VisiFerm™ DO
VisiFerm™ DO Arc

Modbus RTU
Programmer’s Manual

Firmware version:

ODOUM043

Rev.	Revision Date	Author	Change Description
80	27.06.2008	PA	Initial version Modbus_030
00	02.07.2009	RD	Update to Modbus_036
01	19.04.2010	AM PA RD	Update to ODOUM039
02	16.02.2011	LW	Update to ODOUM040
03	16.05.2012	JB	Update to ODOUM041
04	09.12.2013	PW	Update to ODOUM042
05	21.06.2016	LW	Update to ODOUM043

Table of Content

1 Modbus RTU General Information

1.1 Introduction

This document describes in detail the VisiFerm DO (Arc) Modbus RTU interface. It is addressed to software programmers.
Chapter 1 is a general description of the Modbus RTU interface and is therefore valid for all Arc Sensors: VisiFerm DO, VisiFerm DO Arc, pH Arc Sensors, Conducell Arc, Conducell PW Arc, EDO Arc and ORP Arc Sensors.
The following chapters contain the VisiFerm DO specific programming.

1.2 Hamilton Arc Sensors: Modbus Command Structure

This definition of the command structure is valid for all members of the Hamilton Arc Sensor family, having the following firmware versions:

- ODOUM0xx (VisiFerm DO / VisiFerm DO Arc Sensor)
- EPHUM0xx (pH Arc Sensors)
- CONUM0xx (Conducell Arc Sensors)
- CPWUM0xx (Conducell PW Arc Sensors)
- EDOUM0xx (EDO Arc Sensors)
- ERXUM0xx (ORP Arc Sensors)

Please check by reading register 1032 (see chapter 2.9.1).

This definition of the command structure is an additional document to the Operating Instructions of the specific 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 master protocols operate with register-count starting at address 0. Usually, the Modbus master software translates the addressing. Thus, the register address of 2088 will be translated by Modbus master software to 2087 which is sent to the sensor (Modbus slave). This must be observed during programming. Please check the specifications of the Modbus master 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:

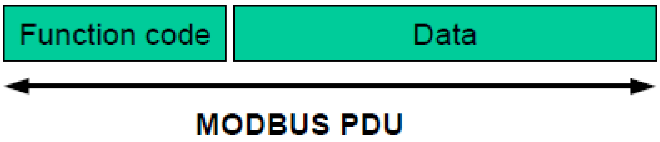

Figure 1.2.2.1: Modbus Protocol Data Unit.

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.

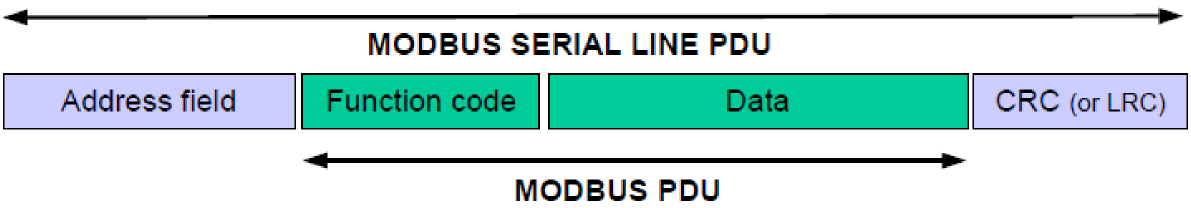

Figure 1.2.2.2: Modbus frame over Serial Line.

- On Modbus Serial Line, the Address field only contains the <u>slave address</u>.

<u>Note:</u>
Arc Sensors support only slave addresses 1 to 32.

A master addresses a slave by placing the slave address in the address field of the message. When the slave returns its response, it places its own address in the response address field to let the master know which slave 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 <u>must</u> 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 1.2.3.1: 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 1.2.3.2: 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 <u>must</u> be detected and errors <u>must</u> be set as a result.

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

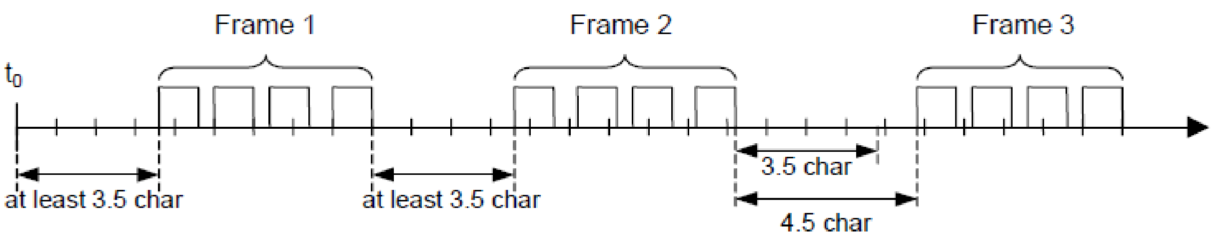

Figure 1.2.4.1: Valid frames with silent intervals.

MODBUS message

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

Figure 1.2.4.2: RTU Message Frame.

The entire message frame <u>must</u> 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.

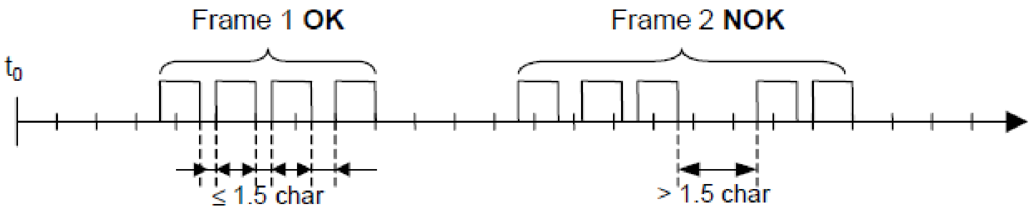

Figure 1.2.4.3: Data transmission of a frame.

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.

	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

Figure 1.3.1: Modbus definition for data transmission.

The RS485 interface is configured as follows:

	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

Figure 1.3.2: RS485 definitions for Arc Sensors.

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 1.4.1.1: 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 1.4.1.2: 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 1.4.2.1: 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 1.4.2.2: 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 1.4.3.1: 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 1.4.3.2: 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)

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

Figure 1.5.1.1: Definition Floating point Single Precision (4 bytes resp. 2 Modbus registers).

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	**0.85** * 2	= 1.70	=> 1	MSB
31 / 2	= 15	residue 1		0.70 * 2	= 1.40	=> 1	
15 / 2	= 7	residue 1		0.40 * 2	= 0.80	=> 0	
7 / 2	= 3	residue 1		0.80 * 2	= 1.60	=> 1	
3 / 2	= 1	residue 1		0.60 * 2	= 1.20	=> 1	
1 / 2	= 0	residue 1	MSB	0.20 * 2	= 0.40	=> 0	
	= **111110**			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: $\mathbf{0}_{binary}$ = **0** (positive sign)
E: $\mathbf{10000100}_{binary} = 1*2^7 + 0*2^6 + 0*2^5 + 0*2^4 + 0*2^3 + 1*2^2 + 0*2^1 + 0*2^0$
= 128 + 0 + 0 + 0 + 0 + 4 + 0 + 0
= **132**
M: $\mathbf{11110110110011001100110}_{binary}$ = **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.

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

Figure 1.6.1: implemented Error-Codes (see "Modbus_Application_Protocol_V1.1b" for details)

2 VisiFerm DO Commands in Modbus RTU

2.1 General

In order to communicate with a VisiFerm DO sensor over Modbus RTU protocol a Modbus master 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 Master 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 master protocol operates with register addresses starting at 0. Usually, the Modbus master software translates the addressing. Thus, the register address of 2090 will be translated by the Modbus master software to 2089 which is sent to the sensor (Modbus slave).

⚠ 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. Furthermore, for the Free User Memory Space (see chapter 2.9.3), the write operations are limited to 10'000.

2.2 Operator levels and Passwords

2.2.1 Reading / Setting Operator Level

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

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

Figure 2.2.1.1: Definition of operator level and default passwords

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.

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

Figure 2.2.1.2: Definition of register 4288.

Command: Operator level		Modbus address: **4288**	Length: **4**	Type: **3** Read
Parameter:	Operator level	Password		
Format:	hex	decimal		
Value:	**0x03**	**0**		

Figure 2.2.1.3: Example to read the active operator level (function code 3, start register address 4288, number of registers 4): The active operator level is 0x03 (User). The sensor does not report the password. The value 0 is returned instead.

Command: Operator level		Modbus address: **4288**	Length: **4**	Type: **3** Read
Parameter:	Operator level	Password		
Format:	hex	decimal		
Value:	**0x30**	**0**		

Figure 2.2.1.4: Example to read the active operator level: the active level is 0x30 (Specialist). The sensor does not report the password. The value 0 is returned instead.

Command: Operator level		Modbus address: **4288**	Length: **4**	Type: **16** Write
Parameter:	Operator level	Password		
Format:	hex	decimal		
Value:	**0x03**	**0**		

Figure 2.2.1.5: Example to set the operator level to 0x03 (User). The password 0 has to be sent.

Command: Operator level		Modbus address: **4288**	Length: **4**	Type: **16** Write
Parameter:	Operator level	Password		
Format:	hex	decimal		
Value:	**0x0C**	**18111978**		

Figure 2.2.1.6: Example to set the active operator level to 0x0C (Administrator). The correct password has to be sent.

Command: Operator level		Modbus address: **4288**	Length: **4**	Type: **16** Write
Parameter:	Operator level	Password		
Format:	hex	decimal		
Value:	**0x0B**	**18111978**		

Figure 2.2.1.7: Example for a Modbus error. If the level or the password is not correct, (Operator level = 0x0B), the sensor answers with a Modbus error message “Slave device exception response” (see chapter 1.6).

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. The new password will remain stored after power down.

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

Figure 2.2.2.1: Definition of register 4292.

Command: Password		Modbus address: **4292**	Length: **4**	Type: **16** Write
Parameter:	Operator level	Pass number		
Format:	Hex	Decimal		
Value:	**0x30**	**12345678**		

Figure 2.2.2.2: Example to set the Password of operator level S (code 0x30) to 12345678.

2.3 Configuration of the serial RS485 Interface

Factory settings of the RS485 (see chapter 1.3):
Parity is none, 1 start bit, 8 data bits, 2 stop bits (in total: 11 bits).

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	Modbus function code	Read access	Write access
4096	2	device address	3, 4, 16	U/A/S	S

Figure 2.3.1.1.1: Definition of register 4096.

Command: Com address		Modbus address: **4096**	Length: **2**	Type: **3** Read
Parameter:	Modbus address			
Format:	Decimal			
Value:	**1**			

Figure 2.3.1.1.2: Example to read the device address.

The device address can be set by S (Specialist), default value is 1.

Command: Com address		Modbus address: **4096**	Length: **2**	Type: **16** Write
Parameter:	Modbus address			
Format:	Decimal			
Value:	**3**			

Figure 2.3.1.1.3: Example to set the device address to 3.

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	Reg3 / Reg4	Modbus function code	Read access	Write access
4098	4	Min. device address	Max. device address	3, 4	U/A/S	none

Figure 2.3.1.2.1: Definition of register 4098.

Command: Com address limits		Modbus address: **4098**	Length: **4**	Type: **3** Read
Parameter:	Min value	Max value		
Format:	Decimal	Decimal		
Value:	**1**	**32**		

Figure 2.3.1.2.2: Example to read the device address limits: Min = 1, Max = 32.

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	Modbus function code	Read access	Write access
4102	2	Baud rate code (definition see below)	3, 4, 16	U/A/S	S

Figure 2.3.2.1.1: Definition of register 4102.

The code for the baud rate is defined as follows:

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

Figure 2.3.2.1.2: Code for the baud rates.

Command: Com baud rate		Modbus address: **4102**	Length: **2**	Type: **3** Read
Parameter:	Baud rate code			
Format:	Decimal			
Value:	**4**			

Figure 2.3.2.1.3: Example to read the baud rate code, 4 corresponds 19200 baud.

The baud rate can be set by S (Specialist), default is 19200.

Command: Com baud rate		Modbus address: **4102**	Length: **2**	Type: **16** Write
Parameter:	Baud rate code			
Format:	Decimal			
Value:	**5**			

Figure 2.3.2.1.4: Example to set the baud rate to 38400 baud with code 5.

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	Reg3 / Reg4	Modbus function code	Read access	Write access
4104	4	Min. Baud rate code	Max. Baud rate code	3, 4	U/A/S	none

Figure 2.3.2.2.1: Definition of register 4104.

Command: Com baud limits		Modbus address: **4104**	Length: **4**	Type: **3** Read
Parameter:	Min Baud rate code	Max Baud rate code		
Format:	Decimal	Decimal		
Value:	**2**	**7**		

Figure 2.3.2.2.2: Example to read the baud rate code limits: Min = 2, Max = 7 (see Figure 2.3.2.1.2).

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

2.4.1 Available Analog Interfaces

VisiFerm has one physical analog output - defined in register 4320:

- Analog Output Interface 1 (AO1)

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

Figure 2.4.1.1: Definition of register 4320.

Command: Avail analog interfaces		Modbus address: **4320**	Length: **2**	Type: **3** Read
Parameter:	Available analog interfaces			
Format:	Hex			
Value:	**0x01**			

Figure 2.4.1.2: Example to read the available analog outputs. It is "0x01" meaning that there exists only one Analog Interface 1 (AO1).

Attention:
Unlike to pH Arc Sensors, Conducell Arc Sensors, Conducell PW Arc Sensors, EDO Arc Sensors and ORP Arc Sensors which have AO1 and AO2, VisiFerm DO / VisiFerm DO Arc Sensors only have AO1 !

2.4.2 Description of the Analog Interface 1

VisiFerm DO has one single physical analog output interface (AO1) that can be used in two different interface modes:

- 4-20 mA standard interface, or
- ECS - electrochemical sensor interface (Hamilton proprietary)

Attention:
VisiFerm DO Arc has no ECS!

Reading the description of the analog 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

Figure 2.4.2.1: Definition of register 4352.

Command: Current interface text		Modbus address: **4352**	Length: **8**	Type: **3** Read
Parameter:	Text			
Format:	Character			
Value:	**mA/ECS-Interface**			

Figure 2.4.2.2: Example to read the description of the analog output interface AO1. It is "mA/ECS-Interface". For VisiFerm DO Arc, this text is "mA-Interface".

2.4.3 Selection of an Analog Interface Mode

As both interfaces (4-20 mA and ECS) are using the same physical output (AO1) of the sensor, only one interface can be operated at a time. The way the analog interface is operated, is called the "analog interface mode".

The available analog interface modes are defined in register 4322.

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

Figure 2.4.3.1: Definition of register 4322. Reg 1 / Reg 2 define what analog interface modes are available for AO1. The analog interface modes are described in Figure 2.4.3.2.

Analog Interface Mode (Hex)	**VisiFerm DO**	**VisiFerm DO Arc**	Description
0x0000	Both 4-20 mA and ECS inactive	4-20 mA inactive	Analog interface deactivated
0x0001	4-20 mA fixed	4-20 mA fixed	Set to a constant output value for current loop testing
0x0002	4-20 mA linear	4-20 mA linear	Linear output of measurement (PMC1 / 6)
0x0004	4-20 mA bilinear	4-20 mA bilinear	Bilinear output of measurement(PMC1 / 6)
0x0100	ECS fixed	Not available	Set to a constant output value for current loop testing
0x0200	ECS	Not available	nA output linked to oxygen reading (PMC1)

Figure 2.4.3.2: Definition of the analog interface modes (see Figure 2.4.4.6.3 and Figure 2.4.4.6.4).

Command: Analog Interface Modes	Modbus address: **4322**	Length: **8**	Type: **3**	Read
Parameter:	Available Analog Interface Modes	reserved	reserved	reserved
Format:	Hex	Hex	Hex	Hex
Value:	**0x0307**	**0x0**	**0x0**	**0x0**

Figure 2.4.3.3: Example to read register 4322 with VisiFerm DO: all modes defined in Figure 2.4.3.2 are available. Note: VisiFerm DO Arc returns the value 0x0007.

The analog interface mode is selected by programming the analog interface mode register 4360.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
4360	2	Code for analog interface mode	3, 4, 16	U/A/S	S

Figure 2.4.3.4: Definition of register 4360. Only one bit can be set.

Command: Active interface mode	Modbus address: **4360**	Length: **2**	Type: **16**	Write
Parameter:	Mode			
Format:	Hex			
Value:	**0x0002**			

Figure 2.4.3.5: Example to set the analog interface mode of AO1 to 0x0002 (4-20 mA linear output).

⚠ Attention:
When the sensor is programmed to ECS mode (0x0100/0x0200), but the external wiring is done for driving a 4-20 mA current, the electronics of the sensor can be seriously damaged. Please be careful when modifying the analog interface mode! We recommend programming only while the sensor is not connected to any analog interface.

2.4.4 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 2.4.3).

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

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
4362	2	Available Primary Measurement Channels	3, 4	U/A/S	none

Figure 2.4.4.1.1: Definition of register 4362.

For the definition of the Primary Measurement Channels (PMC), see chapter 2.5.

Command: Available PMC 4-20 mA		Modbus address: **4362**	Length: **2**	Type: **3** Read
Parameter:	Avail. PMC 4-20 mA			
Format:	Hex			
Value:	**0x21**			

Figure 2.4.4.1.2: Example to read the available Primary Measurement Channels (PMC). The hexadecimal value of "0x21" defines that Primary Measurement Channel 1 (oxygen) or Primary Measurement Channel 6 (temperature) can be mapped onto the 4-20 mA analog output (see chapter 2.4.4.2).

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

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
4364	2	Selected Primary Measurement Channel	3, 4, 16	U/A/S	S

Figure 2.4.4.2.1: Definition of register 4364. Only one bit can be set.

Code (hex)	Primary Measurement Channel (PMC)
0x01	PMC1 (oxygen)
	not available
0x20	PMC6 (temperature)

Figure 2.4.4.2.2: Code for selection of the primary measurement channel.

Command: Active PMC 4-20 mA		Modbus address: **4364**	Length: **2**	Type: **3** Read
Parameter:	Act PMC 4-20 mA			
Format:	Hex			
Value:	**0x01**			

Figure 2.4.4.2.3: Example to read the current primary measurement channel. The Primary Measurement Channel 1 for oxygen is selected as the channel to be mapped to the 4-20 mA analog output (this is the factory setting).

