the max is 300.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
3498	8	Physical unit	Current value	Min value	Max value	3, 4	U/A/S	none

The default settings are:

- Physical unit of PA13: 0x00000001 (none)
- Current value of PA13: 3
- Min value of PA13: 1
- Max value of PA13: 300

Note:

If the PA13 (measurement interval) is set to 1s or 2s, the current value of PA10 will internally be set to 3.
If the PA13 (measurement interval) is set to a value greater than 2s, PA10 remains unchanged.

2.7.8 PA14: Sensor Cap Part Number

The VisiFerm RS485 can be used with different sensor cap types. Each sensor cap type has its specific measurement characteristics. The measurement parameter PA14 allows configuring the sensor cap type used by entering the corresponding part number which can be found engraved on the sensor cap.

2.7.8.1 Description of PA14 (Sensor Cap Part Number)

In register 3520, a plain text ASCII description of PA14 is given. It returns "SensorCap PartNr".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3520	8	Description of PA14	3, 4	U/A/S	none

2.7.8.2 Selecting the Physical Unit and Writing the Value for PA14

In register 3528, the available physical units for PA14 are defined. The only one available here is "none" (0x01). For the definition of the physical units see Table 15.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3528	2	Available physical units for PA14	3, 4	U/A/S	none

By writing to register 3530/4, the active physical unit of PA14 can be selected, by choosing one of the physical units that are defined in register 3528. According to register 3530 only one bit for the physical unit can be set. The value of the parameter can be set as well. Only valid sensor cap part numbers are accepted by the sensor.

By default, the following sensor cap part numbers are defined:
- 243515: ODO cap H0
- 243505: ODO cap H2
- 10068400: ODO cap H3
- 10078261: ODO cap H4

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
3530	4	Select physical unit for PA14	Value for PA14 (0-1000000; default: depends on the order code)	16	none	S

PA14 can take values between 0 and 1000000.

2.7.8.3 Reading all Values for PA14

By reading register 3530/8, the active physical unit, the current value, and the min and max values can be read.
The unit is always none (0x01), the min is 0 and the max is 1000000.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
3530	8	Physical unit	Current value	Min value	Max value	3, 4	U/A/S	none

2.8 Sensor Cap History

The VisiFerm RS485 sensor offers the functionality, to track sensor cap replacements within the sensor. The history has a depth of max. 10 sensor caps, if exceeded the oldest sensor caps entry in the history is overwritten.

A sensor cap history dataset consists of:
- Sensor Cap part number
- Sensor Cap serial number
- Time stamp of sensor cap replacement

A replacement of a new sensor cap must be manually communicated to the sensor, by using Reg 8220.
The latest manually communicated sensor cap replacement always occupies the first element (index 0) and the oldest always occupies the last element (index 9) of the cap history.

2.8.1 Number of Cap replacements

The manually communicated sensor cap replacement event is counted by the sensor and can be read out with Reg 3648.

Start register	Number of registers	Reg1 / Reg2 (uint)	Modbus function code	Read access	Write access
3648	2	Number of Sensor Cap Replacements	3, 4	U/A/S	none

2.8.2 Reading the sensor cap history

The history has a depth of max. 10 sensor caps. Reading the sensor cap history out from the sensor, at first the desired history index must be written to the sensor with Reg 3650.

Start register	Number of registers	Reg1 / Reg2 (uint)	Modbus function code	Read access	Write access
3650	2	Cap history index (0-9), see Table 25	3, 4	U/A/S	U/A/S

Table 25 Sensor Cap history - dataset

Sensor Cap history index (Reg 3650/2)	Sensor Cap history dataset
0	Dataset of the latest sensor cap replacement - Sensor Cap part number — Reg 3652/4 - Sensor Cap serial number — Reg 3652/4 - Time stamp of sensor cap replacement — Reg 3656/8
…	…
9	Dataset of the oldest sensor cap replacement - Sensor Cap part number — Reg 3652/4 - Sensor Cap serial number — Reg 3652/4 - Time stamp of sensor cap replacement — Reg 3656/8

After setting the desired cap history index, the requested history dataset can now be accessed with Reg 3652, reading sensor cap reference number and serial number and with Reg 3656, reading the time stamp of the cap replacement.

Start register	Number of registers	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
3652	4	Sensor cap replacement history: Sensor Cap part number	Sensor cap replacement history: Sensor Cap serial number	16	U/A/S	None

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3656	8	Sensor cap replacement history: Time stamp of sensor cap replacement	3, 4	U/A/S	None

2.8.3 Store sensor cap history

The VisiFerm RS485 can be used with different sensor cap types. Each sensor cap type has its specific measurement characteristics. The measurement parameter PA14 allows configuring the sensor cap type used by entering the corresponding part number which can be found engraved on the sensor cap.

In case another sensor cap type replaced the old sensor cap and screwed on the sensor, the part number of the new sensor must be written with Reg 3530/4 into the sensor, see chapter 2.7.8.

The corresponding sensor cap serial number, of the new sensor cap, which can be found engraved on the sensor cap, must entered by using Reg 3626.

Start register	Number of registers	Reg1 / Reg2 (uint)	Modbus function code	Read access	Write access
3626	2	Sensor Cap serial number	3, 4	S	S

Time stamp of the current ongoing sensor cap replacement in 16 ASCII character format with Reg 8224, should be written into the sensor.

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
8224	8	Time stamp of sensor cap replacement	3, 4	U/A/S	S

The replacement of a new sensor cap must be manually communicated to the sensor, by using Reg 8220.
To complete a sensor cap replacement successfully, the correct password (Reg1/Reg2 = 86974214) and command (Reg3/Reg4 = 1) must be sent within Reg 8220.

Start register	Number of registers	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
8220	4	Password = 86974214	Store cap replacement command = 1	16	none	S

2.9 Verification

The main idea of the verification parameter (VPA) is to verify the current sensor measurement value with the last sensor calibration.
When performing such a verification, measurement parameters that are also defined within the standard calibration points must be adjust in the same way as in the last valid standard calibration point.
After adjusting the measurement parameters, the current measurement value can be compared with the last valid standard calibration value.

The verification process can be done by adjusting the measurement parameter via the measurement parameter command, the value is stored persistently into the sensor. In case that the connection between sensor and host is interrupted, the current measurement parameter is modified, and a possible fermentation process can run with wrong measurement parameter, even after a power up of the sensor.

The feature of verification parameter must be switched on or off with the command in register 3684. The verification command is not stored persistently into the sensor, a restart of the sensor the verification command is automatically switched off.

To activate the verification feature, it must be switched on in register 3684 with the verification command code 0x00000001 (Start Verification) as shown in Table 26. After the activation of the verification feature, only then a write process for VPA2 (Air Pressure) and VPA3 (Humidity) is possible. If this is not the case, a Modbus exception with the error code illegal function 0x01 is generated.

By sending the verification command code 0x00000000 (Stop Verification) in register 3684 the verification feature is deactivated, and the sensor parameter values are restored again from the sensor memory.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3684	2	Verification Command (see Table 26)	3, 4, 16	U/A/S/D/H	S/D/H

Table 26: Bitwise definition of the verification command

Hex value	Description
0x00000000	Stop Verification
0x00000001	Start Verification

2.9.1 VPA1 – Salinity

In register 3686, a plain text ASCII description of Verification Parameter VPA1 is given. It returns "Salinity".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3686	8	Description of Verification Parameter	3, 4	U/A/S	None

In register 3694, Verification Parameter Salinity value is given.
By reading register 3694/6 the active physical unit and the current value values can be read.

In register 3112, the available physical units for PA1 are defined. The only one available unit here is mS/cm (0x00000400). For the definition of the physical units see Table 15.
Therefore, the unit for VPA1 is the same as defined for PA1.
The unit is always mS/cm (0x00000400) and the first parameter is always zero and is not relevant.

By writing to register 3694/6, a selection of an incorrect unit has no influence on the written value. An incorrect unit is in no case stored and is ignored by the sensor.
The value of the verification parameter can be set as well. The limits of the verification parameter VPA1 are the same as defined in register 3114/8, the min is 0 (mS/cm) and the max is 50 (mS/cm).

The first parameter in register 3694/6 is not relevant and is ignored by the sensor.

VPA1 can take values between 0 and 50.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (float)	Modbus function code	Read access	Write access
3694	6	Not relevant	Unit	Verification Parameter Air Pressure value	3, 4, 16	U/A/S	S

Table 27 Example to set the value of the verification parameter 1 to 10 mS/cm

Command: VPA1 – Set Value		Modbus address: **3708**	Length: **6**	Type: **16** Write
Parameter:	VPA1 - Not relevant	VPA1 - Unit	VPA1 – Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x00000400**	**10**	

2.9.2 VPA2 – Pressure

In register 3700, a plain text ASCII description of Verification Parameter VPA2 is given. It returns "Pressure".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3700	8	Description of Verification Parameter	3, 4	U/A/S	None

In register 3708, Verification Parameter Pressure value is given.
By reading register 3708/6 the active physical unit and the current value values can be read.

In register 3144, the available physical units for PA2 are defined. The only one available unit here is mbar (0x00800000). For the definition of the physical units see Table 15.
Therefore, the unit for VPA2 is the same as defined for PA2.
The unit is always mbar (0x00800000) and the first parameter is always zero and is not relevant

By writing to register 3708/6, a selection of an incorrect unit has no influence on the written value and is in no case stored and is ignored by the sensor.
The value of the verification parameter can be set as well. The limits of the verification parameter VPA2 are the same as defined in register 3146/8, the min is 10 (mbar) and the max is 12000 (mbar).

The first parameter in register 3708/6 is not relevant and is ignored by the sensor.

VPA2 can take values between 10 and 12000.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (float)	Modbus function code	Read access	Write access
3708	6	Not relevant	Unit	Verification Parameter Air Pressure value	3, 4, 16	U/A/S	S

Table 28 Example to set the value of the verification parameter 2 to 200 mbar

Command: VPA2 – Set Value	Modbus address: **3708**	Length: **6**	Type: **16**	Write
Parameter:	VPA2 - Not relevant	VPA2 - Unit	VPA2 – Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x00800000**	**200**	

2.9.3 VPA3 – Humidity

In register 3714, a plain text ASCII description of Verification Parameter VPA3 is given. It returns "Humidity".

