



pH Arc Sensors

Modbus RTU Programmer's Manual

Firmware version:
EPHUM040

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1 Modbus RTU General Information

1.1 Introduction

This document describes in detail the pH Arc Modbus RTU interface. It is addressed to software programmers.

The general information about Modbus command structures and its implementation in the Hamilton Arc Sensor family is described in detail in chapter 2.

1.2 Hamilton Arc Sensors: Modbus Command Structure

This manual describes the specific command structure for pH Arc sensors with firmware version EPHUM040

You can confirm the firmware version by reading register 1032 (see chapter 2.9.8).



Attention: The current **version** of the pH Arc sensor is built on an updated electronics platform. These updates maintain the measurement specifications, performance, and compliance of the previous version.

For reference:

- **Updated version** user-end reference number: **10162645**, compatible firmware EPHUM040 – EPHUM069
- **Earlier version** user-end reference number: **242480**, compatible firmware EPHUM030 – EPHUM039

You can confirm the user-end reference number by reading register 1056 (see chapter 2.9.8).

Firmware versions are not interchangeable between the two platforms: each sensor ships with the correct firmware pre-installed.

This definition of the command structure supplements the operating instructions for pH Arc sensors. Please ensure the operating instructions have been read and understood before using this manual.

1.2.1 Modbus RTU: Definitions According to Modbus IDA

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

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

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



Attention:

- In this manual the register counting starts per definition at address 1. Some Modbus client protocols operate with register-count starting at address 0. Usually, the Modbus client software translates the addressing. Thus, the register address of 2088 will be translated by Modbus client software to 2087 which is sent to the sensor (Modbus server). This must be observed during programming. Please check the specifications of the Modbus client that you are using.
- Representation of data formats in this document:
 - decimal values are displayed as numbers without any prefix, for example 256
 - hexadecimal values are displayed as: 0x2A
 - ASCII-characters or ASCII strings are displayed as: “Text”
 - floating-point values are displayed as decimal numbers with a fractional part, for example 3.14 or -0.001 (IEEE 754 format)

1.2.2 Command Structure

The Modbus application protocol defines a simple **Protocol Data Unit (PDU)** independent of the underlying communication layers:

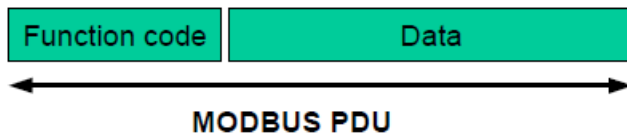


Figure 1 Modbus Protocol Data Unit.

The mapping of Modbus protocol on a specific bus or network introduces some additional fields on the **Protocol Data Unit**. The client that initiates a Modbus transaction builds the Modbus PDU, and then adds fields in order to build the appropriate communication PDU.

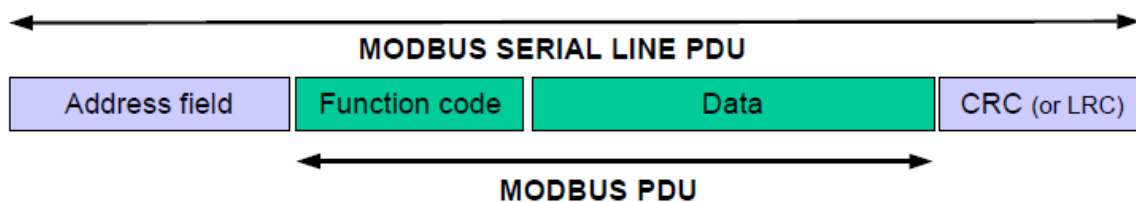


Figure 2 Modbus frame over Serial Line.

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



Note:

Arc Sensors support only server addresses 1 to 32.

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

- The function code indicates to the server what kind of action to perform. The function code can be followed by a data field that contains request and response parameters.
- The CRC field is the result of a “Redundancy Checking” calculation that is performed on the message contents.

1.2.3 Modbus RTU Transmission Mode

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

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

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

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

How characters are transmitted serially:

Each character or byte is sent in this order (left to right):
Least Significant Bit (LSB)...Most Significant Bit (MSB)

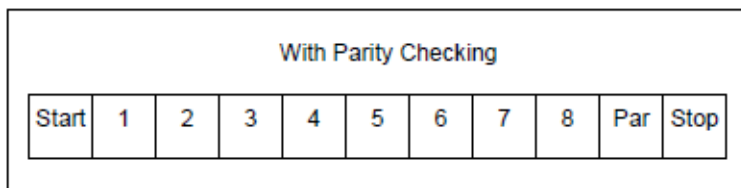


Figure 3 Bit sequence in RTU mode.

Frame Checking Field:

Cyclical Redundancy Checking (CRC)

Frame description:

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

Figure 4 RTU Message Frame.

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

1.2.4 Modbus RTU Message Framing

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

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

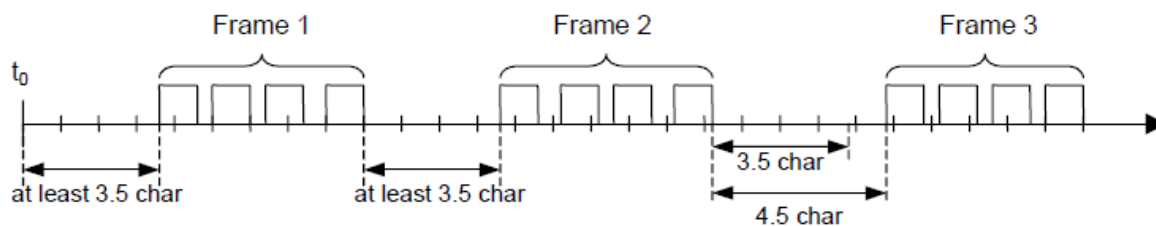


Figure 5 Valid frames with silent intervals.

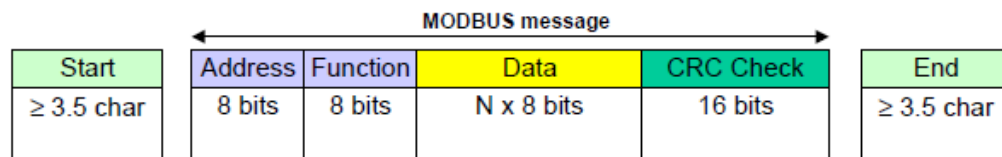


Figure 6 RTU Message Frame.

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

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

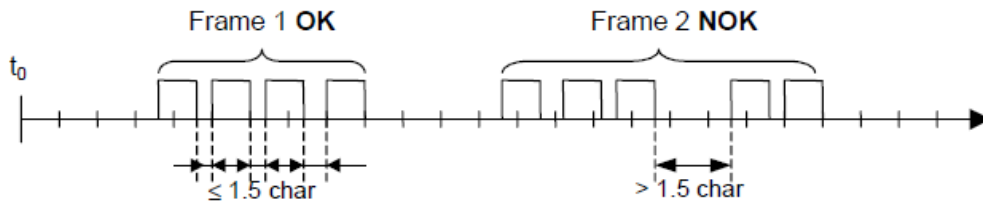


Figure 7 Data transmission of a frame.

1.2.5 Modbus RTU CRC Checking

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

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

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

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

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

The CRC calculation is started by first pre-loading a 16-bit register to all 1's. Then a process begins of applying successive 8-bit bytes of the message to the current contents of 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" from <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 $n \times 8$ bits. The data string contains the starting address of the register and the number of registers to read/write.

The checksum CRC is 16 bits long.

Table 1 Modbus definition for data transmission

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

The RS485 interface is configured as follows:

Table 2 RS485 definitions for Arc Sensors

Modbus RTU implementation in Hamilton Arc Sensors	
Start Bits	1
Data Bits	8
Parity	none (default), even or odd configurable
Stop Bit	2 (default), 1 configurable
String length	11 Bits
Baud Rate	19200 (default), other baud rates configurable

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 of registers. The PDU Registers are addressed starting at zero. Therefore, registers numbered 1 – 16 are addressed as 0 – 15.

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

Request

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

Response

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

*N = Quantity of Registers

Error

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

Figure 8 Definition of Holding Registers.

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

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

1.4.2 Modbus function code #4: Read Input Registers

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

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

Request

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

Response

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

*N = Quantity of Input Registers

Error

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

Figure 10 Definition of Input Registers.

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

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

1.4.3 Modbus Function Code #16: Write Multiple Registers

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

Request

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

*N = Quantity of Registers

Response

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

Error

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

Figure 12 Definition of Write Multiple Registers.

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

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

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

0 10000100 11110110110011001100110

1 Bit Sign + 8 Bit Exponent + 23 Bit Mantissa

S: **0** _{binary} = **0** (positive sign)

E: **10000100** _{binary} = $1 \cdot 2^7 + 0 \cdot 2^6 + 0 \cdot 2^5 + 0 \cdot 2^4 + 0 \cdot 2^3 + 1 \cdot 2^2 + 0 \cdot 2^1 + 0 \cdot 2^0$
 $= 128 + 0 + 0 + 0 + 0 + 4 + 0 + 0$
 $= \mathbf{132}$

M: **11110110110011001100110** _{binary} = **8087142**

Step 2: Calculate the decimal value

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

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
 $= \mathbf{0x21FBE1}$

1.6 Modbus RTU Error Messages

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

Table 4 Implemented Error-Codes

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

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

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

2 pH Arc Commands in Modbus RTU

2.1 General

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

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

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



Attention:

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

2.2 Operator levels and Passwords

2.2.1 Reading / Setting Operator Level

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

Table 5 Definition of operator level and default passwords

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

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

The active operator level can be read and written in register 4288.

The Password itself can't be read, the information in Reg 3/ Reg 4 is always read as zero.

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



Attention:

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

2.2.2 Changing Passwords for Operator Level

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

The new password will remain stored after power down.

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

2.3 Configuration of the serial RS485 Interface

Factory settings for the RS485 interface:

Table 6 RS485 factory settings

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

2.3.1 Device Address

2.3.1.1 Reading and Writing the Device Address

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

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

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



Attention:

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

2.3.1.2 Reading the Device Address Limits

The device address limits can be read in register 4098.

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

Device address limits are:

Minimal device address: 1

Maximal device address: 32

2.3.1.3 Broadcast

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

2.3.2 Baud Rate

2.3.2.1 Reading and Writing the Baud Rate

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

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

The code for the baud rate is defined as follows:

Table 7 Code for the baud rates.

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



Attention:

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

2.3.2.2 Reading the Baud Rate Limits

The baud rate limits can be read in register 4104.

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

The baud rate limits are:

Minimal baud rate code: 2

Maximal baud rate code: 7

2.3.3 Parity and Stop Bits

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

The interface parameter is coded as following:

0xAABCCDD where

AA = no meaning (reading: 0x00)

BB = Parity (0x00: no parity, 0x01: even, 0x02: odd)

CC = Stop bits (0x00: 1 stop bit, 0x04: 2 stop bits)

DD = no meaning (reading 0x00)

Table 8 Example: Read the interface parameter settings with 2 stop bits and no parity

Command:	Avail analog interfaces	Modbus address:	4108	Length:	2	Type:	3	Read
Parameter:	Available analog interfaces							
Format:	Hex							
Value:	0x00000400							

When writing to register 4108 set Bytes AA and DD to 0x00.

**Attention:**

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

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

2.4.1 Available Analog Interfaces

The pH Arc Sensor has two individual physical analog interfaces that have identical functionalities but can be configured independently from each other.

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

The number of analog interfaces is defined in register 4320.

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

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

2.4.2 Available Analog Interface Modes

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

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

Register 4322 defines the analog interface modes available for AO1 and AO2. The analog interface modes are described in Table 9.

Table 9 Definition of the analog interface modes

Code (Hex)	Analog Interface Mode	Description
0x00000000	4-20 mA inactive	Analog interface is deactivated
0x00000001	4-20 mA fixed	Set to a constant output value for current loop testing. See 2.4.5.7
0x00000002	4-20 mA linear	Linear output of measurement (PMC1 / 6)
0x00000004	4-20 mA bilinear	Bilinear output of measurement (PMC1 / 6)

The answer is a bitwise combination (OR) of the available modes defined in Table 9.

Reg1/Reg2 return "0x00000007" meaning that 4-20 mA fixed, 4-20 mA linear and 4-20 mA bilinear mode are available.