2.4.4.3 Reading the Minimum and Maximum Possible Output Current for the 4-20 mA Interface

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

Figure 2.4.4.3.1: Definition of register 4366.

Command: Limits 4-20 mA	Modbus address: **4366**	Length: **4**	Type: **3**	Read
Parameter:	Min limit [mA]	Max limit [mA]		
Format:	Float	Float		
Value:	**2**	**22**		

Figure 2.4.4.3.2: Example to read the min and max output current. Min is fixed to 2 and Max is fixed to 22 mA (Currents above 20 and below 4 mA indicate erroneous measurements or errors).

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

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

Figure 2.4.4.4.1: Definition of register 4370 (see Figure 2.4.4.6.3).

Command: MinMaxMid curr 4-20 mA	Modbus address: **4370**	Length: **6**	Type: **3**	Read
Parameter:	Min curr 4-20 mA	Max curr 4-20 mA	Mid curr 4-20 mA	
Format:	Float	Float	Float	
Value:	**4**	**20**	**12**	

Figure 2.4.4.4.2: Example to read the min, max and mid output current for measurement values. They are fixed to 4, 20 and 12 mA.

<u>Note:</u>
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.

2.4.4.5 Reading the Selected Physical Unit for 4-20 mA Output

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
4376	2	Selected physical unit of analog output (see chapter 2.5.1)	3, 4	U/A/S	none

Figure 2.4.4.5.1: Definition of register 4376.

Command: Avail unit 4-20 mA	Modbus address: **4376**	Length: **2**	Type: **3**	Read
Parameter:	Available unit			
Format:	Hex			
Value:	**0x20**			

Figure 2.4.4.5.2: Example to read the selected unit of primary measurement channel, 0x20 (%-sat). The physical unit for PMC is defined in Reg. 2090 or 2410 and applies automatically for 4-20 mA output.

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

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
4378	6	Measurement value at Min Output Current	Measurement value at Max Output Current	Measurement value at Mid Output Current	3, 4, 16	U/A/S	S

Figure 2.4.4.6.1: Definition of register 4378.

Command: MinMaxMid val 4-20mA	Modbus address: **4378**	Length: **6**	Type: **16**	Write
Parameter:	Min value 4-20 mA	Max value 4-20 mA	Mid value 4-20 mA	
Format:	Float	Float	Float	
Value:	**0**	**62.85**	**10**	

Figure 2.4.4.6.2: Example to set the min value to 0 (for 4 mA), the max value to 62.85 (for 20 mA) and the mid value to 10 (for 12 mA). The corresponding physical unit is defined in Reg. 2090 or 2410.

<u>Note:</u>
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.

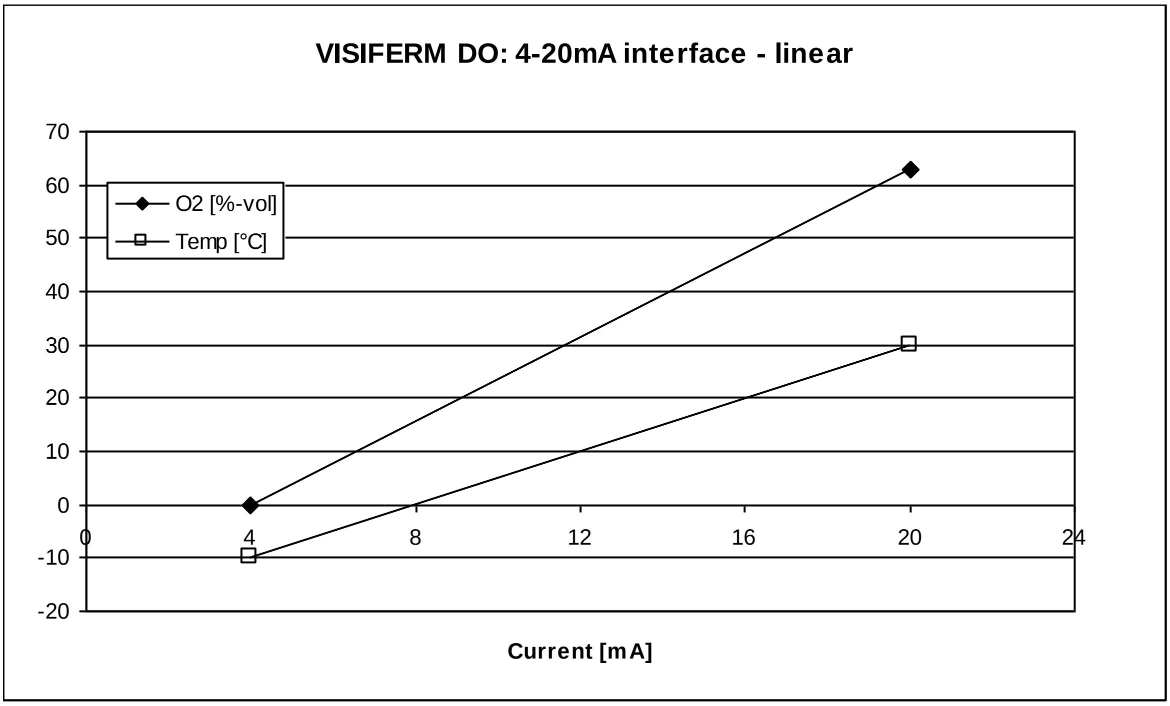

Figure 2.4.4.6.3: Example of linear 4-20 mA output characteristics for Oxygen or Temperature.

Current	Oxygen	Temperature
4 mA	0 %-vol	-10°C
20 mA	62.85 %-vol	+30°C

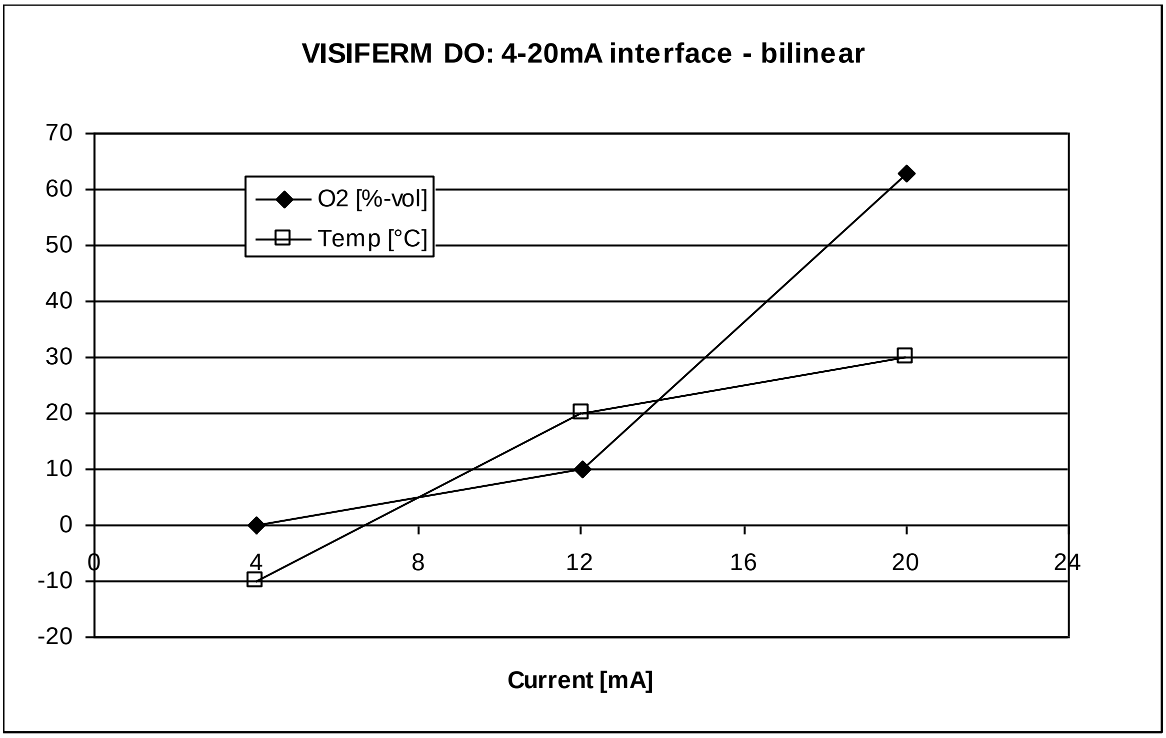

Figure 2.4.4.6.4: Example of bilinear 4-20 mA output characteristics for Oxygen or Temperature.

Current	Oxygen	Temperature
4 mA	0 %-vol	-10°C
12 mA	10 %-vol	+20°C
20 mA	62.85 %-vol	+30°C

⚠ 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 register 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 measurement interval (PA13) is equal to zero.
  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).

Example:
Register 4364 is set to 1 (PMC1 (oxygen) is mapped to 4-20 mA analog output).
Register 2090 is set to 16 (the unit "%-vol" is assigned to PMC1).
Register 4378 is set to 0 and 62.85 (4 mA = 0 %-vol, 20 mA = 62.85 %-vol).
In air, the sensor reads 20.95 %, the output at the 4-20 mA is accordingly 9.33 mA.
The operator now re-assigns register 2090 to the value of 32 (%-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 generate an interface warning.

2.4.4.7 Defining a Constant Current Output for Testing

Note:
For constant current output, VisiFerm must be set to analog interface mode 0x01 (see chapter 2.4.3):

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

Figure 2.4.4.7.1: Definition of register 4384.

Command: Fixed value 4-20 mA	Modbus address: **4384**	Length: **2**	Type: **3**	Read
Parameter:	Fixed value [mA]			
Format:	Float			
Value:	**10**			

Figure 2.4.4.7.2: Example to read the constant current output in mode 0x01. It is set to 10 mA.

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

Errors and warnings can be mapped to the analog output.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
4386	8	Code of warnings and errors (see Figure 2.4.4.8.2)	Current in case of "warning" [mA]	Current in case of "error" [mA]	Current in case of "T exceed" [mA]	3, 4, 16	U/A/S	S

Figure 2.4.4.8.1: Definition of register 4386.

Bit #	Hex Code	Behaviour of the 4-20 mA interface in case of errors and warnings
0 (LSB)	0x000001	Error continuous output
		not available
16	0x010000	Warning continuous output
		not available

Figure 2.4.4.8.2: Code for the 4-20 mA interface in case of errors and warnings.

If the corresponding bits for the errors and warnings are not set (=0), the respective options are inactive.

The default settings are:
Code 0x01, current "warnings" 3.5 mA, current "errors" 3.5 mA and current "T exceed" 3.5 mA.

Command: ErrorWarnings 4-20 mA	Modbus address: **4386**	Length: **8**	Type: **3**	Read
Parameter:	Warning code	Current "warning" [mA]	Current "error" [mA]	Current "T exceed" [mA]
Format:	Hex	Float	Float	Float
Value:	**0x010001**	**21**	**22**	**3.5**

Figure 2.4.4.8.3: Example: Read the settings for the 4-20mA interface in case of warnings and errors. Warning code 0x010001 corresponds to the continuous output current warning mode (code 0x010000) and continuous output current "error" (code 0x01) of 22 mA. The output current "Temperature exceed" is 3.5 mA.

2.4.5 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 DO 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 ECS interface does NOT exist in VisiFerm DO Arc
- 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 2.4.3).
- 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 measurement interval (PA13) is equal to zero.
  or
- the current temperature is outside the user defined measurement temperature range (reg. 4624).

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

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	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

Figure 2.4.5.1.1: Definition of register 4394.

Command: Limits ECS		Modbus address: **4394**	Length: **4**	Type: **3** Read
Parameter:	Min limit [nA]	Max limit [nA]		
Format:	Float	Float		
Value:	**0**	**500**		

Figure 2.4.5.1.2: Example to read the current range at the cathode. It is fixed to 0-500 nA.

2.4.5.2 Defining the Characteristics of the Emulated Electrochemical Sensor

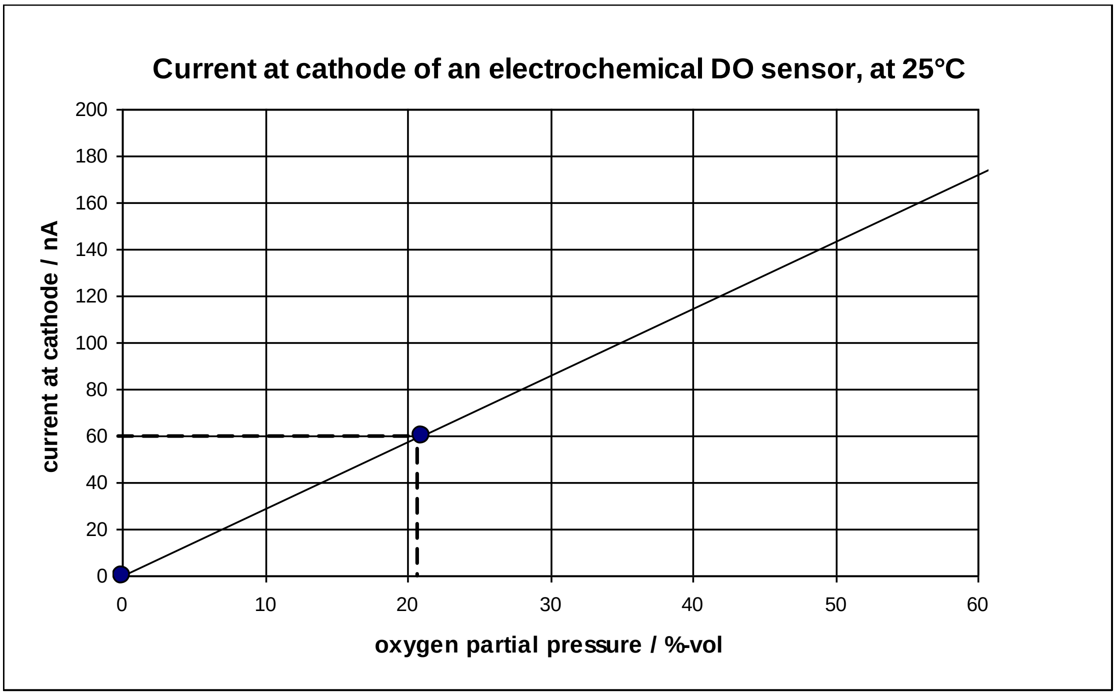

Figure 2.4.5.2.1: Typical characteristic of an electrochemical DO sensor at fixed temperature (here 25 °C): the current generated at the cathode by the reduction of oxygen is proportional to the oxygen partial pressure, here expressed as %-vol in a gas mixture. If no oxygen is present, the current is 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.

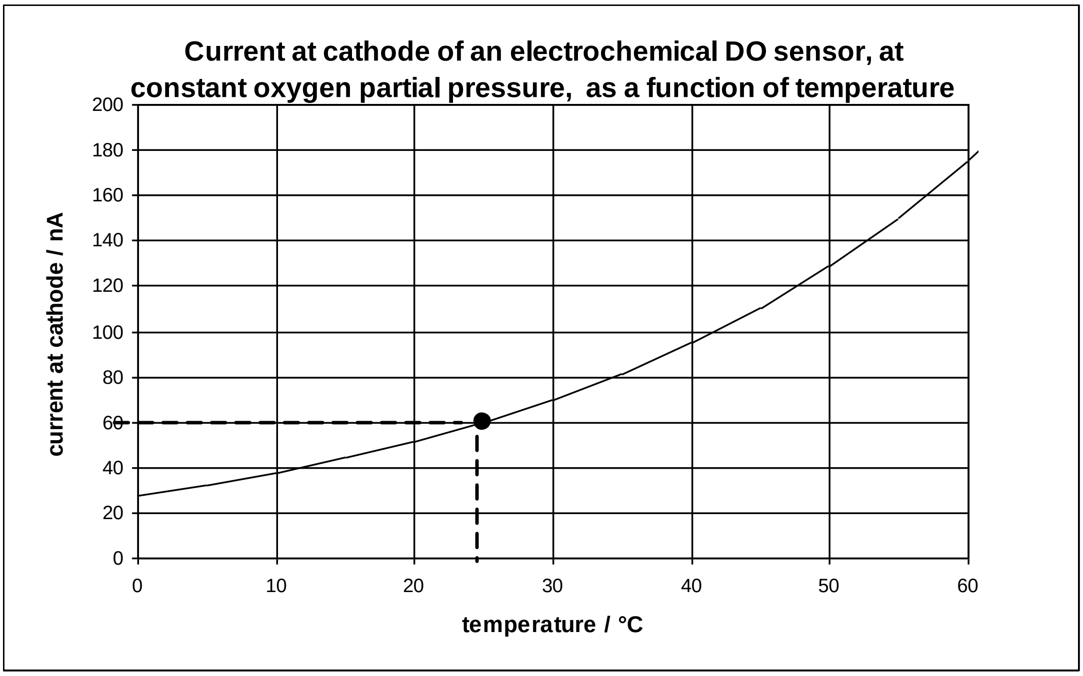

Figure 2.4.5.2.2: Measurement current of a typical electrochemical DO sensor as a function of temperature, at fixed oxygen partial pressure (here 20.95 %-vol). The current generated at the cathode is an exponential function of temperature. At 25 °C, the current is typically 60 nA.

The exponential function is defined as:

$$I_{Teff} = I_{25°C} * EXP(0.0306*(T_{eff} -25))$$

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 0.0306 (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 ECS.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	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

Figure 2.4.5.2.3: Definition of register 4398: parameters of the electrochemical sensor to be simulated.

Command: Output ECS		Modbus address: **4398**	Length: **6** Type: **3**	Read
Parameter:	Zero Oxygen [nA]	Air [nA]	Temperature coefficient [%/K]	
Format:	Float	Float	Float	
Value:	**0**	**60**	**3.1**	

Figure 2.4.5.2.4: Example to read the current in zero oxygen: 0 nA, the current in air: 60 nA and the temperature coefficient: 3.1 %/°C.

The ECS output current is calculated by VisiFerm DO 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.

2.4.5.3 Defining a Constant Current Output for Testing

Note:
For constant ECS output current, VisiFerm must be set to the analog interface mode 0x0100 (see chapter 2.4.3).

