



Conducell ARC Sensors

Modbus RTU Programmer's Manual

Firmware version:
CONUM011

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1 Modbus RTU general information

1.1 Introduction

This document describes in detail the Conducell ARC Sensors Modbus RTU interface. It is addressed to software programmers.

The general information about Modbus command structures and its implementation in the HAMILTON ARC Sensor family is described in detail in Chapter 1 of the

“VISIFERM DO Modbus RTU Programmer’s Manual” (p/n 624179/01).

If you need this general information about Modbus programming, then please consult p/n 624179/01.

In the present manual, only the specific command structure for the Conducell ARC Sensors is described. It is valid for the firmware version:

CONUM011

Please check the software version by reading register 1032.

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

2 Conducell ARC Sensor Commands in Modbus RTU

2.1 General

In order to communicate with a Conducell ARC Sensor over Modbus RTU protocol a Modbus master terminal application software is needed. The Modbus RTU is an open standard and a number of free and commercial application toolkits are available.

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

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



Attention:

When configuring and calibrating the sensor, please limit write operations to a reasonable number. More than 100'000 write operations will physically damage the memory of the sensor. Furthermore, for the Free User Memory Space (see chapter 2.9.3), the write operations are limited to 10'000.

2.2 Operator levels and Passwords

2.2.1 Reading / Setting Operator Level

A Conducell ARC Sensor can be operated in three different operator levels. Each operator level allows a defined access to a specific set of commands.

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

Figure 2.2.1.1: Definition of operator level and default passwords

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

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

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

Figure 2.2.1.2: Definition of register 4288.

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

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

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

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

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

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

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

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

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

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

2.2.2 Changing Passwords for Operator Level

The passwords for accessing the operator levels A and S can be modified by S (Specialist) only. U (User) and A (Administrator) have no right to change any password. The new password will remain stored after power down.

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

Figure 2.2.2.1: Definition of register 4292.

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

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

2.3 Configuration of the serial RS485 Interface

Factory settings of the RS485:

Parity is none, 1 start bit, 8 data bits, 2 stop bits (in total: 11 bits).

2.3.1 Device Address

2.3.1.1 Reading and Writing the Device Address

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

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

Figure 2.3.1.1.1: Definition of register 4096.

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

Figure 2.3.1.1.2: Example to read the device address.

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

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

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

2.3.1.2 Reading the Device Address Limits

The device address limits can be read in register 4098.

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

Figure 2.3.1.2.1: Definition of register 4098.

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

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

2.3.2 Baud Rate

2.3.2.1 Reading and Writing the Baud Rate

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

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

Figure 2.3.2.1.1: Definition of register 4102.

The code for the baud rate is defined as follows:

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

Figure 2.3.2.1.2: Code for the baud rates.

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

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

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

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

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

2.3.2.2 Reading the Baud Rate Limits

The baud rate limits can be read in register 4104.

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

Figure 2.3.2.2.1: Definition of register 4104.

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

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

2.4 Configuration of the Analog Interfaces

2.4.1 Available Analog Interfaces

A Conducell 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	Modbus function code	Read access	Write access
4320	2	Available analog interfaces	3, 4	U/A/S	none

Figure 2.4.1.1: Definition of register 4320.

Command: Avail analog interfaces		Modbus address: 4320	Length: 2	Type: 3	Read
Parameter:	Available analog interfaces				
Format:	Hex				
Value:	0x03				

Figure 2.4.1.2: Example to read the available analog interfaces. The answer 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	Reg3 / Reg4	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

Figure 2.4.2.1: Definition of register 4322. It defines the analog interface modes available for AO1 and AO2. The analog interface modes are described in Figure 2.4.2.2.

Code (Hex)	Analog Interface Mode	Description
0x00	4-20 mA inactive	Analog interface deactivated
0x01	4-20 mA fixed	Set to a constant output value for current loop testing
0x02	4-20 mA linear	Linear output of measurement (PMC1 / 6)
0x04	4-20 mA bilinear	Bilinear output of measurement (PMC1 / 6)

Figure 2.4.2.2: Definition of the analog interface modes, valid for both AO1 and AO2.

Command: Analog Interface Modes		Modbus address: 4322	Length: 8	Type: 3	Read
Parameter:	Available Analog Interface Modes for AO1	Available Analog Interface Modes for AO2	reserved	reserved	
Format:	Hex	Hex	Hex	Hex	
Value:	0x07	0x07	0x0	0x0	

Figure 2.4.2.3: Example to read register 4322: all modes defined in figure 2.4.2.2 are available for both AO1 and AO2.

2.4.3 Description of the Analog Interfaces 1 and 2

Register 4352 / 4480 contain the descriptions of AO1 / AO2 as plain text ASCII:

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

Figure 2.4.3.1: Definition of register 4352 and 4480

Command: Current interface text		Modbus address: 4352	Length: 8	Type: 3	Read
Parameter:	Text				
Format:	Character				
Value:	mA interface #1				

Figure 2.4.3.2: Example to read the description of AO1. The text is "mA interface #1". Accordingly, AO1 is physically configured as a 4-20 mA current output.

Command: Current interface text		Modbus address: 4480	Length: 8	Type: 3	Read
Parameter:	Text				
Format:	Character				
Value:	mA interface #2				

Figure 2.4.3.3: Example to read the description of AO2. The text is "mA interface #2". Accordingly, AO2 is physically configured as a 4-20 mA current output.



Attention:

- Conducell ARC Sensors do not have an ECS (in contrast to VISIFERM DO)!
- Data structure: register address offset between AO1 and AO2 is always 128.

2.4.4 Selection of an Analog Interface Mode

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

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

Figure 2.4.4.1: Definition of register 4360 / 4488. Only one bit can be set.

Command: Active interface mode		Modbus address: 4360	Length: 2	Type: 16	Write
Parameter:	Mode				
Format:	Hex				
Value:	0x02				

Figure 2.4.4.2: Example to set the analog interface mode of AO1 to 0x02 (4-20 mA linear output).

2.4.5 Configuration of the 4-20 mA Interface

Note:

The configuration of AO1 / AO2 is only effective if register 4360 / 4488 (active analog interface mode) is set to the value 0x01, 0x02 or 0x04.

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

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

Figure 2.4.5.1.1: Definition of register 4362 / 4490.