Reg3/Reg4 return "0x00000007" meaning that 4-20 mA fixed, 4-20 mA linear and 4-20 mA bilinear mode are available.

Reg5 to Reg8 return always zero.

How to select or change the analog interface mode, see 2.4.4.

2.4.3 Description of the Analog Interface

Register 4352 / 4480 contain the descriptions of AO1 / AO2 as plain text ASCII. AO1 for pH Arc is called "mA interface #1". AO2 for pH Arc is called "mA interface #2".

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

2.4.4 Selection of an Analog Interface Mode

The analog interface mode of AO1 / AO2 is selected by programming the analog interface mode in register 4360 / 4488 (see chapter Table 9).

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

For available analog interface modes are see register 4322.

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

2.4.5 Configuration of the 4-20 mA Interface



Note:

The configuration of the 4-20 mA interface is only effective if register 4360 (analog interface mode) is set to the value 0x00000001, 0x00000002 or 0x00000004 (see chapter Table 9).

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

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

Table 10 Code for selection of the primary measurement channel

Code (Hex)	Primary Measurement Channel (PMC)
0x00000001	PMC1 (pH)
0x00000020	PMC6 (Temperature)

Reading the available Primary Measurement Channels (PMC) always return the hexadecimal value of "0x00000021" meaning that PMC1 or PMC6 can be mapped to AO1 respectively AO2.

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

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

Write this register to change the mapped measurement channel to AO1 respectively AO2. Make sure that only one bit is set, according to Table 10. Writing 0 or an illegal code will leave the selection unchanged. Only one bit can be set!

Reading this register returns the selected PMC for AO1 respectively AO2 according to Table 10.

The factory setting for register 4364 is "0x00000001" mapping PMC1 to AO1.

The factory setting for register 4492 is "0x00000020" mapping PMC6 to AO2.

2.4.5.3 Reading the Minimal and Maximal Possible Physical Output Current

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

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

The limits are fixed to:

Minimum is 3.5mA

Maximum is 22 mA



Note:

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

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

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

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



Note:

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

2.4.5.5 Reading the Selected Physical Unit for Analog Interface

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

Read the selected unit of the selected PMC of AO1 respectively AO2. The value returned has to be interpreted as a hex value that represents the unit according to Table 15.

The physical unit for the PMC is defined in Reg. 2090 or 2410 and applies automatically for 4-20 mA output.

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

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

These registers define the relation between measurement value and output current in linear and bilinear mode. Reg1/Reg2 define the measurement value at 4mA, Reg3/Reg4 define the measurement value at 20mA and Reg5/Reg6 define the measurement value at 12mA (if bilinear mode is selected). When writing, write 0 or any random value. The corresponding physical unit can be read in register 4376 / 4504 respectively in the corresponding PMC register (2090 for PMC1 and 2410 for PMC6).

**Attention:**

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

- The PMC you have mapped to AO1 / AO2 (register 4364 / 4492)
- The physical unit currently in use for the selected PMC (register 2090 for PMC1 and register 2410 for PMC6).

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

**Note:**

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

Example 1:

Register 4364 is set to 0x00000001 (PMC1 is mapped to AO1).

Register 4492 is set to 0x00000020 (PMC6 is mapped to AO2).

Register 2090 is set to 0x00001000 (the unit "pH" is assigned to PMC1).

Register 2410 is set to 0x00000004 (the unit "°C" is assigned to PMC6).

Register 4360 is set to 0x00000002 (linear analog output of PMC1).

Register 4488 is set to 0x00000002 (linear analog output of PMC6).

Register 4378 is set to 2 and 9 (4 mA = 2 pH, 20 mA = 9 pH) as shown in Figure 14.

Register 4506 is set to -10 and 30 (4 mA = -10 °C, 20 mA = 30 °C) as shown in Figure 14.

The sensor is placed in pH 7 buffer solution and currently reads a value of 7.00 pH, the output at the 4-20 mA accordingly is 15.43 mA (7 pH) for AO1.

The sensor currently reads a value of 29 °C, the output at the 4-20 mA accordingly is 19.6 mA (29 °C) for AO2.

The operator reassigns register 2090 to the value 0x00200000 but does not modify the remaining registers. As a result, the sensor reads 0 mV. At the analog output, 4 mA corresponds to a value of 2 as defined in register 4378. Therefore, the output current drops to its minimum value of 4 mA. No interface warning is generated. It is therefore important to adjust the values of the registers defined in chapter 2.4.5.6.

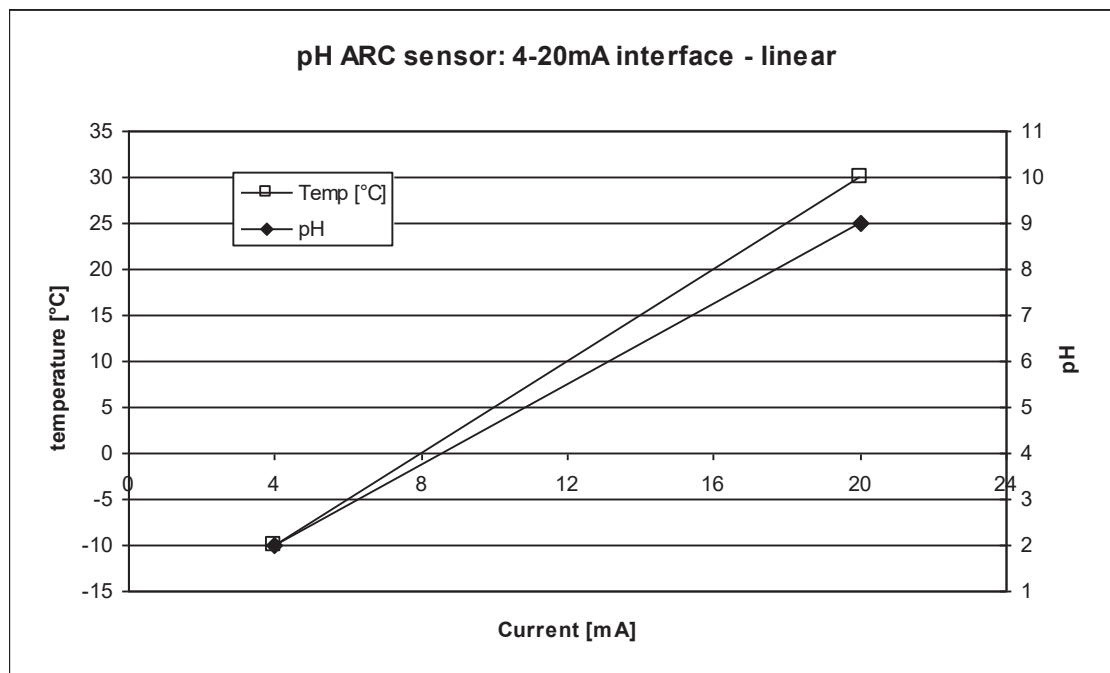


Figure 14 Example of linear 4-20mA output characteristics

Example 2:

Register 4364 is set to 0x00000001 (PMC1 is mapped to AO1).

Register 4492 is set to 0x00000020 (PMC6 is mapped to AO2).

Register 2090 is set to 0x00001000 (the unit "pH" is assigned to PMC1).

Register 2410 is set to 0x00000004 (the unit "°C" is assigned to PMC6).

Register 4360 is set to 0x00000004 (bilinear analog output of PMC1).

Register 4488 is set to 0x00000004 (bilinear analog output of PMC6).

Register 4378 is set to 1, 9 and 10 (4 mA = 1 pH (min), 20 mA = 10 pH (max), 12 mA = 9 pH (mid)) as shown in Figure 15.

Register 4506 is set to -10, 20 and 30 (4 mA = -10 °C (min), 20 mA = 30 °C (max), 12 mA = 20 °C (mid)) as shown in Figure 15.

The sensor is placed in pH 4.01 buffer solution and currently reads a value of 4.01 pH, the output at the 4-20 mA accordingly is 7.01 mA (4.01 pH) for AO1.

The sensor currently reads a value of 20 °C, the output at the 4-20 mA accordingly is 12 mA (20 °C) for AO2.

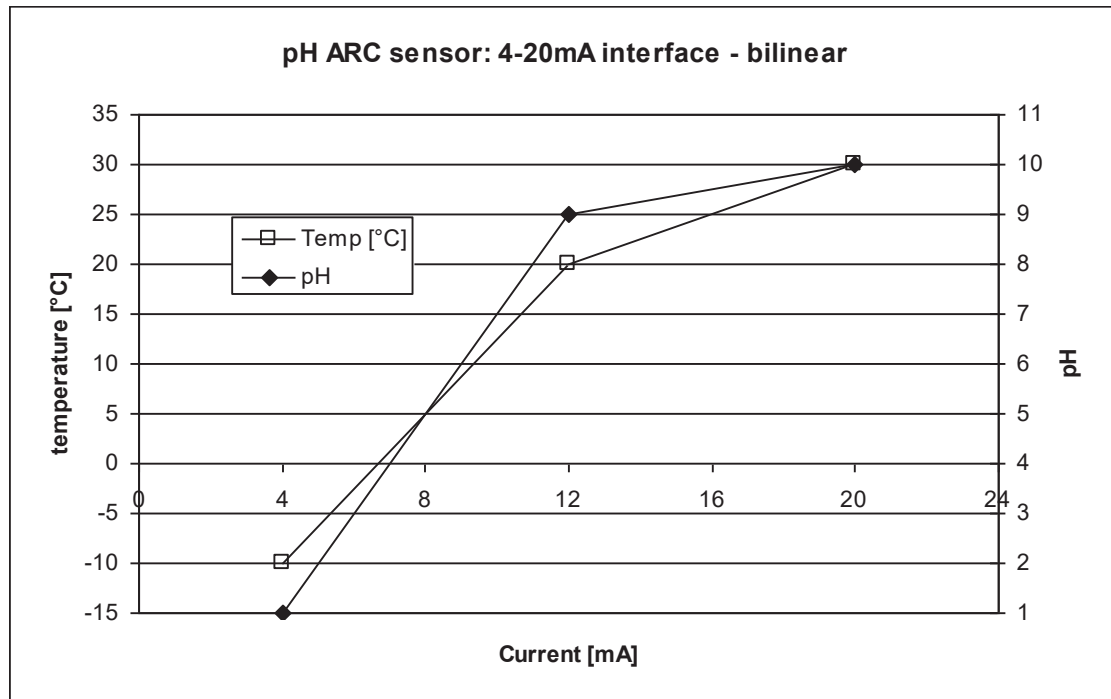


Figure 15 Example of bilinear 4-20mA output characteristics

**Attention:**

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

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

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

2.4.5.7 Defining a Constant Current Output for Testing



Note:

For constant current output, the AO1 / AO2 must be set to analogue interface mode 4-20 mA fixed (0x01) (see Table 9):

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

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

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

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

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

Table 11 Code for the 4-20 mA interface in case of errors and warnings.

Code (Hex)	Behavior of the 4-20 mA interface in case of errors and warnings
0x00000001	Error continuous output
0x00010000	Warning continuous output

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

"T exceed" is always active. What means that in case of a measurement temperature limit violation (register 4624), the output current will be as the specified value. "T exceed" values lower than 3.5mA respectively higher than 4mA will automatically be set within the limits.

The "T exceeds" limits are:

Minimal current value: 3.5 mA

Maximal current value: 4 mA

The default settings are:

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

Table 12 Example: Read the settings for AO1 in case of warnings and errors

Command: ErrorWarnings AO1		Modbus address: 4386		Length: 8	Type: 3	Read
Parameter:	Warning code	Current in case of warning [mA]	Current in case of error [mA]	Current in case of temperature exceed [mA]		
Format:	Hex	Float	Float	Float		
Value:	0x00010001	3.5	3.5	3.5		

Warning code 0x00010001 corresponds to the continuous output current in case of warning (0x00010000) and continuous output current in case of error (0x00000001) of 3.5 mA. The output current in case of temperature exceed is 3.5 mA.

For more information about warnings, errors and temperature limits, see chapter 2.9.3, 2.9.4 and 2.9.1.