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

Figure 2.4.5.3.1: Definition of register 4404.

Command: Fixed value ECS	Modbus address: **4404**	Length: **2**	Type: **3**	Read
Parameter:	Fixed value [nA]			
Format:	Float			
Value:	**100**			

Figure 2.4.5.3.2: Example to read the constant current output in mode 0x0100. It is set to 100 nA.

Note:
The constant output current is a test value and completely independent from oxygen reading and temperature.

2.4.5.4 Defining Error and Warning Output of ECS

Errors and warnings can be mapped to the ECS.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
4406	8	Code of warnings and errors (Figure 2.4.5.4.2)	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

Figure 2.4.5.4.1: Definition of register 4406.

Bit #	Code	4-20 mA interface in case of errors and warnings
0 (LSB)	0x000001	Error continuous output
		not available
16	0x010000	Warning continuous output
		not available

Figure 2.4.5.4.2: Code for the ECS interface in case of errors and warnings. 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

Command: Error Warnings ECS	Modbus address: **4406**	Length: **8**	Type: **3**	Read
Parameter:	Warning code	Current “warning” [nA]	Current “error” [nA]	Current “T exceed” [nA]
Format:	Hex	Float	Float	Float
Value:	**0x010001**	**433**	**466**	**499**

Figure 2.4.5.4.3: Example to read the settings for the ECS interface in case of errors and warnings. code 0x010001 (0x010000 + 0x000001) is set and defines

- 433 nA continuous current in case of “warning”,
- 466 nA continuous current in case of “error” and
- 499 nA continuous current in case of “T exceed”.

2.4.6 Reading the Internally Measured Output Current

Reg. 4414 provides internal parameters of the analog output interface AO1 (both 4-20 mA or ECS):

- 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 in order to compare against the externally measured electrical current.

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

Figure 2.4.6.1: Definition of register 4414.

Command: Int. values 4-20mA / ECS	Modbus address: **4414**	Length: **4**	Type: **3**	Read
Parameter:	Set point [mA] / [nA]	Internally measured [mA] / [nA]		
Format:	Float	Float		
Value:	**9.99186**	**9.99742**		

Figure 2.4.6.2: Example to read the internal values AO1 (4-20 mA or ECS), depending on the analog interface mode.

In order to know which current loop is active, please refer to chapter 2.4.3.

2.5 Measurement

2.5.1 Definition of Measurement Channels and Physical Units

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

Bit #	Hex value	Description	Definition in VisiFerm DO
0 (LSB)	**0x000001**	**PMC1**	**Oxygen**
1	0x000002	PMC2	not available
			not available
4	0x000010	PMC5	not available
5	**0x000020**	**PMC6**	**Temperature**
6	0x000040	SMC1	not available
			…
20	0x100000	SMC15	not available
21 (MSB)	0x200000	SMC16	not available

Figure 2.5.1.1: Definition of PMC1 to 6 and SMC1 to 16.

In Register 2048, the available PMC and SMC are defined.

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

Figure 2.5.1.2: Definition of register 2048.

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

Figure 2.5.1.3: Example to read Reg. 2048. The hex value 0x21 defines the channels PMC1 and PMC6.

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

Bit #	Hex value	Physical unit	Start register. (8 ASCII characters, length 4 registers, Type 3, read for U/A/S)
0 (LSB)	0x00000001	none	1920
1	0x00000002	K	1924
2	0x00000004	°C	1928
3	0x00000008	°F	1932
4	0x00000010	%-vol	1936
5	0x00000020	%-sat	1940
6	0x00000040	ug/l ppb	1944
7	0x00000080	mg/l ppm	1948
8	0x00000100	g/l	1952
9	0x00000200	uS/cm	1956
10	0x00000400	mS/cm	1960
11	0x00000800	1/cm	1964
12	0x00001000	pH	1968
13	0x00002000	mV/pH	1972
14	0x00004000	kOhm	1976
15	0x00008000	MOhm	1980
16	0x00010000	pA	1984
17	0x00020000	nA	1988
18	0x00040000	uA	1992
19	0x00080000	mA	1996
20	0x00100000	uV	2000
21	0x00200000	mV	2004
22	0x00400000	V	2008
23	0x00800000	mbar	2012
24	0x01000000	Pa	2016
25	0x02000000	Ohm	2020
26	0x04000000	%/°C	2024
27	0x08000000	°	2028
28	0x10000000	not used	2032
29	0x20000000	not used	2036
30	0x40000000	not used	2040
31 (MSB)	0x80000000	SPECIAL	2044

Figure 2.5.1.4: Definition of physical units used for PMC and SMC.

2.5.2 Primary Measurement Channel 1 (Oxygen)

2.5.2.1 Description of PMC1

In register 2080, a plain text ASCII description of PMC1 is given.

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
2080	8	Description of PMC1	3, 4	U/A/S	none

Figure 2.5.2.1.1: Definition of register 2080.

Command: PMC 1 text	Modbus address: **2080**	Length: **8**	Type: **3**	Read
Parameter:	Text			
Format:	Character			
Value:	**DO**			

Figure 2.5.2.1.2: Example to read the description. It is "DO" (Dissolved Oxygen).

2.5.2.2 Selecting the Physical Unit for PMC1

In register 2088, the available physical units for this channel are defined.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
2088	2	Available physical units of PMC1	3, 4	U/A/S	none

Figure 2.5.2.2.1: Definition of register 2088.

Command: PMC1 available units	Modbus address: **2088**	Length: **2**	Type: **3**	Read
Parameter:	Units			
Format:	Hex			
Value:	**0x8000F0**			

Figure 2.5.2.2.2: Example to read the available physical units of PMC1: %-vol (0x10), %-sat (0x20), ug/l ppb (0x40), mg/l ppm (0x80), mbar (0x800000). Total 0x8000F0. For the definition of the physical units see chapter 2.5.1.

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.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
2090	2	Selected active physical unit of PMC1	16	none	S

Figure 2.5.2.2.3: Definition of register 2090. Only one bit can be set.

Command: PMC1 set unit	Modbus address: **2090**	Length: **2**	Type: **16**	Write
Parameter:	Unit			
Format:	Hex			
Value:	**0x20**			

Figure 2.5.2.2.4: Example to set the physical unit of PMC1 to %-sat (0x20).

Attention:
Changing the physical unit 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 have to be redefined after changing the physical unit! See chapter 2.4.3 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 Slave 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	Slave 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	Slave 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 Slave 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

2.5.2.3 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	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Reg9 / Reg10	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

Figure 2.5.2.3.1: Definition of register 2090. Measurement value of PMC1.
(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.

Command: PMC1 read		Modbus address: **2090**		Length: **10**	Type: **3** Read
Parameter:	Unit	Value	Status	Min limit	Max limit
Format:	Hex	Float	Hex	Float	Float
Value:	**0x10**	**21.10335**	**0x00**	**0**	**200**

Figure 2.5.2.3.2: Example to read register 2090. Physical unit is set to 0x10 (%-vol), PMC1 is 21.10 (%-vol), Status is 0x00, Min allowed value is 0 (%-vol), Max allowed value is 200 (%-vol).

Command: PMC1 read		Modbus address: **2090**		Length: **10**	Type: **3** Read
Parameter:	Unit	Value	Status	Min limit	Max limit
Format:	Hex	Float	Hex	Float	Float
Value:	**0x20**	**100.5764**	**0x00**	**0**	**954.6541**

Figure 2.5.2.3.3: Example to read register 2090. Physical unit is set to 0x20 (%-sat), PMC1 is 100.57 (%-sat), Status is 0x00, Min allowed value is 0 (%-sat), Max allowed value is 954.65 (%-sat).

For the definition of the Measurement Status see chapter 2.5.4.

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

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	Slave 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	Slave 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)

2.5.3.1 Description of PMC6

In register 2400, a plain text ASCII description of PMC6 is given

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
2400	8	Description of PMC6	3, 4	U/A/S	none

Figure 2.5.3.1.1: Definition of register 2400.

Command: PMC6 text		Modbus address: **2400**	Length: **8**	Type: **3** Read
Parameter:	Text			
Format:	Character			
Value:	**T**			

Figure 2.5.3.1.2: Example to read the description. It is "T" (Temperature).

2.5.3.2 Selecting the Physical Unit for PMC6

In register 2408, the available physical units of PMC6 are defined.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
2408	2	Available physical units of PMC6	3, 4	U/A/S	none

Figure 2.5.3.2.1: Definition of register 2408.

Command: PMC6 available units		Modbus address: **2408**	Length: **2**	Type: **3** Read
Parameter:	Units			
Format:	Hex			
Value:	**0x04**			

Figure 2.5.3.2.2: Example to read the available physical units of PMC6. The only one is °C (0x04). For the definition of the physical units see chapter 2.5.1.

In register 2410, the active physical unit of PMC6 can be selected, by choosing one of the physical units that are defined in register 2408.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
2410	2	Selected active physical unit of PMC6	16	none	U/A/S

Figure 2.5.3.2.3: Definition of register 2410. Only one bit can be set.

Command: PMC6 set unit		Modbus address: **2410**	Length: **2**	Type: **16** Write
Parameter:	Unit			
Format:	Hex			
Value:	**0x04**			

Figure 2.5.3.2.4: Example to set the physical unit of PMC6 to °C (0x04).

2.5.3.3 Reading the measurement value of PMC6

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

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

Figure 2.5.3.3.1: Definition of register 2410. Measurement value of PMC6.

(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.

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**

Figure 2.5.3.3.2: Example to read register 2410. 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).

For definition of the measurement status see chapter 2.5.4.

⚠ Attention:

You cannot read selectively the registers 3 and 4 for the measurement value only. You have to 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	Slave 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	Slave 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.

2.5.3.4 Input of an Externally Measured Temperature

One has the possibility to feed the measurement value of an external temperature sensor to VisiFerm DO sensor.

External temperature data can be written into register 2410. The value has to 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	Reg3 / Reg4	Modbus function code	Read access	Write access
2410	4	Physical unit (bitwise defined)	External temperature	16	none	S

Figure 2.5.3.4.1: Definition of register 2410. Writing the physical unit and the external temperature.

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

Figure 2.5.3.4.2: Example to set the physical unit to °C (0x04) and the value of the external temperature.

Attention:
Once the operator has written external temperature data to register 2410, he needs to guarantee regular data update.

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):

Bit #	Hex value	Description
0 (LSB)	0x01	Temperature out of user defined measurement temperature range (see chapter 2.8.1)
1	0x02	Temperature out of operating range (see chapter 2.8.1)
2	0x04	Calibration status not zero (see chapter 2.7.4)
3	0x08	Warning not zero (see chapter 2.8.3)
4	0x10	Error not zero (see chapter 2.8.4)

Figure 2.5.4.1: Definition of measurement status for Primary Measurement Channels.

2.6 Configuration of the Measurement

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

2.6.1 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 Figure 2.6.1.2)	3, 4	U/A/S	none

Figure 2.6.1.1: Definition of register 3072.

Bit #	Hex value	Description	Definition in VisiFerm DO
0 (LSB)	**0x0001**	**PA1**	**Salinity**
1	**0x0002**	**PA2**	**Atmospheric pressure**
2	0x0004	PA3	not available
			not available
7	0x0080	PA8	not available
8	**0x0100**	**PA9**	**Moving average**
9	**0x0200**	**PA10**	**Number of sub-measurements**
10	**0x0400**	**PA11**	**Minimum number of sub-measurements in the automatic mode**
11	0x0800	PA12	not available
12	**0x1000**	**PA13**	**Measurement interval**
13	**0x2000**	**PA14**	**Sensor cap part number**
14	0x4000	PA15	not available
15 (MSB)	0x8000	PA16	not available

Figure 2.6.1.2: Bitwise definition of all parameters PA1 to PA16, valid for VisiFerm.

Command: Available parameters		Modbus address: **3072**	Length: **2**	Type: **3** Read
Parameter:	Measurement parameters			
Format:	Hex			
Value:	**0x3703**			

Figure 2.6.1.3: Example to read the available Parameters with operator level S. The hex value 0x3703 corresponds to 0x0001 (PA1) + 0x0002 (PA2) + 0x0100 (PA9) + 0x0200 (PA10) + 0x0400 (PA11) + 0x1000 (PA13) + 0x2000 (PA14).

General note:

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

2.6.2 PA1: Salinity

The physical measurement of VisiFerm DO 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 DO 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 is the solubility.

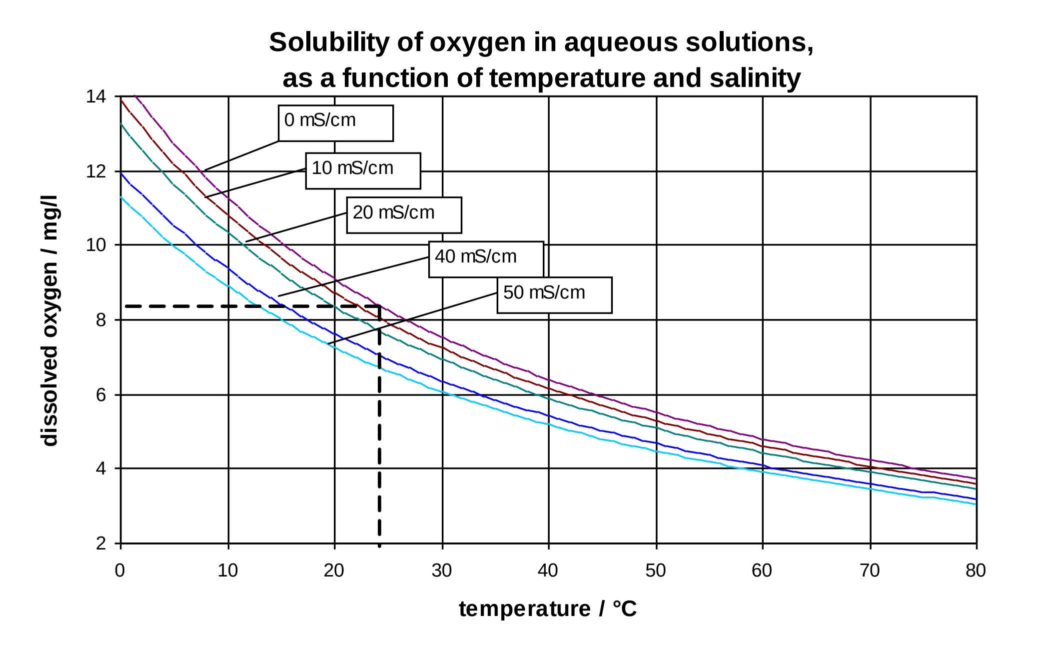

Figure 2.6.2.1: Solubility of oxygen as a function of temperature and salinity, in air saturated aqueous solution. Temperature range is from 0-85 °C. Salinity can be entered from 0-50 mS/cm.

2.6.2.1 Description of PA1 (Salinity)

In register 3104, a plain text ASCII description of PA1 is given.

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

Figure 2.6.2.1.1: Definition of register 3104.

Command: Salinity text		Modbus address: **3104**	Length: **8**	Type: **3** Read
Parameter:	Text			
Format:	Character			
Value:	**Salinity**			

Figure 2.6.2.1.2: Example to read the description as an ASCII string. It is “Salinity“.

2.6.2.2 Selecting the Physical Unit and Writing the Value for PA1

In register 3112, the available physical units for PA1 are defined.

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

Figure 2.6.2.2.1: Definition of register 3112.

Command: Salinity available units		Modbus address: **3112**	Length: **2**	Type: **3** Read
Parameter:	Units			
Format:	Hex			
Value:	**0x400**			

Figure 2.6.2.2.2: Example to read the available physical units for PA1. The only one available here is mS/cm (0x400). For the definition of the physical units see chapter 2.5.1.

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. The value of the parameter can be set as well.

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

Figure 2.6.2.2.3: Definition of register 3114. Only one bit for the physical unit can be set.

Command: Salinity		Modbus address: **3114**	Length: **4**	Type: **16** Write
Parameter:	Unit	Value		
Format:	Hex	Float		
Value:	**0x400**	**10**		

Figure 2.6.2.2.4: Example to set the physical unit of PA1 to mS/cm (0x400) and the value to 10 (mS/cm).

2.6.2.3 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.

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

Figure 2.6.2.3.1: Definition of register 3114.

Command: Salinity		Modbus address: **3114**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Float	Float	Float
Value:	**0x400**	**10**	**0**	**50**

Figure 2.6.2.3.2: Example to read PA1. The unit is mS/cm (0x400), the value is currently set to 10 (mS/cm); the min is 0 (mS/cm) and the max is 50 (mS/cm).

2.6.3 PA2: Air Pressure

The VisiFerm DO 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. In order 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 and this value is used for internal calculation.

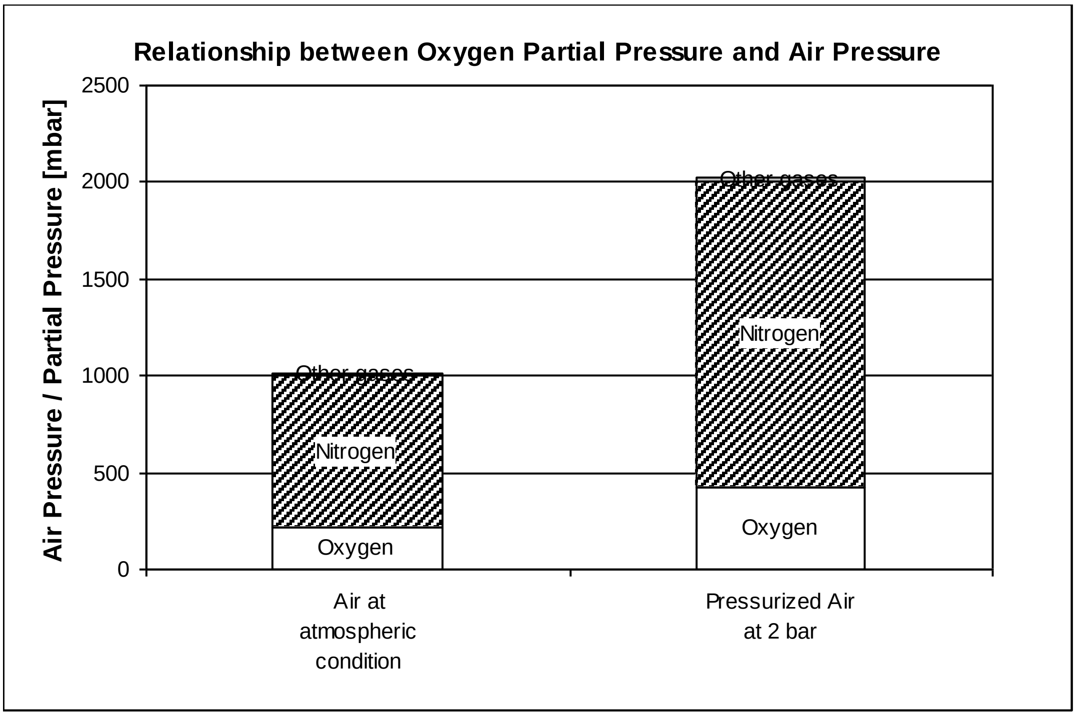

Figure 2.6.3.1: Influence of air pressure on the partial pressure of oxygen. Doubling the air pressure also doubles the oxygen partial pressure.