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

Code (Hex)	Primary Measurement Channel (PMC)
0x01	PMC1 (conductivity)
	not available
0x20	PMC6 (temperature)

Figure 2.4.5.1.2: Code for selection of the primary measurement channel.

Command: Available PMC AO1		Modbus address: 4362		Length: 2	Type: 3	Read
Parameter:	Available PMC 20 mA					
Format:	hex					
Value:	0x21					

Figure 2.4.5.1.3: Example to read the available Primary Measurement Channels (PMC) for AO1. The hexadecimal value of "0x21" defines that PMC1 (conductivity) or PMC6 (temperature) can be mapped to AO1. Register 4490 contains the same value "0x21". Accordingly, PMC1 or PMC6 can be mapped to AO2 as well.

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

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

Figure 2.4.5.2.1: Definition of register 4364 / 4492. Only one bit can be set.

Command: Active PMC AO1		Modbus address: 4364		Length: 2	Type: 3	Read
Parameter:	Current PMC 20mA					
Format:	hex					
Value:	0x01					

Figure 2.4.5.2.2: Example to read the current primary measurement channel mapped to AO1, defined in register 4364. The value "0x01" is returned, saying that PMC1 is mapped to AO1 (factory setting).

The factory setting for register 4492 is "0x20", mapping PMC6 to AO2.

2.4.5.3 Reading the Minimum and Maximum Possible Physical Output Current

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	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

Figure 2.4.5.3.1: Definition of register 4366 / 4494

Command: Limits AO1		Modbus address: 4366		Length: 4	Type: 3	Read
Parameter:	Min limit [mA]	Max limit [mA]				
Format:	Float	Float				
Value:	3.5	22				

Figure 2.4.5.3.2: Example to read the min and max output current of AO1. Min is fixed to 3.5 and Max is fixed to 22 mA (Currents above 20 and below 4 mA indicate erroneous measurements or errors).

The same values are stored in register 4494 for AO2.

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

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

Figure 2.4.5.4.1: Definition of register 4370 / 4498

Command: MinMaxMid current AO1		Modbus address: 4370		Length: 6	Type: 3	Read
Parameter:	Min current [mA]	Max current [mA]	Mid current [mA]			
Format:	Float	Float	Float			
Value:	4	20	12			

Figure 2.4.5.4.2: Example to read the min, max and mid output current for measurement values for AO1. They are fixed to 4, 20 and 12 mA.

The same values are stored in register 4498 for AO2.

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	Modbus function code	Read access	Write access
4376	2	Selected physical unit of AO1 (see chapter 2.5.1)	3, 4	U/A/S	none
4504	2	Selected physical unit of AO2 (see chapter 2.5.1)	3, 4	U/A/S	none

Figure 2.4.5.5.1: Definition of register 4376 / 4504.

Command: Avail unit AO1		Modbus address: 4376		Length: 2	Type: 3	Read
Parameter:	Available unit					
Format:	Hex					
Value:	0x0000200					

Figure 2.4.5.5.2: Example to read the selected unit of the selected PMC of AO1. The value returned is "0x0200", accordingly, the unit is $\mu\text{S/cm}$. The physical unit for 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	Reg3 / Reg4	Reg5 / Reg6	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

Figure 2.4.5.6.1: Definition of register 4378 / 4506.

Command: MinMaxMid value AO1		Modbus address: 4378		Length: 6	Type: 16	Write
Parameter:	Min value	Max value	Mid value			
Format:	Float	Float	Float			
Value:	1	10001	2001			

Figure 2.4.5.6.2: Example to set the min value to 1 (for 4 mA), the max value to 10'001 (for 20 mA) and the mid value to 2'001 (for 12 mA). The corresponding physical unit (in this example $\mu\text{S/cm}$) can be read in register 4376 / 4504 and in 2090 / 2410.

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.

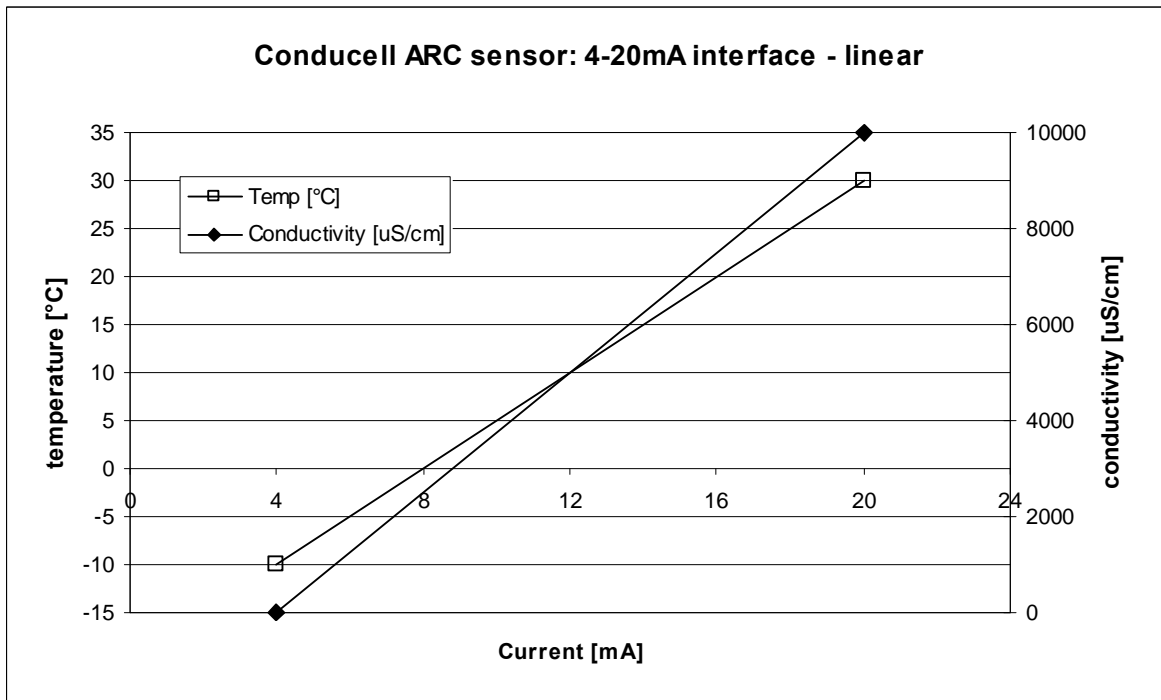


Figure 2.4.5.6.3: Example of linear 4-20 mA output characteristics for conductivity or temperature.