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3714	8	Description of Verification Parameter	3, 4	U/A/S	none

In register 3722, Verification Parameter Humidity value is given.
By reading register 3722/6 the active physical unit and the current value values can be read.

In register 3176, the available physical units for PA3 are defined. The only one available unit here is percent (0x20000000). For the definition of the physical units see Table 15.
Therefore, the unit for VPA3 is the same as defined for PA3.
The unit is always percent (0x20000000) and the first parameter is always zero and is not relevant

By writing to register 3722/6, a selection of an incorrect unit has no influence on the written value and is in no case stored and is ignored by the sensor.
The value of the verification parameter can be set as well. The limits of the verification parameter VPA3 are the same as defined in register 3178/8, the min is 0 (%) and the max is 100 (%).

The first parameter in register 3722/6 is not relevant and is ignored by the sensor.

VPA3 can take values between 0 and 100.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (float)	Modbus function code	Read access	Write access
3722	6	Not relevant	Unit	Verification Parameter Humidity value	3, 4, 16	U/A/S	S

Table 29 Example to set the value of the verification parameter 3 to 10 %

Command: VPA3 – Set Value	Modbus address: **3708**	Length: **6**	Type: **16**	Write
Parameter:	VPA3 - Not relevant	VPA3 - Unit	VPA3 – Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x20000000**	**10**	

2.10 Calibration

Note:

The VisiFerm RS485 is designed to allow backward-compatible calibration. For details about the calibration, refer to the VisiFerm DO Arc Sensors Modbus RTU Programmer's Manual (REF 624179) on the Hamilton website (www.hamiltoncompany.com).

2.10.1 Available Calibration Points

In register 10256, the available number of Calibration Points (CP) for Primary Measurement Channel 1 (PMC1) are defined.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
10256	2	Available number of CP for PMC1 (see Table 30)	3, 4	U/A/S	none

Table 30 Bitwise definition of CP1 to CP6

Code (Hex)	Description	Definition in VisiFerm RS485
0x02	CP1	Calibration low point
0x04	CP2	Calibration high point
0x40	CP6	Product calibration

Table 31 Example to read the available CPs

Command: Available cali points		Modbus address: **10256**	Length: **2**	Type: **3** Read
Parameter:	Points			
Format:	Hex			
Value:	**0x46**			

The hex value 0x46 in Table 31 corresponds to 0x02 (CP1) + 0x04 (CP2) + 0x40 (CP6).

As shown in Figure 23 the VisiFerm RS485 sensor allow 2 calibration points (CP1 and CP2) for the standard calibration.
As shown in Figure 24 the product calibration with CP6 is used to adjust the standard calibration function to specific process conditions.

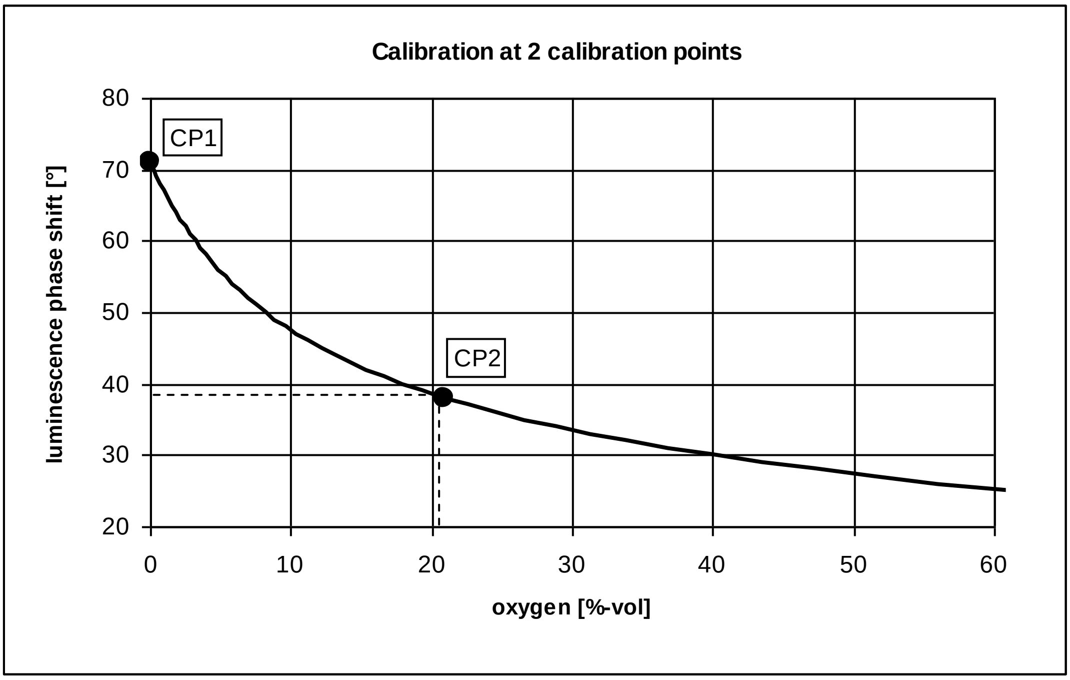


Figure 23 Standard 2-Point Calibration

2.10.2 Definitions of Calibration Points

2.10.2.1 Calibration Unit

The available calibration units for CP1, CP2 and CP6 is defined in register 10272.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
10272	2	Available calibration units, see chapter 2.5.1	3, 4	U/A/S	none
10274	2	Selected physical unit for calibration, see chapter 2.5.1	3, 4	U/A/S	S

In register 10272, the available physical units for calibration are defined. The available physical units for Calibration: 0x108000F0 → ppm gas, mbar, mg/l ppm, ug/l ppb, %-sat and %-vol

In register 10274, the active physical unit for the calibration can be selected, by choosing one of the physical units that are defined in register 10272.
Selecting an invalid unit code will leave the current unit unchanged.

Table 32 Example to set the physical calibration unit to %-vol (0x00000010)

Command: Calibration unit		Modbus address: **10274**	Length: **2**	Type: **16** Write
Parameter:	Unit			
Format:	Hex			
Value:	**0x00000010**			

Note:
A change of the calibration unit has no impact on the PMC1 unit.

2.10.2.2 Calibration limits

The min and max limits for calibration point CP1, CP2 and CP6 are defined in register 10318, 11038 and 13918.

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
10318	4	Min value for CP1 (in the physical unit as defined in register 10274)	Max value for CP1 (in the physical unit as defined in register 10274)	3, 4	U/A/S	none
11038	4	Min value for CP2 (in the physical unit as defined in register 10274)	Max value for CP2 (in the physical unit as defined in register 10274)	3, 4	U/A/S	none
13918	4	Min value for CP6 (in the physical unit as defined in register 10274)	Max value for CP6 (in the physical unit as defined in register 10274)	3, 4	U/A/S	none

Note:
When changing the active physical unit for PMC1 (using register 2090) or the calibration unit (using register 10274), the min and max value in register 10318, 11038 and 13918 will be updated automatically to the new physical unit. Temperature, atmospheric pressure and salinity are compensated.

2.10.2.3 Calibration stability criteria

When initiating the calibration at CP1 and CP2, the measured phase and temperature must be stable for at least 100 seconds. The stability criteria are defined in register 10278:

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
10278	4	Max. Drift PMC1 CO2 [mbar/min]	Max. Drift PMC6 Temperature [K/min]	3, 4, 16	U/A/S	S

Attention:
The stability criteria defined in register 10278 is valid for CP1 and CP2 only, but NOT for CP6.

2.10.2.4 Calibration Parameters and Coefficients

In register 10276, available calibration parameters and calibration coefficients are defined. Bitmask is valid for calibration point CP1, CP2 and CP6.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
10276	2	Available calibration parameters and calibration coefficients, see Table 33	3, 4	U/A/S	none

The available calibration parameters and calibration coefficients has a bit mask of 0x01C001FF:

- CPA1 (Calibration parameter index 1) – CPA9 (Calibration parameter index 9)
- CCO1 (Calibration coefficient index 1) – CCO3 (Calibration coefficient index 3)

Table 33 Bitwise definition of available calibration parameters and calibration coefficients.

Code (Hex)	Definition
0x00000001	CPA1 (Calibration parameter index 1)
0x00000002	CPA2 (Calibration parameter index 2)
0x00000004	CPA3 (Calibration parameter index 3)
0x00000008	CPA4 (Calibration parameter index 4)
0x00000010	CPA5 (Calibration parameter index 5)
0x00000020	CPA6 (Calibration parameter index 6)
0x00000040	CPA7 (Calibration parameter index 7)
0x00000080	CPA8 (Calibration parameter index 8)
0x00000100	CPA9 (Calibration parameter index 9)
0x00400000	CCO1 (Calibration coefficient index 1)
0x00800000	CCO2 (Calibration coefficient index 2)
0x01000000	CCO3 (Calibration coefficient index 3)

2.10.2.4.1 CPA1 - Measured value

At the time of a valid CP1, CP2 or CP6 calibration, the current luminescence shift value is stored within CPA1.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Calibration point	Modbus function code	Read access	Write access
10328	8	Description of CPA1	CP1	3, 4	U/A/S	none
11048	8	Description of CPA1	CP2	3, 4	U/A/S	none
13928	8	Description of CPA1	CP6	3, 4	U/A/S	none

In register 10328 for CP1, register 11048 for CP2 and register 13928 for CP6, a plain text ASCII description of CPA1 is given. CPA1 for VisiFerm RS485 is called “Measured value”.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (float)	Calibration point	Modbus function code	Read access	Write access
10336	6	Not relevant	Unit	Value	CP1	3, 4	U/A/S	none
11056	6	Not relevant	Unit	Value	CP2	3, 4	U/A/S	none
13936	6	Not relevant	Unit	Value	CP6	3, 4	U/A/S	none

From the last valid CP1, CP2 or CP6 calibration, register 10336 for CP1, register 11056 for CP2 and register 13936 for CP6 can be used to read the Phase values at that time with the fixed unit ° (0x08000000).

Note:
The first parameter is not relevant and is always zero.