2.4.6 Reading the Internally Calculated Output Current

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

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

2.5 Measurement

2.5.1 Definition of Measurement Channels and Physical Units

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

Table 13 Definition of PMC1 to 6 and SMC1 to 16

Hex code	Description	Definition
0x00000001	PMC1	pH
0x00000020	PMC6	Temperature
0x00000040	SMC1	R glass
0x00000200	SMC4	E pH vs. ref
0x00002000	SMC8	pH act
0x00004000	SMC9	T act

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

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

Table 14 Example to read Reg. 2048

Command: Avail. meas. channels		Modbus address: 2048		Length: 2	Type: 3	Read
Parameter:	Avail. meas. ch. PMC and SMC					
Format:	Hex					
Value:	0x00006261					

In case of operator level U or A the value 0x00000261 is returned. In case of operator level S the value 0x00006261 is returned.

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

Table 15 Definition of physical units

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

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

Command: Unit text		Modbus address: 1968	Length: 4	Type: 3	Read
Parameter:	Text				
Format:	8 ASCII characters				
Value:	"pH"				

2.5.2 Primary Measurement Channel 1 (pH)

2.5.2.1 Definition of PMC1

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

In register 2080, a plain text ASCII description of PMC1 is given. PMC1 for pH Arc is called "pH".

In register 2088, the available physical units for this channel are defined. The available physical units for Measurement: 0x00201000 → pH and mV.

In register 2090, the active physical unit for this channel can be selected, by choosing one of the physical units that are defined in register 2088.

Selecting an invalid unit code will leave the current unit unchanged.

Table 17 Example to set the physical unit of PMC1 to pH (0x00001000)

Command: PMC1 set unit		Modbus address: 2090		Length: 2	Type: 16	Write
Parameter:	Unit					
Format:	Hex					
Value:	0x00001000					



Attention:

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

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

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

Request:

The command in HEX-format sent to the sensor:

0x 01 03 08 27 00 02 76 60

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

Response:

The answer received in HEX-format from the sensor:

0x 01 03 10 00 F0 00 20 FF 2B

0x 01 Server address (decimal "01")

0x 03 Function code "Read Holding Registers"

0x 04 Data-Byte count (decimal "04")

0x 10 00 Register 1 (decimal "4096") Available physical unit – low register

0x 00 20 Register 2 (decimal "32") Available physical unit – high register

0x FF 2B CRC

Registers 2 and 1 together result in 0x00201000 which represents the available physical units pH (0x00001000) and mV (0x00200000), see chapter Table 1Table 15.

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

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 00 00 20 57 C5

0x 01 Server address (decimal "01")

0x 10 Function code "Write Multiple Registers"

0x 08 29 Starting address (decimal "2089")

0x 00 02 Quantity of registers (decimal "2")

0x 04 Byte count (decimal "4")

0x 00 00 Register 1 (hex) Physical unit – low register

0x 00 20 Register 2 (hex) Physical unit – high register

0x 57 C5 CRC

Response:

The answer received in HEX-format from the sensor:

0x 01 10 08 29 00 02 92 60

0x 01 Server address (decimal "01")

0x 10 Function code "Write Multiple Registers"

0x 08 29 Starting address (decimal "2089")

0x 00 02 Quantity of registers (decimal "2")

0x 92 60 CRC

2.5.2.2 Reading the measurement value of PMC1

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

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

⁽¹⁾ Value is always in the physical unit defined in register 2090.

⁽²⁾ Definition of the status see chapter 2.5.4. All bits set to zero means: no problem.

Table 18 Example to read register 2090

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:	0x00001000	4.02503	0x00000000	0.0	14.0		

Physical unit is set to pH, PMC1 is 4.02503 (pH), Status is 0x00000000, Min allowed value is 0 pH, Max allowed value is 14 pH.



Attention:

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

Example: Reading PMC1 (pH)

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

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

Request:

The command in HEX-format send to the sensor:

0x 01 03 08 29 00 0A 16 65

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

Response:

The answer received in HEX-format from the sensor:

0x 01 03 14 00 00 00 20 D9 04 C1 38 00 00 00 00 1A D3 43 CF 1A C3 CF 64 C5

0x 01	Server address (decimal "01")	
0x 03	Function code "Read Holding Registers"	
0x 14	Data-Byte count (decimal "20")	
0x 00 00	Register 1 (hex)	Physical unit – low register
0x 00 20	Register 2 (hex)	Physical unit – high register
0x D9 04	Register 3 (floating point)	Measurement value PMC1 – low register
0x C1 38	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 1A D3	Register 7 (floating point)	Min allowed value – low register
0x 43 CF	Register 8 (floating point)	Min allowed value – high register
0x 1A D3	Register 9 (floating point)	Max allowed value – low register
0x C3 CF	Register 10 (floating point)	Max allowed value – high register
0x 64 C5	CRC	

Now extract the desired information:

- The physical unit 0x00200000 of registers 2 and 1 represents mV, see chapter 2.5.1.
- The measurement value 0xC138D904 of registers 4 and 3 transformed to a floating-point figure results in the decimal value -11.552982.
- The status 0x00000000 of registers 6 and 5 indicate that there is no error or warning.
- The min allowed value 0x43CF1AD3 in registers 8 and 7 transformed to a floating-point figure results in the decimal value 414.21.
- The max allowed value 0xC3CF1AD3 in registers 10 and 9 transformed to a floating-point figure results in the decimal value -414.21.

2.5.3 Primary Measurement Channel 6 (Temperature)

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

2.5.3.1 Definition of PMC6

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

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

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

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

Selecting an invalid unit code will leave the current unit unchanged.



Attention:

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

2.5.3.2 Reading the measurement value of PMC6

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

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

⁽¹⁾ Value is always in the physical unit defined in register 2410, length 2.

⁽²⁾ For definition of the status see chapter 2.5.4. All bits set to zero means: no problem.

Table 19 Example to read register 2410

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

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



Attention:

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

Example: Reading PMC6 (Temperature)

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

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

Request:

The command in HEX-format send to the sensor:

0x 01 03 09 69 00 0A 16 4D

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

Response:

The answer received in HEX-format from the sensor:

0x 01 03 14 00 04 00 00 2A E0 41 D1 00 00 00 00 00 00 C2 20 00 00 43 02 70 E5

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

Now extract the desired information:

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

2.5.4 Definition of the Measurement Status for PMC1 / PMC6

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

Table 20 Definition of measurement status for Primary Measurement Channels

Code (Hex)	Description
0x01	Temperature out of user defined measurement temperature range (see chapter 2.9.1)
0x02	Temperature out of operating range (see chapter 2.9.1)
0x04	Not available
0x08	Warning not zero (see chapter 2.9.3)
0x10	Error not zero (see chapter 2.9.4)

2.5.5 Secondary Measurement Channels 1-19

pH Arc Sensors do allow access to secondary measurement values (19 in total). The access to the individual SMC depends on the operator level. The available SMC are defined in register 2048 according to the selected operator level and the sensor type (see chapter 2.5.1).

2.5.5.1 Description of SMC

The registers defined here give a plain text ASCII description of each available SMC.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Modbus function code	Read access	Write access
Address	8	Description of each SMC	3, 4	U/A/S	none

Description	Address	Plain Text (16 ASCII)	Description
SMC1	2464	R glass	Resistance of the pH glass
SMC4	2560	E pH vs. ref	Electrical potential between glass and reference electrode
SMC8	2688	pH act	Current pH value (1-second reading)
SMC9	2720	T act	Current T value (1-second reading)

Example:

Table 21 Example to read register 2464

Command: SMC 1 text		Modbus address: 2464		Length: 8	Type: 3	Read
Parameter:	Text					
Format:	Character					
Value:	R glass					

2.5.5.2 Reading the measurement value of SMC

The registers defined here are used to read the measurement values of each SMC.

Start reg.	Num-ber of reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
Address	6	Physical unit	Measurement value of SMC	Reserved	3, 4	See Table 22	none

Table 22 SMC availability by operator level

Description	Address	Text	Unit	Min value	Max value	Read access
SMC1	2472	R glass	MOhm	30	600	U/A/S
SMC4	2568	E pH vs. ref	mV	-900	900	U/A/S
SMC8	2696	pH act	pH	-0.5	14	S
SMC9	2728	T act	K	253	403	S

Example:

Table 23 Example to read register 2472

Command: SMC1 read		Modbus address: 2472		Length: 6	Type: 3	Read
Parameter:	Unit	Value	Reserved			
Format:	Hex	Float	Hex			
Value:	0x00008000	247.56	0			

Physical unit is set to MOhm (0x00008000), SMC1 is 247.56 (MOhm).

2.6 Measurement Hold Mode

The measurement hold mode is not persistently stored in the pH Arc, therefore on every sensor start up, the measurement hold mode is in the "on" mode (default mode).

A detailed description of the measurement hold mode is described in Figure 16.

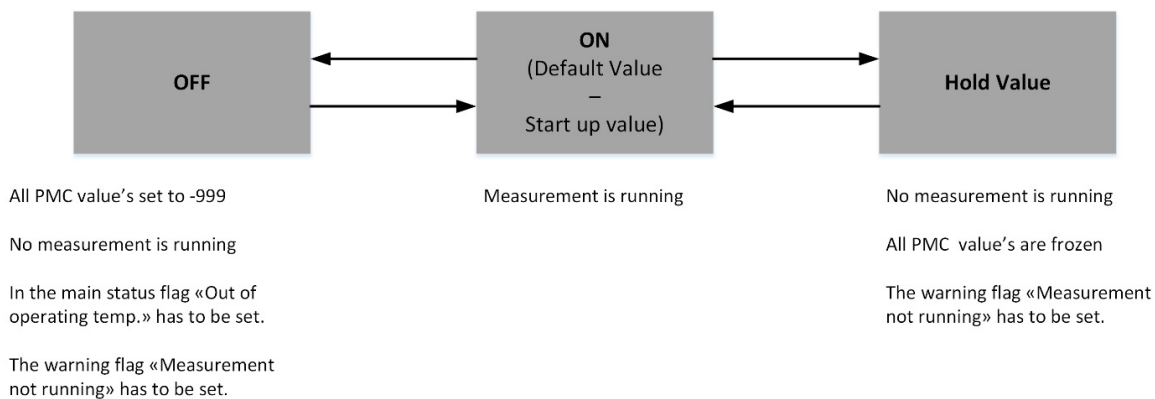


Figure 16: Description of the measurement hold mode functionality

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

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
2064	2	Measurement Hold Mode, see Table 24	3, 4, 16	S	S

Table 24 Code for selection of the measurement hold mode

Code (Hex)	Description
0x00000000	Off - All PMC and all SMC values set to -999 - Measurement status "Temperature out of operating range" is set, see chapter 2.5.4 - Measurement warning "Measurement not running" is set, see chapter 2.9.3
0x00000001	On current measured value output of All PMC and all SMC
0x000000Se02	Hold Value - All PMC and all SMC values are frozen - Measurement warning "Measurement not running" is set, see chapter 2.9.3

2.7 Configuration of the Measurement

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

2.7.1 Available Parameters

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

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3072	2	Available parameters (see Table 25)	3, 4	U/A/S	none

Table 25 Bitwise definition of all available parameters PA1 to PA16

Code (Hex)	Description	Definition in pH Arc
0x00000100	PA9	Moving average
0x00000800	PA12	Moving average R

Table 26 Example to read the available Parameters with operator level S

Command: Available parameters		Modbus address: 3072		Length: 2	Type: 3	Read
Parameter:	Measurement parameters					
Format:	Hex					
Value:	0x00000900					

The hex value 0x00000900 corresponds to 0x00000100 (PA9) + 0x00000800 (PA12).



Note:

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

2.7.2 PA9: Moving Average

pH Arc calculates new pH readings with a measurement interval of one second. One has the possibility to smoothen the pH and temperature reading (PMC1 and PMC6) by means of a moving average. Figure 17 shows a comparison between no moving average (n=1) and a moving average over 16 readings at a measurement interval of 1 second.