Current	Conductivity	Temperature
4 mA	1 μ S/cm	-10 $^{\circ}$ C
20 mA	10'001 μ S/cm	+30 $^{\circ}$ C

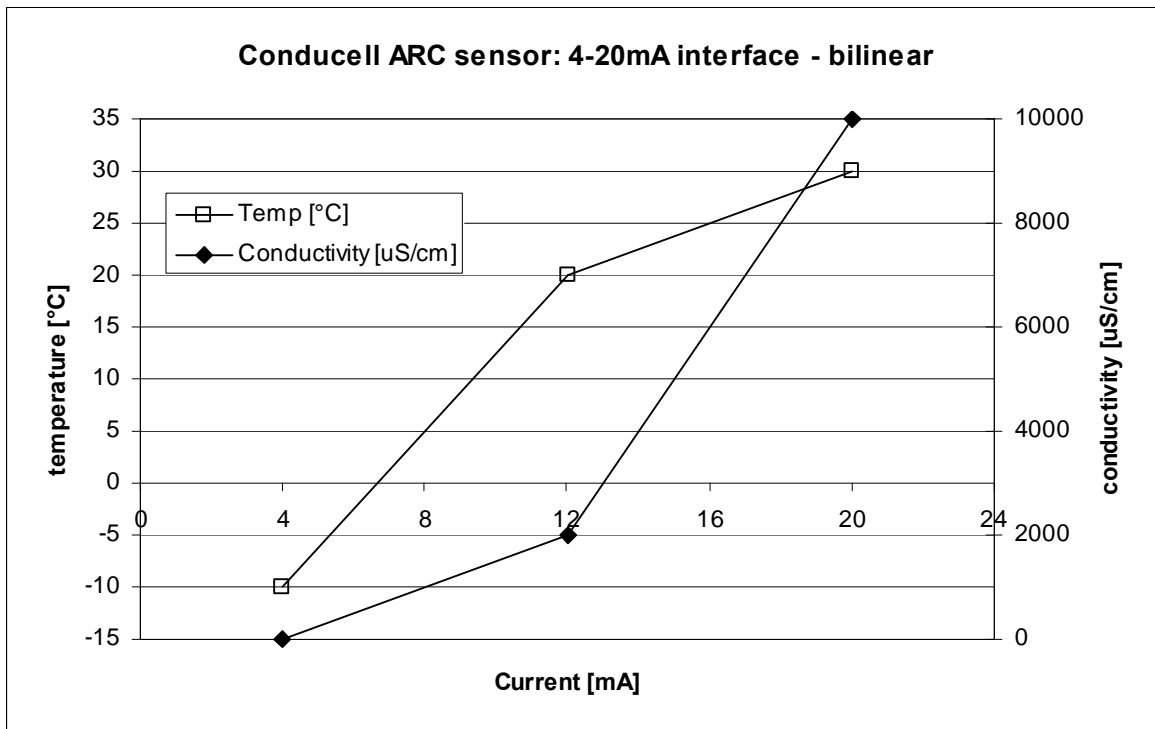


Figure 2.4.5.6.4: Example of bilinear 4-20 mA output characteristics for conductivity or temperature.

Current	Conductivity	Temperature
4 mA	1 μ S/cm	-10 $^{\circ}$ C
12 mA	2'001 μ S/cm	+20 $^{\circ}$ C
20 mA	10'001 μ S/cm	+30 $^{\circ}$ C



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 (conductivity) and register 2410 for PMC6 (temperature)).

Therefore, when the operator redefines one of the register 4364 / 4492, 2090 / 2410, the definitions of the register 4378 / 4506 should be reviewed. If not, the current output at the 4-20 mA interfaces may be wrong.

Note:

The physical unit of the analog output corresponds always to the unit that is set for the selected PMC (register 2090 for PMC1 or register 2410 for PMC6). Accordingly, not only the physical unit $\mu\text{S/cm}$ is selectable at the 4-20 mA interface, but also the units mS/cm , $\text{k}\Omega$ and $\text{M}\Omega$ (for conductivity), as well as degrees centigrade or Kelvin (for temperature).

Example:

Register 4364 is set to 1 (PMC1 is mapped to AO1).

Register 2090 is set to 0x0400 (the unit "mS/cm" is assigned to PMC1).

Register 4378 is set to 1 and 10 (4 mA = 1 mS/cm, 20 mA = 10 mS/cm).

The sensor reads currently 2.5 mS/cm, the output at the 4-20 mA is accordingly 8 mA.

The operator now re-assigns register 2090 to the value of 0x0200 (unit = $\mu\text{S/cm}$), but does not modify all other registers. As the sensor is still immersed in the same measurement solution, it reads now 2500 $\mu\text{S/cm}$. At the analog output, as 20 mA is programmed to a value of 10 by register 4378, the current will go to the maximum value of 20 mA. This will generate an interface warning "4-20 mA current set point not met".

2.4.5.7 Defining a Constant Current Output for Testing

Note:

For constant current output, the AO1 / AO2 must be set to analog interface mode 0x01:

Start register	Number of registers	Reg1 / Reg2	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

Figure 2.4.5.7.1: Definition of register 4384 / 4512.

Command: Fixed value AO1		Modbus address: 4384	Length: 2	Type: 3	Read
Parameter:	Fixed value [mA]				
Format:	Float				
Value:	10				

Figure 2.4.5.7.2: Example to read the constant current output in mode 0x01 for AO1. It is set to 10 mA.

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	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
4386	8	Code of warnings and errors (see Figure 2.4.4.8.2) for AO1	Current in case of "warning" [mA] for AO1	Current in case of "error" [mA] for AO1	Current in case of "T exceed" [mA] for AO1	3, 4, 16	U/A/S	S
4514	8	Code of warnings and errors (see Figure 2.4.4.8.2) for AO2	Current in case of "warning" [mA] for AO2	Current in case of "error" [mA] for AO2	Current in case of "T exceed" [mA] for AO2	3, 4, 16	U/A/S	S

Figure 2.4.5.8.1: Definition of register 4386 / 4514.