2.10.2.4.2 CPA2 - Assigned value

At the time of a valid CP1, CP2 or CP6 calibration, the assigned calibration value (oxygen concentration) is stored within CPA2.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Calibration point	Modbus function code	Read access	Write access
10360	8	Description of CPA2	CP1	3, 4	U/A/S	none
11080	8	Description of CPA2	CP2	3, 4	U/A/S	none
13960	8	Description of CPA2	CP6	3, 4	U/A/S	none

In register 10360 for CP1, register 11080 for CP2 and register 13960 for CP6, a plain text ASCII description of CPA2 is given. CPA2 for VisiFerm RS485 is called “Assigned value”.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (float)	Calibration point	Modbus function code	Read access	Write access
10368	6	Not relevant	Unit	Value	CP1	3, 4	U/A/S	none
11088	6	Not relevant	Unit	Value	CP2	3, 4	U/A/S	none
13968	6	Not relevant	Unit	Value	CP6	3, 4	U/A/S	none

From the last valid CP1, CP2 or CP6 calibration, register 10368 for CP1, register 11088 for CP2 and register 13968 for CP6 can be used to read the assigned values with the calibration unit, set at that time.
In register 10272, the available physical units for calibration are defined, see chapter 2.10.2.1.

Note:
The first parameter is not relevant and is always zero.

2.10.2.4.3 CPA3 - Temperature

At the time of a valid CP1, CP2 or CP6 calibration, the current temperature value is stored within CPA3.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Calibration point	Modbus function code	Read access	Write access
10392	8	Description of CPA3	CP1	3, 4	U/A/S	none
11112	8	Description of CPA3	CP2	3, 4	U/A/S	none
13992	8	Description of CPA3	CP6	3, 4	U/A/S	none

In register 10392 for CP1, register 11112 for CP2 and register 13992 for CP6, a plain text ASCII description of CPA3 is given. CPA3 for VisiFerm RS485 is called "Temperature".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (float)	Calibration point	Modbus function code	Read access	Write access
10400	6	Not relevant	Unit	Value	CP1	3, 4	U/A/S	none
11120	6	Not relevant	Unit	Value	CP2	3, 4	U/A/S	none
14000	6	Not relevant	Unit	Value	CP6	3, 4	U/A/S	none

From the last valid CP1, CP2 or CP6 calibration, register 10400 for CP1, register 11120 for CP2 and register 14000 for CP6 can be used to read the temperature values with the PMC6 unit, set at that time.
In register 2408, the available physical units for PMC6 are defined, see chapter 2.5.3.1.

Note:
The first parameter is not relevant and is always zero.

2.10.2.4.4 CPA4 - Number of calib.

At the time of a valid CP1, CP2 or CP6 calibration, the Amount of calibration value is stored within CPA4.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Calibration point	Modbus function code	Read access	Write access
10424	8	Description of CPA4	CP1	3, 4	U/A/S	none
11144	8	Description of CPA4	CP2	3, 4	U/A/S	none
14024	8	Description of CPA4	CP6	3, 4	U/A/S	none

In register 10328 for CP1, register 11048 for CP2 and register 13928 for CP6, a plain text ASCII description of CPA4 is given. CPA4 for VisiFerm RS485 is called "Number of calib.".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (uint)	Calibration point	Modbus function code	Read access	Write access
10432	6	Not relevant	Unit	Value	CP1	3, 4	U/A/S	none
11152	6	Not relevant	Unit	Value	CP2	3, 4	U/A/S	none
14032	6	Not relevant	Unit	Value	CP6	3, 4	U/A/S	none

From the last valid CP1, CP2 or CP6 calibration, register 10336 for CP1, register 11056 for CP2 and register 13936 for CP6 can be used to read the Amount of calibration values at that time with no unit (0x00000001).

Note:
The first parameter is not relevant and is always zero.

Note:
The calibration counter is only incremented when CP1 and CP2 are calibrated. In case of CP6 the counter value will be incremented after a successful assign step (second step of CP6).

2.10.2.4.5 CPA5 - Operating hours

At the time of a valid CP1, CP2 or CP6 calibration, the sensor operating hours value is stored within CPA5.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Calibration point	Modbus function code	Read access	Write access
10456	8	Description of CPA5	CP1	3, 4	U/A/S	none
11176	8	Description of CPA5	CP2	3, 4	U/A/S	none
14056	8	Description of CPA5	CP6	3, 4	U/A/S	none

In register 10456 for CP1, register 11176 for CP2 and register 14056 for CP6, a plain text ASCII description of CPA5 is given. CPA5 for VisiFerm RS485 is called "Operating hours".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (uint)	Calibration point	Modbus function code	Read access	Write access
10432	6	Not relevant	Unit	Value	CP1	3, 4	U/A/S	none
11152	6	Not relevant	Unit	Value	CP2	3, 4	U/A/S	none
14032	6	Not relevant	Unit	Value	CP6	3, 4	U/A/S	none

From the last valid CP1, CP2 or CP6 calibration, register 10432 for CP1, register 11152 for CP2 and register 14032 for CP6 can be used to read the sensor operating hours values at that time with no unit (0x00000001).

Note:
The first parameter is not relevant and is always zero.

Note:
The "operating hour" for CP6 is the moment of the "initial measurement" (first step of CP6).

2.10.2.4.6 CPA6 - Time stamp

At the time of a valid CP1, CP2 or CP6 calibration, the sensor Time stamp (the current system time, see chapter 2.11.2) value is stored within CPA6.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Calibration point	Modbus function code	Read access	Write access
10488	8	Description of CPA6	CP1	3, 4	U/A/S	none
11208	8	Description of CPA6	CP2	3, 4	U/A/S	none
14088	8	Description of CPA6	CP6	3, 4	U/A/S	none

In register 10488 for CP1, register 11208 for CP2 and register 14088 for CP6, a plain text ASCII description of CPA6 is given. CPA6 for VisiFerm RS485 is called "Time stamp".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (uint)	Calibration point	Modbus function code	Read access	Write access
10496	6	Not relevant	Unit	Value	CP1	3, 4	U/A/S	none
11216	6	Not relevant	Unit	Value	CP2	3, 4	U/A/S	none
14096	6	Not relevant	Unit	Value	CP6	3, 4	U/A/S	none

From the last valid CP1, CP2 or CP6 calibration, register 10496 for CP1, register 11216 for CP2 and register 14096 for CP6 can be used to read the sensor Time stamp values at that time with no unit (0x00000001).

Note:

The first parameter is not relevant and is always zero.

Note:

For CP6, the system time is set during the action "initial measurement". The system time is explained in chapter 2.11.2.

According to Table 34 the Time Stamp value has no unit (0x00000001), the value is 1614089002 (no unit), means the initial measurement of the product calibration has been performed on February 23th 2021 at 15:03.

Table 34 Example to read the unit and value of CPA6 (Time Stamp) of CP6

Command: Time Stamp CP6		Modbus address: 14096	Length: 6	Type: **3** Read
Parameter:	Cali. Par.6 - Not relevant	Cali. Par.6 - Unit	Cali. Par.6 - Value	
Format:	Hex	Hex	Decimal	
Value:	**0x00000000**	**0x00000001**	**1614089002**	

2.10.2.5 CPA7 - Salinity

At the time of a valid CP1, CP2 or CP6 calibration the current adjusted PA1 value is stored within CPA7.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Calibration point	Modbus function code	Read access	Write access
10520	8	Description of CPA7	CP1	3, 4	U/A/S	none
11240	8	Description of CPA7	CP2	3, 4	U/A/S	none
14120	8	Description of CPA7	CP6	3, 4	U/A/S	none

In register 10520 for CP1, register 11240 for CP2 and register 14120 for CP6, a plain text ASCII description of CPA7 is given. CPA7 for VisiFerm RS485 is called "Salinity".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (float)	Calibration point	Modbus function code	Read access	Write access
10528	6	Not relevant	Unit	Value	CP1	3, 4	U/A/S	none
11248	6	Not relevant	Unit	Value	CP2	3, 4	U/A/S	none
14128	6	Not relevant	Unit	Value	CP6	3, 4	U/A/S	none

From the last valid CP1, CP2 or CP6 calibration, register 10528 for CP1, register 11248 for CP2 and register 14128 for CP6 can be used to read the measurement parameter salinity values with the fixed unit mS/cm (0x00000400) set at that time.

Note:

The first parameter is not relevant and is always zero.

2.10.2.5.1 CPA8 - Pressure

At the time of a valid CP1, CP2 or CP6 calibration the current adjusted PA8 value is stored within CPA8.

When a new CPA8 value is entered, it is stored directly in the calibration point CP1, CP2 or CP6 and temporarily assigned to the regular Pressure value PA2 of the measurement parameter set. So that the dissolved oxygen measurement runs with the calibration parameter setting. The PA2 value in the measurement parameter set, is automatically reset to the original Pressure value after a calibration or after a sensor restart (see Example CPA8: Pressure).

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Calibration point	Modbus function code	Read access	Write access
10552	8	Description of CPA8	CP1	3, 4	U/A/S	none
11272	8	Description of CPA8	CP2	3, 4	U/A/S	none
14152	8	Description of CPA8	CP6	3, 4	U/A/S	none

In register 10552 for CP1, register 11272 for CP2 and register 14152 for CP6, a plain text ASCII description of CPA8 is given. CPA8 for VisiFerm RS485 is called “Pressure”.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (float)	Calibration point	Modbus function code	Read access	Write access
10560	6	Not relevant	Unit	Value	CP1	3, 4	U/A/S	S
11280	6	Not relevant	Unit	Value	CP2	3, 4	U/A/S	S
14160	6	Not relevant	Unit	Value	CP6	3, 4	U/A/S	S

From the last valid CP1, CP2 or CP6 calibration, register 10560 for CP1, register 11280 for CP2 and register 14160 for CP6 can be used to read the measurement parameter pressure values with the fixed unit mbar (0x00800000) set at that time.

Note:

The first parameter is not relevant and is always zero.

Example CPA8: Pressure

As shown in Table 35 the physical unit for calibration parameter 8 is mbar (0x00800000) and is fixed and cannot be changed and the value is 1013 (mbar).

Table 35 Example to read the unit and the value of CPA8 (pressure) of CP1

Command: CP1 – CPA8 Pressure value	Modbus address: **10560**	Length: **6**	Type: **3**	Read
Parameter:	Cali. Par.8 - Not relevant	Cali. Par.8 - Unit	Cali. Par.8 - Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x00800000**	**1013**	

As shown in Table 36 the unit is mbar (0x00800000), the value is 1013 (mbar), the min is 10 (mbar) and the max is 12000 (mbar).