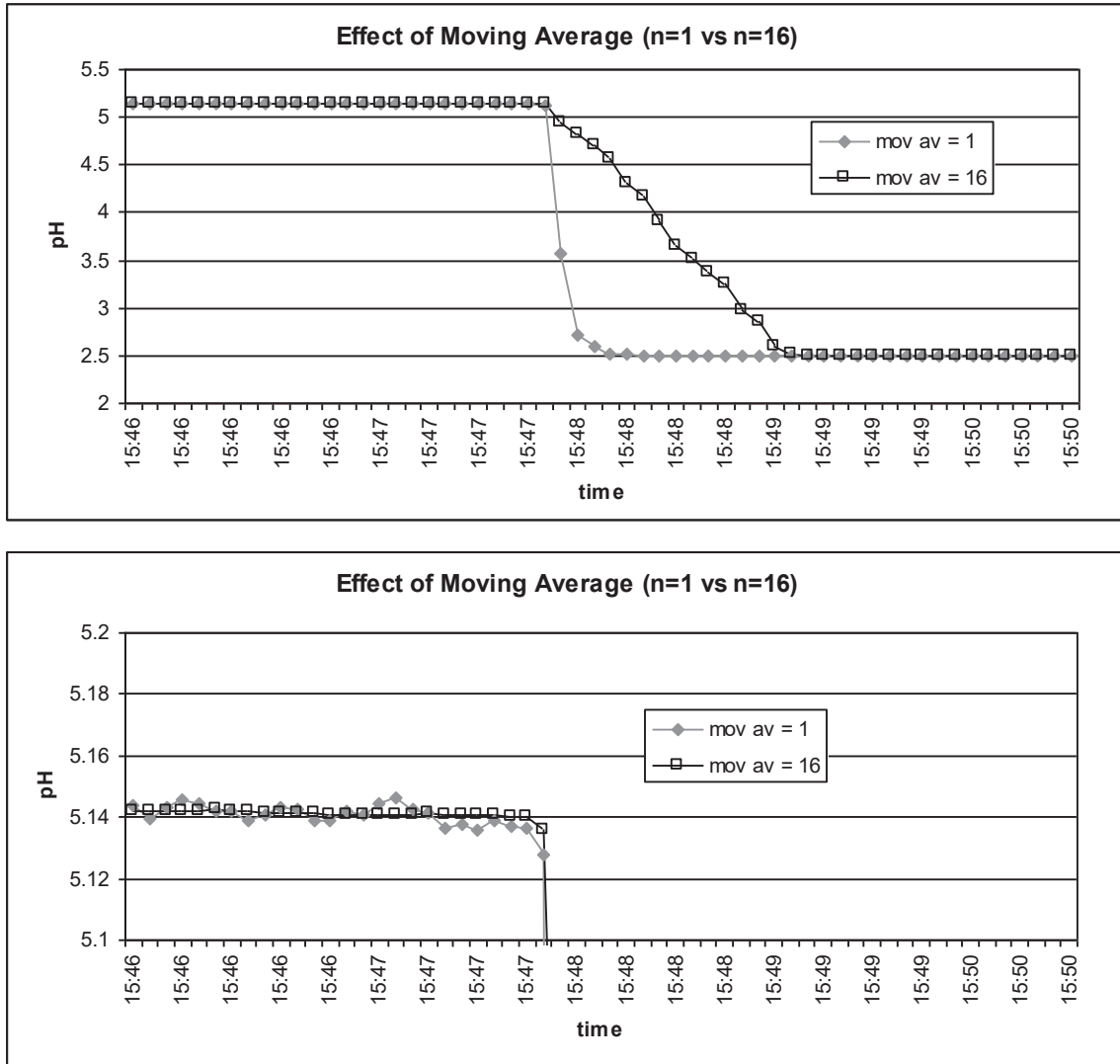


Figure 17 Comparison of the response of pH Arc to a change to a change from pH 5.1 to pH 2.5

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 16 samples results in a response time of at least 16 seconds.



Note:

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

2.7.2.1 Description of PA9 (Moving Average)

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

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

2.7.2.2 Selecting the Physical Unit and Writing the Value for PA9

In register 3368, the available physical units for PA9 are defined. The only one available here is "none" (0x00000001). For the definition of the physical units see Table 15.

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

By writing to register 3370/4, the active physical unit for PA9 can be selected, by choosing one of the physical units that are defined in register 3368. According to register 3368 only one bit for the physical unit can be set (0x00000001). The value of the parameter can be set as well.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
3370	4	Select physical unit for PA9 (only 0x00000001 possible)	Value for PA9 (1-150, default: 2)	16	none	S

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

2.7.2.3 Reading all Values for PA9

By reading register 3370/8, the active physical unit of measurement, the current value, and the min and max values can be read.

The unit is always none (0x00000001), the min is 1 and the max is 150.

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

The default settings are:

- Physical unit of PA9: 0x00000001 (none)
- Current value of PA9: 2
- Min value of PA9: 1
- Max value of PA9: 150

2.7.3 PA12: Moving Average R

pH Arc Sensors allow to have a separate moving average on the secondary measurement value glass resistance.

The moving average can be applied on 1 to 150 1-s measurement values. The default value is 10. Especially if high resistances are measured, it is recommended to choose a higher moving average.

2.7.3.1 Description of PA12 (Moving Average R)

In register 3456, a plain text ASCII description of PA12 is given. It returns "Moving average R".

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Modbus function code	Read access	Write access
3456	8	Description of PA12	3, 4	U/A/S	none

2.7.3.2 Selecting the Physical Unit and Writing the Value for PA12

In register 3464, the available physical units for PA12 are defined. The only one available here is "none" (0x00000001). For the definition of the physical units see Table 15.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3464	2	Available physical units for PA12	3, 4	U/A/S	none

By writing to register 3466/4, the active physical unit for PA9 can be selected, by choosing one of the physical units that are defined in register 3464. According to register 3464 only one bit for the physical unit can be set (0x00000001). The value of the parameter can be set as well.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
3466	4	Select physical unit for PA12 (only 0x00000001 possible)	Value for PA12 (1-150, default: 4)	16	none	S

PA12 can take values between 1 and 150. The value of 1 does not influence the response time of the sensor, the value of 10 increases the response time 10 times the value of the measurement interval.

2.7.3.3 Reading all Values for PA12

By reading register 3466/8, the active physical unit of measurement, the current value, and the min and max values can be read.

The unit is always none (0x00000001), the min is 1 and the max is 150.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
3466	8	Physical unit	Current value	Min value	Max value	3, 4	U/A/S	none

The default settings are:

- Physical unit of PA12: 0x00000001 (none)
- Current value of PA12: 4
- Min value of PA12: 1
- Max value of PA12: 150

2.8 Calibration



Note:

The updated version of the pH Arc is designed to allow backward-compatible handling with the old calibration procedure. For details about the old calibration procedure, refer to the previous version of the pH Arc Modbus RTU Programmer's Manual (REF 624300) available on the Hamilton website (www.hamiltoncompany.com).

2.8.1 Available Calibration Points

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

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
10256	2	Available number of CP for PMC1 (see Table 27)	3, 4	U/A/S	none

Table 27 Bitwise definition of CP1 to CP6

Code (Hex)	Description	Definition in pH Arc
0x00000002	CP1	Calibration low point
0x00000004	CP2	Calibration high point
0x00000040	CP6	Product calibration

Table 28 Example to read the available CPs

Command: Available cali points		Modbus address: 10256		Length: 2	Type: 3	Read
Parameter:	Points					
Format:	Hex					
Value:	0x00000046					

The hex value 0x46 in Table 28 corresponds to 0x00000002 (CP1) + 0x00000004 (CP2) + 0x00000040 (CP6).

As shown in Figure 18 the pH Arc sensor allow 2 calibration points (CP1 and CP2) for the standard calibration.

As shown in Figure 21 the product calibration with CP6 is used to adjust the standard calibration function to specific process conditions.

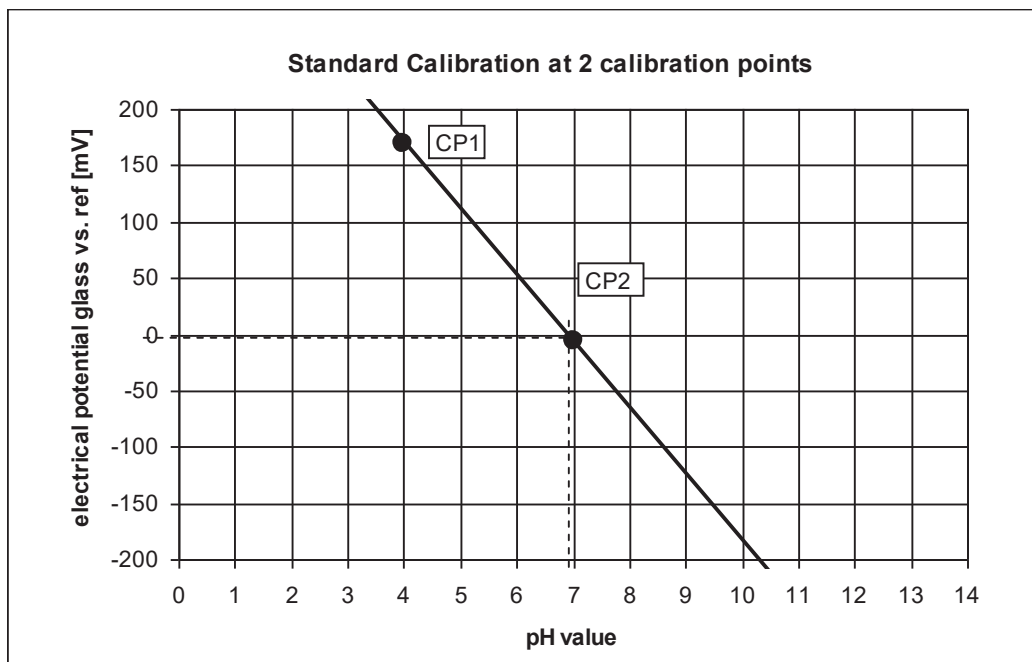


Figure 18 Standard 2-Point Calibration

2.8.2 Definitions of Calibration Points

2.8.2.1 Calibration Unit

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

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
10272	2	Available calibration units, see chapter 2.5.1	3, 4	U/A/S	none
10274	2	Selected physical unit for calibration, see chapter 2.5.1	3, 4, 16	U/A/S	S

In register 10272, the available physical units for calibration are defined. The available physical units for Calibration: 0x00001000 → pH

As only pH (0x00001000) can be calibrated for the pH Arc sensor, this is the only unit that is available.

Table 29 Example to read the physical calibration unit to pH (0x00001000)

Command: Calibration unit		Modbus address: 10274		Length: 2	Type: 3	Read
Parameter:	Unit					
Format:	Hex					
Value:	0x00001000					

2.8.2.2 Calibration limits

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

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

2.8.2.3 Calibration stability criteria

When initiating the calibration at CP1 and CP2, the measured voltage and temperature must be stable for at least 3 minutes. The stability criteria are defined in register 10278:

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



Attention:

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

Table 30 Example to read the default values of the calibration stability criteria

Command: Calibration stability criteria		Modbus address: 10278		Length: 4	Type: 3	Read
Parameter:	Max. Drift PMC1	Max. Drift PMC6				
Format:	float	float				
Value:	0.1	0.5				

2.8.2.4 Calibration Parameters and Coefficients

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

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
10276	2	Available calibration parameters and calibration coefficients, see Table 31	3, 4	U/A/S	none

The available calibration parameters and calibration coefficients has a bit mask of 0x01C0003F:

- CPA1 (Calibration parameter index 1) – CPA6 (Calibration parameter index 6)
- CCO1 (Calibration coefficient index 1) – CCO3 (Calibration coefficient index 3)

Table 31 Bitwise definition of available calibration parameters and calibration coefficients.

Code (Hex)	Definition
0x00000001	CPA1 (Calibration parameter index 1)
0x00000002	CPA2 (Calibration parameter index 2)
0x00000004	CPA3 (Calibration parameter index 3)
0x00000008	CPA4 (Calibration parameter index 4)
0x00000010	CPA5 (Calibration parameter index 5)
0x00000020	CPA6 (Calibration parameter index 6)
0x00400000	CCO1 (Calibration coefficient index 1)
0x00800000	CCO2 (Calibration coefficient index 2)
0x01000000	CCO3 (Calibration coefficient index 3)

2.8.2.4.1 CPA1 - Measured value

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

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

In register 10328 for CP1, register 11048 for CP2 and register 13928 for CP6, a plain text ASCII description of CPA1 is given. CPA1 for pH Arc is called "Measured value".