2.6.3.1 Description of PA2 (Air Pressure)

In register 3136, a plain text ASCII description of PA2 is given.

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

Figure 2.6.3.1.1: Definition of register 3136.

Command: Pressure text		Modbus address: **3136**	Length: **8**	Type: **3** Read
Parameter:	Text			
Format:	Character			
Value:	**Air Pressure**			

Figure 2.6.3.1.2: Example to read the description. It is "Air Pressure".

2.6.3.2 Selecting the Physical Unit and Writing the Value for PA2

In register 3144, the available physical units for PA2 are defined.

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

Figure 2.6.3.2.1: Definition of register 3144.

Command: Pressure available units		Modbus address: **3144**	Length: **2**	Type: **3** Read
Parameter:	Units			
Format:	Hex			
Value:	**0x800000**			

Figure 2.6.3.2.2: Example to read the available physical units for PA2. The only one available here is mbar (0x800000). For the definition of the physical units see chapter 2.5.1.

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. The value of the parameter can be set as well.

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

Figure 2.6.3.2.3: Definition of register 3146. Only one bit for the physical unit can be set.

Command: Pressure		Modbus address: **3146**	Length: **4**	Type: **16** Write
Parameter:	Unit	Value		
Format:	Hex	Float		
Value:	**0x800000**	**1013**		

Figure 2.6.3.2.4: Example to set the physical unit of PA2 to mbar (0x800000) and the value to 1013 (mbar).

2.6.3.3 Reading All Values for PA2

By reading register 3146, the active physical unit, the selected value, and the min and max allowed values can be read.

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

Figure 2.6.3.3.1: Definition of register 3146.

Command: Pressure		Modbus address: **3146**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Float	Float	Float
Value:	**0x800000**	**1013**	**10**	**12000**

Figure 2.6.3.3.2: Example to read PA2. The unit is mbar (0x800000), the value is 1013 (mbar), the min is 10 (mbar) and the max is 12000 (mbar).

2.6.4 PA9: Moving Average

VisiFerm DO calculates new oxygen readings with a measurement interval defined in PA13. One has the possibility to smoothen the oxygen reading (PMC1) by means of a moving average.

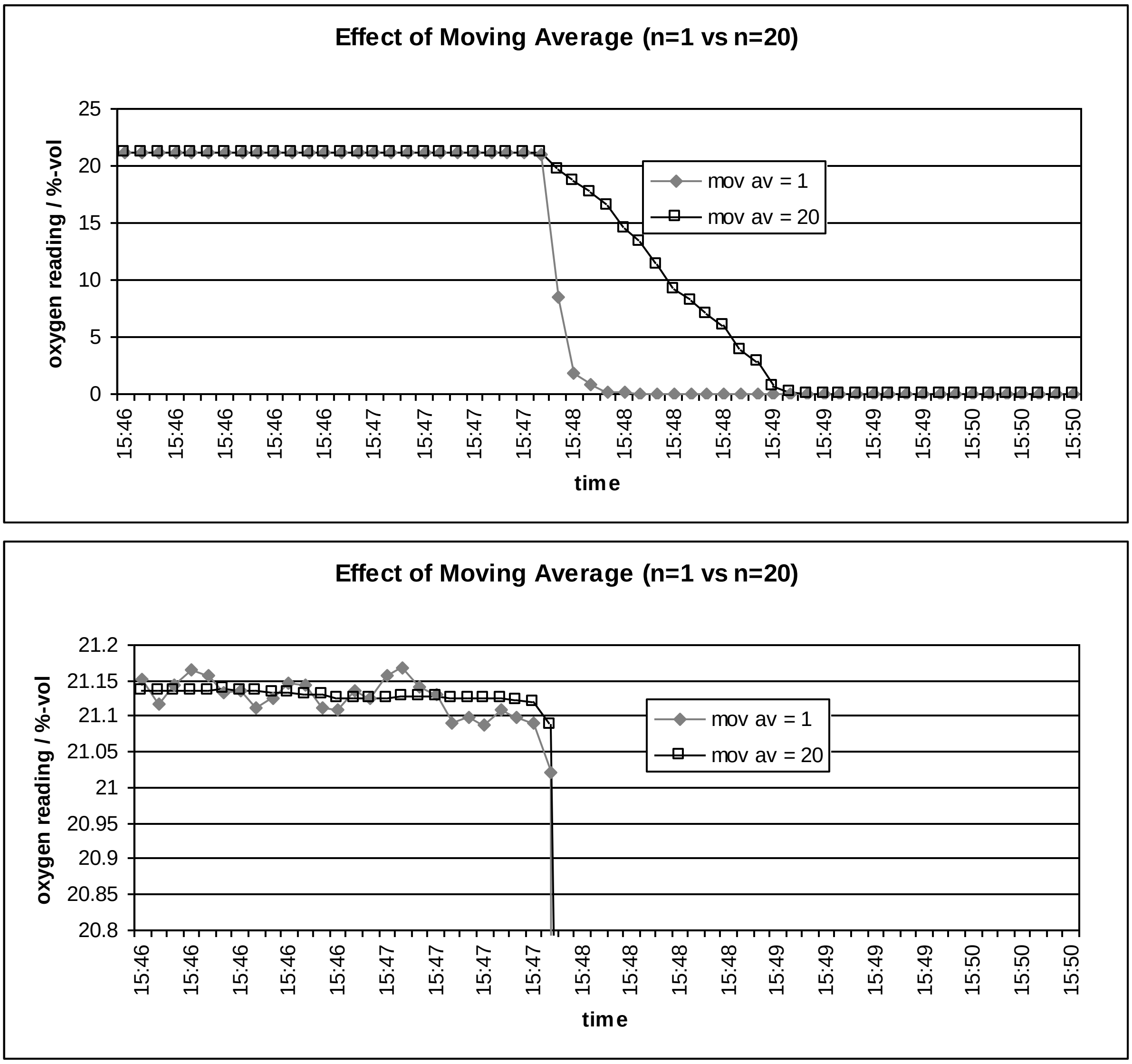

Figure 2.6.4.1: Comparison of the response of VisiFerm DO to a change from air to zero oxygen, using no moving average (n=1) or a moving average over 20 readings (PA13 = 3s).

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 20 samples results in a response time of at least 20 times the measurement interval defined in PA13.

<u>Note:</u>
The moving average defined by PA9 is applied to both PMC1 and PMC6

2.6.4.1 Description of PA9 (Moving Average)

In register 3360, a plain text ASCII description of PA9 is given.

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

Figure 2.6.4.1.1: Definition of register 3360.

Command: Moving average text		Modbus address: **3360** Length: **8**	Type: **3**	Read
Parameter:	Text			
Format:	Character			
Value:	**Moving average**			

Figure 2.6.4.1.2: Example to read the description for "Moving average".

2.6.4.2 Selecting the Physical Unit and Writing the Value for PA9

In register 3368, the available physical units for PA9 are defined.

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

Figure 2.6.4.2.1: Definition of register 3368.

Command: Moving average av. units		Modbus address: **3368** Length: **2**	Type: **3**	Read
Parameter:	Units			
Format:	Hex			
Value:	**0x01**			

Figure 2.6.4.2.2: Example to read the available physical units for PA9. The only one available here is "none" (0x01). For the definition of the physical units see chapter 2.5.1.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4	Modbus function code	Read access	Write access
3370	4	Select physical unit for PA9	Value for PA9 (0-30, default: 0)	16	none	S

Figure 2.6.4.2.3: Definition of register 3370. Only one bit for the physical unit can be set. PA9 can be set to the value: 0 = auto, 1-30 = fixed value. The value of 1 does not influence the response time of the sensor, the value of 30 increases the response time 30 times the value of the measurement interval.

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

By setting 0, the Automatic mode is activated. In this case the value is automatically and dynamically adjusted between 1 and 30.

Command: Moving average		Modbus address: **3370** Length: **4**	Type: **16**	Write
Parameter:	Unit	Value		
Format:	Hex	Decimal		
Value:	**0x01**	**0**		

Figure 2.6.4.2.4: Example to set the physical unit of PA9 to "none" (0x01) and the value of the moving average to auto (0).

2.6.4.3 Reading all Values for PA9

By reading register 3370, the active physical unit of measurement, the selected value, and the min and max values can be read.
When reading the register while PA9 is in automatic mode, an offset of 100 is added to the currently active value.

For example, the value 127 indicates:
- automatic mode is active
- currently, an average over 27 samples is applied

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

Figure 2.6.4.3.1: Definition of register 3370.

Command: Moving average	Modbus address: **3370**	Length: **8**	Type: **3**	Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Decimal	Decimal	Decimal
Value:	**0x01**	**130**	**1**	**30**

Figure 2.6.4.3.2: Example to read PA9. The physical unit is 0x01 ("none"), the value is 130 – that means auto mode with 30 averages per reading, and the limits of 1 to 30.

2.6.5 PA10: Number of Sub-Measurements (Resolution)

The measurement value of VisiFerm DO 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, where 0 activates the automatic mode. 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.

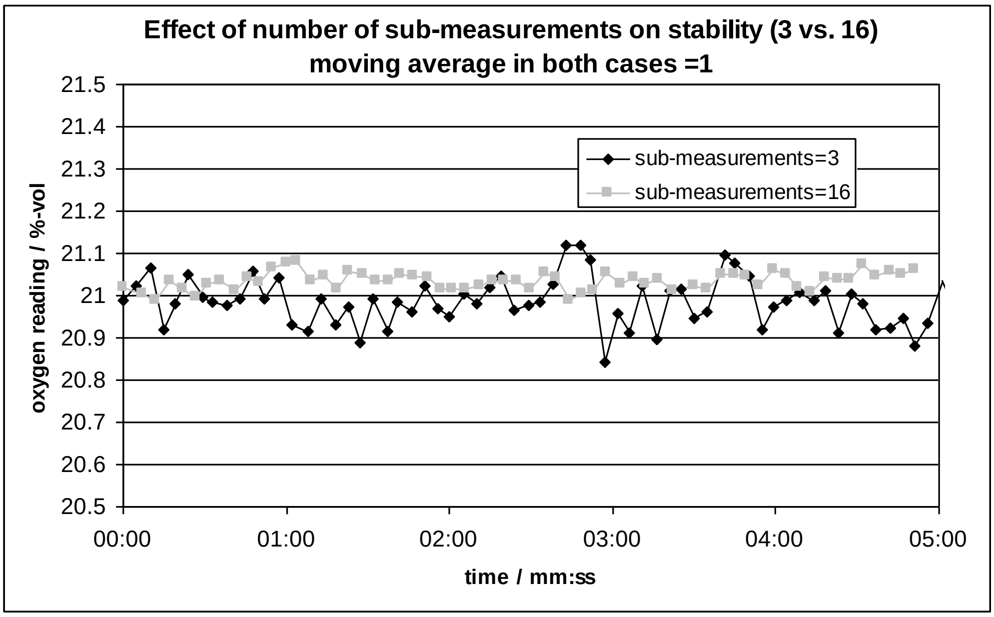

Figure 2.6.5.1: Comparison of the signal stability of VisiFerm DO when using number of sub-measurements = 16 or number of sub-measurements = 3.

2.6.5.1 Description of PA10 (Number of Sub-Measurements)

In register 3392, a plain text ASCII description of PA10 is given.

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

Figure 2.6.5.1.1: Definition of register 3392.

Command: Sub-Measurements text		Modbus address: **3392**	Length: **8**	Type: **3** Read
Parameter:	Text			
Format:	Character			
Value:	**Resolution**			

Figure 2.6.5.1.2: Example to read the description. It is “Resolution“.

2.6.5.2 Selecting the Physical Unit and Writing the Value for PA10

In register 3400, the available physical units for PA10 are defined.

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

Figure 2.6.5.2.1: Definition of register 3400.

Command: Sub-Meas. available units	Modbus address: **3400**	Length: **2**	Type: **3**	Read
Parameter:	Units			
Format:	Hex			
Value:	**0x01**			

Figure 2.6.5.2.2: Example to read the available physical units for PA10. The only one available here is "none" (0x01). For the definition of the physical units see chapter 2.5.1.

By writing to register 3402, the active physical unit of PA10 can be selected, by choosing one of the physical units that are defined in register 3400. Also the value of the parameter can be set.

By entering 0, the automatic mode for the number of sub-measurements will be activated, where the sensor continuously adjusts the value between the limits defined by PA11 (lower limit) and 16 (upper limit).

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4	Modbus function code	Read access	Write access
3402	4	Select physical unit for PA10	Value for PA10 (0, PA11-16; default: 0)	16	none	S

Figure 2.6.5.2.3: Definition of register 3402. Only one bit for the physical unit can be set and the value: 0 = auto, 1-16 = fixed value.

Command: Sub-Measurements	Modbus address: **3402**	Length: **4**	Type: **16**	Write
Parameter:	Unit	Value		
Format:	Hex	Decimal		
Value:	**0x01**	**0**		

Figure 2.6.5.2.4: Example to set the physical unit of PA10 to "none" (0x01) and the value for the number of sub-measurements to auto (0).

2.6.5.3 Reading all Values for PA10

By reading register 3402, the active physical unit, the selected value, and the min and max values can be read.
When reading the register while PA10 is in automatic mode, an offset of 100 is added to the currently active value.
For example, the value 108 indicates:

- automatic mode is active
- currently, the number of sub-measurements is 8

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

Figure 2.6.5.3.1: Definition of register 3402.

Command: Sub-Measurements		Modbus address: **3402** Length: **8**	Type: **3**	Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Decimal	Decimal	Decimal
Value:	**0x01**	**103**	**1**	**16**

Figure 2.6.5.3.2: Example to read PA10. The physical unit is 0x01 ("none"), the value is 103 – that means auto mode with 3 numbers of sub-measurements, and the limits of 1 to 16.

Note:

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

	MI < 3	MI ≥ 3
Fixed mode	1 to 3	1 to 16
Automatic mode	PA11 to 3	PA11 to 16

⚠ Attention:

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

2.6.6 PA11: Minimum Number of Sub Measurements in the Automatic Mode

If PA10 is set to 0, i.e. the number of sub-measurements is set to auto, this parameter (PA11) defines the lower limit for the number of sub-measurements in the automatic mode. A value of 3 is the factory setting and the auto mode has in this case the same behavior as with the Firmware ODOUM040 or earlier.
With a high value on this parameter, the measurement is more precise but the luminophore has more degeneration. With a low value, the measurement is more imprecise but the life expectancy is higher.
In case the measurement interval is set to 1 or 2 seconds, this parameter is limited to 1 to 3. If previously a value greater than 3 is active, the parameter will be reset to 3. If the previous value is between 1 and 3, this parameter keeps its value.

2.6.6.1 Description of PA11 (Minimum Number of Sub-Measurements for Automatic Mode)

In register 3424, a plain text ASCII description of PA11 is given.

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3424	8	Description of PA11	3, 4	U/A/S	none

Figure 2.6.6.1.1: Definition of register 3424.

Command: Min auto resol. text	Modbus address: **3424**	Length: **8**	Type: **3**	Read
Parameter:	Text			
Format:	Character			
Value:	**Min auto resol.**			

Figure 2.6.6.1.2: Example to read the description. It is “Min auto resol. “.

2.6.6.2 Selecting the Physical Unit and Writing the Value for PA11

In register 3432, the available physical units for PA11 are defined.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3432	2	Available physical units for PA11	3, 4	U/A/S	none

Figure 2.6.6.2.1: Definition of register 3432.

Command:Min resol. available units	Modbus address: **3432**	Length: **2**	Type: **3**	Read
Parameter:	Units			
Format:	Hex			
Value:	**0x01**			

Figure 2.6.6.2.2: Example to read the available physical units for PA11. The only one available here is “none” (0x01). For the definition of the physical units see chapter 2.5.1.

By writing to register 3434, the active physical unit of PA11 can be selected, by choosing one of the physical units that are defined in register 3432. Also the value of the parameter can be set.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4	Modbus function code	Read access	Write access
3434	4	Select physical unit for PA11	Value for PA11 (0, 1-16; default: 3)	16	none	S

Figure 2.6.6.2.3: Definition of register 3434. Only one bit for the physical unit can be set and the value: 1-16.

Command: Min auto resol.	Modbus address: **3434**	Length: **4**	Type: **16**	Write

Parameter:	Unit	Value		
Format:	Hex	Decimal		
Value:	**0x01**	**4**		

Figure 2.6.6.2.4: Example to set the physical unit of PA11 to "none" (0x01) and the value for the minimum number of sub-measurements in the automatic mode to 4.

2.6.6.3 Reading all Values for PA11

By reading register 3434, the active physical unit, the selected value, and the min and max values can be read.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
3434	8	Physical unit	Current value	Min value	Max value	3, 4	U/A/S	none

Figure 2.6.6.3.1: Definition of register 3434.

Command: Sub-Measurements		Modbus address: **3434**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Decimal	Decimal	Decimal
Value:	**0x01**	**4**	**1**	**16**

Figure 2.6.6.3.2: Example to read PA11. The physical unit is 0x01 ("none"), the value is 4.

Attention:
If PA13 (Measurement Interval) is set to one or two, PA11 (Minimum number of sub-measurements in the automatic mode) will be limited from one to three.