Table 36 Example to read PA2

Command: PA2 – Pressure value		Modbus address: **3146**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Float	Float	Float
Value:	**0x00800000**	**1013**	**10**	**12000**

Before a new CP1 calibration is initiated, the momentary environmental pressure must be assigned to the CPA8 (pressure) and PA2 (pressure) is temporary assigned to this value. From that point on the dissolved oxygen measurement is using this setting.

As shown in Table 37, the unit for CP1 is set to mbar (0x00800000) and the value to 900 (mbar).

Table 37 Example to set the physical unit of CPA8 value (pressure) of CP 1

Command: CP1 – CPA8 Pressure value		Modbus address: **10560**	Length: **6**	Type: **16** Write
Parameter:	Cali. Par.8 - Not relevant	Cali. Par.8 - Unit	Cali. Par.8 - Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x00800000**	**900**	

As shown in Table 38 the unit is mbar (0x00800000), the value is 900 (mbar), the min is 10 (mbar) and the max is 12000 (mbar).

Table 38 Example to read PA2

Command: PA2 – Pressure value		Modbus address: **3146**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Float	Float	Float
Value:	**0x00800000**	**900**	**10**	**12000**

A new calibration is initiated at CP1 by writing to register 10314, whether successful or not, the PA2 (pressure) is reset to the origin value of 1013 mbar.

As shown in Table 39 the physical unit is mbar (0x00800000) and is fixed and cannot be changed and the value is 900 (mbar).

Table 39 Example to read the unit and value of CPA8 (pressure) of CP1

Command: CP1 – CPA8 Pressure value		Modbus address: **10560**	Length: **6**	Type: **3** Read
Parameter:	Cali. Par.8 - Not relevant	Cali. Par.8 - Unit	Cali. Par.8 - Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x00800000**	**900**	

As shown in Table 40, PA2 is automatically reset to the original Pressure value. The unit is mbar (0x00800000), the value is 1013 (mbar), the min is 10 (mbar) and the max is 12000 (mbar).

Table 40 Example to read PA2

Command: PA2 – Pressure value		Modbus address: **3146**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Float	Float	Float
Value:	**0x00800000**	**1013**	**10**	**12000**

2.10.2.5.2 CPA9 - Humidity

At the time of a valid CP1, CP2 or CP6 calibration the currently adjusted PA3 value is stored within CPA9.

When a new CPA9 value is entered, it is stored directly in the calibration point CP1, CP2 or CP6 and temporarily assigned to the regular humidity value PA3 of the measurement parameter set. So that the dissolved oxygen measurement runs with the calibration parameter setting. The PA3 value in the measurement parameter set, is automatically reset to the original humidity value after a calibration or after a sensor restart (see Example Calibration Parameter 9: Humidity).

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Calibration point	Modbus function code	Read access	Write access
10584	8	Description of CPA9	CP1	3, 4	U/A/S	none
11304	8	Description of CPA9	CP2	3, 4	U/A/S	none
14184	8	Description of CPA9	CP6	3, 4	U/A/S	none

In register 10584 for CP1, register 11304 for CP2 and register 14184 for CP6, a plain text ASCII description of CPA9 is given. CPA9 for VisiFerm RS485 is called "Humidity".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (float)	Calibration point	Modbus function code	Read access	Write access
10592	6	Not relevant	Unit	Value	CP1	3, 4	U/A/S	S
11312	6	Not relevant	Unit	Value	CP2	3, 4	U/A/S	S
14192	6	Not relevant	Unit	Value	CP6	3, 4	U/A/S	S

From the last valid CP1, CP2 or CP6 calibration, register 10592 for CP1, register 11312 for CP2 and register 14192 for CP6 can be used to read the measurement parameter humidity values with the fixed unit % (0x20000000) set at that time.

Note:

The first parameter is not relevant and is always zero.

Example Calibration Parameter 9: Humidity

As shown in Table 41 the physical unit for CPA9 is percent (0x20000000) and is fixed and cannot be changed and the value is 100 (percent).

Table 41 Example to read the unit and value of CPA9 (humidity) of CP2

Command: CP2 – CPA9 Humidity value	Modbus address: **11312**	Length: **6**	Type: **3**	Read
Parameter:	Cali. Par.9 - Not relevant	Cali. Par.9 - Unit	Cali. Par.9 - Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x20000000**	**100**	

As shown in Table 42 the unit for PA3 is percent (0x20000000), the value is 100 (percent), the min is 0 (percent) and the max is 100 (percent).

Table 42 Example to read PA3

Command: PA3 – Humidity value		Modbus address: **3178**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Float	Float	Float
Value:	**0x20000000**	**100**	**0**	**100**

Before a new CP2 calibration is initiated, the momentary environmental humidity must be assigned to the CPA9 humidity and also the PA3 humidity is temporary assigned with this value. From that point on the dissolved oxygen measurement is using this setting.

As shown in Table 43 the physical unit is set to percent (0x20000000) and the value to 0 (percent).

Table 43 Example to set the unit and value of CPA9 (humidity) of CP2

Command: CP2 – CPA9 Humidity value		Modbus address: **11312**	Length: **6**	Type: **16** Write
Parameter:	Cali. Par.9- Not relevant	Cali. Par.9 - Unit	Cali. Par.9 - Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x20000000**	**0**	

As shown in Table 44 the unit is percent (0x20000000), the value is 0 (percent), the min is 0 (percent) and the max is 100 (percent).

Table 44 Example to read PA3

Command: PA3 – Humidity value		Modbus address: **3178**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Float	Float	Float
Value:	**0x20000000**	**0**	**0**	**100**

A new calibration is initiated at CP2 by writing to register 11312, whether successful or not, the PA3 humidity must be reset to the origin value of 100 %.

As shown in Table 45 the physical unit is percent (0x20000000) and is fixed and cannot be changed and the value is 0 (percent).

Table 45 Example to read the unit and value of CPA9 (humidity) of CP2

Command: CP2 – CPA9 Humidity value		Modbus address: **11312**	Length: **6**	Type: **3** Read
Parameter:	Cali. Par.9 - Not relevant	Cali. Par.9 - Unit	Cali. Par.9 - Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x20000000**	**0**	

As shown in Table 46, PA3 is automatically reset to the original humidity value. The unit is percent (0x20000000), the value is 100 (percent), the min is 0 (percent) and the max is 100 (percent).

Table 46 Example to read PA3

Command: PA3 – Humidity value		Modbus address: **3178**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Float	Float	Float
Value:	**0x20000000**	**100**	**0**	**100**

2.10.2.5.3 CCO1…CCO3 – Calibration Coefficients

At the time of a valid CP1, CP2 or CP6 calibration the calibration coefficients Phi0 at 25°C (CCO1) and the corresponding Stern-Volmer (CCO2) values are stored.
The calibration coefficient Reference temperature (CCO3) is fixed to 25°C.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Modbus function code	Read access	Write access
14632	8	Description of CCO1	3, 4	U/A/S	none
14664	8	Description of CCO2	3, 4	U/A/S	none
14696	8	Description of CCO3	3, 4	U/A/S	none

In register 14632 a plain text ASCII description of CCO1 is given. CCO1 for VisiFerm RS485 is called "Phase 0".

In register 14664 a plain text ASCII description of CCO2 is given. CCO2 for VisiFerm RS485 is called "Stern-Volmer".

In register 14696 a plain text ASCII description of CCO3 is given. CCO3 for VisiFerm RS485 is called "Ref. Temperature".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (float)	Calibration Coefficient Index	Modbus function code	Read access	Write access
14640	6	Not relevant	Unit	Value	CCO1	3, 4	U/A/S	none
14672	6	Not relevant	Unit	Value	CCO2	3, 4	U/A/S	none
14704	6	Not relevant	Unit	Value	CCO3	3, 4	U/A/S	none

From the last valid CP1, CP2 or CP6 calibration, register 14640 can be used to read the calibration coefficient Phase 0 value with the fixed unit ° (0x08000000).

From the last valid CP1, CP2 or CP6 calibration, register 14672 can be used to read the calibration coefficient Stern-Volmer value with the fixed unit none (0x00000001).

Register 14704 can be used to read the calibration coefficient Reference Temperature value with the fixed unit °C (0x00000004). The calibration coefficient Reference temperature (CCO3) is fixed to 25°C.

Note:
The first parameter is not relevant and is always zero.

2.10.3 Calibration Procedure

2.10.3.1 Calibration at CP1 and CP2 (Standard Calibration)

VisiFerm RS485 has a unique calibration routine. When initiating the calibration, the data set of the VisiFerm RS485 is automatically traced back within the last 100 seconds and a decision is made immediately if the calibration is successful or not. The operator therefore gets an immediate result. The criteria for a successful calibration are:

- the stability of phase and temperature over the last 100 seconds
- the phase is in a reasonable phase window
- the oxygen content is in the limits defined for CP1 / CP2

Attention:

If the Measurement Hold Mode is in Hold Mode or Off, see chapter 2.6, the initial measurement command has no effect.

Attention:

It is important that VisiFerm RS485 is in a defined calibration media at least 100 seconds BEFORE the calibration is started.

If the sensor has a measurement interval greater than 3 and / or the temperature is out of the user defined measurement temperature range, the procedure is as follows:

1. Send calibration command to the sensor. The sensor will return "drift oxygen" (0x2000 for CP1 and CP2 in the calibration status register)
2. Send calibration command after at least 100s again to the sensor. If the stability is ok, the sensor returns "calibration successful" (0x00 in the calibration status register), if the stability is not ok, the sensor sets the corresponding bit in the calibration status register (register 10312 for CP1 or register 11032 for CP2).

In the previous case, the sensor temporarily expands the measurement temperature range to the maximum allowed for the sensor and sets the measurement interval to 3 if greater than 3. 10 minutes after the last calibration command or after a power up, these settings are reset and the sensor runs with the originally entered values.

The calibration is initiated at CP1 by writing to register 10314 and at CP2 by writing to register 11034.

The calibration value (dissolved oxygen value) must be given in the physical unit defined within register 10274.