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

From the last valid CP1, CP2 or CP6 calibration, register 10336 for CP1, register 11056 for CP2 and register 13936 for CP6 can be used to read the voltage values at that time with the fixed unit mV (0x00200000).



Note:

The first parameter is not relevant and is always zero.

2.8.2.4.2 CPA2 - Assigned value

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

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

In register 10360 for CP1, register 11080 for CP2 and register 13960 for CP6, a plain text ASCII description of CPA2 is given. CPA2 for pH Arc is called "Assigned value".

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

From the last valid CP1, CP2 or CP6 calibration, register 10368 for CP1, register 11088 for CP2 and register 13968 for CP6 can be used to read the assigned values with the calibration unit, set at that time.

In register 10272, the available physical units for calibration are defined, see chapter 2.8.2.1 (only pH for pH Arc).



Note:

The first parameter is not relevant and is always zero.

2.8.2.4.3 CPA3 - Temperature

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

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

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

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

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



Note:

The first parameter is not relevant and is always zero.

2.8.2.4.4 CPA4 - Number of calib.

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

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

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

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

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

**Note:**

The first parameter is not relevant and is always zero.

**Note:**

The calibration counter is only incremented after a successful CP1 or CP2. In case of CP6 the counter value will be incremented after a successful assign step (second step of CP6).

2.8.2.4.5 CPA5 - Operating hours

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

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

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

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (bitwise defined)	Reg5 / Reg6 (uint)	Calibration point	Modbus function code	Read access	Write access
10464	6	Not relevant	Unit	Value	CP1	3, 4	U/A/S	none
11184	6	Not relevant	Unit	Value	CP2	3, 4	U/A/S	none
14064	6	Not relevant	Unit	Value	CP6	3, 4	U/A/S	none

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



Note:

The first parameter is not relevant and is always zero.



Note:

The “operating hour” for CP6 is the moment of the “initial measurement” (first step of CP6).

2.8.2.4.6 CPA6 - Time stamp

At the time of a valid CP1, CP2 or CP6 calibration, the sensor Time stamp (the current system time, see chapter 2.9.2) value is stored within CPA6.

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

In register 10488 for CP1, register 11208 for CP2 and register 14088 for CP6, a plain text ASCII description of CPA6 is given. CPA6 for pH Arc is called “Time stamp”.

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

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



Note:

The first parameter is not relevant and is always zero.

**Note:**

For CP6, the system time is set during the action "initial measurement". The system time is explained in chapter 2.9.2.

According to Table 32 the Time Stamp value has no unit (0x00000001), the value is 1760763300 (no unit), means the initial measurement of the product calibration has been performed on October 18th 2025 at 06:55.

Table 32 Example to read the unit and value of CPA6 (Time Stamp) of CP6

Command: Time Stamp CP6		Modbus address: 14096		Length: 6	Type: 3	Read
Parameter:	Cali. Par.6 - Not relevant	Cali. Par.6 - Unit	Cali. Par.6 - Value			
Format:	Hex	Hex	Decimal			
Value:	0x00000000	0x00000001	1760763300			

2.8.2.4.7 CCO1...CCO3 – Calibration Coefficients

At the time of a valid CP1, CP2 or CP6 calibration the calibration coefficients Offset at pH 7 (CCO1) and the corresponding Slope (CCO2) values are stored.

The calibration coefficient Reference temperature (CCO3) is fixed to 25°C.

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

In register 14632 a plain text ASCII description of CCO1 is given. CCO1 for pH Arc is called "Offset at pH 7".

In register 14664 a plain text ASCII description of CCO2 is given. CCO2 for pH Arc is called "Slope".

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

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

From the last valid CP1, CP2 or CP6 calibration, register 14640 can be used to read the calibration coefficient Offset at pH 7 value with the fixed unit mV (0x00200000).

From the last valid CP1, CP2 or CP6 calibration, register 14672 can be used to read the calibration coefficient Slope value with the fixed unit mv/pH (0x00002000).

Register 14704 can be used to read the calibration coefficient Reference Temperature value with the fixed unit K (0x00000002). The calibration coefficient Reference temperature (CCO3) is fixed to 298.15 K.



Note:

The first parameter is not relevant and is always zero.

2.8.3 Calibration Procedure

2.8.3.1 Calibration at CP1 and CP2 (Standard Calibration)

The pH Arc Sensor has a unique calibration routine. When initiating the calibration, the data set of the sensor is automatically traced back within the last 3 minutes, 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 pH value and temperature over the last 3 minutes (see register 10278)
- the currently measured pH value fits to one of the calibration standards defined in the selected set of calibration standards
- the limits of slope and offset at pH 7 have to be met



Attention:

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



Attention:

It is important that pH Arc is in a defined calibration media at least 3 minutes BEFORE the calibration is started.

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

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

The command code defines whether calibration is performed automatically or manually (see Table 33):

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
10314	4	Command Code	Calibration value	16	none	S
11034	4	Command Code	Calibration value	16	none	S

Table 33 Definition of the commands related to the standard calibration

Code (Hex)	Definition of commands
0x00000001	Perform automatic calibration
0x00000002	Perform manual calibration

Table 34 Example to perform an automatic calibration for CP1

Command: CP1		Modbus address: 10314		Length: 4	Type: 16	Write
Parameter:	Command code	Calibration value				
Format:	Hex	Float				
Value:	0x00000001	0.0				

Table 35 Example to perform a manual calibration for CP2

Command: CP2		Modbus address: 11034		Length: 4	Type: 16	Write
Parameter:	Command code	Calibration value				
Format:	Hex	Float				
Value:	0x00000002	7.0				

Automatic recognition: command code value=0x00000001 (calibration value is not taken into account): the sensor tries to assign the measured electrical potential to one of the calibration standards available for automatic calibration.

Manual selection: command code value=0x00000002 enter the actual pH value at 25°C (the value must be within the tolerance range of the nominal value of one of the calibration standards available for manual selection)

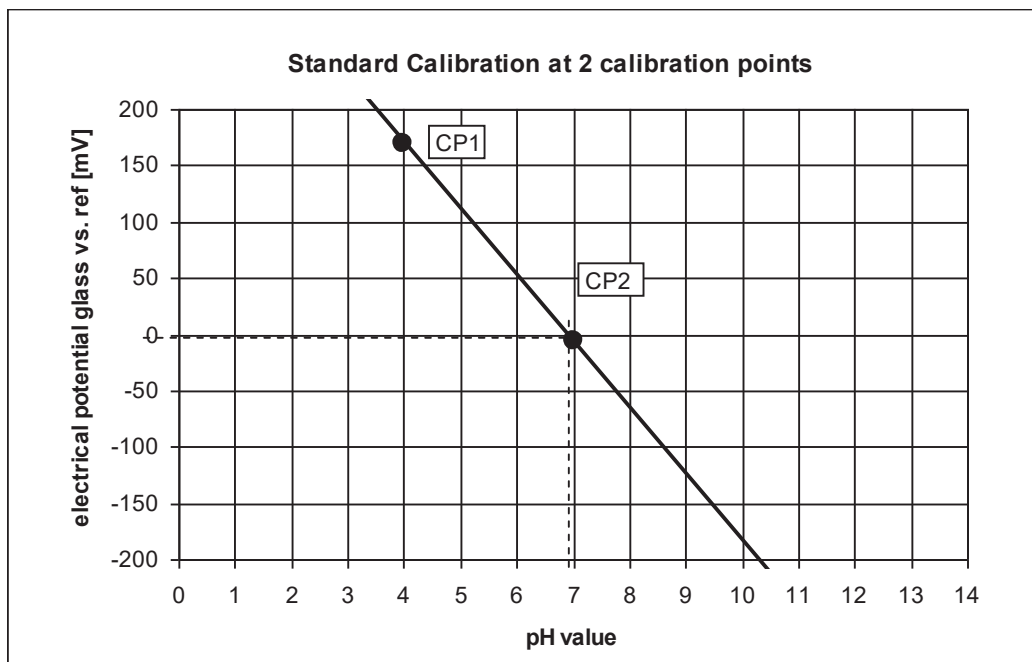


Figure 19 Standard 2-Point Calibration

CP1 and CP2 define a linear relationship between the electrical potential and the pH value. This linear calibration function is defined by an offset at pH 7 [mV] and a slope [mV/pH]. These two values are stored in the registers 14640 and 14672.

Note: the pH value of CP1 can be lower or higher than the pH value of CP2. However, the difference in pH between CP1 and CP2 must always be greater than 1 pH unit.

Notes:

- In order to perform a standard calibration at CP1 and CP2, it is necessary to use commercially available calibration standards. The operator is restricted to use those standards that are defined in the six sets of calibration standards (see chapter 2.8.5).
- There are two ways of performing a standard calibration:
 - standard calibration with **automatic recognition** of the calibration standard:
 - in this case, the sensor decides on itself in what calibration standard it is immersed.
 - The criteria to decide on is the electrical potential measured. The sensor checks the list of calibration standards that are available for automatic recognition (see chapter 2.8.5)
 - standard calibration with **manual selection** of the calibration standard:
 - the operator is selecting the calibration standard in which the sensor is immersed.
- Factory calibration is pH 4.01 at CP1 and pH 7 at CP 2.

Standard Calibration with Automatic Recognition of the Standard

Prior to calibration, the specialist selects - for each set of calibration standards - a list of calibration standards allowed for automatic recognition (see chapter 2.8.5).

When the calibration is initiated, the sensor screens this list of allowed calibration standards and checks if the currently measured electrical potential is within the allowed range of electrical potentials, defined for the individual calibration standards in this list.

If the sensor does find a corresponding calibration standard, the nominal pH value of the specific calibration standard is assigned to the currently measured electrical potential. The temperature dependency of the calibration standard is considered during the assignment.

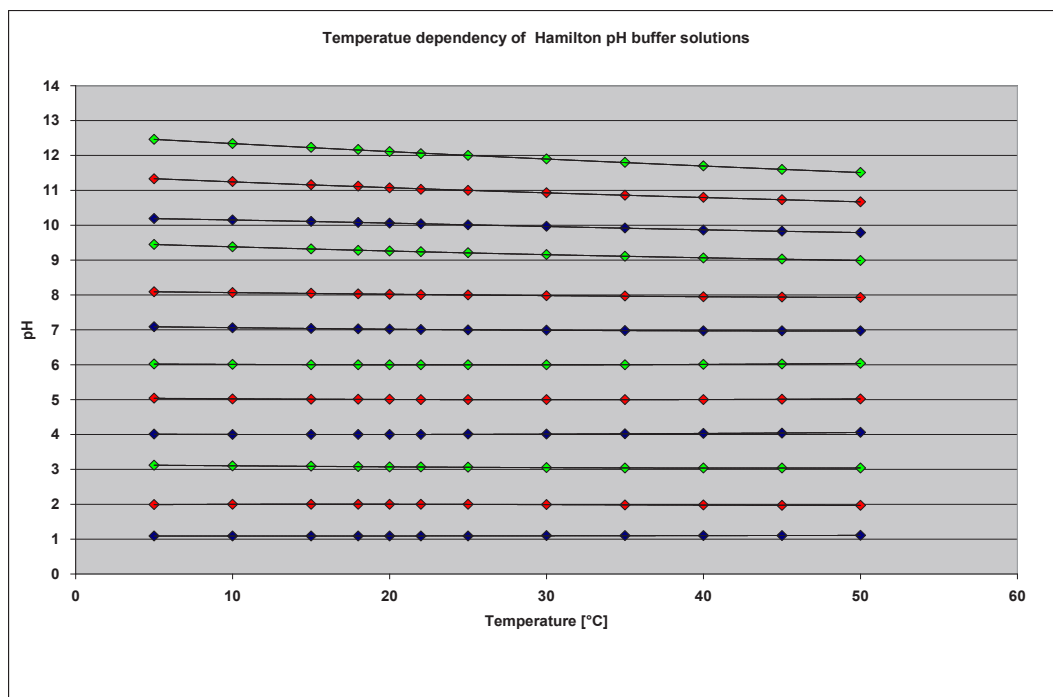


Figure 20: Temperature dependency of the pH value of Hamilton DURACAL calibration standards.

If the sensor does not find any corresponding calibration standard, the bit representing the corresponding status "no matching calibration standard" is set in the calibration status register.