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

Figure 2.4.5.8.2: Code for the 4-20 mA interface in case of errors and warnings.

If the corresponding bits for the errors and warnings are not set (=0x00), the respective options are inactive.

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 temperature exceed: 3.5 mA

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

Figure 2.4.5.8.4: Example: Read the settings for AO1 in case of warnings and errors. Warning code 0x010001 corresponds to the continuous output current in case of warning (0x010000) and continuous output current in case of error (0x01) of 3.5 mA. The output current in case of temperature exceed is 3.5 mA.

2.4.6 Reading the Internally Measured Output Current

Reg. 4414 / 4542 provides internal parameters of AO1 / AO2:

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

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

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Modbus function code	Read access	Write access
4414	4	Set point [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

Figure 2.4.6.1: Definition of register 4414 / 4542.

Command: Internal values AO1		Modbus address: 4414		Length: 4	Type: 3	Read
Parameter:	Set point [mA]	Internally measured [mA]				
Format:	Float	Float				
Value:	9.99186	9.99742				

Figure 2.4.6.2: Example to read the internal values of AO1, depending on the analog interface mode.

2.5 Measurement

2.5.1 Definition of Measurement Channels and Physical Units

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

Bit #	Hex code	Description	Definition
0 (LSB)	0x000001	PMC1	Conductivity
1	0x000002	PMC2	not available
			not available
4	0x000010	PMC5	not available
5	0x000020	PMC6	Temperature
6	0x000040	SMC1	Resistance 2- EI
7	0x000080	SMC2	Resistance 4- EI
8	0x000100	SMC3	not available
		...	
21 (MSB)	0x200000	SMC16	not available

Figure 2.5.1.1: Full list of PMC1 to 6 and SMC1 to 16.

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

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

Figure 2.5.1.2: Definition of register 2048.

Command: Avail. PMC and SMC		Modbus address: 2048	Length: 2	Type: 3	Read
Parameter:	Avail. PMC and SMC				
Format:	Hex				
Value:	0xA1				

Figure 2.5.1.3: Example to read Reg. 2048 for Polilyte Plus ARC. The value returned depends on the currently active operator level.

In case of operator A/U, the value 0xA1 is returned. In other words the following PMC and SMC are available to A/U: **PMC1 / PMC6 / SMC2**

In case of operator S, the value 0xE1 is returned. In other words the following PMC and SMC are available to S: **PMC1 / PMC6 / SMC1 / SMC2**

The Conducell ARC Sensor register structure uses the following physical units used for Primary or Secondary Measurement Channels.

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

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

Command: Unit text		Modbus address: 1960	Length: 4	Type: 3	Read
Parameter:	Text				
Format:	Character				
Value:	mS/cm				

Figure 2.5.1.5: Example to read the physical unit in plain text ASCII in register 1960

2.5.2 Primary Measurement Channel 1 (Conductivity)

2.5.2.1 Description of PMC1

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

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

Figure 2.5.2.1.1: Definition of register 2080.

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

Figure 2.5.2.1.2: Example to read the description. It is "Cond".

2.5.2.2 Selecting the Physical Unit for PMC1

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

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

Figure 2.5.2.2.1: Definition of register 2088.

Command: PMC1 available units		Modbus address: 2088	Length: 2	Type: 3	Read
Parameter:	Units				
Format:	Hex				
Value:	0x0000C600				

Figure 2.5.2.2.2: Example to read the available physical units of PMC1: $\mu\text{S}/\text{cm}$ (0x0200), mS/cm (0x0400), $\text{k}\Omega$ (0x4000), $\text{M}\Omega$ (0x8000), in total 0xC600.

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

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

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

Command: PMC1 set unit		Modbus address: 2090	Length: 2	Type: 16	Write
Parameter:	Unit				
Format:	Hex				
Value:	0x0400				

Figure 2.5.2.2.4: Example to set the physical unit of PMC1 to mS/cm (0x0400).



Attention:

Changing the physical unit 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 have to be redefined after changing the physical unit!

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

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

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

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

Command: PMC1 read		Modbus address: 2090		Length: 10	Type: 3	Read
Parameter:	Unit	Value	Status	Min limit	Max limit	
Format:	Hex	Float	Hex	Float	Float	
Value:	0x0200	8.037725	0x00	0.1	600000	

Figure 2.5.2.3.2: Example to read register 2090. Physical unit is set to $\mu\text{S/cm}$ (0x0200), PMC1 is 8.03 ($\mu\text{S/cm}$), Status is 0x00, Min allowed value is 0.1 ($\mu\text{S/cm}$), Max allowed value is 600'000 ($\mu\text{S/cm}$).

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:	0x0400	1.469648E-02	0x00	0.0001	600	

Figure 2.5.2.3.3: Example to read register 2090. Physical unit is set to mS/cm (0x0400), PMC1 is 0.014 (mS/cm), Status is 0x00, Min allowed value is 0.0001 (mS/cm), Max allowed value is 600 (mS/cm).

For the definition of the measurement status see chapter 2.5.4.



Attention:

- You cannot read selectively the registers 3 and 4 for the measurement value only. You have to read the entire length of the command (10 registers) and extract the desired information.
- The PMC1 readings at register 2090 depend on the parameter PA4 (temperature compensation factor) (please refer to chapter 2.6.2).
 If PA4=0, the register 2090 reports the conductivity reading at the effective measurement temperature.
 If PA4 is set to the correct temperature compensation factor of the measurement solution, the register 2090 reports the hypothetical conductivity of the measurement solution, calculated to the reference temperature (25°C). The specialist has to make sure that PA4 corresponds to the measurement solution.

2.5.3 Primary Measurement Channel 6 (Temperature)

2.5.3.1 Description of PMC6

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

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

Figure 2.5.3.1.1: Definition of register 2400.

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

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

2.5.3.2 Selecting the Physical Unit for PMC6

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

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

Figure 2.5.3.2.1: Definition of register 2408.

Command: PMC6 available units		Modbus address: 2408	Length: 2	Type: 3	Read
Parameter:	Units				
Format:	Hex				
Value:	0x06				

Figure 2.5.3.2.2: Example to read the available physical unit for PMC6. K (0x02) + °C (0x04), total 0x06.

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

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

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

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

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



Attention:

Changing the physical unit 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 have to be redefined after changing the physical unit!