Automatic Mode:
By entering 0 as calibration value the automatic calibration for the respecting calibration point will be started, which calibrates at CP1 by 0 %-vol oxygen (low point) and at CP2 by 20.95 %-vol oxygen = in air (high point).

Manual Mode:
By entering a calibration value of unequal zero, the manual calibration for the respecting calibration point will be started. The entered calibration value for the respecting calibration point must be inside the defined limits, for CP1 it is defined in register 10318 and for CP2 it is defined in register 11038. If the entered calibration value is not within the defined limits, the sensor will return either "below calibration range" (0x40) or "above calibration range" (0x80) in the calibration status register for the respecting calibration point.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
10314	4	Not relevant	Calibration value	3, 4, 16	none	S
11034	4	Not relevant	Calibration value	3, 4, 16	none	S

Attention:
CP1 is fixed to a calibration in an oxygen-free medium (0 %-vol oxygen) – low point, and CP2 is fixed to a calibration between 2.045 %-vol (20mbar) and 56.242 %-vol (550mbar) oxygen – high point.
There is an automatic mode for both CP1 and CP2 when using 0 as parameter. In this mode, the operator declares that CP1 is performed in oxygen-free media, and CP2 in air or air-saturated water. The operator does not need to care about the physical units that are currently active.

2.10.3.2 Calibration Point 6 (Product Calibration)

The product calibration is a process to adjust the measurement of a correctly calibrated VisiFerm RS485 sensor to specific process conditions.
Product calibration is a two-stage process:

1. An initial measurement is performed while the operator takes a sample of the process solution. At that time point the VisiFerm RS485 sensor stores its raw measurement value, temperature and operating hour in the memory.

   While the operator takes the sample to the analytics lab for reference analysis the VisiFerm RS485 sensor is still running on its prior standard calibration (CP1 and CP2) while the initial measurement data for the ongoing product calibration is kept in the VisiFerm RS485 sensors memory.

2. When the result of the reference analysis is available, this value is assigned to a second time point to the former initial measurement data, which is stored in the VisiFerm RS485 sensor.

   The sensor is now, after valid assignment, running on a calibration function which is compensated for the correct process conditions. The product calibration (CP6) is now active.

Performing a cancel command for the product calibration (CP6) brings the sensor back to its stored standard calibration (CP1 and CP2).
If a product calibration is active and a standard calibration (CP1 or CP2) is performed, then the product calibration (CP6) is cancelled.
If the operator needs to adjust an active product calibration (old CP6) by a new product calibration (new CP6) the above process applies in the same way. After initial measurement the VisiFerm RS485 sensor is running on the first product calibration (old CP6) until a valid assignment has been done (new CP6).

What happens to the VisiFerm RS485 calibration function upon product calibration (CP6)?
A product calibration for VisiFerm RS485 sensor corresponds to a manual calibration at CP2. On active product calibration (CP6) the VisiFerm RS485 calibration function is calculated from the data of CP1 and from the data of the product calibration (CP6).
The product calibration procedure allows larger measurement deviations compared to the standard calibration.

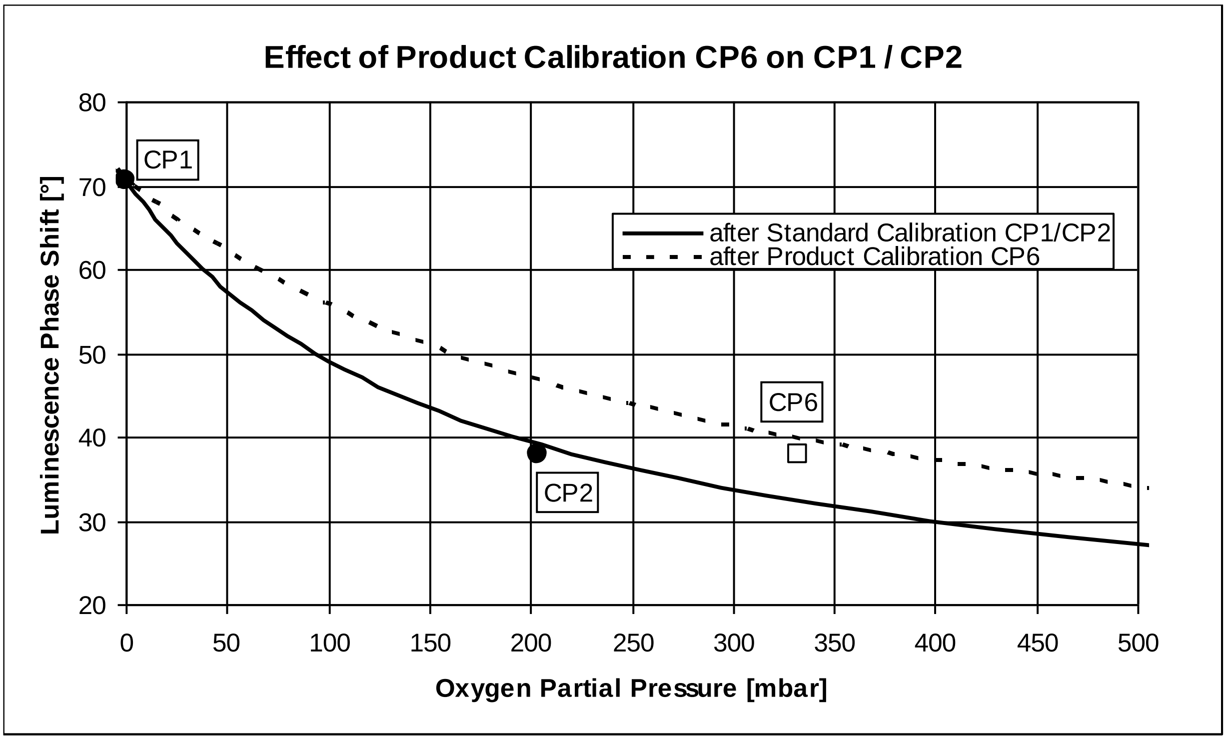


Figure 24 Effect of the product calibration CP6 on an existing standard calibration function defined by CP1 and CP2.

Example:
The operator starts with a standard calibration with calibration points CP1 and CP2:

Calibration point	Oxygen value in mbar	Temperature in °C	Measured phase in °
CP1	0	27.77	70.7
CP2	203.92	28.71	37.98

The sensor internally calculates the calibration function, using the calibration points **CP1** and **CP2**. The resulting calibration function, compensated to the standard temperature 25°C, is shown as a straight line. The calibration function is described by two parameters: the phase at zero oxygen and the Stern-Volmer coefficient (these two values can be read in register 14640 and register 14672, see chapter 2.10.2.5.3).
Some weeks later, the operator believes that the standard calibration function is not correct anymore. As the process is running and he is not able to perform a standard calibration under defined conditions in the lab, he decides to perform a product calibration CP6, in other words adjusting the standard calibration function to the process conditions:

Calibration point	Oxygen value in mbar	Temperature in °C	Measured phase in °
CP6	332	28.79	37.99

The sensor internally recalculates the calibration function at 25°C, using the calibration points **CP1** and **CP6.** The new calibration function, compensated to the standard temperature 25°C, is shown as a dotted line.

Another special feature of this calibration point is to switch off and back on again a product calibration. These functions are called “restore standard calibration” and “restore product calibration”.

The sensor's internal criteria for a successful product calibration are:
- the sensor is currently in an environment corresponding to the VisiFerm RS485 measurement range.
- the oxygen content is within the calibration limits defined for CP6 (see above)
- the parameters for the product calibration defined by CP1 and CP6 are in the following range:
  - the phase at zero oxygen remains the same (since it is defined by CP1)
  - the Stern-Volmer coefficient does not deviate from the one defined by prior (e.g. CP1/CP2) calibration by more than ±40 %.

The different functionalities of product calibration (CP6) are accessible through the following sensor commands:
- Initial measurement
- Assignment
- Cancel
- Restore standard calibration
- Restore product calibration

All commands are executed by writing a command to the register 13914. The command codes are defined according to Table 47.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
13914	2	Code as defined in Table 47	Calibration value	3, 4, 16	U/A/S	S

Table 47 Definition of the commands related to the product calibration

Code (Hex)	Definition of commands
0x0010	Perform initial measurement
0x0020	Assign product calibration
0x0040	Cancel an active product calibration
0x0080	Restore a standard calibration from an active product calibration
0x0100	Restore a product calibration from an active standard calibration

2.10.3.2.1 Product calibration: Initial measurement

Upon process sample collection for laboratory analysis the command for initial measurement is sent to the sensor.
This is achieved by writing the command 0x0010 to register 13914 which performs the initial measurement and stores the corresponding measurement values in the sensor.

Table 48 Example to start the product calibration procedure

Command: CP6: Initial measurement	Modbus address: **13914**	Length: **4**	Type: **16**	Write
Parameter:	Command	Value		
Format:	Hex	Float		
Value:	**0x00000010**	**0.0**		

Note:

The second parameter is for the product calibration initialisation not relevant and is ignored by the sensor. As default value during a product calibration initialisation, it is recommended to set the value to zero.

As shown in Table 49, after successful initial measurement the corresponding calibration status is "CP6: Initial measurement" (0x20000000, see also Table 47).

The sensor continues the measurement with the previous standard calibration.

Table 49 Example to read the current product calibration status

Command: CP6: Initial measurement		Modbus address: **13912**	Length: **2**	Type: **3** Read
Parameter:	Command			
Format:	Hex			
Value:	**0x20000000**			

Attention:
If the Measurement Hold Mode is in Hold Mode or Off, see chapter 2.6, the initial measurement command has no effect.

2.10.3.2.2 Product calibration: Assignment

After successful initial measurement a correct value must be assigned to the initially stored measurement data. As shown in Table 50, this is achieved by writing the dissolved oxygen value in the unit of PMC1 during initial measurement (here 195 mbar) to 13914.

Table 50 Example to assign a calibration value to the above performed initial measurement

Command: CP6: Assignment		Modbus address: **13914**	Length: **4**	Type: **16** Write
Parameter:	Command	Value		
Format:	Hex	Float		
Value:	**0x00000020**	**195**		

From now on the sensor is measuring using the here performed product calibration.