Note that only the nominal value of the calibration standard is used for calibration. The actual value of the calibration solution, which may deviate from the nominal value, is not taken into account and cannot be set by the operator.

Standard Calibration with Manual Selection of the Calibration Standard

If the operator knows in what calibration standard the sensor is immersed, he can initiate the calibration procedure by means of setting the pH value to the actual value of the calibration standard. The sensor now screens the list of calibration standards that are allowed for manual selection (see chapter 2.8.5). If the pH value entered by the operator fits in the allowed pH range of one of the allowed calibration standards, the entered pH value is assigned to the currently measured electrical potential. The temperature dependency of the calibration standard is considered during the assignment.

If the sensor does not find any corresponding calibration standard, the bit representing the corresponding status "no matching calibration standard" is set in the calibration status register.

Note: using manual selection only, the actual pH value of the calibration standard can be set. However, the actual value must be within the given tolerance of the standard in use.

Perform the following steps to do a standard calibration at CP1 and CP2:

Step1: Select the desired set of calibration standards (see chapter 2.8.5)

Step 2: Immerse the sensor into one of the calibration standards available in the selected set



Attention:

It is important that the pH Arc Sensor is immersed in a defined calibration standard at least 3 minutes BEFORE the calibration is started.

Step 3: Choose one of the calibration points CP1 or CP2.



Attention:

The assignment of both CP1 and CP2 to the same pH value is rejected.

Try to avoid the following situations:

For example, the sensor was calibrated earlier at pH 4.01 (CP1) and at pH 7 (CP2):

- You want to perform a new calibration at CP1: it is possible to assign CP1 to pH 4 or to pH 10, but not to pH 7 (already used for CP2).
- You want to perform a new calibration at CP2: it is possible to assign CP2 to pH 7 or pH 10, but not to pH 4 (already used for CP1).
- If you calibrate now CP1 at pH 10, pH 4 will later be free for selection at CP2. In this case you can calibrate CP2 at pH 4 or pH 7, but not at pH 10 (CP1).

Step 4: Start the calibration (automatic recognition or manual selection, see Table 34 or Table 35)

Step 5: Read the calibration status (see chapter 2.8.4)

Step 6: Check the number of calibrations (see chapter 2.8.2.4.4, should be incremented by 1)

Step 7: Check the pH Arc Sensor's quality indicator (see chapter 2.9.7)

2.8.3.2 Calibration Point 6 (Product Calibration)

The product calibration is a process to adjust the measurement of a correctly calibrated pH Arc 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 pH Arc 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 pH Arc 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 pH Arc sensors memory.

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

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

Performing a cancel command for the product calibration (CP6) brings the sensor back to its stored standard calibration (CP1 and CP2).

If a product calibration is active and a standard calibration (CP1 or CP2) is performed, then the product calibration (CP6) is cancelled.

If the operator needs to adjust an active product calibration (old CP6) by a new product calibration (new CP6) the above process applies in the same way. After initial measurement the pH Arc sensor is running on the first product calibration (old CP6) until a valid assignment has been done (new CP6).

What happens to the pH Arc calibration function upon product calibration (CP6)?

A product calibration adds an offset to the linear calibration function defined by the standard calibration at CP1 and CP2. Slope remains the same.

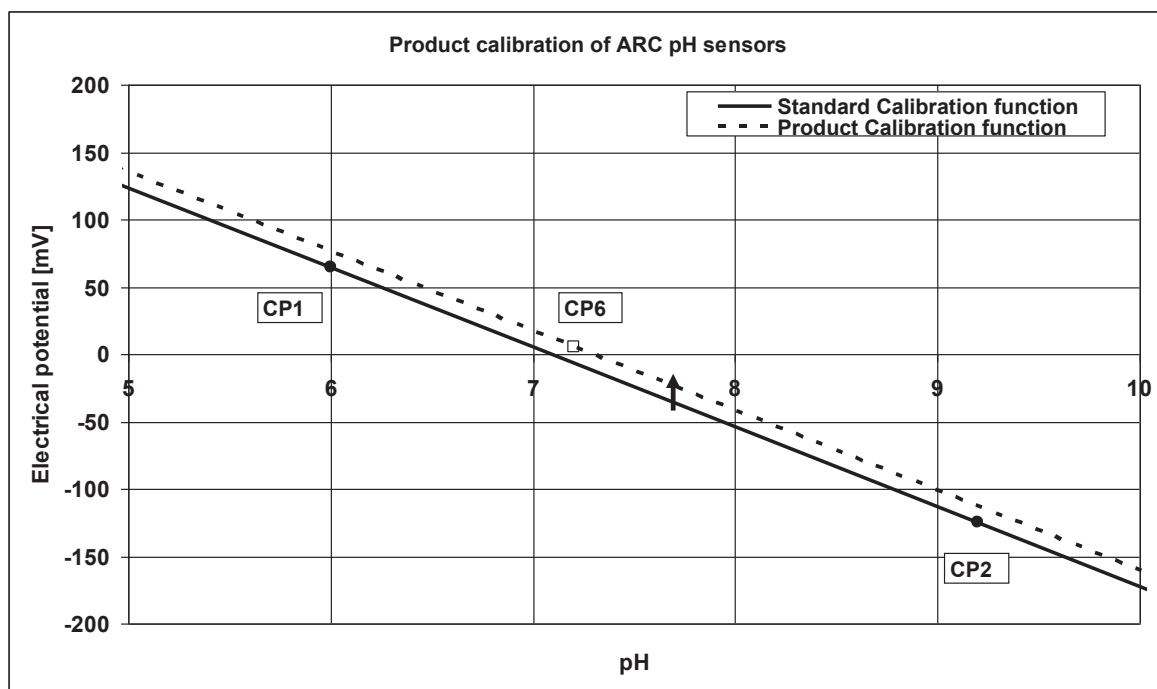


Figure 21 Effect of the product calibration CP6 on an existing standard calibration function defined by CP1 and CP2.

Example:

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

Calibration point	Assigned value in pH	Temperature in °C	Measured voltage in mV
CP1	6	27.77	64.2 mV
CP2	9.21	28.71	-125.2 mV

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 offset at pH 7 and the slope (these two values can be read in register 14640 and register 14672, see chapter 2.8.2.4.7).

If the measured value differs from the offline value after a sample is taken, the sensor allows you to adjust the offset by performing a product calibration CP6 to align the measured value with the offline value:

Calibration point	Assigned value in pH	Temperature in °C	Measured voltage in mV
CP6	7.2	28.79	5

The sensor internally adds an offset to the calibration curve. The slope remains unchanged. 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 pH Arc measurement range.
- the manually assigned pH value does not deviate more than 2 pH units from the value measured prior the product calibration

The different functionalities of product calibration (CP6) are accessible through the following sensor commands:

- Initial measurement
- Assignment
- Cancel
- Restore standard calibration
- Restore product calibration

All commands are executed by writing a command to the register 13914. The command codes are defined according to Table 36.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
13914	4	Code as defined in Table 36	Calibration value	16	None	S

Table 36 Definition of the commands related to the product calibration

Code (Hex)	Definition of commands
0x00000010	Perform initial measurement
0x00000020	Assign product calibration
0x00000040	Cancel an active product calibration
0x00000080	Restore a standard calibration from an active product calibration
0x00000100	Restore a product calibration from an active standard calibration

2.8.3.2.1 Product calibration: Initial measurement

Upon process sample collection for laboratory analysis the command for initial measurement is sent to the sensor.

This is achieved by writing the command 0x0010 to register 13914 which performs the initial measurement and stores the corresponding measurement values in the sensor.

Table 37 Example to start the product calibration procedure

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



Note:

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

As shown in Table 38, after successful initial measurement the corresponding calibration status is "CP6: Initial measurement" (0x20000000, see also Table 47).

The sensor continues the measurement with the previous standard calibration.

Table 38 Example to read the current product calibration status

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



Attention:

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

2.8.3.2.2 Product calibration: Assignment

After successful initial measurement a correct value must be assigned to the initially stored measurement data. As shown in Table 39, this is achieved by writing the pH value in the unit of pH during initial measurement (here 7.2 pH) to 13914.

Table 39 Example to assign a calibration value to the above performed initial measurement

Command: CP6: Assignment		Modbus address: 13914	Length: 4	Type: 16	Write
Parameter:	Command	Value			
Format:	Hex	Float			
Value:	0x00000020	7.2			

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

According to Table 40 the calibration status of the sensor is 0x50000000 meaning that a correct value has been assigned and that the product calibration is active (see Table 47).

Table 40 Example to read the current product calibration status, after performing a product calibration.

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

2.8.3.2.3 Product calibration: Cancel

To cancel an active product calibration or an active initial measurement the command 0x00000040 is written to register 13914 (see Table 41). The calibration value is not considered in this product calibration cancel phase and the value is not saved within the sensor.

Table 41 Example to cancel an active product calibration or an initial measurement

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

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

As shown in Table 42 after cancelling a product calibration the sensors calibration status will be reading 0x00000000 again (see Table 47).

Table 42 Example to read the current product calibration status

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

2.8.3.2.4 Product calibration: Restore standard calibration

If a product calibration is active this product calibration can be temporarily switched off by writing the command "restore standard calibration" (0x00000080) (see Table 47) to register 13914 (see Table 43). The calibration value is not considered in this restore standard calibration phase, but the value is saved within the sensor.

Performing this action, the values of the product calibration remain stored in the sensor's memory.

Table 43 Example to restore a standard calibration from an active product calibration

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

From now on the sensor is measuring using its prior CP1 / CP2 standard calibration.

As shown in Table 44 the sensor's calibration status will be reading "CP6 assigned" (0x40000000) (see Table 47) meaning that a valid assignment for a product calibration is available in the sensor's memory.

Table 44 Example to read the current product calibration status after a restoring a standard calibration

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

2.8.3.2.5 Product calibration: Restore product calibration

If a valid but inactive product calibration is available in the sensor's memory, the calibration status is reading 0x40000000 ("CP 6 assigned", see Table 44). This stored product calibration can be restored or reactivated by writing command "restore product calibration" 0x00000100 (see Table 47) to register 13914 according to Table 45. The calibration value is not considered in this restore product calibration phase and the value is not saved within the sensor.

Table 45 Example to restore an available product calibration from an active standard calibration

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

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

From now on the sensor is measuring using its prior CP6 product calibration. As shown in Table 46 the sensors calibration status will be reading 0x50000000 (corresponding to "CP6 assigned" and "CP6 active") again. (see Table 47)

Table 46 Example to read the current product calibration status, after a restoring a product calibration

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

2.8.4 Reading the Calibration Status

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

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

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
10312	2	Status CP1 (see Table 47)	3, 4	U/A/S	none
11032	2	Status CP2 (see Table 47)	3, 4	U/A/S	none
13912	2	Status CP6 (see Table 47)	3, 4	U/A/S	none

Table 47 Definition of the calibration status for registers 10312, 11032 and 13912

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

2.8.5 Calibration Standards



Note:

The updated version of the pH Arc is designed to allow backward-compatible handling with the standards. For details about the standards, refer to the previous version of the pH Arc Modbus RTU Programmer's Manual (REF 624300) available on the Hamilton website (www.hamiltoncompany.com).

2.8.5.1 Available Sets of Calibration Standards

pH Arc sensors can store and operate six different sets of calibration standards each having max 12 calibration standards. Before calibration the operator has to select one defined set to operate with. Default setting is the Hamilton set of calibration standards.

The operator can change the selection of sets at any time, without compromising prior calibration data at CP1 / CP2.

In register 10268 the available sets of calibration standards are defined.

Start register	Number of registers	Reg1 / Reg2 (Bit, see Table 33)	Modbus function code	Read access	Write access
10268	2	Available calibration standard sets	3, 4	U/A/S	none

Table 48 Definition of available sets of calibration standards.

Bit #	Hex value	Description	Definition
0 (LSB)	0x00000001	Set 1	HAMILTON
1	0x00000002	Set 2	MERCK TITRISOL
2	0x00000004	Set 3	DIN 19267
3	0x00000008	Set 4	NIST Standard
4	0x00000010	Set 5	METTLER-TOLEDO
5	0x00000020	Set 6	RADIOMETER

Table 49: Example to read the available calibration sets: Set 1 (0x00000001) + set 2 (0x00000002) + set 3 (0x00000004) + set 4 (0x00000008) + set 5 (0x00000010) + set 6 (0x00000020), in total 0x0000003F.