2.6.7 PA13: Measurement Interval

The measurement interval for the VisiFerm can be set between 1s and 300s (5min). The DO measurement can also 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 using the brewery mode, the measurement interval is limited between 3 and 60 s.
2) 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 2.7.3 for more details.
3) When a CP6 calibration is performed, the measurement interval is not changed by the sensor. If the measurement interval is 0 s, initial measurement on CP6 will not be executed as the DO measurement is not running.

2.6.7.1 Description of PA13 (Measurement Interval)

In register 3488, a plain text ASCII description of PA13 is given.

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

Figure 2.6.7.1.1: Definition of register 3488.

Command: Meas. interval	Modbus address: **3488**	Length: **8**	Type: **3**	Read
Parameter:	Text			
Format:	Character			
Value:	**Meas. interval**			

Figure 2.6.7.1.2: Example to read the description. It is “Meas. interval “.

2.6.7.2 Selecting the Physical Unit and Writing the Value for PA13

In register 3496, the available physical units for PA13 are defined.

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

Figure 2.6.7.2.1: Definition of register 3496.

Command:Meas. Int. available units	Modbus address: **3496**	Length: **2**	Type: **3**	Read
Parameter:	Units			
Format:	Hex			
Value:	**0x01**			

Figure 2.6.7.2.2: Example to read the available physical units for PA13. The only one available here is “none” (0x01). For the definition of the physical units see chapter 2.5.1.

By writing to register 3498, the active physical unit of PA13 can be selected, by choosing one of the physical units that are defined in register 3496. Also the value of the parameter can be set.

Start	Number of	Reg1 / Reg2	Reg3 / Reg4	Modbus	Read	Write

register	registers	(bitwise defined)		function code	access	access
3498	4	Select physical unit for PA13	Value for PA13 (0-300; default: 3)	16	none	S

Figure 2.6.7.2.3: Definition of register 3496. Only one bit for the physical unit can be set and the value: 0-300.

Command: Meas. Interval		Modbus address: **3498**	Length: **4**	Type: **16** Write
Parameter:	Unit	Value		
Format:	Hex	Decimal		
Value:	**0x01**	**30**		

Figure 2.6.7.2.4: Example to set the physical unit of PA13 to "none" (0x01) and the measurement interval to 30.

2.6.7.3 Reading all Values for PA13

By reading register 3498, the active physical unit, the selected value, and the min and max values can be read.

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

Figure 2.6.7.3.1: Definition of register 3498.

Command: Meas. Interval		Modbus address: **3498**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Decimal	Decimal	Decimal
Value:	**0x01**	**30**	**0**	**300**

Figure 2.6.7.3.2: Example to read PA13. The physical unit is 0x01 ("none"), and the measurement interval is 30 seconds.

Attention:
Setting PA13 to 0 deactivates DO reading completely. Temperature readings are still active. Bit 31 of "Warning Measurement" is set which means "Measurement not running".
The DO value is frozen on the analog and digital output.

Note:
If the measurement interval is set to 1s or 2s, the current values of PA10 and PA11 are overwritten to 3 if the values were greater than 3.
If the measurement interval is set to a value greater than 2s, PA10 and PA11 remain unchanged.

2.6.8 PA14: Sensor Cap Part Number

The VisiFerm DO 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.

2.6.8.1 Description of PA14 (Sensor Cap Part Number)

In register 3488, a plain text ASCII description of PA14 is given.

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

Figure 2.6.8.1.1: Definition of register 3488.

Command: SensorCap PartNr	Modbus address: **3520**	Length: **8**	Type: **3**	Read
Parameter:	Text			
Format:	Character			
Value:	**SensorCap PartNr**			

Figure 2.6.8.1.2: Example to read the description. It is “SensorCap PartNr“.

2.6.8.2 Selecting the Physical Unit and Writing the Value for PA14

In register 3528, the available physical units for PA14 are defined.

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

Figure 2.6.8.2.1: Definition of register 3528.

Command: SensorCap PartNr available units	Modbus address: **3528**	Length: **2**	Type: **3**	Read
Parameter:	Units			
Format:	Hex			
Value:	**0x01**			

Figure 2.6.8.2.2: Example to read the available physical units for PA14. The only one available here is “none” (0x01). For the definition of the physical units see chapter 2.5.1.

By writing to register 3530, the active physical unit of PA14 can be selected, by choosing one of the physical units that are defined in register 3528. Also the value of the parameter can be set. Only valid sensor cap part numbers are accepted by the sensor.

By default the following sensor cap part numbers are defined:
- 242427: ODO cap P0
- 243510: ODO cap P1
- 243515: ODO cap H0
- 243500: ODO cap H1
- 243505: ODO cap H2

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4	Modbus function code	Read access	Write access
3530	4	Select physical unit for PA14	Value for PA14 (0-1000000; default: 242427)	16	none	S

Figure 2.6.8.2.3: Definition of register 3530. Only one bit for the physical unit can be set and the value: 0-1000000. Only valid sensor cap part numbers are accepted by the sensor.

Command: SensorCap PartNr		Modbus address: **3530**	Length: **4**	Type: **16** Write
Parameter:	Unit	Value		
Format:	Hex	Decimal		
Value:	**0x01**	**243515**		

Figure 2.6.8.2.4: Example to set the physical unit of PA14 to "none" (0x01) and the sensor cap part number to 243515.

2.6.8.3 Reading all Values for PA14

By reading register 3530, the active physical unit, the selected value, and the min and max values can be read.

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

Figure 2.6.8.3.1: Definition of register 3530.

Command: SensorCap PartNr		Modbus address: **3530**	Length: **8**	Type: **3** Read
Parameter:	Unit	Value	Min value	Max value
Format:	Hex	Decimal	Decimal	Decimal
Value:	**0x01**	**242427**	**0**	**1000000**

Figure 2.6.8.3.2: Example to read PA14. The physical unit is 0x01 ("none"), and the sensor cap part number is 242427.

2.7 Calibration

2.7.1 Available Calibration Points

In register 5120, the available number of Calibration Points (CP) for Primary Measurement Channel 1 (PMC1) is defined. 8 individual CP are theoretically possible.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
5120	2	Available number of CP for PMC1 (see Figure 2.7.1.2)	3, 4	U/A/S	none

Figure 2.7.1.1: Definition of register 5120.

Bit #	Hex value	Description	Definition in VisiFerm DO
0 (LSB)	**0x01**	**CP1**	**Calibration low point**
1	**0x02**	**CP2**	**Calibration high point**
2	0x04	CP3	not available
…	…	…	not available
5	**0x20**	**CP6**	**Product calibration**
6	...	CP7	not available
7 (MSB)	0x80	CP8	not available

Figure 2.7.1.2: Bitwise definition of CP1 to CP8.

Command: Available cali points		Modbus address: **5120**	Length: **2**	Type: **3** Read
Parameter:	Points			
Format:	Hex			
Value:	**0x23**			

Figure 2.7.1.3: Example to read the available CPs. 0x23 = 0x01 (CP1) + 0x02 (CP2) + 0x20 (CP6).

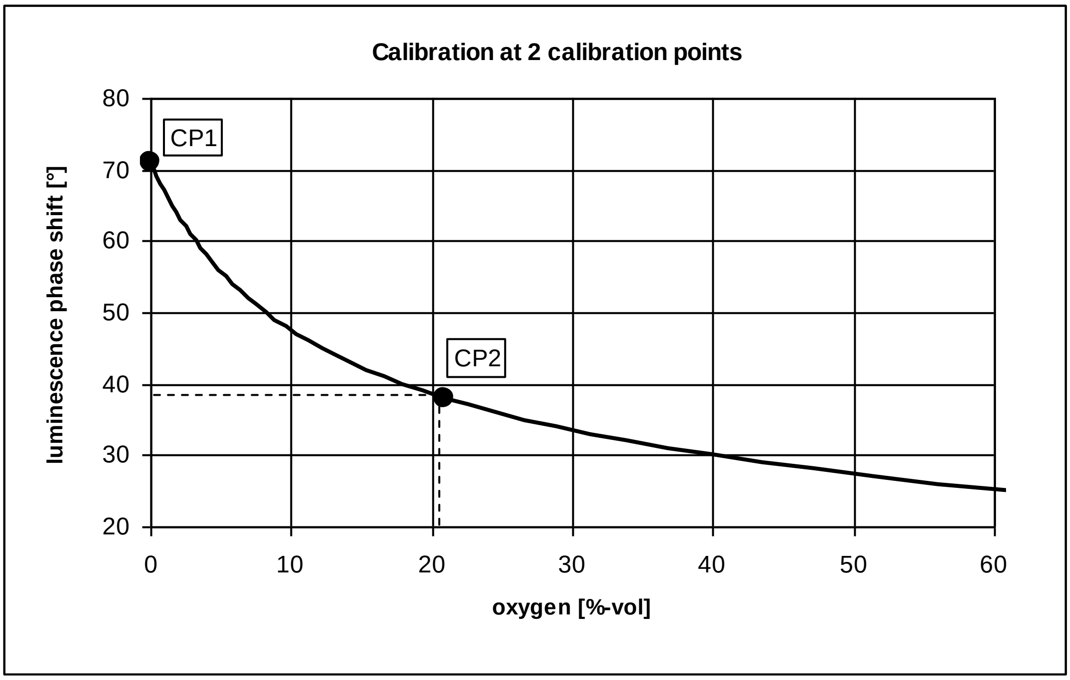

Figure 2.7.1.4: VisiFerm DO allows 3 calibration points:
CP1 and CP2 are used for standard calibration (shown in this figure).
The product calibration CP6 is used to adjust the standard calibration function to specific process conditions (the effect of CP6 is shown in Figure 2.7.3.2.1.1).

2.7.2 Definitions of Calibration Points

2.7.2.1 Calibration Points 1 and 2 (Standard Calibration)

The limits for the calibration point 1 are defined in register 5152, for calibration point 2 in register 5184.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
5152	6	Physical unit currently active for CP1	Min value for CP1 (in the physical unit as defined in Reg1 and 2)	Max value for CP1 (in the physical unit as defined in Reg1 and 2)	3, 4	U/A/S	none
5184	6	Physical unit currently active for CP2	Min value for CP2 (in the physical unit as defined in Reg1 and 2)	Max value for CP2 (in the physical unit as defined in Reg1 and 2)	3, 4	U/A/S	none

Figure 2.7.2.1.1: Definition of register 5152 for CP1 and 5184 for CP2.

Command: Calibration limits CP1	Modbus address: **5152**	Length: **6**	Type: **3**	Read
Parameter:	Unit	Min value	Max value	
Format:	Hex	Float	Float	
Value:	**0x20**	**0**	**0**	

Figure 2.7.2.1.2: Example to read the limits of CP1. Currently active physical unit is %-sat (0x20), the min and max value are both 0 (%-sat).

Command: Calibration limits CP2	Modbus address: **5184**	Length: **6**	Type: **3**	Read
Parameter:	Unit	Min value	Max value	
Format:	Hex	Float	Float	
Value:	**0x20**	**9.729055**	**267.549**	

Figure 2.7.2.1.3: Example to read the limits of CP2. Currently active physical unit is %-sat (0x20), the min value is 9.73 (%-sat) and the max value is 267.55 (%-sat).

Command: Calibration limits CP2	Modbus address: **5184**	Length: **6**	Type: **3**	Read
Parameter:	Unit	Min value	Max value	
Format:	Hex	Float	Float	
Value:	**0x800000**	**20**	**550**	

Figure 2.7.2.1.4: Example to read the limits of CP2. Currently active physical unit is mbar (0x800000), the min value is 20 (mbar) and the max value is 550 (mbar). When changing the active physical unit for PMC1 (using register 2090), the min and max value will be updated automatically to the new physical unit. Temperature, atmospheric pressure and salinity are compensated.

When initiating the calibration at CP1 and CP2, the measured oxygen and temperature have to be stable for at least 3 minutes. The stability criteria are defined in register 5128:

Start register	Number of registers	Reg1 / Reg2 (Float)	Reg3 / Reg4 (Float)	Modbus function code	Read access	Write access
5128	4	Max. Drift PMC1 oxygen [°/10min]	Max. Drift PMC6 Temperature [K/10min]	3, 4, 16	U/A/S	S

Figure 2.7.2.1.5: Definition of register 5128.

Command: Read calibration stability		Modbus address: **5128**	Length: **4**	Type: **3** Read
Parameter:	Max drift oxygen [°/10min]	Max drift Temp [K/10min]		
Format:	Float	Float		
Value:	**0.05**	**0.05**		

Figure 2.7.2.1.6: Example to read the calibration stability.

Command: Set calibration stability		Modbus address: **5128**	Length: **4**	Type: **16** Write
Parameter:	Max drift oxygen [°/10min]	Max drift Temp [K/10min]		
Format:	Float	Float		
Value:	**0.05**	**0.05**		

Figure 2.7.2.1.7: Example to set the calibration stability.

⚠ Attention:

The stability criteria defined in register 5128 is valid for CP1 and CP2 only, but NOT for CP6.

2.7.2.2 Calibration Point 6 (Product Calibration)

The limits for calibration point 6 are given in register 5312.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
5312	6	Physical unit during initial measurement CP6	Min value for CP6 (in the physical unit as defined in Reg1 and 2)	Max value for CP6 (in the physical unit as defined in Reg1 and 2)	3, 4	U/A/S	none

Figure 2.7.2.2.1: Definition of register 5312 for CP6.

Command: Calibration limits CP6	Modbus address: **5312**	Length: **6**	Type: **3**	Read
Parameter:	Unit	Min value	Max value	
Format:	Hex	Float	Float	
Value:	**0x20**	**9.729055**	**267.549**	

Figure 2.7.2.2.2: Example to read the limits of CP6. The physical unit of the limits is the unit of PMC1 at the time of initial measurement. In this example it is %-sat (0x20), the min value is 9.73 (%-sat) and the max value is 267.55 (%-sat) (between 20 and 550 mbar, respectively). When changing the active physical unit for PMC1 (using register 2090), the min and max value will not be updated to the new physical unit. Temperature, atmospheric pressure and salinity are compensated.

2.7.3 Calibration Procedure

2.7.3.1 Calibration at CP1 and CP2 (Standard Calibration)

VisiFerm DO has a unique calibration routine. When initiating the calibration, the data set of the VisiFerm DO 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:

It is important that VisiFerm DO 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 or equals 0 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" (0x80 for CP1 or 0x8000 for CP2 in the 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 status register), if the stability is not ok, the sensor sets the corresponding bit in the calibration status register (reg. 5158 or 5190).

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 or 0. 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 5162 and at CP2 by writing to register 5194.

By entering 0 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).

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
5162	2	Oxygen value at CP1 (physical unit as defined with register 2090)	16	none	A/S
5194	2	Oxygen value at CP2 (physical unit as defined with register 2090)	16	none	A/S

Figure 2.7.3.1.1: Definition of register 5162 and 5194. The oxygen value (0 = auto) has to be given in the physical unit defined with register 2090.

Command: Make calibration CP1	Modbus address: **5162**	Length: **2**	Type: **16**	Write
Parameter:	Value			
Format:	Float			
Value:	**0**			

Figure 2.7.3.1.2: Example to start the calibration at CP1, giving a value of 0 for auto or oxygen (0 %-vol in this case).

Command: Make calibration CP2	Modbus address: **5194**	Length: **2**	Type: **16**	Write
Parameter:	Value			
Format:	Float			
Value:	**0**			

Figure 2.7.3.1.3: Example to start the calibration at CP2, giving a value of 0 for auto (20.95 %-vol in this case).

Command: Make calibration CP2	Modbus address: **5194**	Length: **2**	Type: **16**	Write
Parameter:	Value			
Format:	Float			
Value:	**21.05**			

Figure 2.7.3.1.4: Example to start the calibration at CP2, giving a value of 21.05 (%-vol in this case). The value has to be inside the defined limits.

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.

Example 1:
Register 2090 is set to physical unit "mg/l ppm" (0x80).

Command: Calibration limits CP2	Modbus address: **5184**	Length: **6**	Type: **3**	Read
Parameter:	Unit	Min value	Max value	
Format:	Hex	Float	Float	
Value:	**0x80**	**0.7544258**	**20.74671**	

Figure 2.7.3.1.5: Example: Accordingly, VisiFerm DO transforms the limits for CP2 (register 5184) from the defined range of 20-550 mbar to dissolved oxygen concentration at current salinity (0 mS/cm) and at current temperature (26.5 °C), which is 0.75-20.75 mg/l.

Command: Make calibration CP2	Modbus address: **5194**	Length: **2**	Type: **16**	Write
Parameter:	Value			
Format:	Float			
Value:	**8**			

Figure 2.7.3.1.6: Example: The calibration is performed by telling VisiFerm DO, that the oxygen concentration in the calibration media is 8 mg/l.

Command: PMC 1 read		Modbus address: **2090**	Length: **10**	Type: **3**	Read
Parameter:	Unit	Value	Status	Min limit	Max limit
Format:	Hex	Float	Hex	Float	Float
Value:	**0x80**	**7.99898**	**0x00**	**0**	**22.97096**

Figure 2.7.3.1.7: Example: After calibration, the oxygen reading is then 8 mg/l, as desired.

Example 2:
Register 2090 is set to physical unit "mg/l ppm" (0x80).

Command: Make calibration CP2	Modbus address: **5194**	Length: **2**	Type: **16**	Write
Parameter:	Value			
Format:	Float			
Value:	**0**			

Figure 2.7.3.1.8: Example: With the automatic mode (value = 0), the calibration at CP2 is started.

Command: PMC 1 read		Modbus address: **2090**	Length: **10**	Type: **3**	Read
Parameter:	Unit	Value	Status	Min limit	Max limit
Format:	Hex	Float	Hex	Float	Float
Value:	**0x80**	**7.602702**	**0x00**	**0**	**22.92315**

Figure 2.7.3.1.9: Example: As a result of the calibration, the oxygen reading is 7.6 (mg/l ppm), as the temperature reading at the same time is 26.5 °C. The theoretical concentration of DO in water with 26.5 °C and having a salinity of 0 mS/cm is 7.6 mg/l.

2.7.3.2 Calibration Point 6 (Product Calibration)

The product calibration is a process in order to adjust the measurement of a correctly calibrated VisiFerm DO 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 DO 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 DO 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 DO sensors memory.