According to Table 51 the calibration status of the sensor is 0x50000000 meaning that a correct value has been assigned and that the product calibration is active (see Table 58).

Table 51 Example to read the current product calibration status, after performing a product calibration.

Command: CP6: Initial measurement		Modbus address: **13912**	Length: **2**	Type: **3** Read
Parameter:	Command			
Format:	Hex			
Value:	**0x50000000**			

2.10.3.2.3 Product calibration: Cancel

To cancel an active product calibration or an active initial measurement the command 0x00000040 is written to register 13914 (see Table 52). The calibration value is not considered in this product calibration cancel phase and the value is not saved within the sensor.

Table 52 Example to cancel an active product calibration or an initial measurement

Command: CP6: Cancel		Modbus address: **13914**	Length: **4**	Type: **16** Write
Parameter:	Command	Value		
Format:	Hex	Float		
Value:	**0x00000040**	**0.0**		

Performing this action, the product calibration or any initial measurements are canceled. The values of the prior product calibration are removed from the sensor's memory. From now on the sensor is measuring using its prior CP1 / CP2 standard calibration.

As shown in Table 53 after cancelling a product calibration the sensors calibration status will be reading 0x00000000 again (see Table 58).

Table 53 Example to read the current product calibration status

Command: CP6: Initial measurement	Modbus address: **13912**	Length: **2**	Type: **3**	Read
Parameter:	Command			
Format:	Hex			
Value:	**0x00000000**			

2.10.3.2.4 Product calibration: Restore standard calibration

If a product calibration is active this product calibration can be temporarily switched off by writing the command "restore standard calibration" (0x00000080) (see Table 58) to register 13914 (see Table 54). The calibration value is not considered in this restore standard calibration phase and the value is not saved within the sensor.
Performing this action, the values of the product calibration remain stored in the sensor's memory.

Table 54 Example to restore a standard calibration from an active product calibration

Command: CP6: Restore standard	Modbus address: **13914**	Length: **4**	Type: **16**	Write
Parameter:	Command	Value		
Format:	Hex	Float		
Value:	**0x00000080**	**0.0**		

From now on the sensor is measuring using its prior CP1 / CP2 standard calibration.
As shown in Table 55 the sensor's calibration status will be reading "CP6 assigned" (0x40000000) (see Table 58) meaning that a valid assignment for a product calibration is available in the sensor's memory.

Table 55 Example to read the current product calibration status after a restoring a standard calibration

Command: CP6: Initial measurement	Modbus address: **13912**	Length: **2**	Type: **3**	Read
Parameter:	Command			
Format:	Hex			
Value:	**0x40000000**			

2.10.3.2.5 Product calibration: Restore product calibration

If a valid but inactive product calibration is available in the sensor's memory, the calibration status is reading 0x40000000 ("CP 6 assigned", see Table 55). This stored product calibration can be restored or reactivated by writing command "restore product calibration" 0x00000100 (see Table 58) to register 13914 according to Table 56. The calibration value is not considered in this restore product calibration phase and the value is not saved within the sensor.

Table 56 Example to restore an available product calibration from an active standard calibration

Command: CP6: Restore product	Modbus address: **13914**	Length: **4**	Type: **16**	Write
Parameter:	Command	Value		
Format:	Hex	Float		
Value:	**0x00000100**	**0.0**		

If this command is performed without available product calibration in the sensors memory the sensor will respond with a Modbus exception since this command is not valid.

From now on the sensor is measuring using its prior CP6 product calibration. As shown in Table 57 the sensors calibration status will be reading 0x50000000 (corresponding to "CP6 assigned" and "CP6 active") again. (see Table 58)

Table 57 Example to read the current product calibration status, after a restoring a product calibration

Command: CP6: Initial measurement	Modbus address: **13912**	Length: **2**	Type: **3**	Read
Parameter:	Command			
Format:	Hex			
Value:	**0x50000000**			

2.10.4 Reading the Calibration Status

A calibration is not always successful. To analyze what has gone wrong, three different calibration status registers can be read:

- Register 10312 for CP1
- Register 11032 for CP2
- Register 13912 for CP6

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
10312	2	Status CP1 (see Table 58)	3, 4	U/A/S	none
11032	2	Status CP2 (see Table 58)	3, 4	U/A/S	none
13912	2	Status CP6 (see Table 58)	3, 4	U/A/S	none

Table 58 Definition of the calibration status for registers 10312, 11032 and 13912

Code (Hex)	Calibration Point relevant			Definition
	CP1	CP2	CP6	
0x00000000	X	X	X	calibration successful
0x00000040	X	X		Dissolved oxygen value to be calibrated at is too low (see register 10318 or register 11038)
0x00000080	X	X		Dissolved oxygen value to be calibrated at is too high (see register 10318 or register 11038)
0x00000100	X	X		current temperature reading is too low (see register 4616)
0x00000200	X	X		current temperature reading is too high (see register 4616)
0x00000400	X	X		The current luminescence shift value is too low for the carbon dioxide value to be calibrated.
0x00000800	X	X		The current luminescence shift value is too high for the carbon dioxide value to be calibrated.
0x00001000	X	X		Temperature reading during calibration is not stable (see register 10278)
0x00002000	X	X		Luminescence shift reading during calibration is not stable (see register 10278)
0x00004000			X	out of calibration range (wrong dissolved oxygen value entered)
0x00008000			X	out of range (luminescence shift value out of range)
0x10000000			X	active
0x20000000			X	initial measurement
0x40000000			X	assigned

Note:

Registers 10312 and 11032 contain the same information!

2.10.5 Special Commands for Calibration with VISICAL

The VISICAL calibration device allows calibration of VisiFerm RS485 sensors at CP1 or CP2. The VISICAL associated calibration parameters for CP1 and CP2 are those predefined and stored in corresponding registers of VisiFerm RS485 sensor.
Register 5164 defines the oxygen value for CP1 and register 5196 defines the oxygen value for CP2, which are only valid for use with VISICAL. The same calibration limits for the oxygen value are used as for standard calibration at CP1 and CP2 (register 10314 and 11034 respectively).

Attention:

- It is not possible to perform a product calibration using VISICAL.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
5180	2	Oxygen value at CP1 (physical unit is fixed to %-vol) (default: 0 %-vol)	3, 4, 16	U/A/S	S
5212	2	Oxygen value at CP2 (physical unit is fixed to %-vol) (default: 20.95 %-vol)	3, 4, 16	U/A/S	S

Figure 2.10.5.1: Definition of register 5180 for CP1 and 5212 for CP2 with VISICAL.

Command: VISICAL CP1		Modbus address: **5180**	Length: **2**	Type: **3** Read
Parameter:	Value [%-vol]			
Format:	Float			
Value:	**0**			

Figure 2.10.5.2: Example to read the oxygen value valid for CP1. It is 0 %-vol. Accordingly, the next time when a calibration is started using VISICAL at LOW, VisiFerm RS485 assumes that the oxygen value is 0 %-vol.

Command: VISICAL CP2		Modbus address: **5212**	Length: **2**	Type: **16** Write
Parameter:	Value [%-vol]			
Format:	Float			
Value:	**25**			

Figure 2.10.5.3: Example to set the oxygen value valid for CP2 to 25 %-vol.

Command: VISICAL CP2		Modbus address: **5212**	Length: **2**	Type: **3** Read
Parameter:	Value [%-vol]			
Format:	Float			
Value:	**25**			

Figure 2.10.5.4: Example to read the oxygen value valid for CP2. It is 25 %-vol. Accordingly, the next time when a calibration is started using VISICAL at HIGH, VisiFerm RS485 assumes that the oxygen value is 25 %-vol.

2.11 Sensor Status

2.11.1 Temperature Ranges

In registers 4608, 4612, 4616 and 4624 four different temperature ranges are defined:

- Operation is the maximum temperature range to which the sensor can be exposed to during operation and storage. If the current temperature is out of this range, the corresponding bit in the measurement status register is set, see chapter 2.5.4.
- Measurement – is the maximum allowable range where dissolved oxygen measurement is possible.
- Calibration – in this range the sensor can be calibrated.
- User defined measurement – the specialist can adjust the range in which dissolved oxygen reading is active. The user defined measurement temperature range is a sub range of the measurement temperature range.

Note: When performing a calibration i.e. CP1 or CP2, not CP6, the user defined measurement temperature range is temporarily set to the values of the measurement temperature range from register 4612. After 10 minutes after the last calibration command or after a power up, the user defined measurement temperature range in register 4624 is reset to the values the user has defined.

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
4608	4	Operating temperature min	Operating temperature max	3, 4	U/A/S	none
4612	4	Measurement temperature min	Measurement temperature max)	3, 4	U/A/S	none
4616	4	Calibration temperature min	Calibration temperature max	3, 4	U/A/S	none
4624	4	User defined measurement temperature min	User defined measurement temperature max	3, 4, 16	U/A/S	S

The unit of the temperatures is according to the selected unit of PMC6 (see 2.5.3.1 Definition of PMC6).

If operating- or the measurement temperature range is exceeded, the measurement status will be set accordingly (see chapter 2.5.4).

For VisiFerm RS485 the ranges are as follows:

- Operating temperature: -20 .. +140°C
- Measurement temperature: -20 .. +85°C
- Calibration temperature: +5 .. +50°C
- User defined measurement temperature: -20 .. +85°C (default values)

Note:

Temperature reading is active at any time, regardless of the current temperature.

2.11.2 Operating Hours, Counters and System Time

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
4676	6	Operating hours [h] (float)	Operating hours above max measurement temperature [h] (float)	Operating hours above max operating temperature [h] (float)	3, 4	U/A/S	none
4682	6	Number of Power ups (uint)	Number of Watchdog resets (uint)	Heartbeat (uint)	3, 4	U/A/S	none
4688	4	Number of SIP cycles (uint)	Number of CIP cycles (uint)		3, 4	U/A/S	none
4692	2	Number of autoclavings (uint)			3, 4, 16	U/A/S	S
8232	2	System Time Counter [s] (uint)			3, 4, 16	U/A/S	S

In register 4676 are stored:
- total operating hours
- operating hours above max measurement temperature (see chapter 2.11.1)
- the operating hours above max operating temperature (see chapter 2.11.1)

In register 4682 are stored:
- number of power ups
- number of watchdog resets
- number of heartbeats

In register 4688 are stored:
- number of sterilizations in place (SIP) (see chapter 2.11.6)
- number of cleanings in place (CIP) (see chapter 2.11.6)

In register 4692 is stored
- number of autoclavings
  This register has no effect on the sensor and is only for the user to store the number of autoclavings.