Command: Available cali sets	Modbus address: 10268	Length: 2	Type: 3	Read
Parameter: Calibration sets				
Format: Hex				
Value: 0x0000003F				

In register 10270 the selected set of calibration standards is defined.

Start register	Number of registers	Reg1 / Reg2 (Bit, see Table 33)	Modbus function code	Read access	Write access
10270	2	Selected set of calibration standard	3, 4, 16	U/A/S	S

Table 50: Example to read the selected set of calibration standards. Set 1 (HAMILTON) (0x00000001) is active.

Command: Selected set of cal stand.	Modbus address: 10270	Length: 2	Type: 3	Read
Parameter: Calibration set				
Format: Hex				
Value: 0x00000001				

Table 51: Example to set the calibration standard set to DIN 19267 (0x04).

Command: Select set of cal stand.	Modbus address: 10270	Length: 2	Type: 16	Write
Parameter: Calibration set				
Format: Hex				
Value: 0x00000004				

2.8.5.2 Definitions for Individual Sets of Calibration Standards

The name and two bit masks are available for each buffer set, which indicate which of the individual buffers in the buffer set are available for automatic and manual calibration:

- the available calibration standards for manual selection of the pH value
- the available calibration standards for automatic recognition of the pH value

The indexes of the individual buffer sets are defined in Table 52.

Start register	Number of registers	Reg 1 + Reg 2	Reg 3 + Reg 4	Reg 5 + Reg 6	Reg 7 + Reg 8	Modbus function code	Read access	Write access
38656 + Index * 12	8	Manufacturer of set 1 (16 ASCII characters)				3, 4	U/A/S	none
38664 + Index * 12	4	Available buffers for manual calibration of set 1	Available buffers for automatic calibration of set 1			3, 4	U/A/S	S

Table 52 Definition of the buffer set indexes.

Index	Description
0	Buffer set 1
1	Buffer set 2
2	Buffer set 3
3	Buffer set 4
4	Buffer set 5
5	Buffer set 6

Table 53: Example to read the information of register 38664. For the definition of the bits, see Table 54.

The value 0x00000FFF says that (for buffer set 1 of calibration standards):

- all 12 calibration standards are selected for manual calibration
- only calibration standards 3, 7 and 10 are selected for automatic recognition

Command: Available standards		Modbus address: 38664	Length: 4	Type: 3	Read
Parameter:	Standard fields manual	Standard fields automatic			
Format:	Hex				
Value:	0x00000FFF	0x00000248			

Table 54: Availability / Selection for the 12 calibration standards within one given set.

Bit	Hex code	Index of Calibration Standard
0 (LSB)	0x00000001	1
1	0x00000002	2
2	0x00000004	3
3	0x00000008	4
4	0x00000010	5
5	0x00000020	6
6	0x00000040	7
7	0x00000080	8
8	0x00000100	9
9	0x00000200	10
10	0x00000400	11
11	0x00000800	12

Table 55: Example to set the standard fields to 12 calibration standards for manual calibration and calibration standard 3 (0x00000004), 5 (0x00000010), 7 (0x00000040), 9 (0x00000100) and 11 (0x00000400) for automatic recognition.

Command:	Selected standard fields	Modbus address: 38664	Length: 4	Type: 16	Write
Parameter:	Standard fields manual	Standard fields automatic			
Format:	Hex				
Value:	0x00000FFF	0x00000554			



Attention:

The standards selected for automatic recognition must exhibit a difference in pH of at least 2 pH units.

2.8.5.3 Availability of each buffer for manual and automatic calibration of each buffer set

Table 56: Availability of each buffer for manual and automatic calibration of buffer set 1 "HAMILTON"

Buffer set 1: "HAMILTON"		
Standard	Manual calibration	Automatic calibration
Standard 1 - 1.09 pH	☒	☐
Standard 2 - 2 pH	☒	☐
Standard 3 - 3.06 pH	☒	☐
Standard 4 - 4.01 pH	☒	☒
Standard 5 - 5 pH	☒	☐
Standard 6 - 6 pH	☒	☐
Standard 7 - 7 pH	☒	☒
Standard 8 - 8 pH	☒	☐
Standard 9 - 9.21 pH	☒	☐
Standard 10 - 10.01 pH	☒	☒
Standard 11 - 11 pH	☒	☐
Standard 12 - 12 pH	☒	☐

Table 57: Availability of each buffer for manual and automatic calibration of buffer set 2 "MERCK TITRISOL"

Buffer set 2: "MERCK TITRISOL"		
Standard	Manual calibration	Automatic calibration
Standard 1 - 1 pH	☒	☒
Standard 2 - 2 pH	☒	☐
Standard 3 - 3 pH	☒	☒
Standard 4 - 4 pH	☒	☐
Standard 5 - 5 pH	☒	☒
Standard 6 - 6 pH	☒	☐
Standard 7 - 7 pH	☒	☒
Standard 8 - 8 pH	☒	☐
Standard 9 - 9 pH	☒	☒
Standard 10 - 10 pH	☒	☐
Standard 11 - 11 pH	☒	☒
Standard 12 - 12 pH	☒	☐

Table 58: Availability of each buffer for manual and automatic calibration of buffer set 3 "DIN 19267"

Buffer set 3: "DIN 19267 "		
Standard	Manual calibration	Automatic calibration
Standard 1 - 1.09 pH	☒	☒
Standard 2 - 0 pH	☐	☐
Standard 3 - 3.06 pH	☒	☒
Standard 4 - 0 pH	☐	☐
Standard 5 - 4.65 pH	☒	☒
Standard 6 - 0 pH	☐	☐
Standard 7 - 6.79 pH	☒	☒
Standard 8 - 0 pH	☐	☐
Standard 9 - 9.23 pH	☒	☒
Standard 10 - 0 pH	☐	☐
Standard 11 - 0 pH	☐	☐
Standard 12 - 12.75 pH	☒	☐

Table 59: Availability of each buffer for manual and automatic calibration of buffer set 4 "NIST STANDRAD"

Buffer set 4: "NIST Standard "		
Standard	Manual calibration	Automatic calibration
Standard 1 - 0 pH	☐	☐
Standard 2 - 1.68 pH	☒	☒
Standard 3 - 0 pH	☐	☐
Standard 4 - 4.01 pH	☒	☒
Standard 5 - 0 pH	☐	☐
Standard 6 - 0 pH	☐	☐
Standard 7 - 6.86 pH	☒	☒
Standard 8 - 0 pH	☐	☐
Standard 9 - 9.18 pH	☒	☒
Standard 10 - 0 pH	☐	☐
Standard 11 - 0 pH	☐	☐
Standard 12 - 12.45 pH	☒	☒

Table 60: Availability of each buffer for manual and automatic calibration of buffer set 5 "METTLER TOLEDO"

Buffer set 5: "METTLER TOLEDO "		
Standard	Manual calibration	Automatic calibration
Standard 1 - 0 pH	☐	☐
Standard 2 - 2 pH	☒	☒
Standard 3 - 0 pH	☐	☐
Standard 4 - 4.01 pH	☒	☒
Standard 5 - 0 pH	☐	☐
Standard 6 - 0 pH	☐	☐
Standard 7 - 7 pH	☒	☒
Standard 8 - 0 pH	☐	☐
Standard 9 - 9.21 pH	☒	☒
Standard 10 - 0 pH	☐	☐
Standard 11 - 11 pH	☒	☒
Standard 12 - 0 pH	☐	☐

Table 61: Availability of each buffer for manual and automatic calibration of buffer set 6 "RADIOMETER"

Buffer set 6: "RADIOMETER "		
Standard	Manual calibration	Automatic calibration
Standard 1 - 1.09 pH	☒	☒
Standard 2 - 2 pH	☒	☐
Standard 3 - 0 pH	☐	☐
Standard 4 - 4.01 pH	☒	☒
Standard 5 - 0 pH	☐	☐
Standard 6 - 6 pH	☒	☐
Standard 7 - 7 pH	☒	☒
Standard 8 - 8 pH	☒	☐
Standard 9 - 9.21 pH	☒	☐
Standard 10 - 10.01 pH	☒	☒
Standard 11 - 0 pH	☐	☐
Standard 12 - 0 pH	☐	☐

Once the operator has selected a set of calibration standards (register 10270) the register 38784 and following give all information on the selected set of calibration standards. The indexes of the individual buffer sets are defined in Table 62.

Start register	Number of registers	Reg 1 + Reg 2	Reg 3 + Reg 4	Reg 5 + Reg 6	Reg 7 + Reg 8	Modbus function code	Read access	Write access
38784 + Index * 32	8	Info 1 of the selected set (16 ASCII characters)				3, 4, 16	U/A/S	S
38792 + Index * 32	8	Info 2 of the selected set (16 ASCII characters)				3, 4, 16	U/A/S	S
38800 + Index * 32	8	Unit Standard [pH]	Nominal value [pH]	Tolerance (manual) (±) [pH]	Tolerance (automatic) (±) [pH]	3, 4, 16	U/A/S	S
38808 + Index * 32	8	T-poly 3	T-poly 2	T-poly 1	T-poly 0	3, 4, 16	U/A/S	S

Table 62 Definition of the buffer indexes.

Index	Description
0	Buffer 1
1	Buffer 2
2	Buffer 3
3	Buffer 4
4	Buffer 5
5	Buffer 6
6	Buffer 7
7	Buffer 8
8	Buffer 9
9	Buffer 10
10	Buffer 11
11	Buffer 12

Table 63: Example to read info 1 for calibration standard 4 within the "HAMILTON" set. In this case, Info 1 corresponds to "pH buffers"

Command: Unit text	Modbus address: 38880	Length: 8	Type: 3	Read
Parameter: Text				
Format: 8 ASCII characters				
Value: "pH buffers"				

Table 64: Example to read info 2 for calibration standard 4 within the "HAMILTON" set. In this case, Info 2 corresponds to "NIST certified"

Command: Unit text	Modbus address: 38888	Length: 8	Type: 3	Read
Parameter: Text				
Format: 8 ASCII characters				
Value: "NIST certified"				

Table 65: Example to read the values for calibration standard 4 within the "HAMILTON" set. This standard has a nominal value of 4.01 ± 0.02 pH until expiry date as defined by Hamilton.

Command: Read standard 4	Modbus address: 38896	Length: 8	Type: 3	Read
Parameter: T-poly 3	T-poly 2	T-poly 3	T-poly 0	
Format: Hex	Float	Float	Float	
Value: 0x00001000	4.01	0.02	0.5	

Table 66: Example to read the polynomial coefficients for calibration standard 4 in the "HAMILTON" set.

Command: Read standard 4		Modbus address: 38904	Length: 8	Type: 3	Read
Parameter:	Unit Standard [pH]	Nominal value [pH]	Tolerance (manual) ($\pm$) [pH]	Tolerance (automatic) ($\pm$) [pH]	
Format:	Float	Float	Float	Float	
Value:	-2.88443E-07	3.11278E-04	-0.107703	16.0902	

During standard calibration with automatic recognition the sensor accepts a range of pH readings between 3.51 and 4.51 pH (4.01 ± 0.5 pH) to be assigned to this standard. Of course, the pH reading used for this assignment considers on the currently active offset at pH 7 and slope.

During standard calibration with manual recognition only pH values between 3.99 and 4.03 pH (4.01 ± 0.02 pH) can be assigned to this standard.

Note: The decision, if this standard calibration is valid, is made after calculation of the offset at pH 7 and of the slope. If one of those two parameters is out of limits, the calibration using this standard will be denied.

Note: Make sure that calibration standards selected for automatic calibration do not exhibit overlapping acceptance ranges!

2.9 Sensor Status

2.9.1 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 pH measurement is possible.
- Calibration – in this range the sensor can be calibrated.
- User defined measurement – the specialist can adjust the range in which pH reading is active. The user defined measurement temperature range is a sub range of the measurement temperature range.