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

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

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

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

Command: PMC6 read		Modbus address: 2410		Length: 10	Type: 3	Read
Parameter:	Unit	Value	Status	Min limit	Max limit	
Format:	Hex	Float	Hex	Float	Float	
Value:	0x02	296.2684	0x00	253.15	403.15	

Figure 2.5.3.3.2: Example to read register 2410. Physical unit is set to K (0x02), PMC6 is 296.2 (K), Status is 0x00, Min allowed value is 253.15 (K), Max allowed value is 403.15 (K).

For definition of the measurement status see chapter 2.5.4.



Attention:

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

2.5.3.4 Input of an Externally Measured Temperature

Unlike to the VISIFERM DO, this feature is not available for Conducell ARC Sensors.

2.5.4 Definition of the Measurement Status for PMC1 / PMC6

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

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

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

2.5.5 Secondary Measurement Channels 1-16

Conducell ARC Sensors do allow access to secondary measurement values (16 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 (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 ... Reg8 16 ASCII characters	Modbus function code	Read access	Write access
Address	8	Description of each SMC	3, 4	U/A/S	none

Figure 2.5.5.1.1: Definition of registers at Address

Description	Address	Plain Text (16 ASCII)	Description
SMC1	2464	Resistance 2- EI	Resistance in 2-electrodes setup
SMC2	2496	Resistance 4- EI	Resistance in 4-electrodes setup

Figure 2.5.5.1.2: Full list of starting register addresses for the plain text ASCII description of each SMC

Example:

Command: SMC 1 text		Modbus address: 2464		Length: 8	Type: 3	Read
Parameter:	Text					
Format:	Character					
Value:	Resistance 2- EI					

Figure 2.5.5.1.3: Example to read the description of SMC1 at address 2464. It is "Resistance 2- EI".

Note:

Conducell ARC Sensors are so called 4 electrodes contacting conductivity sensors. The conductivity of the measurement solution is determined by driving a current through 2 outer electrodes, and measuring the voltage drop at two inner electrodes. By knowing current and voltage drop, the sensor calculates the resistance of the measurement solution by applying Ohm's law.

The "Resistance 4-EI" is the ratio of voltage drop at the inner electrodes and the applied current at the outer electrodes. This resistance is the basis for the calculation of the conductivity of the measurement solution by means of the cell constant.

The "Resistance 2-EI" is the ratio of voltage drop at the outer electrodes and the applied current at the outer electrodes. This resistance allows to monitor the integrity of the outer electrodes and is used for diagnosis only. Only operator S can read this value.

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.	Number of reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
Address	6	Physical unit	Measurement value of SMC	Standard deviation	3, 4	U/A/S	none

Figure 2.5.5.2.1: Definition of register at Address. Measurement value of each SMC.

Description	Address	Text	Unit	Min value	Max value
SMC1	2472	Resistance 2- EI	kOhm	0.000'22	31'000
SMC2	2504	Resistance 4- EI	kOhm	0.000'22	21'000

Figure 2.5.5.2.2: Full list of register addresses for the measurement values of SMC1 to SMC9.

Example:

Command: SMC1 read		Modbus address: 2472		Length: 6	Type: 3	Read
Parameter:	Unit	Value	Standard dev.			
Format:	Hex	Float	Float			
Value:	0x4000	29.14372	0			

Figure 2.5.5.2.3: Example to read register 2472. Physical unit is kOhm (0x4000), the measurement value of SMC1 is 29.14 kOhm, standard deviation of SMC1 is 0 kOhm

2.6 Configuration of the Measurement

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

2.6.1 Available Parameters

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

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3072	2	Available parameters (see figure 2.6.1.2)	3, 4	U/A/S	none

Figure 2.6.1.1: Definition of register 3072.

Bit #	Hex value	Description	Definition in CONDUCELL ARC Sensors
0 (LSB)	0x0001	PA1	not available
			not available
2	0x0004	PA3	not available
3	0x0008	PA4	T comp. factor
4	0x0010	PA5	not available
			not available
7	0x0080	PA8	not available
8	0x0100	PA9	Moving average
9	0x0200	PA10	not available
			not available
15 (MSB)	0x8000	PA16	not available

Figure 2.6.1.2: Bitwise definition of parameters PA1 to PA16, valid for Conducell ARC Sensors

Command: Available parameters		Modbus address: 3072	Length: 2	Type: 3	Read
Parameter:	Measurement parameters				
Format:	Hex				
Value:	0x0108				

Figure 2.6.1.3: Example to read the available parameters. The value 0x0108 corresponds to 0x0100 (PA9) + 0x08 (PA4). Parameter 4 and 9 are available.

General note:

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

2.6.2 PA4: Temperature Compensation Factor

It is a matter of fact that the conductivity of a solution depends on temperature. The root cause is the temperature dependency of both the ion mobility and the viscosity of a given measurement solution. This temperature dependency is normally expressed as relative change per °C (linearized).

Below some typical values for aqueous solutions :

- 1.5 %/°C for concentrated, aqueous solutions
- 2.3 %/°C for low concentrated aqueous solutions
- 5.2 %/°C for ultrapure water

Conducell ARC Sensors allow to calculate the conductivity of a solution, measured at a given temperature, to a hypothetical conductivity at a reference temperature (25°C). This is useful for comparing conductivity values, measured at different temperatures and different moments in time.

In order to allow a correct calculation to 25°C, one has to know the exact temperature dependency of the solution to be measured. PA4 allows to set the temperature compensation factor of the measurement solution as a linear approximation. The unit of PA4 is %/°C. Values can be entered between 0 (no compensation) and 10 %/°C.