In register 8232 is stored
- system time counter.
  When the sensor is powered up, the system time is set to 0. A value between 0 and 2^{32} - 1 can be written into this register. From this value, the sensor increments this value every second. We recommend using as base date the so-called UNIX timestamp (hint: www.epochconverter.com) which starts at 1st of January 1970 GMT. Be sure to update this register if needed after every power up of the sensor.

Note:

Accuracy of the system time, if not updated by the operator: The deviation of the system time is less than one minute per week.

2.11.3 Warnings

A "Warning" is a notification message which still allows further functioning of the system. This message alerts the operator of a possible problem that could lead to uncertain results.

2.11.3.1 Currently Active Warnings

The currently active warnings are stored in register 4736. For the definition of warnings, see chapter 0.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (bitwise defined)	Reg7 / Reg8 (bitwise defined)	Modbus function code	Read access	Write access
4736	8	Active warnings measurement	Active warnings calibration and membrane	Active warnings interface	Active warnings hardware	3, 4	U/A/S	none

2.11.3.2 Definition of Warnings

Table 59 Definition of warnings "measurement".

<table>
<tr><th>Bit #</th><th>Code (Hex)</th><th>Description</th></tr>
<tr><td rowspan="2">0 (LSB)</td><td>0x01</td><td>PMC1 DO reading below lower limit</td></tr>
<tr><td colspan="2">The oxygen reading is too low (DO < 0%-sat). Make a new zero-point calibration.</td></tr>
<tr><td rowspan="2">1</td><td>0x02</td><td>PMC1 DO reading above upper limit</td></tr>
<tr><td colspan="2">The oxygen reading is too high (DO > 300%-sat). Either make a new calibration at CP2. If not successful, replace the sensor cap.</td></tr>
<tr><td rowspan="2">25</td><td>0x02000000</td><td>PMC6 T reading below lower limit</td></tr>
<tr><td colspan="2">The temperature is below the user defined measurement temperature range. If outside this range, the sensor will not perform DO readings.</td></tr>
<tr><td rowspan="2">26</td><td>0x04000000</td><td>PMC6 T reading above upper limit</td></tr>
<tr><td colspan="2">The temperature is above the user defined measurement temperature range. If outside this range, the sensor will not perform DO readings.</td></tr>
<tr><td rowspan="2">31</td><td>0x80000000</td><td>Measurement not running</td></tr>
<tr><td colspan="2">Causes that trigger this warning:
• Measurement Hold Mode is in Hold- or Off mode, see chapter 2.6.
• Sensor operating voltage range is not between 10-27 VDC
• The temperature measurement is outside the user defined temperature range, see chapter 2.11.1.</td></tr>
</table>

Table 60 Definition of warnings "calibration and membrane".

Bit #	Code (Hex)	Description
0 (LSB)	0x01	PMC1 DO calibration recommended
	Perform a calibration to ensure reliable measurement.	
2	0x04	PMC1 DO replace sensor cap
	The sensor cap of VisiFerm RS485 must be replaced and the sensor needs to be recalibrated with the new cap. This warning is active if the sensor cap quality is below 40%	

Table 61 Definition of warnings "interface".

Bit #	Code (Hex)	Description
6	0x40	ECS current set-point not met
	Reconfigure the ECS interface.	

Table 62 Definition of warnings "hardware".

Bit #	Code (Hex)	Description
0 (LSB)	0x01	Sensor supply voltage too low
	The sensor supply voltage is too low for the sensor to operate correctly. Ensure stable supply voltage within the sensor's specifications.	
1	0x02	Sensor supply voltage too high
	The sensor supply voltage is too high for the sensor to operate correctly. Ensure stable supply voltage within the sensor's specifications.	
9	0x0200	Replace Sensor recommended
	The Sensor Quality Indicator is below 40%. The quality of the sensor is sufficient for reliable measurement, but replacement of the sensor will be needed in near future	

2.11.4 Errors

An "Error" message indicates a serious problem of the sensor which does not allow further proper functioning of the sensor. This problem must be solved.

2.11.4.1 Currently Active Errors

The currently active errors are stored in register 4800.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (bitwise defined)	Reg7 / Reg8 (bitwise defined)	Modbus function code	Read access	Write access
4800	8	Active errors measure-ment	Active errors calibration and membrane	Active errors interface	Active errors hardware	3, 4	U/A/S	none

2.11.4.2 Definition of Errors

Table 63 Definition of errors "measurement".

Bit #	Code (Hex)	Description
0 (LSB)	0x00000001	PMC1 dissolved oxygen reading failure
	Sensor cap is missing or the PMC1 has failed. In latter case, please call our Technical support.	
1	0x00000002	PMC1 DO p(O2) exceeds air pressure
	Measured partial pressure of oxygen is higher than the air pressure set by the operator. Reconfigure the air pressure parameter (PA2).	
25	0x02000000	PMC6 T sensor defective
	The internal temperature sensor is defective.	

Table 64 Definition of errors "calibration and membrane".

Bit #	Code (Hex)	Description
0 (LSB)	0x01	PMC1 DO sensor cap missing
	The DO sensor cap has been removed. Do not place a sensor showing this error in a measurement solution. The sensor needs to be equipped with a sensor cap and calibrated to perform reliable measurement.	
1	0x02	Sensor failure (Sensor Cap Quality value < 10%)
	Sensor Cap is defective or Sensor Cap Quality Indicator is below 10%. The quality of the sensor cap is not sufficient for reliable measurement. Sensor cap needs to be replaced.	

Table 65 Definition of errors "interface".

Bit #	Code (Hex)	Description
		Not available

Table 66 Definition of errors "hardware".

Bit #	Code (Hex)	Description
0 (LSB)	0x000001	Sensor supply voltage far too low
	The sensor supply voltage is below 10V. Please check your power supply.	
1	0x000002	Sensor supply voltage far too high
	The sensor supply voltage is above 27V. Please check your power supply.	
2	0x000004	Temperature reading far below min
	The measured temperature is below the operation temperature (Reg. 4608)	
3	0x000008	Temperature reading far above max
	The measured temperature is above the operation temperature (Reg. 4608)	
9	0x000200	Sensor Defective
	Sensor is defective or Sensor Quality Indicator is below 10%. The quality of the sensor is not sufficient for reliable measurement. Sensor needs to be replaced.	
16	0x010000	Red channel failure
	Measurement channel failure. Please call our Technical Support.	
22	0x400000	EEPROM comm. (I2C) error Userend
	Internal I2C communication error Reset the sensor and try again. Please call our Technical Support.	
24	0x01000000	Internal communication (I2C) failure Userend
	Internal I2C communication error Reset the sensor and try again. Please call our Technical Support.	
25	0x02000000	Internal communication failure (frontend)
	No communication between Frontend and Userend. Reset the sensor and try again. Please call our Technical Support.	
26	0x04000000	Stackoverflow
	Internal memory failure Reset the sensor and try again. Please call our Technical Support.	

Note:

If an internal error occurs, reset the sensor and try again or get in contact with our Technical Support.

2.11.5 PMCs output in case of sensor error / warning

2.11.5.1 Measurement values - Exceeds Temperature range, and DO measurement errors

In case that the current measurement temperature exceeds the user defined temperature range, following warning bits are set:

Category	Code (Hex)	Description
Measurement Warning	0x02000000	T reading below lower limit
	0x04000000	T reading above upper limit
	0x80000000	Measurement not running

In case that the current measurement temperature exceeds the operating temperature range or the dissolved oxygen measurements is erroneous, following error bits must be set:

Category	Code (Hex)	Description
Hardware Error	0x00000004	Temperature reading far below min
	0x00000008	Temperature reading far above max
	0x00010000	Red channel failure
Calibration Error	0x00000001	DO sensor cap missing
Measurement Error	0x00000001	DO reading failure

The measurement output values for these cases are defined in Table 67.

Table 67 Measurement values (PMCs) - Exceeds Temperature range, and DO measurement errors

Bit #	Code (Hex)	Description	Definition	Measurement output values (float)
0 (LSB)	0x00000001	PMC1	DO	-999.0
5	0x00000020	PMC6	T (temperature measurement value)	Current temp. value

2.11.5.2 Measurement values – no measurement within the frontend is running

In case that the current supply voltage is not within the defined supply voltage range, following warning bits are set:

Category	Code (Hex)	Description
Hardware Warning	0x00000001	Sensor supply voltage too low
	0x00000002	Sensor supply voltage too high
Measurement Warning	0x80000000	Measurement not running

The measurement output values for these cases, are defined in Table 68.

Table 68 Measurement values (PMCs) in case no communication within the frontend is running

Bit #	Code (Hex)	Description	Definition	Measurement output values (float)
0 (LSB)	0x00000001	PMC1	TCD	-999.0
5	0x00000020	PMC6	T (temperature measurement value)	-999.0

2.11.5.3 Measurement values – Hardware related errors

In case that the current measurement temperature exceeds the operating temperature range or the dissolved oxygen measurements is erroneous, following error bits must be set:

Category	Code (Hex)	Description
Hardware Error	0x00000200	Sensor Defective
	0x00400000	EEPROM comm. (I2C) error
	0x01000000	Internal communication (I2C) failure
	0x02000000	Internal communication failure (frontend)
	0x04000000	Stackoverflow
Measurement Error	0x02000000	T sensor defective

The measurement output values for these cases, are defined in Table 69.

Table 69 Measurement values (PMCs) in case Hardware errors

Bit #	Code (Hex)	Description	Definition	Measurement output values (float)
0 (LSB)	0x00000001	PMC1	TCD	-999.0
5	0x00000020	PMC6	T (temperature measurement value)	-999.0

2.11.6 Reading Definition of SIP and CIP

VisiFerm RS485 is counting special cleaning events such as sterilizations or cleaning cycles by means of tracking typical temperature profiles (see chapter 2.11.2).