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Modbus function code	Read access	Write access
4608	4	Operating temperature min	Operating temperature max	3, 4	U/A/S	none
4612	4	Measurement temperature min	Measurement temperature max ¹⁾	3, 4	U/A/S	none
4616	4	Calibration temperature min	Calibration temperature max	3, 4	U/A/S	none
4624	4	User defined measurement temperature min	User defined measurement temperature max	3, 4, 16	U/A/S	S

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

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

For pH Arc the ranges are as follows:

- Operating temperature: -20 .. +140°C
- Measurement temperature: 0.. +110°C
- Calibration temperature: +5 .. +50°C
- User defined measurement temperature: 0 .. +110°C (default values)



Note:

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

2.9.2 Operating Hours, Counters and System Time

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
4676	6	Operating hours [h] (float)	Operating hours above max measurement temperature [h] (float)	Operating hours above max operating temperature [h] (float)	3, 4	U/A/S	none
4682	6	Number of Power ups (uint)	Number of Watchdog resets (uint)	Heartbeat (uint)	3, 4	U/A/S	none
4686	1	Heartbeat (uint 16)			3, 4	U/A/S	none
4688	4	Number of SIP cycles (uint)	Number of CIP cycles (uint)		3, 4	U/A/S	none
4692	2	Number of autoclavings (uint)			3, 4, 16	U/A/S	S
8232	2	System Time Counter [s] (uint)			3, 4, 16	U/A/S	S

In register 4676 are stored:

- total operating hours
- operating hours above max measurement temperature (see chapter 2.9.1)
- the operating hours above max operating temperature (see chapter 2.9.1)

In register 4682 are stored:

- number of power ups
- number of watchdog resets
- number of heartbeats. The number gets increased every second by 1 and ranges from 0 to 19.

In register 4686 is stored:

- number of heartbeats.
The Number is stored as an unsigned integer with the length of 16 bit. The number gets increased every second by 1 and ranges from 0 to 19.

In register 4688 are stored:

- number of sterilizations in place (SIP) (see chapter 2.9.6)
- number of cleanings in place (CIP) (see chapter 2.9.6)

In register 4692 is stored

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

In register 8232 is stored

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



Note:

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

2.9.3 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.

2.9.3.1 Currently Active Warnings

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

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

2.9.3.2 Definition of Warnings

Table 67 Definition of warnings "measurement".

Bit #	Code (Hex)	Description
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 pH 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 pH readings.
31	0x80000000	Measurement not running
		Causes that trigger this warning: Measurement Hold Mode is in Hold- or Off mode, see chapter 2.6.

Table 68 Definition of warnings "calibration".

Bit #	Code (Hex)	Description
0 (LSB)	0x00000001	PMC1 pH calibration recommended
		Perform a calibration to ensure reliable measurement.

Table 69 Definition of warnings "interface".

Bit #	Code (Hex)	Description
		Not available

Table 70 Definition of warnings "hardware".

Bit #	Code (Hex)	Description
0 (LSB)	0x00000001	Sensor supply voltage too low
		The sensor supply voltage is too low for the sensor to operate correctly. Ensure stable supply voltage within the sensor's specifications.
1	0x00000002	Sensor supply voltage too high
		The sensor supply voltage is too high for the sensor to operate correctly. Ensure stable supply voltage within the sensor's specifications.
9	0x00000200	Replace Sensor recommended
		The Sensor Quality Indicator is below 30%. The quality of the sensor is sufficient for reliable measurement, but replacement of the sensor will be needed in near future

2.9.4 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.

2.9.4.1 Currently Active Errors

The currently active errors are stored in register 4800.

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

2.9.4.2 Definition of Errors

Table 71 Definition of errors "measurement".

Bit #	Code (Hex)	Description
0 (LSB)	0x00000001	PMC1 pH reading failure
	This error occurs, when any other error is active, please call our Technical support.	
5	0x00000020	SMC1 Glass resistance too high
	Measured glass resistance is higher than the max value defined in 2.5.5.2	
6	0x00000040	SMC1 Glass resistance too low
	Measured glass resistance is lower than the min value defined in 2.5.5.2	
25	0x20000000	Temperature sensor defective
	The internal temperature sensor is defective.	

Table 72 Definition of errors "calibration".

Bit #	Code (Hex)	Description
1	0x00000002	Sensor Failure
	Quality value < 15%	

Table 73 Definition of errors "interface".

Bit #	Code (Hex)	Description
		Not available

Table 74 Definition of errors "hardware".

Bit #	Code (Hex)	Description
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)
22	0x400000	EEPROM comm. (I2C) error Userend
		Internal I2C communication error Reset the sensor and try again. Please call our Technical Support.
24	0x01000000	Internal communication (I2C) failure Userend
		Internal I2C communication error Reset the sensor and try again. Please call our Technical Support.
25	0x02000000	Internal communication failure (frontend)
		No communication between Frontend and Userend. Reset the sensor and try again. Please call our Technical Support.
26	0x04000000	Stackoverflow
		Internal memory failure Reset the sensor and try again. Please call our Technical Support.

**Note:**

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

2.9.5 PMCs output in case of sensor error / warning

2.9.5.1 Measurement values - Exceeds Temperature range, and pH measurement errors

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

Category	Code (Hex)	Description
Measurement Warning	0x02000000	T reading below lower limit
	0x04000000	T reading above upper limit

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

Category	Code (Hex)	Description
Hardware Error	0x00000004	Temperature reading far below min
	0x00000008	Temperature reading far above max
Measurement Error	0x00000001	pH reading failure

The measurement output values for these cases are defined in Table 75.

Table 75 Measurement values (PMCs) - Exceeds Temperature range, and pH measurement errors

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

2.9.5.2 Measurement values – Supply voltage warnings

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

Category	Code (Hex)	Description
Hardware Warning	0x00000001	Sensor supply voltage too low
	0x00000002	Sensor supply voltage too high

The measurement output values for these cases, are defined in Table 76.

Table 76 Measurement values (PMCs) in case no communication within the frontend is running

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

2.9.5.3 Measurement values – Hardware related errors

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

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

The measurement output values for these cases, are defined in Table 77.

Table 77 Measurement values (PMCs) in case Hardware errors

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

2.9.6 Reading Definition of SIP and CIP

pH Arc is counting special cleaning events such as sterilizations or cleaning cycles by means of tracking typical temperature profiles (see chapter 2.9.2).

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

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

CIP / SIP time maximum values: 180 min

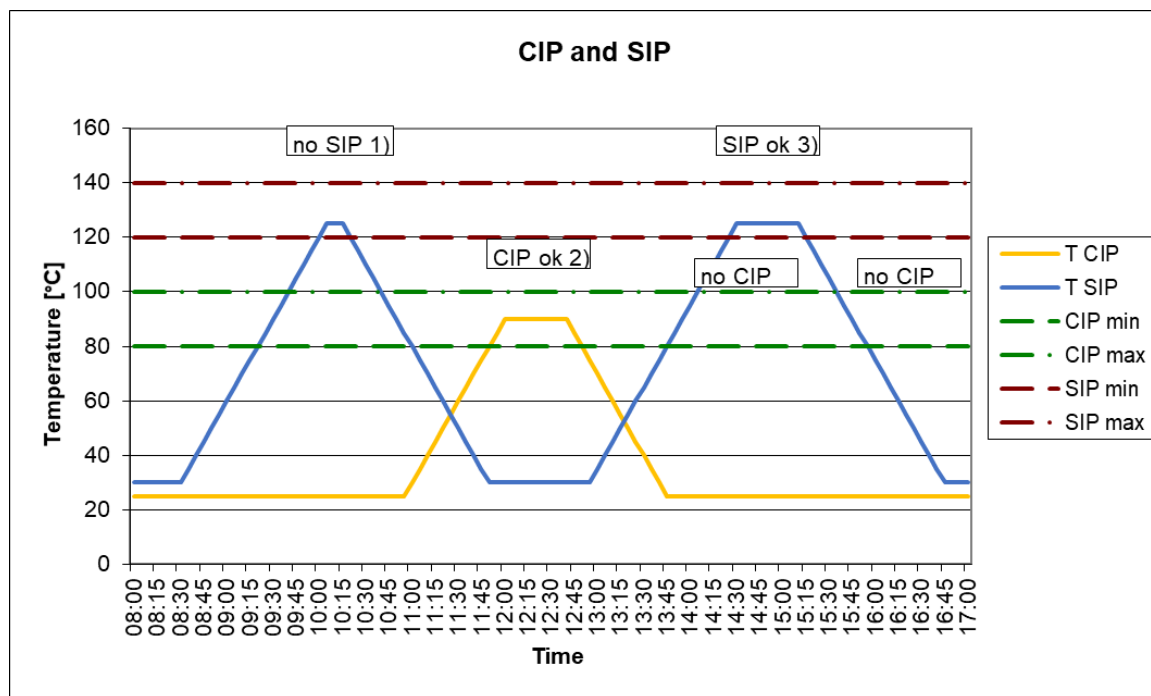


Figure 22: Definition of CIP and SIP cycles.

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

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Reg7 / Reg8	Modbus function code	Read access	Write access
4988	8	SIP Temperature min [°C]	SIP Temperature max [°C]	SIP Process time min [min]	Empty	3, 4, 16	U/A/S	S
4996	8	CIP Temperature min [°C]	CIP Temperature max [°C]	CIP Process time min [min]	Empty	3, 4, 16	U/A/S	S

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

2.9.7 Quality Indicator

2.9.7.1 Reading the Sensor Cap Quality

In register 4872 the sensor's quality indicator (0-100%) is given.

Start register	Number of registers	Reg1 / Reg2 (float)	Modbus function code	Read access	Write access
4872	2	Quality [%]	3, 4	U/A/S	none

Table 78: Example to read the sensor's quality indicator.

Command: Quality indicator	Modbus address: 4872	Length: 2	Type: 3	Read
Parameter:	Quality [%]			
Format:	Float			
Value:	100			

The sensor's quality indicator is influenced by:

- Offset at pH 7 (updated after calibration)
- Slope (updated after calibration)
- Errors (updated during measurement)

Sensor Identification and Information

2.9.8 General Information

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

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Example of content	Modbus function code	Read access	Write access
1024	8	Userend FW Date	2026-06-10	3, 4	U/A/S	none
1032	8	Userend FW	EPHUM040	3, 4	U/A/S	none
1040	8	Userend BL Date	2022-05-16	3, 4	U/A/S	none
1048	8	Userend BL	BL5UX101	3, 4	U/A/S	none
1056	8	Userend Ref	10162645/00	3, 4	U/A/S	none
1064	8	Userend SN	1234	3, 4	U/A/S	none
1072	8	Userend (space holder)	not available	3, 4	U/A/S	none
1080	8	Userend (space holder)	not available	3, 4	U/A/S	none
1088	8	Frontend FW Date	2025-05-14	3, 4	U/A/S	none
1096	8	Frontend FW	EPHFJ101	3, 4	U/A/S	none
1104	8	Frontend BL Date	not available	3, 4	U/A/S	none
1112	8	Frontend BL	not available	3, 4	U/A/S	none
1120	8	Frontend Ref	not available	3, 4	U/A/S	none
1128	8	Frontend SN	not available	3, 4	U/A/S	none
1136	8	Frontend (space holder)	not available	3, 4	U/A/S	none
1144	8	Frontend (space holder)	not available	3, 4	U/A/S	none

2.9.9 Sensor Identification

Definition of registers containing sensor identification:

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Example of content	Modbus function code	Read access	Write access
1280	8	Sensor Ref	242428-1313/08	3, 4	U/A/S	none
1288	8	Sensor name	Polilyte Plus	3, 4	U/A/S	none
1296	8	Sensor Lot	3214567	3, 4	U/A/S	none
1304	8	Sensor Lot date	22.02.2021	3, 4	U/A/S	none
1312	8	Sensor SN	0001001	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 e. pH Sensor	3, 4	U/A/S	none
1344	8	Power supply	010..027V 0500mW	3, 4	U/A/S	none
1352	8	Pressure range	0 ... 6 bar	3, 4	U/A/S	none
1360	8	Sensor ID	242111-0001001	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	H-Glass	3, 4	U/A/S	none

2.9.10 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	242111-0001001	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	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1672	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1680	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1688	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1696	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1704	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1712	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1720	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1728	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1736	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1744	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none
1752	8	Userspace	*FREE USERSPACE*	3, 4	U/A/S	none

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



Attention:

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

2.10 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:

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

remains unchanged.

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

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

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Abbreviations

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



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