Example:

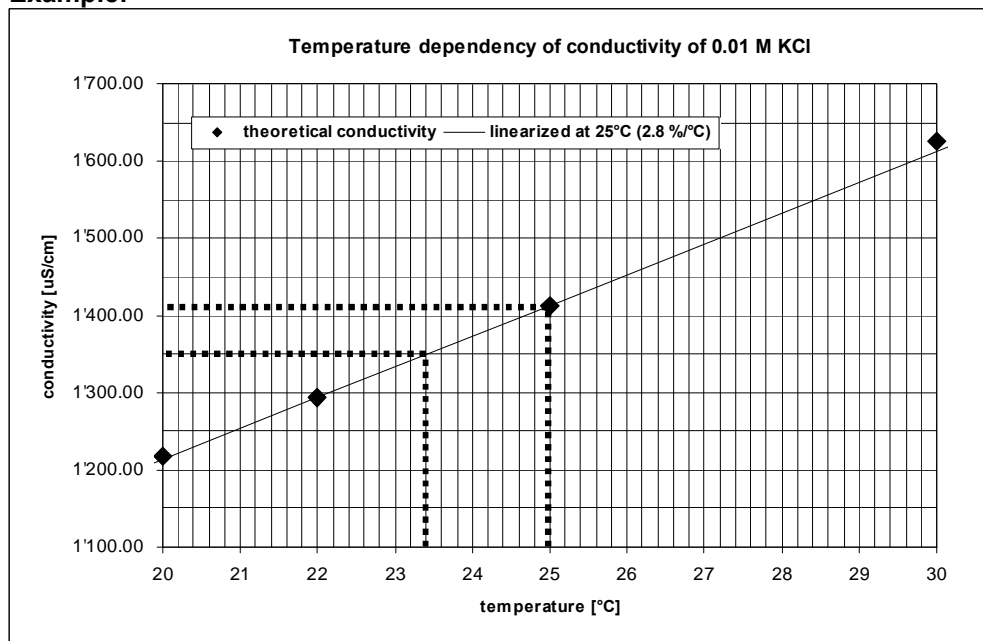


Figure 2.6.2.1: Temperature dependency of a KCl-solution having a concentration of 0.01 M. The dots are the theoretical values from literature. The line shows the linear approximation having a slope of 2.8 %/°C (linearization calculated at 25°C).

The Conducell ARC Sensor is immersed in 0.01 M KCl solution. The sensor reports for PMC6 a temperature of 23.4°C. According to figure 2.6.2.1, the expected conductivity at this temperature is 1349 µS/cm.

- with PA4 set to zero, the measurement value at PMC1 is reported as 1349.88 µS/cm. This is the effective conductivity measurement of the sensor at 23.4 °C.
- with PA4 set to 2.8 %/°C (which is the linearized temperature dependency of the KCl-solution used), the measurement value at PMC1 is reported as 1412.94 µS/cm. This is the hypothetical conductivity at the reference temperature of 25°C. The calculated hypothetical value is very close to the theoretical value of 1413 µS/cm at 25°C.

Remember:

- If the operator wants to read the conductivity at the effective temperature, PA4 has to be set to zero
- If the operator wants to read the hypothetical conductivity at 25°C, PA4 has to be set to the correct temperature compensation factor.

2.6.2.1 Description of PA4 (Temperature compensation factor)

In register 3456, a plain text ASCII description of PA4 is given.

Start register	Number of registers	Reg1 ... Reg8 16 ASCII characters	Modbus function code	Read access	Write access
3200	8	Description of PA4	3, 4	U/A/S	none

Figure 2.6.2.1.1: Definition of register 3456.

Command: Moving average text		Modbus address: 3200	Length: 8	Type: 3	Read
Parameter:	Text				
Format:	Character				
Value:	T comp. factor				

Figure 2.6.2.1.2: Example to read the description for "T comp. factor".

2.6.2.2 Selecting the Physical Unit and Writing the Value for PA4

In register 3208, the available physical units for PA4 are defined.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
3208	2	Available physical units for PA4	3, 4	U/A/S	none

Figure 2.6.2.2.1: Definition of register 3208.

Command: Moving average av. units		Modbus address: 3208	Length: 2	Type: 3	Read
Parameter:	Units				
Format:	Hex				
Value:	0x04000000				

Figure 2.6.2.2.2: Example to read the available physical units for PA4. The only one available here is "%/°C" (0x04000000). For the definition of the physical units see chapter 2.5.1.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4	Modbus function code	Read access	Write access
3210	4	Select physical unit for PA4	Value for PA4 (0-10) (Float)	16	none	S

Figure 2.6.2.2.3: Definition of register 3210. Only one bit for the physical unit can be set. PA4 can be set to values between 0 and 10 %/°C.

By writing to register 3210, the active physical unit for PA4 can be selected, by choosing one of the physical units that are defined in register 3208. The value of the parameter can be set as well.

Command: Moving average		Modbus address: 3210	Length: 4	Type: 16	Write
Parameter:	Unit	Value			
Format:	Hex	Float			
Value:	0x04000000	2.3			

Figure 2.6.2.2.4: Example to set the physical unit of PA9 to "%/°C" (0x04000000) and the value of the temperature compensation factor to 2.3.

2.6.2.3 Reading all Values for PA4

By reading register 3210, the active physical unit of measurement, the selected value, and the min and max values can be read.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
3210	8	Physical unit	Current value	Min value	Max value	3, 4	U/A/S	none

Figure 2.6.2.3.1: Definition of register 3210.

Command: Moving average		Modbus address: 3210		Length: 8	Type: 3	Read
Parameter:	Unit	Value	Min value	Max value		
Format:	Hex	Float	Float	Float		
Value:	0x04000000	2.3	0	10		

Figure 2.6.2.3.2: Example to read PA4. The physical unit is 0x04000000 ("%°C"), the currently active value is 2.3, and the limits are 0 to 10.

2.6.3 PA9: Moving Average

The Conducell ARC Sensor provides new conductivity readings every 3 seconds. One has the possibility to smoothen the conductivity reading (PMC1) by means of a moving average applied to the 3-seconds-readings.

PA9 can be applied on 1 to 16 3-seconds-readings. The default value is 2.