Register 4988 defines the temperature profile for SIP (sterilization in place) and register 4996 the temperature profile for CIP (cleaning in place). For the explanation the following values are given:

CIP temperature min: 80 °C　　CIP temperature max: 100 °C　　CIP time min: 30 minutes
SIP temperature min: 120 °C　　SIP temperature max: 140 °C　　SIP time min: 30 minutes

CIP / SIP time maximum values: 180 min

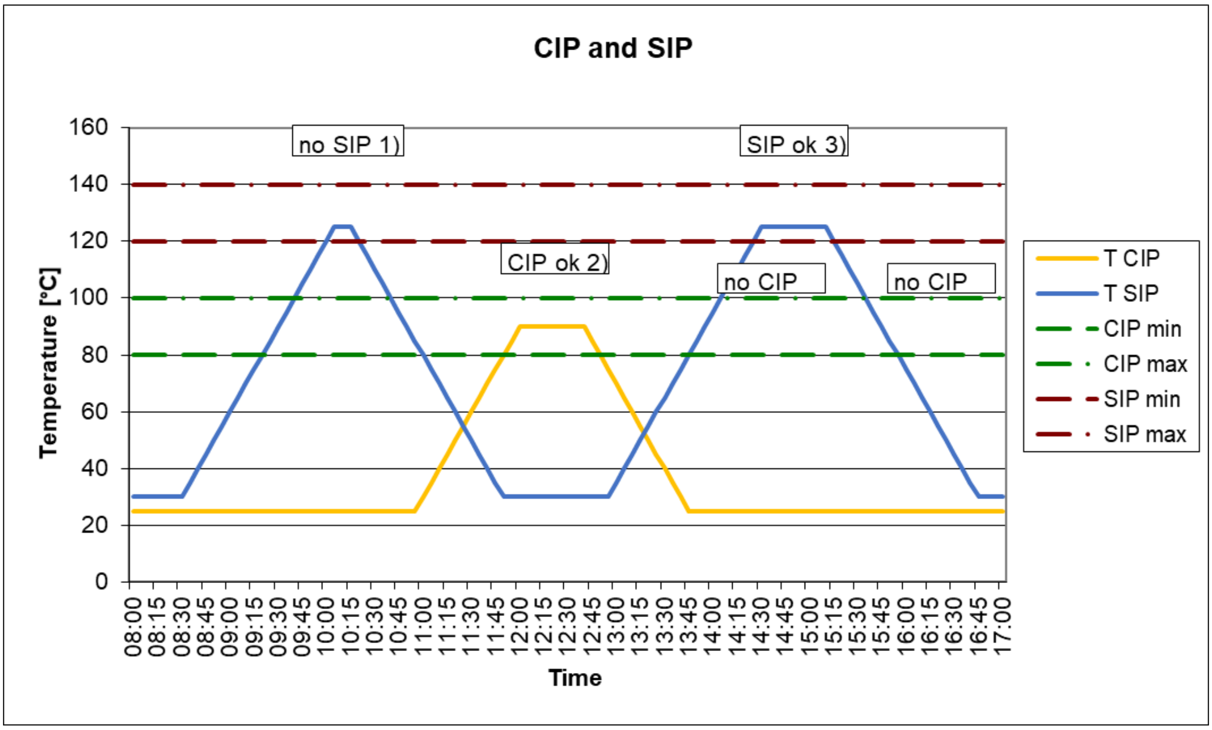


Figure 29: Definition of CIP and SIP cycles.
1) no SIP-cycle counted, because time too short less than 30 minutes.
2) CIP-cycle counted, because time greater than 30 minutes and in CIP temperature range.
3) SIP-cycle counted, because time greater than 30 minutes and in SIP temperature range.
4) no CIP-cycle counted, because of reaching the SIP-min limit.

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Reg7 / Reg8	Modbus function code	Read access	Write access
4988	8	SIP Tempera-ture min [°C]	SIP Tempera-ture max [°C]	SIP Process time min [min]	Empty	3, 4	U/A/S	S
4996	8	CIP Tempera-ture min [°C]	CIP Tempera--ture max [°C]	CIP Process time min [min]	Empty	3, 4	U/A/S	S

The unit of the temperatures is according to the selected unit of PMC6 (see 2.5.3.1 Definition of PMC6).

2.11.7 Quality Indicator

2.11.7.1 Reading the Sensor Cap Quality

In register 5472 with a command length of 2, the sensor cap quality (0-100%) is given in 10% percent steps. Hamilton recommends the replacement of the sensor at a value less than 40 % (see Table 60).

Start register	Number of registers	Reg1 / Reg2 (float)	Modbus function code	Read access	Write access
5472	2	Sensor Cap Quality [%]	3, 4	U/A/S	none

2.11.7.2 Reading the Measurement Quality Indicator

In register 5472 with a command length of 6, the sensor cap quality (0-100%) in 10% percent steps, the sensor quality (0-100%) in 10% percent steps and the measurement quality is given.
Hamilton recommends the replacement of the sensor if the sensor cap quality (see Table 60) or the sensor quality is less than 40 % (see Table 62).

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Modbus function code	Read access	Write access
5472	6	Sensor Cap Quality [%]	Sensor quality [%]	Measurement quality, see Table 70	3, 4	U/A/S	none

Table 70 Definition of measurement quality values

Value	Description
100	Good: => 40 % sensor quality (no actions)
50	Bad: < 40 % sensor quality (maintenance required)
0	Defect: < 10 % sensor quality (senser defective)

2.12 Sensor Identification and Information

2.12.1 General Information

General information about the sensor is available as shown in the Table below.

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Example of content	Modbus function code	Read access	Write access
1024	8	Userend FW Date	2024-01-08	3, 4	U/A/S	none
1032	8	Userend FW	ODOUM104	3, 4	U/A/S	none
1040	8	Userend BL Date	2022-05-16	3, 4	U/A/S	none
1048	8	Userend BL	BL5UX101	3, 4	U/A/S	none
1056	8	Userend Ref	10104849	3, 4	U/A/S	none
1064	8	Userend SN	1234	3, 4	U/A/S	none
1072	8	Userend (space holder)	not available	3, 4	U/A/S	none
1080	8	Userend (space holder)	not available	3, 4	U/A/S	none
1088	8	Frontend FW Date	2013-02-08	3, 4	U/A/S	none
1096	8	Frontend FW	ODOFJ001	3, 4	U/A/S	none
1104	8	Frontend BL Date	not available	3, 4	U/A/S	none
1112	8	Frontend BL	not available	3, 4	U/A/S	none
1120	8	Frontend Ref	not available	3, 4	U/A/S	none
1128	8	Frontend SN	not available	3, 4	U/A/S	none
1136	8	Frontend (space holder)	not available	3, 4	U/A/S	none
1144	8	Frontend (space holder)	not available	3, 4	U/A/S	none

2.12.2 Sensor Identification

Definition of registers containing sensor identification:

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Example of content	Modbus function code	Read access	Write access
1280	8	Sensor Ref	10118255/00	3, 4	U/A/S	none
1288	8	Sensor name	VisiFerm RS485	3, 4	U/A/S	none
1296	8	Sensor Lot	1354271	3, 4	U/A/S	none
1304	8	Sensor Lot date	2023-08-09	3, 4	U/A/S	none
1312	8	Sensor SN	2076	3, 4	U/A/S	none
1320	8	Manufacturer part 1	HAMILTON Bonaduz	3, 4	U/A/S	none
1328	8	Manufacturer part 2	AG Switzerland	3, 4	U/A/S	none
1336	8	Sensor type	ARC ODO Sensor	3, 4	U/A/S	none
1344	8	Power supply	10 - 27V 1.5W	3, 4	U/A/S	none
1352	8	Pressure range	10 - 12000mbar	3, 4	U/A/S	none
1360	8	Sensor ID	10118255-2076	3, 4	U/A/S	none
1368	8	a-length	120	3, 4	U/A/S	none
1376	8	(space holder)	not available	3, 4	U/A/S	none
1384	8	Electrical connection	VP 8.0	3, 4	U/A/S	none
1392	8	Process connection	PG 13.5	3, 4	U/A/S	none
1400	8	Sensing material	ODO H3	3, 4	U/A/S	none

2.12.3 Free User Memory Space

These registers can be used to store any customer specific information in the sensor. There are different registers which can be read by everybody, but only specific operators can write them.

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Example of content	Modbus function code	Read access	Write access
1536	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1544	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1552	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1560	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1568	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1576	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1584	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1592	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1600	8	Measuring Point	10118255-2076	3, 4, 16	U/A/S	S
1608	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1616	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1624	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1632	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1640	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1648	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1656	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1664	8	ext. OEM Sensor Name	*FREE_USERSPACE*	3, 4	U/A/S	none
1672	8	ext. OEM PartNumber	*FREE_USERSPACE*	3, 4	U/A/S	none
1680	8	ext. OEM Customer 1	*FREE_USERSPACE*	3, 4	U/A/S	none
1688	8	ext. OEM Customer 2	*FREE_USERSPACE*	3, 4	U/A/S	none
1696	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1704	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1712	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1720	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1728	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1736	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1744	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1752	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none

An important register is 1600, as it is the description of the measuring point. This information is used by ArcAir to identify individual sensors.

Attention:
The Free User Memory Space is located in a memory which allows in total max 1'000'000 write operations.

2.13 System Commands

2.13.1 Recall Sensor’s Factory Settings

Using register 8192 you can recall the sensor manufacturer values (interfaces, calibration data and passwords), except:

- SIP counter,
- CIP counter,
- Power up counter,
- Number of Watchdog Resets,
- Number of autoclaving’s,
- Operating hours,
- Operating hours above max measurement temperature,
- Operating hours above max operating temperature and
- all calibration counter values
- measuring point

remains unchanged.

By sending the recall value “911”, all configuration values will be set to default.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
8192	2	Recall by value 911	16	none	S

3 Appendix

3.1 List of tables

3.2 List of figures

Abbreviations

AO	Analog Output Interface
DO	Dissolved Oxygen
CP	Calibration Point
ECS	Electrochemical Sensor Interface
PA	Parameter
VPA	Verification Parameter
CPA	Calibration Parameter
CCO	Calibration Coefficient
PMC	Primary Measurement Channel
SMC	Secondary Measurement Channel
MC	Measurement Channel
SIP	Sterilization In Place
CIP	Cleaning In Place

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