2. When the result of the reference analysis is available this value is assigned at a second time point to the former initial measurement data stored in the VisiFerm DO 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 still stored standard calibration (CP1 and CP2).
If a product calibration is still active and a standard calibration (CP1 or CP2) is performed the product calibration (CP6) is cancelled.
If the operator needs to overrun a 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 DO

sensor is still running on the first product calibration (old CP6) until a valid assignment has been done (new CP6).

What happens to the VisiFerm DO calibration function upon product calibration (CP6)?
A product calibration for VisiFerm DO and VisiFerm DO Arc Sensors corresponds to a manual calibration at CP2. On active product calibration (CP6) the VisiFerm's calibration function is calculated from the data of Calibration point 1 and from the data of the product calibration (CP6).
For more flexibility the product calibration procedure allows larger deviations from the Arc Sensors current measurement than the standard calibration.

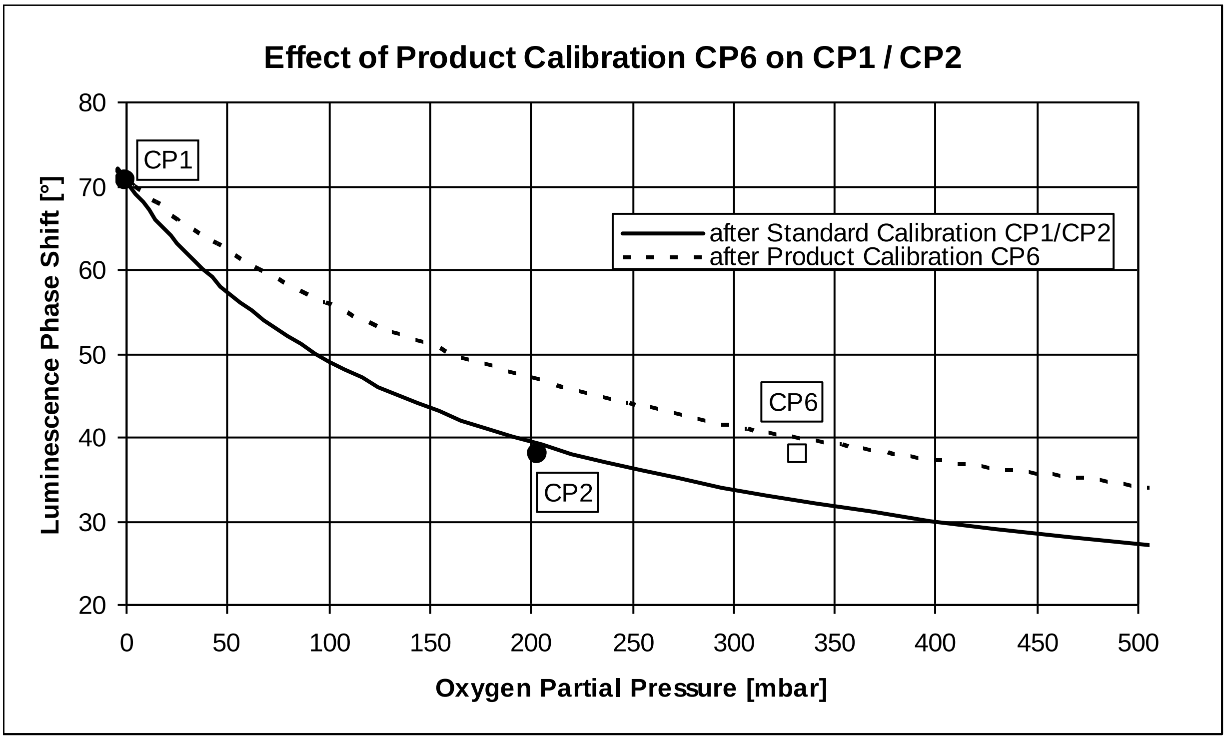

Figure 2.7.3.2.1: Effect of the product calibration CP6 on an existing standard calibration function defined by CP1 and CP2.

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

CP1: oxygen value: 0 mbar temperature: 27.77°C measured phase red: 70.7°
CP2: oxygen value: 203.92 mbar temperature: 28.71°C measured phase red: 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 5448, see chapter 2.7.8).

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:

CP6: oxygen value: 332 mbar temperature: 28.79°C measured phase red: 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 DO's 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 5340 except for assignment where the calibration value is written to register 5322 (see below).

Definition of the commands for product calibration

The commands for register 5340 are defined as follows:

Hex Code	Definition of commands
0x01	Perform initial measurement
0x02	Cancel an active product calibration
0x03	Restore a standard calibration from an active product calibration
0x04	Restore a product calibration from an active standard calibration

Figure 2.7.3.2.2: Definition of the commands related to the product calibration

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
5340	2	Code as defined in Figure 2.7.3.2.2	3, 4, 16	A/S	A/S

Figure 2.7.3.2.3: Definition of register 5340

2.7.3.2.1 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 0x01 to register 5340 which performs the initial measurement and stores the corresponding measurement values in the sensor.

Command: CP6: Initial measurement	Modbus address: **5340**	Length: **2**	Type: **16**	Write
Parameter:	Command			
Format:	Hex			
Value:	**0x01**			

Figure 2.7.3.2.1.1: Example to start the product calibration procedure. Writing command 0x01 (initial measurement) to the CP6 command register 5340.

After successful initial measurement the corresponding calibration status is "CP6: Initial measurement" (0x08000000) (see Figure 2.7.4.1.1).
The sensor continues measuring using the prior standard calibration.

Note:
If the measurement interval is equal to 0, the initial measurement command has no effect.

2.7.3.2.2 Product calibration: Assignment

After successful initial measurement a correct value must be assigned to the initially stored measurement data.
This is achieved by writing the correct calibration value to register 5322.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
5322	2	Oxygen value in the unit of PMC1 during initial measurement (floating)	16	none	A/S

Figure 2.7.3.2.2.1: Definition of register 5322

Command: CP6: Assignment		Modbus address: **5322**	Length: **2**	Type: **16** Write
Parameter:	Value			
Format:	Float			
Value:	**195**			

Figure 2.7.3.2.2.2: Example to assign a calibration value to the above performed initial measurement. This is achieved by writing the correct oxygen value in the unit of PMC1 during initial measurement (here 195 mbar) to 5322.

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

The calibration status of the sensor is 0x14000000 meaning that a correct value has been assigned and that the product calibration is active (see Figure 2.7.4.1.1).

2.7.3.2.3 Product calibration: Cancel

To cancel an active product calibration or an active initial measurement the command 0x02 is written to register 5340.

Command: CP6: Cancel		Modbus address: **5340**	Length: **2**	Type: **16** Write
Parameter:	Command			
Format:	Hex			
Value:	**0x02**			

Figure 2.7.3.2.3.1: Example to cancel an active product calibration or an initial measurement. Writing command 0x02 (cancel) to the CP6 command register 5340.

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.

The sensor's calibration status will be reading 0x00 again (see Figure 2.7.4.1.1).

2.7.3.2.4 Product calibration: Restore standard calibration

If a product calibration is active this product calibration can be temporarily switched off by writing the command 0x03 to register 5340.
Performing this action the values of the product calibration remain stored in the sensor's memory.

Command: CP6: Restore standard		Modbus address: **5340**	Length: **2**	Type: **16** Write
Parameter:	Command			
Format:	Hex			
Value:	**0x03**			

Figure 2.7.3.2.4.1: Example to restore a standard calibration from an active product calibration. Writing command 0x03 (restore standard calibration) to the CP6 command register 5340.

From now on the sensor is measuring using its prior CP1 / CP2 standard calibration.
The sensor's calibration status will be reading "CP6 assigned" (0x10000000) meaning that a valid assignment for a product calibration is available in the sensor's memory (see Figure 2.7.4.1.1).

2.7.3.2.5 Product calibration: Restore product calibration

If a valid but inactivated product calibration is available in the sensors memory, the calibration status is reading 0x10000000 ("CP 6 assigned", see Figure 2.7.4.1.1), this stored product calibration can be restored or reactivated by writing command 0x04 to register 5340.

Command: CP6: Restore product		Modbus address: **5340**	Length: **2**	Type: **16** Write
Parameter:	Command			
Format:	Hex			
Value:	**0x04**			

Figure 2.7.3.2.5.1: Example to restore an available product calibration from an active standard calibration. Writing command 0x04 (restore product calibration) to the CP6 command register 5340.

From now on the sensor is measuring using its prior CP6 product calibration.
The sensors calibration status will be reading 0x14000000 (corresponding to "CP6 assigned" and "CP6 active" (see Figure 2.7.4.1.1) again.

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

2.7.4 Reading the Calibration Status

2.7.4.1 Reading the Calibration Status of CP1 and CP2 (Standard Calibration)

A standard calibration is not always successful. In order to analyze what has gone wrong, two different calibration status registers can be read:

- Register 5158 for CP1
- Register 5190 for CP2

Note:
Registers 5158 and 5190 contain the same information!

Bit #	Hex value	Definition in VisiFerm DO / VisiFerm DO Arc
0 (LSB)	0x00000001	CP1: Oxygen value to be calibrated at is too low (see register 5152)
1	0x00000002	CP1: Oxygen value to be calibrated at is too high (see register 5152)
2	0x00000004	CP1: current temperature reading is too low
3	0x00000008	CP1: current temperature reading is too high
4	0x00000010	CP1: temperature reading during calibration is not stable
5	0x00000020	CP1: Phase is too low for the oxygen value to be calibrated at
6	0x00000040	CP1: Phase too high for the oxygen value to be calibrated at
7	0x00000080	CP1: Phase reading during calibration is not stable
8	0x00000100	CP2: Oxygen value to be calibrated at is too low (see register 5184)
9	0x00000200	CP2: Oxygen value to be calibrated at is too high (see register 5184)
10	0x00000400	CP2: current temperature reading is too low
11	0x00000800	CP2: current temperature reading is too high
12	0x00001000	CP2: temperature reading during calibration is not stable
13	0x00002000	CP2: Phase is too low for the oxygen value to be calibrated at
14	0x00004000	CP2: Phase too high for the oxygen value to be calibrated at
15	0x00008000	CP2: Phase reading during calibration is not stable
16-23	…	not available
24	0x01000000	CP6: out of calibration range
25	0x02000000	CP6: out of range
26	0x04000000	CP6: active
27	0x08000000	CP6: initial measurement
28	0x10000000	CP6: assigned
29-31	…	not available

Figure 2.7.4.1.1: Definition of the register at 5158, 5190 (and 5318) (see also Figure 2.7.4.1.2).

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
5158	6	Status CP1 (see figure 2.7.4.1.1)	Physical unit of the last successful calibration CP1	Oxygen value of the last successful calibration CP1	3, 4	U/A/S	none
5190	6	Status CP2 (see figure 2.7.4.1.1)	Physical unit of the last successful calibration CP2	Oxygen value of the last successful calibration CP2	3, 4	U/A/S	none

Figure 2.7.4.1.2: Definition of register 5158 for CP1 and register 5190 for CP2.

Command: Calibration status CP1	Modbus address: **5158**	Length: **6**	Type: **3**	Read
Parameter:	Status	Unit	Value	
Format:	Hex	Hex	Float	
Value:	**0x80**	**0x800000**	**0**	

Figure 2.7.4.1.3: Example to read the calibration status of CP1 after having tried to calibrate CP1 at 0 = auto. The status says: “CP1 Phase reading during calibration is not stable” (0x80). The physical unit of the last calibration is 0x800000 (mbar), the last successful calibration has been performed at 0 (mbar).

Command: Calibration status CP2	Modbus address: **5190**	Length: **6**	Type: **3**	Read
Parameter:	Status	Unit	Value	
Format:	Hex	Hex	Float	
Value:	**0x80**	**0x10**	**20.95**	

Figure 2.7.4.1.4: Example to read the calibration status of CP2 after calibrating CP2 at 20.95 %-vol. All bits of CP2 are zero, indicating that the calibration was successful. The physical unit of the last calibration is %-vol (0x10), the last successful calibration has been performed at 20.95 (%-vol). Please note that the status says: “CP1 Phase reading during calibration is not stable”. This is a status bit for CP1. All bits of CP1 will remain unaffected when calibrating CP2.

Command: Calibration status CP2	Modbus address: **5190**	Length: **6**	Type: **3**	Read
Parameter:	Status	Unit	Value	
Format:	Hex	Hex	Float	
Value:	**0x0180**	**0x10**	**20.95**	

Figure 2.7.4.1.5: Example to read the calibration status of CP2 after attempt to calibrate CP2 at 1 %-vol, which is out of the allowed limit (register 5184). The value you see is 0x0180 = 0x080 + 0x0100. Shown is still 0x0080 of CP1 and new 0x0100 of CP2, which says: “CP2 Oxygen value is too low for calibration” (see register 5184).

2.7.4.2 Reading the Calibration Status of CP6 (Product Calibration)

The calibration status and the current state of the VisiFerm DO Sensor in the product calibration process (CP6) is read in the calibration status register for CP6 (5318).

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
5318	6	Status CP6 (see Figure 2.7.4.1.1)	Physical unit of the last successful calibration CP6	Oxygen value of the last successful calibration CP6	3, 4	U/A/S	none

Figure 2.7.4.2.1: Definition of register 5318 for CP6. For examples, see following chapters.

2.7.4.2.1 Product calibration: Initial measurement

Calibration status after initial measurement command under conditions outside the valid calibration range for CP6 (defined in register 5312):

Command: Calibration status CP6	Modbus address: **5318**	Length: **6**	Type: **3**	Read
Parameter:	Status	Unit	Value	
Format:	Hex	Hex	Float	
Value:	**0x1000000**	**0x800000**	**200**	

Figure 2.7.4.2.1.1: Example to read the calibration status of CP6 after having performed an initial measurement at CP6 under measurement conditions outside the calibration range for CP6.
The status says: "CP6: out of calibration range" (0x1000000). The physical unit of the last calibration is 0x800000 (mbar), the last successful calibration has been performed at 200 (mbar).
The initial measurement in this case was **not** successful.
The sensor is still running on its prior standard calibration.

Calibration status after successful initial measurement:

Command: Calibration status CP6	Modbus address: **5318**	Length: **6**	Type: **3**	Read
Parameter:	Status	Unit	Value	
Format:	Hex	Hex	Float	
Value:	**0x8000000**	**0x800000**	**200**	

Figure 2.7.4.2.1.2: Example to read the calibration status of CP6 after having performed an initial measurement at CP6 under correct measurement conditions.
The status says: "CP6: initial measurement" (0x8000000). The physical unit of the last calibration is 0x800000 (mbar), the last successful calibration has been performed at 200 (mbar).
The initial measurement in this case was successful.
The sensor is still running on its prior standard calibration until a valid calibration value has been assigned to this initial measurement values.

2.7.4.2.2 Product calibration: Assignment

Calibration status after invalid assignment:

Command: Calibration status CP6	Modbus address: **5318**	Length: **6**	Type: **3**	Read
Parameter:	Status	Unit	Value	
Format:	Hex	Hex	Float	
Value:	**0xA000000**	**0x800000**	**200**	

Figure 2.7.4.2.2.1: Example to read the calibration status of CP6 after having performed a valid initial measurement at CP6 and an invalid assignment.
The status says: "CP6: out of range" and "CP6: initial measurement" (0xA000000). The physical unit of the last calibration is 0x800000 (mbar), the last successful calibration has been performed at 200 (mbar).
The initial measurement in this case is still valid and available for further assignment of a product calibration value. The here performed assignment was **not** successful. The sensor remains running on its prior standard calibration.

Calibration status after valid assignment:

Command: Calibration status CP6	Modbus address: **5318**	Length: **6**	Type: **3**	Read
Parameter:	Status	Unit	Value	
Format:	Hex	Hex	Float	
Value:	**0x14000000**	**0x800000**	**195**	

Figure 2.7.4.2.2.2: Example to read the calibration status of CP6 after having performed an initial measurement at CP6 and a valid assignment.
The status says: "CP6: active" and "CP6: assigned" (0x14000000). The physical unit of the last calibration is 0x800000 (mbar), the last successful calibration corresponding to the here performed assignment has been performed at 195 (mbar).
The here performed assignment was successful. The sensor is running using a valid product calibration.

2.7.4.2.3 Product calibration: Cancel

Calibration status after cancelling an active product calibration:

Command: Calibration status CP6	Modbus address: **5318**	Length: **6**	Type: **3**	Read
Parameter:	Status	Unit	Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x800000**	**195**	

Figure 2.7.4.2.3.1: Example to read the calibration status of CP6 after having performed a cancel command at CP6.
The status says: "no calibration status message" (0x00). The physical unit of the last calibration is 0x800000 (mbar), the last successful calibration at CP6 has been performed at 195 (mbar).
The sensor is running on a valid standard calibration and no product calibration is stored.

2.7.4.2.4 Product calibration: Restore standard calibration

Calibration status after restoring a standard calibration from an active product calibration:

Command: Calibration status CP6	Modbus address: **5318**	Length: **6**	Type: **3**	Read
Parameter:	Status	Unit	Value	
Format:	Hex	Hex	Float	
Value:	**0x10000000**	**0x800000**	**195**	

Figure 2.7.4.2.4.1: Example to read the calibration status of CP6 after having restored the standard calibration from an active product calibration (CP6).
The status says: "CP6: assigned" (0x10000000). The physical unit of the last calibration is 0x800000 (mbar), the last successful calibration at CP6 has been performed at 195 (mbar).
The sensor is running on a valid standard calibration but a valid product calibration is still available in the sensor.

2.7.4.2.5 Product calibration: Restore product calibration

Calibration status after restoring an available product calibration from an active standard calibration:

Command: Calibration status CP6	Modbus address: **5318**	Length: **6**	Type: **3**	Read
Parameter:	Status	Unit	Value	
Format:	Hex	Hex	Float	
Value:	**0x14000000**	**0x800000**	**195**	

Figure 2.7.4.2.5.1: Example to read the calibration status of CP6 after having restored an available product calibration (CP6) from an active standard calibration (CP1 / CP2).
The status says: "CP6: active" and "CP6: assigned" (0x14000000). The physical unit of the last calibration is 0x800000 (mbar), the last successful calibration corresponding to the here performed assignment has been performed at 195 (mbar).
The sensor is running on a valid product calibration again.