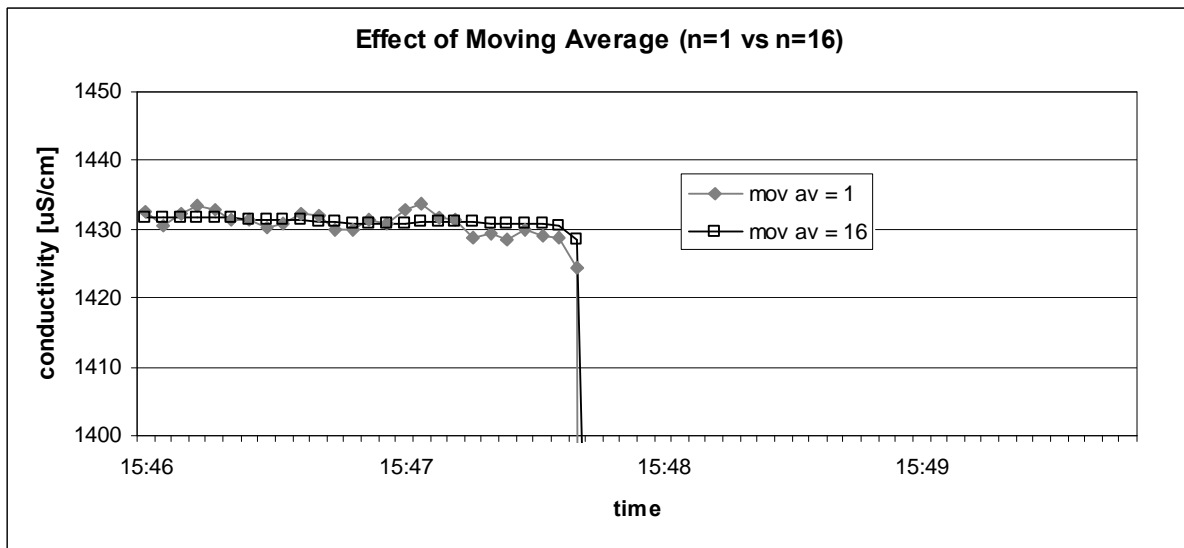
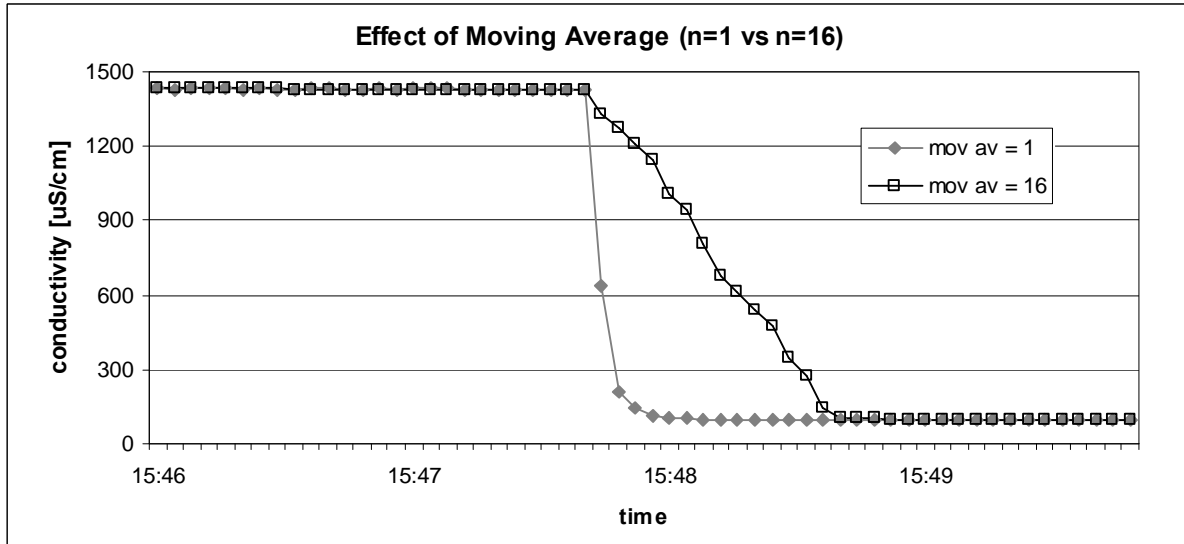


Figure 2.6.3.1: Comparison of the response of a Conducell ARC Sensor to a change from a conductivity standard having nominally 1413 $\mu\text{S}/\text{cm}$ (25°C) to a conductivity standard having nominally 100 $\mu\text{S}/\text{cm}$ (25°C), using no moving average (n=1) or a moving average over 16 3-seconds-readings.

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 48 s.

Note:

- PA9 is applied to both PMC1 and PMC6.

2.6.3.1 Description of PA9 (Moving Average)

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

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

Figure 2.6.3.1.1: Definition of register 3360.

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

Figure 2.6.3.1.2: Example to read the description for "Moving average".

2.6.3.2 Selecting the Physical Unit and Writing the Value for PA9

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

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

Figure 2.6.3.2.1: Definition of register 3368.

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

Figure 2.6.3.2.2: Example to read the available physical units for PA9. The only one available here is "none" (0x01). For the definition of the physical units see chapter 2.5.1.

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

Figure 2.6.3.2.3: Definition of register 3370. Only one bit for the physical unit can be set. PA9 can be set to the value 1-16. A value of 1 does not influence the response time of the sensor, a value of 16 increases the response time of the sensor to 48 s.

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

Command: Moving average		Modbus address: 3370	Length: 4	Type: 16	Write
Parameter:	Unit	Value			
Format:	Hex	Decimal			
Value:	0x01	12			

Figure 2.6.3.2.4: Example to set the physical unit of PA9 to "none" (0x01) and the value of the moving average to 12.

2.6.3.3 Reading all Values for PA9

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

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

Figure 2.6.3.3.1: Definition of register 3370.

Command: Moving average		Modbus address: 3370		Length: 8	Type: 3	Read
Parameter:	Unit	Value	Min value	Max value		
Format:	Hex	Decimal	Decimal	Decimal		
Value:	0x01	10	1	16		

Figure 2.6.3.3.2: Example to read PA9. The physical unit is 0x01 ("none"), the value is 10 and the limit is 1 to 16.

2.7 Calibration

2.7.1 Available Calibration Points

In register 5120, the available number of Calibration Points (CP) for Primary Measurement Channel 1 (PMC1) is defined. 8 individual CP are theoretically possible, however, Conducell ARC Sensors do use only CP1 and CP6.

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

Figure 2.7.1.1: Definition of register 5120.

Bit #	Hex value	Description	Definition in ARC Sensors
0 (LSB)	0x01	CP1	Calibration Point 1
1	0x02	CP2	not available
...	not available
5	0x20	CP6	Product Calibration
6	0x40	CP7	not available
7 (MSB)	0x80	CP8	not available

Figure 2.7.1.2: Bitwise definition of CP1 to CP8.