2.7.5 Currently active Calibration Parameters part 1

In registers 5164 (CP1), 5196 (CP2) and 5324 (CP6) the currently active calibration parameters part 1 are stored. These registers contain the values for temperature, number of calibrations and operating hour upon calibration.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
5164	8	Unit of temperature for CP1 (bitwise defined)	Value of temperature of CP1	Number of calibrations at CP1	Operating hour for CP1	3, 4	U/A/S	none
5196	8	Unit of temperature for CP2 (bitwise defined)	Value of temperature of CP2	Number of calibrations at CP2	Operating hour for CP2	3, 4	U/A/S	none
5324	8	Unit of temperature for CP6 (bitwise defined)	Value of temperature of CP6	Number of calibrations at CP6	Operating hour for CP6	3, 4	U/A/S	none

Figure 2.7.5.1: Definition of register 5164 for CP1, 5196 for CP2 and 5324 for CP6.

Note: the "operating hour" for CP6 is the moment of the "initial measurement".

Command: Calibration CP1 values 1	Modbus address: **5164**	Length: **8**	Type: **3**	Read
Parameter:	Unit of temperature	Temperature	Number of cali	Operating hour
Format:	Hex	Float	Decimal	Float
Value:	**0x04**	**26.08493**	**2**	**162.3167**

Figure 2.7.5.2: Example to read the calibration values 1 for CP1. The physical unit is °C (0x04), the temperature is 26.08 (°C), the number of calibrations at CP1 is 2 and the operating hour is 162.3 (h).

Command: Calibration CP2 values 1	Modbus address: **5196**	Length: **8**	Type: **3**	Read
Parameter:	Unit of temperature	Temperature	Number of cali	Operating hour
Format:	Hex	Float	Decimal	Float
Value:	**0x04**	**26.86173**	**14**	**163.75**

Figure 2.7.5.3: Example to read the calibration values 1 for CP2. The physical unit is °C (0x04), the temperature is 26.86 (°C), the number of calibrations at CP1 is 14 and the operating hour is 163.75 (h).

Command: Calibration CP6 values 1	Modbus address: **5324**	Length: **8**	Type: **3**	Read
Parameter:	Unit of temperature	Temperature	Number of cali	Operating hour
Format:	Hex	Float	Decimal	Float
Value:	**0x04**	**29.93368**	**12**	**379.5167**

Figure 2.7.5.4: Example to read the calibration values 1 for CP6. The physical unit is °C (0x04), the temperature is 29.93 (°C), the number of calibrations at CP1 is 12 and the operating hour is 379.51 (h).

2.7.6 Currently active Calibration Parameters part 2

In registers 5172 (CP1), 5204 (CP2) and 5332 (CP6) the current calibration parameters part 2 are stored. These registers contain the values for atmospheric pressure and salinity.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
5172	8	Unit of pressure for CP1 (bitwise defined)	Value of pressure of CP1	Unit of salinity of CP1 (bitwise defined)	Value of salinity of CP1	3, 4	U/A/S	none
5204	8	Unit of pressure for CP2 (bitwise defined)	Value of pressure of CP2	Unit of salinity of CP2 (bitwise defined)	Value of salinity of CP2	3, 4	U/A/S	none
5332	8	Unit of pressure for CP6 (bitwise defined)	Value of pressure of CP6	Unit of salinity of CP6 (bitwise defined)	Value of salinity of CP6	3, 4	U/A/S	none

Figure 2.7.6.1: Definition of register 5172 for CP1, 5204 for CP2 and 5332 for CP6.

Command: Calibration CP1 values 2	Modbus address: **5172**	Length: **8**	Type: **3**	Read
Parameter:	Unit of pressure	Pressure	Unit of salinity	Salinity
Format:	Hex	Float	Hex	Float
Value:	**0x800000**	**1013**	**0x400**	**10**

Figure 2.7.6.2: Example to read the calibration values 2 for CP1. The physical unit is mbar (0x800000), the pressure is 1013 (mbar), the unit is mS/cm (0x400) and the salinity is 10 (mS/cm).

Command: Calibration CP2 values 2	Modbus address: **5204**	Length: **8**	Type: **3**	Read
Parameter:	Unit of pressure	Pressure	Unit of salinity	Salinity
Format:	Hex	Float	Hex	Float
Value:	**0x800000**	**1013**	**0x400**	**10**

Figure 2.7.6.3: Example to read the calibration values 2 for CP2. The physical unit is mbar (0x800000), the pressure is 1013 (mbar), the unit is mS/cm (0x400) and the salinity is 10 (mS/cm).

Command: Calibration CP6 values 2	Modbus address: **5204**	Length: **8**	Type: **3**	Read
Parameter:	Unit of pressure	Pressure	Unit of salinity	Salinity
Format:	Hex	Float	Hex	Float
Value:	**0x800000**	**1013**	**0x400**	**0**

Figure 2.7.6.4: Example to read the calibration values 2 for CP6. The physical unit is mbar (0x800000), the pressure is 1013 (mbar), the unit is mS/cm (0x400) and the salinity is 0 (mS/cm).

2.7.7 Currently active Calibration Parameters part 3

In register 5520, 5528 and 5560 is stored the oxygen concentration, the luminescence shift, the temperature and the atmospheric pressure upon calibration.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
5520	8	C1 [mbar]	Phase 1 [°]	Temp. 1 [°C]	Pressure 1 [mbar]	3, 4	A/S	none
5528	8	C2 [mbar]	Phase 2 [°]	Temp. 2 [°C]	Pressure 2 [mbar]	3, 4	A/S	none
5560	8	C6 [mbar]	Phase 6 [°]	Temp. 6 [°C]	Pressure 6 [mbar]	3, 4	A/S	none

Figure 2.7.7.1: Definition of register 5520, 5528 and 5560.

Command: Act calibration CP1	Modbus address: **5520**	Length: **8**	Type: **3**	Read
Parameter:	Cali CP1 [mbar]	Phase CP1	Temp CP1	Pressure CP1
Format:	Float	Float	Float	Float
Value:	**0**	**70.80737**	**26.08493**	**1013**

Figure 2.7.7.2: Example to read the current calibration values of CP1. The DO-concentration is 0 mbar, the phase is 70.81, the temperature is 26.08 °C and the pressure is 1013 mbar.

Command: Act calibration CP2	Modbus address: **5528**	Length: **8**	Type: **3**	Read
Parameter:	Cali CP2 [mbar]	Phase CP2	Temp CP2	Pressure CP2
Format:	Float	Float	Float	Float
Value:	**204.8033**	**38.37107**	**26.86173**	**1013**

Figure 2.7.7.3: Example to read the current calibration values of CP2. The DO-concentration is 204.80 mbar, the phase is 38.37, the temperature is 26.86 °C and the pressure is 1013 mbar.

Command: Act calibration CP6	Modbus address: **5560**	Length: **8**	Type: **3**	Read
Parameter:	Cali CP6 [mbar]	Phase CP6	Temp CP6	Pressure CP6
Format:	Float	Float	Float	Float
Value:	**205.187**	**37.85284**	**29.93368**	**1013**

Figure 2.7.7.4: Example to read the current calibration values of CP6. The DO-concentration upon initial measurement is 205.187 mbar, the phase is 37.85, the temperature is 29.93 °C and the pressure is 1013 mbar.

2.7.8 Currently active Calibration Parameters part 4

For standard calibration (CP1 / CP2) register 5448 documents phi0 and Stern-Volmer coefficient (c_{SV}).

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
5448	6	Phi0 (°)	c_{SV}	T_{ref} (°C)	3, 4	U/A/S	none

Figure 2.7.8.1: Definition of register 5448.

Command: Calculated cali values	Modbus address: **5448**	Length: **6**	Type: **3**	Read
Parameter:	Phi0, Phase at zero oxygen	Stern-Volmer coefficient c_{SV}	Reference Temperature	
Format:	Float	Float	Float	
Value:	**70.68**	**0.023**	**25**	

Figure 2.7.8.2: Example to read register 5448: Phi0 at 25°C is 70.68° and the corresponding Stern-Vollmer coefficient has a value of 0.023. The reference temperature is 25°C.

2.7.9 Currently active Calibration Parameters part 5

In register 5182, 5214 and 5342 the system time of the calibration is stored. The system time is explained in chapter 2.8.2.
Note: for CP6, the system time is set during the action "initial measurement".

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
5182	2	System Time CP1	3, 4	U/A/S	none
5214	2	System Time CP2	3, 4	U/A/S	none
5342	2	System Time CP6	3, 4	U/A/S	none

Figure 2.7.9.1: Definition of register 5182 for CP1, 5214 for CP2 and 5342 for CP6.

Command: System Time CP1		Modbus address: **5182**	Length: 2	Type: **3** Read
Parameter:	System Time CP1			
Format:	u-int			
Value:	**1334102400**			

Figure 2.7.9.2: Example to read the system time of CP1. The sensor is calibrated at 1334102400 which is equivalent to the 1st of April 2012 00:00 according to the base date of January 1st 1970.

Command: System Time CP2		Modbus address: **5214**	Length: 2	Type: **3** Read
Parameter:	System Time CP2			
Format:	u-int			
Value**:**	**1333540800**			

Figure 2.7.9.3: Example to read the system time of CP2. CP2 has been performed on the 4th of April 2012 at 12:00.

Command: System Time CP6		Modbus address: **5342**	Length: 2	Type: **3** Read
Parameter:	System Time CP6			
Format:	u-int			
Value:	**1334131200**			

Figure 2.7.9.4: Example to read the system time of CP6. The initial measurement of the product calibration has been performed on April 11th 2012 at 8:00.

2.7.10 Special Commands for Calibration with VISICAL

The VISICAL calibration device allows calibration of VisiFerm DO sensors at CP1 or CP2. The VISICAL associated calibration parameters for CP1 and CP2 are those predefined and stored in corresponding registers of VisiFerm DO 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 5152 and 5184 respectively).

Attention:
- It is not possible to perform a product calibration using VISICAL.
- Physical unit is fixed to %-vol by definition. If the register 5180 and 5212 both contain a 0 for auto, the default physical unit is taken, independent from the definition in register 2090.

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 2.7.10.1: 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 2.7.10.2: 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 DO 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 2.7.10.3: 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 2.7.10.4: 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 DO assumes that the oxygen value is 25 %-vol.

2.8 Sensor Status

2.8.1 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 DO measurement is possible.
- Calibration – in this range the sensor can be calibrated.
- User defined measurement – the specialist can adjust the range in which DO 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	Reg3 / Reg4	Modbus function code	Read access	Write access
4608	4	Operating temperature min [°C]	Operating temperature max [°C]	3, 4	U/A/S	none
4612	4	Measurement temperature min [°C]	Measurement temperature max [°C]	3, 4	U/A/S	none
4616	4	Calibration temperature min [°C]	Calibration temperature max [°C]	3, 4	U/A/S	none
4624	4	User defined measurement temperature min [°C]	User defined measurement temperature max [°C]	3, 4, 16	U/A/S	S

Figure 2.8.1.1: Definition of register 4608, 4612, 4616 and 4624.

Command: Operating T range		Modbus address: **4608**	Length: **4**	Type: **3** Read
Parameter:	Operating T min [°C]	Operating T max [°C]		
Format:	Float	Float		
Value:	**-20**	**140**		

Figure 2.8.1.2: Example to read the operating temperature values min and max.

Command: Measurement T range		Modbus address: **4612**	Length: **4**	Type: **3** Read
Parameter:	Measurement T min [°C]	Measurement T max [°C]		
Format:	Float	Float		
Value:	**-20**	**85**		

Figure 2.8.1.3: Example to read the measurement temperature values min and max.

Command: Calibration T range		Modbus address: **4616**	Length: **4**	Type: **3** Read
Parameter:	Calibration T min [°C]	Calibration T max [°C]		
Format:	Float	Float		
Value:	**0**	**60**		

Figure 2.8.1.4: Example to read the calibration temperature values min and max.

Command: User measurement T	Modbus address: **4624**	Length: **4**	Type: **16**	Write
Parameter:	User measurement T min [°C]	User measurement T max [°C]		
Format:	Float	Float		
Value:	**-10**	**25**		

Figure 2.8.1.5: Example set the user defined measurement temperature range. Below -10°C and above 25°C, the sensor will not perform DO reading and the analog and digital output for DO are frozen.

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

2.8.2 Operating Hours, Counters and System Time

In register 4676 are stored:

- total operating hours
- operating hours above max measurement temperature (see chapter 2.8.1)
- the operating hours above max operating temperature (see chapter 2.8.1)

In register 4682 are stored:

- number of power ups
- number of watchdog resets
- number of writing cycles to flash memory

In register 4688 are stored:

- number of sterilization in place (SIP) (see chapter 2.8.5)
- number of cleaning in place (CIP) (see chapter 2.8.5)

In register 4692 is stored

- number of autoclavings.
  This register has no effect for the sensor and is only for the user to trace the record for himself.

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} can be written into this register. From this value, the sensor increments this value every second.
  We recommend to use as base date the so-called UNIX timestamp (hint: www.epochconverter.com) which starts at 1st of January 1970 GMT. When a calibration is performed the system time value will be copied to the register 5182 for CP1, 5214 for CP2 and 5342 for CP6 (after the action "initial measurement"). With this copied value, the absolute time of calibration can be recovered, even if the sensor has powered down in the meantime.
  Be sure to update this register if needed after every power up of the sensor.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg3 / Reg4	Modbus function code	Read access	Write access
4676	6	Operating hours [h]	Operating hours above max measurement temperature [h]	Operating hours above max operating temperature [h]	3, 4	U/A/S	none
4682	6	Number of Power ups	Number of Watchdog resets	Number of Writing cycles to flash memory	3, 4	U/A/S	none
4688	4	Number of SIP cycles	Number of CIP cycles	-	3, 4	U/A/S	none
4692	2	No of autoclavings			3, 4, 16	U/A/S	S
8232	2	System Time Counter			3, 4, 16	U/A/S	S

Figure 2.8.2.1: Definition of register 4676, 4682, 4688 4692 and 8232.

Command: Operating hours	Modbus address: **4676**	Length: **6**	Type: **3**	Read
Parameter:	Operating hours [h]	Operating hours above max measurement temperature [h]	Operating hours above max operating temperature [h]	
Format:	Float	Float	Float	
Value:	**168.3667**	**0**	**0**	

Figure 2.8.2.2: Example to read the total operating hours, the operating hours above the max measurement temperature and the operating hours above the max operating temperature.

Command: Power & watchdog	Modbus address: **4682**	Length: **6**	Type: **3**	Read
Parameter:	Number of Power ups	Number of Watchdog resets	Number of Writing cycles to flash memory	
Format:	Decimal	Decimal	Decimal	
Value:	**34**	**1**	**16**	

Figure 2.8.2.3: Example to read the number of power ups, the number of watchdog resets and the number of writing cycles to flash memory.

Command: SIP & CIP	Modbus address: **4688**	Length: **4**	Type: **3**	Read
Parameter:	SIP cycles	CIP cycles		
Format:	Decimal	Decimal		
Value:	**0**	**0**		

Figure 2.8.2.4: Example to read the number of SIP cycles and the number of CIP cycles. For the definition of SIP and CIP cycles see chapter 2.8.5.

Command: Autoclaving	Modbus address: **4692**	Length: **2**	Type: **3**	Read
Parameter:	Autoclavings			
Format:	Decimal			
Value:	**7**			

Figure 2.8.2.5: Example to read the number of autoclavings.

Command: Autoclaving	Modbus address: **4692**	Length: **2**	Type: **16**	Write
Parameter:	Autoclavings			
Format:	Decimal			
Value:	**14**			

Figure 2.8.2.6: Example to write the number of autoclavings. A number of 14 is written to the sensor.

Command: System Time	Modbus address: **8232**	Length: **2**	Type: **16**	Write
Parameter:	System Time			
Format:	Decimal			
Value:	**1334137383**			

Figure 2.8.2.7: Example to write the system time into the sensor. On the basis of January 1st 1970, this value represents the 11th of April 2012 at 09:43:03.

Command: System Time	Modbus address: **8232**	Length: **2**	Type: **16**	Read
Parameter:	System Time			
Format:	Decimal			
Value:	**1334150836**			

Figure 2.8.2.8: Example to read the system time into the sensor. On the basis of January 1st 1970, this value represents the 11th of April 2012 at 13:27:16.

Note:
Accuracy of the system time, if not updated by the operator: The deviation of the system time is less than one minute per 24h.

2.8.3 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.

2.8.3.1 Currently Active Warnings

The currently active warnings are stored in register 4736.

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

Figure 2.8.3.1.1: Definition of register 4736 (see chapter 2.8.3.3)

Command: Warning active	Modbus address: **4736**	Length: **8**	Type: **3** Read
Parameter:	W Measurement	W Cal & Membrane	W Interface	W Hardware
Format:	Hex	Hex	Hex	Hex
Value:	**0x00**	**0x00**	**0x00**	**0x00**

Figure 2.8.3.1.2: Example to read the active warnings (see chapter 2.8.3.3)

2.8.3.2 History of Warnings

In register 4756 a record of the last 12 warning events is available.
With the parameter "Number of Reg." One can retrieve the individual warning events between 1 (current) and 12 (old).
With setting "number" =0, you get a a so-called "all-time" list of warnings.
Every 3 seconds the warnings status is checked and refreshed.

Start Reg.	Number of Reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Reg9 / Reg10	Reg11 / Reg12	Modbus function code	Read access	Write access
4756	2	Number (0, 1-12)						16	none	U/A/S
4756	12	Number (0, 1-12)	Opera-ting hours [h]	History warn. mea-sure-ment (bit def)	History warn. cal and mem-brane (bit def)	History warn. inter-face (bit def)	History warn. hard-ware (bit def)	3, 4	U/A/S	none

Figure 2.8.3.2.1: Definition of register 4756.

Command: Warning history			Modbus address: **4756**	Length: **12**	Type: **3**	Read
Parameter:	Number	Operating hours [h]	W Measurement	W Cal & Membrane	W Interface	W Hardware
Format:	Decimal	Float	Hex	Hex	Hex	Hex
Value:	**0**	**0**	**0x2000000**	**0x02**	**0x02**	**0x00**

Figure 2.8.3.2.2: Example to read the history of warnings (all-time-list) (Number = 0).

Command: Warning history		Modbus address: **4756**	Length: **2**	Type: **16** Write
Parameter:	Number			
Format:	Decimal			
Value:	**1**			

Figure 2.8.3.2.3: Example to set the Number to 1.

Command: Warning history			Modbus address: **4756**	Length: **12**	Type: **3**	Read
Parameter:	Number	Operating hours [h]	W Measurement	W Cal & Membrane	W Interface	W Hardware
Format:	Decimal	Float	Hex	Hex	Hex	Hex
Value:	**1**	**163.5167**	**0x00**	**0x00**	**0x00**	**0x00**

Figure 2.8.3.2.4: Example to read the history warnings in case of Number = 1.

2.8.3.3 Definition of Warnings

Bit #	Hex code	Description
0 (LSB)	0x01	PMC1 DO reading below lower limit
	The oxygen reading is too low (DO < 0%-sat). Make a new zero-point calibration.	
1	0x02	PMC1 DO reading above upper limit
	The oxygen reading is too high (DO > 300%-sat). Either make a new calibration at CP2. If not successful, replace the sensor cap.	
2	0x04	PMC1 DO reading unstable
	The DO measurement is unstable (Standard deviation > 1 °). If continuously happening, use a new cap. If the problem still appears, call our Technical Support.	
25	0x02000000	PMC6 T reading below lower limit
	The temperature is below the user defined measurement temperature range. If outside this range, the sensor will not perform DO readings.	
26	0x04000000	PMC6 T reading above upper limit
	The temperature is above the user defined measurement temperature range. If outside this range, the sensor will not perform DO readings.	
31	0x80000000	Measurement not running
	Either the measurement interval (PA13) is set to 0 or the measurement temperature is out of range.	

Figure 2.8.3.3.1: Definition of warnings "measurement".

Bit #	Hex code	Description
0 (LSB)	0x01	PMC1 DO calibration recommended
	Perform a calibration in order to ensure reliable measurement.	
1	0x02	PMC1 DO last calibration not successful
	The last calibrationat CP1 or CP2 failed. The sensor is using the last successful calibration. In order to ensure reliable measurement perform a calibration.	
2	0x04	PMC1 DO replace sensor cap
	The sensor cap of VisiFerm DO Arc must be replaced and the sensor needs to be recalibrated with the new cap. This warning is active as long as the sensor quality is below 35%	

Figure 2.8.3.3.2: Definition of warnings "calibration and membrane".

Bit #	Hex code	Description
0 (LSB)	0x01	4-20 mA value below 4 mA
	The measurement value is below the lower limit of the 4–20 mA interface output. Reconfigure the 4-20mA interface.	
1	0x02	4-20 mA value above 20 mA
	The measurement value is above the upper limit of the 4–20 mA interface output. Reconfigure the 4-20mA interface.	
2	0x04	4-20 mA current set-point not met
	The sensor's 4–20 mA interface is not able to regulate the current requested for the current measurement value according to your 4–20 mA interface configuration. Check the 4–20 mA wiring and supply voltage.	
5	0x20	ECS value above upper limit
	Reconfigure the ECS interface.	
6	0x40	ECS current set-point not met
	Check the wiring of the ECS interface.	
7	0x80	ECS external wiring not correct (short circuit)
	Check the wiring of the ECS interface.	

Figure 2.8.3.3.3: Definition of warnings "interface".

Bit #	Hex code	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 sensors 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 sensors specifications.	

Figure 2.8.3.3.4: Definition of warnings "hardware".

2.8.4 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.

2.8.4.1 Currently Active Errors

The currently active errors are stored in register 4800.

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

Figure 2.8.4.1.1: Definition of register 4800 (see chapter 2.8.4.3)

Command: Errors current	Modbus address: **4800**	Length: **8**	Type: **3**	Read
Parameter:	E Measurement	E Cal & Membrane	E Interface	E Hardware
Format:	Hex	Hex	Hex	Hex
Value:	**0x00**	**0x00**	**0x00**	**0x00**

Figure 2.8.4.1.2: Example to read the active errors.

2.8.4.2 History of Errors

In register 4820 a record of the last 12 errors is available.
With the parameter "Number of Reg." One can retrieve the individual error events between 1 (current) and 12 (old).
With setting "number" =0, you get a a so-called "all-time" list of errors.
Every 3 seconds the errors status is checked and refreshed.

Start reg.	Number of reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Reg9 / Reg10	Reg11 / Reg12	Modbus function code	Read access	Write access
4820	2	Number (0, 1-12)						16	none	U/A/S
4820	12	Number (0, 1-12)	Opera-ting hours [h]	History errors mea-sure-ment (bit def)	History errors cal and mem-brane (bit def)	History errors inter-face (bit def)	History errors hard-ware (bit def)	3, 4	U/A/S	none

Figure 2.8.4.2.1: Definition of register 4820.

Command: Errors history			Modbus address: **4820**	Length: **12**	Type: **3**	Read
Parameter:	Number	Operating hours [h]	E Measurement	E Cal & Membrane	E Interface	E Hardware
Format:	Decimal	Float	Hex	Hex	Hex	Hex
Value:	**0**	**0**	**0x01**	**0x01**	**0x00**	**0x00**

Figure 2.8.4.2.2: Example to read the history of errors in case of the all-time-list (Number = 0).

Command: Errors history		Modbus address: **4820**	Length: **2**	Type: **16** Write
Parameter:	Number			
Format:	Decimal			
Value:	**1**			

Figure 2.8.4.2.3: Example to set the Number to 1.

Command: Errors history			Modbus address: **4820**	Length: **12**	Type: **3** Read	
Parameter:	Number	Operating hours [h]	E Measurement	E Cal & Membrane	E Interface	E Hardware
Format:	Decimal	Float	Hex	Hex	Hex	Hex
Value:	**1**	**103.6667**	**0x01**	**0x01**	**0x01**	**0x01**

Figure 2.8.4.2.4: Example to read the history errors in case of Number = 1.

2.8.4.3 Definition of Errors

Bit #	Hex code	Description
0 (LSB)	0x00000001	PMC1 DO 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.	

Figure 2.8.4.3.1: Definition of errors "measurement".

Bit #	Hex code	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 in order to perform reliable measurement.	

Figure 2.8.4.3.2: Definition of errors "calibration and membrane".

Bit #	Hex code	Description
		Not available

Figure 2.8.4.3.3: Definition of errors "interface".

Bit #	Hex code	Description
0 (LSB)	0x000001	Sensor supply voltage far too low
	The sensor supply voltage is below 6V. Please check your power supply.	
1	0x000002	Sensor supply voltage far too high
	The sensor supply voltage is above 40V. 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)	
16	0x010000	Red channel failure
	Measurement channel failure. Please call our Technical Support.	

Figure 2.8.4.3.4: Definition of errors “hardware”.

2.8.5 Reading Definition of SIP and CIP

VisiFerm DO is counting special cleaning events such as sterilizations or cleaning cycles by means of tracking typical temperature profiles (see chapter 2.8.2).

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: 130 °C SIP time min: 30 minutes

CIP / SIP time maximum values: 180 min (in FW ODOUM040: 60 min)

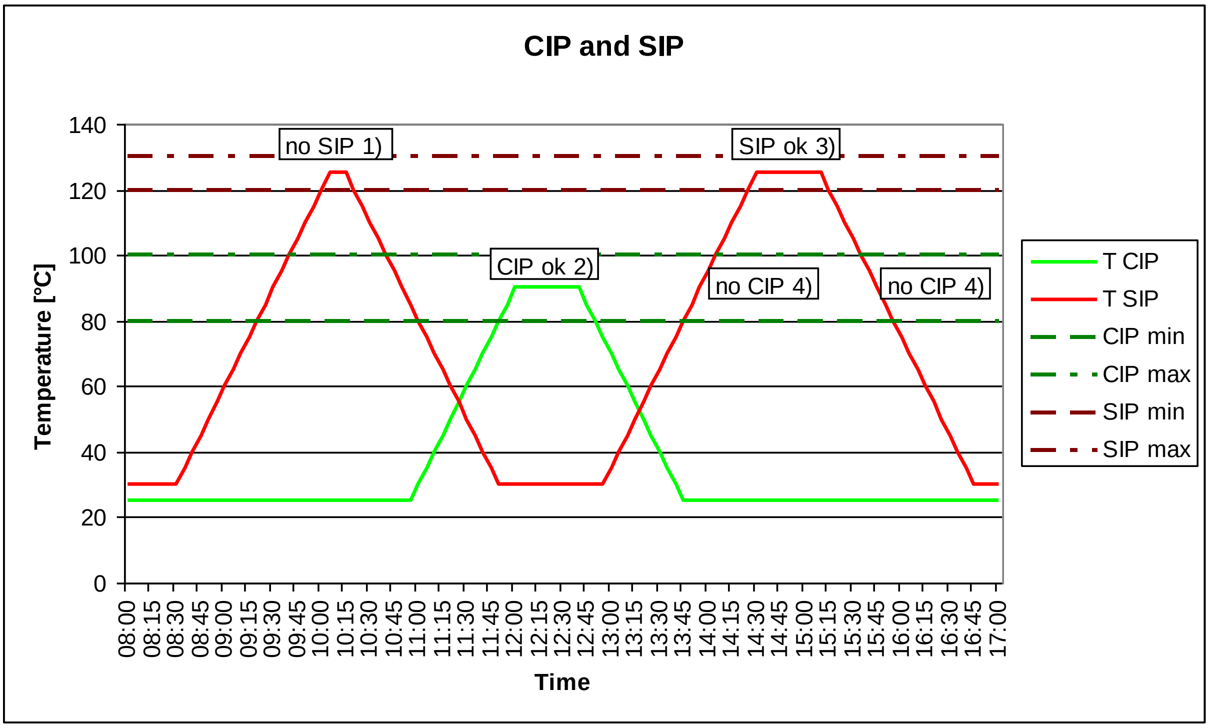

Figure 2.8.5.1: Definition of CIP and SIP cycles.
1) no SIP-cycle counted, because time too short less than 30 minutes.
2) CIP-cycle counted, because time greater than 30 minutes and in CIP temperature range.
3) SIP-cycle counted, because time greater than 30 minutes and in SIP temperature range.
4) no CIP-cycle counted, because of reaching the SIP-min limit.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	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

Figure 2.8.5.2: Definition of register 4988 and 4996.

Command: SIP definition	Modbus address: **4988**	Length: **8**	Type: **16**	Write
Parameter:	T min [°C]	T max [°C]	Time min [min]	Empty
Format:	Float	Float	Float	Float
Value:	**120**	**130**	**30**	**0**

Figure 2.8.5.3: Example to write the SIP definitions.

Command: SIP definition	Modbus address: **4988**	Length: **8**	Type: **3**	Read
Parameter:	T min [°C]	T max [°C]	Time min [min]	Empty
Format:	Float	Float	Float	Float
Value:	**120**	**130**	**30**	**0**

Figure 2.8.5.4: Example to read the SIP definitions.

Command: CIP definition	Modbus address: **4996**	Length: **8**	Type: **16**	Write
Parameter:	T min [°C]	T max [°C]	Time min [min]	Empty
Format:	Float	Float	Float	Float
Value:	**80**	**100**	**30**	**0**

Figure 2.8.5.5: Example to write the CIP definitions.

Command: CIP definition	Modbus address: **4996**	Length: **8**	Type: **3**	Read
Parameter:	T min [°C]	T max [°C]	Time min [min]	Empty
Format:	Float	Float	Float	Float
Value:	**80**	**100**	**30**	**0**

Figure 2.8.5.6: Example to read the CIP definitions.

2.8.6 Reading the Sensor Cap Quality

In register 5472 the sensor cap quality (0-100%) is given. Hamilton recommends the replacement of the sensor cap at a value less than 35 %, see chapter 2.8.3.3.

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

Figure 2.8.6.1: Definition of register 5472.

Command: Sensor cap quality	Modbus address: **5742**	Length: **2**	Type: **3**	Read
Parameter:	Quality [%]			
Format:	Float			
Value:	**100**			

Figure 2.8.6.2: Example to read the membrane status. The sensor cap quality is 100 %.

2.8.7 CIP Correction

CIP correction is used in an environment which does not allow or is very time- or cost-consuming to calibrate a sensor after every CIP cycle.
The luminophore degrades with time and the zero-point oxygen phase drifts with aging.
There are two different CIP correction modes implemented in the sensor:

- CIP compensation
- Brewery

The CIP compensation influences the measured phase. After every CIP cycle the entered value is added to the measured phase and therefore the measured oxygen level is adapted to the real oxygen level. This means when the zero-oxygen point lessens after every CIP cycle, i.e. the oxygen level rises in the same condition with every CIP cycle, the entered CIP correction value has to be set negative to compensate the rising oxygen level.
The Brewery mode consists of the CIP compensation mode and an additional automatic compensation. After every CIP cycle the phase gets corrected by the entered value.
Below 20°C and with an oxygen level below 3 mbar, the sensor adjusts then the zero oxygen level automatically. This function also works without an entered CIP correction value, i.e. the value set to 0. An accurate value for the CIP correction value helps to improve the adaption time for the Brewery mode, but is not necessary.

For a good guess of the CIP correction value, the process has to be monitored and the value has to be found experimentally. For every process, the CIP correction value is different. The value has to be more accurate for the CIP compensation than for the Brewery mode.
In case of the Brewery mode is turned on, the measuring interval (PA13) can only be set between 3s and 60s.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Modbus function code	Read access	Write access
5596	2	Mode	Empty	3, 4, 16	S	S
5600	4	Unit	CIP correction value	3, 4, 16	S	S
5604	4	Unit	CIP cycles since last cali	3, 4	S	None
5608	4	Unit	Accumulated CIP corrections	3, 4	S	none

Figure 2.8.7.1: Definition of the registers 5596, 5600, 5604 and 5608.

In the register 5596, the CIP correction mode can be set.

0x00: CIP correction off
0x01: CIP compensation
0x02: Brewery

Command: CIP correction mode		Modbus address: **5596**	Length: **2**	Type: **16** Write
Parameter:	CIP correction mode			
Format:	Hex			
Value:	**0x02**			

Figure 2.8.7.2: Example to write the CIP correction mode. The brewery mode will be activated.

Command: CIP correction value		Modbus address: **5600**	Length: **4**	Type: **3** Read
Parameter:	Unit	CIP correction value		
Format:	Hex	Hex		
Value:	**0x08000000**	**-0.2**		

Figure 2.8.7.3: Example to read the CIP correction value. A value of -0.2 says, that the zero oxygen phase decreases with every CIP cycle with 0.2°.

Command: CIP cycles since last cali		Modbus address: **5604**	Length: **4**	Type: **3** Read
Parameter:	Unit	CIP cycles since last cali		
Format:	Hex	Dezimal		
Value:	**0x01**	**7**		

Figure 2.8.7.4: Example to read the CIP cycles since last cali. Since the last zero oxygen calibration has been proceeded, the sensor has processed 7 CIPs.

Command: Accumulated CIP corr		Modbus address: **5608**	Length: **4**	Type: **3** Read
Parameter:	Unit	Accumulated CIP corrections		
Format:	Hex	Dezimal		
Value:	**0x08000000**	**-1.4**		

Figure 2.8.7.5: Example to read the accumulated CIP corrections. With 7 CIPs since last cali and a correction of -0.2°, the accumulated correction is -1.4°.

2.9 Sensor Identification and Information

2.9.1 General Information

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	2016-06-07	3, 4	U/A/S	none
1032	8	Userend FW	ODOUM043	3, 4	U/A/S	none
1040	8	Userend BL Date	2006-01-01	3, 4	U/A/S	none
1048	8	Userend BL	BL1UA001	3, 4	U/A/S	none
1056	8	Userend Ref	242998	3, 4	U/A/S	none
1064	8	Userend SN	9999	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	not available	3, 4	U/A/S	none
1096	8	Frontend FW	not available	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

Figure 2.9.1.1: Definition of registers containing read-only information.

Command: Firmware date		Modbus address: **1032**	Length: **8**	Type: **3** Read
Parameter:	Text			
Format:	Character			
Value:	**ODOUM043**			

Figure 2.9.1.2: Example to read register 1032.

2.9.2 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	242163	3, 4	U/A/S	none
1288	8	Sensor name	VISIFERM DO	3, 4	U/A/S	none
1296	8	Sensor Lot	1354271	3, 4	U/A/S	none
1304	8	Sensor Lot date	2009-02-05	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 o. DO Sensor	3, 4	U/A/S	none
1344	8	Power supply	007..030V 0500mW	3, 4	U/A/S	none
1352	8	Pressure range	00010..12000mBar	3, 4	U/A/S	none
1360	8	Sensor ID	242163-2076	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	FDA Membrane	3, 4	U/A/S	none

Figure 2.9.2.1: Definition of registers containing read-only sensor identification.

2.9.3 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	242163-2076	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

Figure 2.9.3.1: Definition of registers containing user information.

An important register is 1600, as it is the description of the measuring point. The information of this register is displayed on the Arc View Handheld in order to identify individual sensors.

Attention:

The Free User Memory Space is located in memory which allows in total max 10'000 write operations.

Command: Info user		Modbus address: **1568**	Length: **8**	Type: **16** Write
Parameter:	Text			
Format:	Character			
Value:	**Hello World**			

Figure 2.9.3.2: Example to write 16 ASCII characters to register 1568 with operator A or S.

Command: Info user		Modbus address: **1568**	Length: **8**	Type: **3** Read
Parameter:	Text			
Format:	Character			
Value:	**Hello World**			

Figure 2.9.3.3: Example to read the register 1568, which text has been written in Figure 2.9.3.2.

2.10 System Commands

2.10.1 Recall Sensor's Factory Settings

Using register 8192 you can recall the sensor manufacturer values (interfaces, calibration data and passwords), except the SIP and CIP data which remain unchanged. By sending the recall value "732255" or "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 "732255" or "911"	16	none	S

Figure 2.10.1.1: Definition of register 8192.

Command: Recall		Modbus address: **8192**	Length: **2**	Type: **16** Write
Parameter:	Recall			
Format:	Decimal			
Value:	**911**			

Figure 2.10.1.2: Example to write the restore command.

3 Abbreviations

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

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June 21th 2016
P/N: 624179/05