Command: Available cali points		Modbus address: 5120	Length: 2	Type: 3	Read
Parameter:	Points				
Format:	Hex				
Value:	0x21				

Figure 2.7.1.3: Example to read the available CPs. 0x21 = 0x01 (CP1) + 0x20 (CP6).

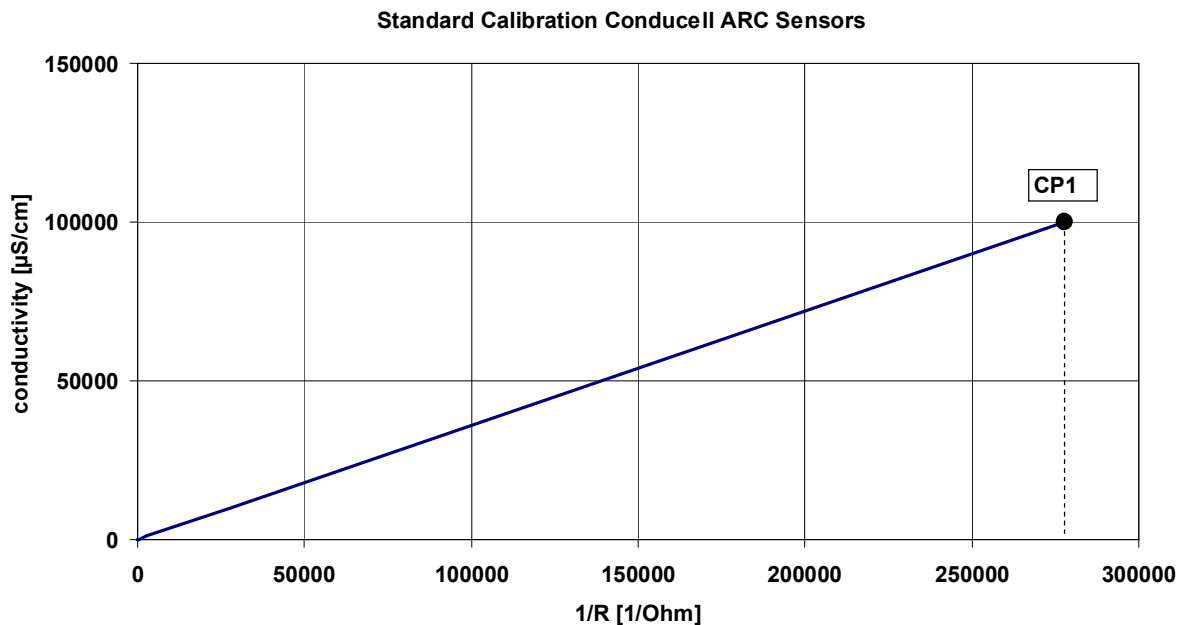


Figure 2.7.1.4: Conducell ARC Sensors allow 2 calibration points:

CP1 is used for standard calibration (shown in this figure). The calibration curve is a 1-point calibration defined by CP1, with zero offset. The slope of the curve is called the cell constant. The product calibration CP6 is used to adjust the standard calibration function to specific process conditions (the effect of CP6 is shown in Figure 2.7.3.2.1).

2.7.2 Definitions of Calibration Points

2.7.2.1 Calibration Point 1 (Standard Calibration)

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

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

Figure 2.7.2.1.1: Definition of register 5152 for CP1.



Attention:

The available physical units for conductivity are defined in register 2088 (see chapter 2.5.2.2) and are as follows: $\mu\text{S/cm}$, mS/cm , $\text{k}\Omega$, $\text{M}\Omega$. The physical unit defined in 5152 and 5312 for CP1 and CP6 is linked to the physical unit defined for PMC1 in register 2090. **However, it is strongly recommended to perform calibrations only when register 2088 is configured to $\mu\text{S/cm}$ or mS/cm .**

Command: Calibration limits CP1		Modbus address: 5152		Length: 6	Type: 3	Read
Parameter:	Unit	Min value	Max value			
Format:	Hex	Float	Float			
Value:	0x0400	0	0			

Figure 2.7.2.1.2: Example to read the limits of CP1. Currently active physical unit is mS/cm (0x0400).

The min and max values are both 0, indicating, that calibration at CP1 can be performed only using defined calibration standards having discrete conductivity values.

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

Start register	Number of registers	Reg1 / Reg2 (Float)	Reg3 / Reg4 (Float)	Modbus function code	Read access	Write access
5128	4	Max drift PMC1 conductivity [%/min]	Max drift PMC6 temperature [K/min]	3, 4, 16	U/A/S	S

Figure 2.7.2.1.3: Definition of register 5128.

Command: Read calibration stability		Modbus address: 5128		Length: 4	Type: 3	Read
Parameter:	Max drift conductivity [%/min]	Max drift temperature [K/min]				
Format:	Float	Float				
Value:	1	0.5				

Figure 2.7.2.1.4: Example to read the calibration stability.

Command: Set calibration stability		Modbus address: 5128		Length: 4	Type: 16	Write
Parameter:	Max drift conductivity [%/min]	Max drift temperature [K/min]				
Format:	Float	Float				
Value:	0.2	0.5				

Figure 2.7.2.1.5: Example to set the calibration stability.



Attention:

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

2.7.2.2 Calibration Point 6 (Product Calibration)

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

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

Figure 2.7.2.2.1: Definition of register 5312 for CP6.

Command: Calibration limits CP6		Modbus address: 5312		Length: 6	Type: 3	Read
Parameter:	Unit	Min value	Max value			
Format:	Hex	Float	Float			
Value:	0x0400	0.0001	1000			

Figure 2.7.2.2.2: Example to read the limits of CP6. The active physical unit is mS/cm (0x0400), the min value is 0.000'1 mS/cm and the max value is 1'000 mS/cm.

Note: the definition of min and max is different than the one for CP1, because CP6 can be set to any conductivity value.

Command: Calibration limits CP6		Modbus address: 5312		Length: 6	Type: 3	Read
Parameter:	Unit	Min value	Max value			
Format:	Hex	Float	Float			
Value:	0x0200	0.1	1000000			

Figure 2.7.2.2.3: Example to read the limits of CP6. The active physical unit is µS/cm (0x0200), the min value is 0.1 µS/cm and the max value is 1'000'000 µS/cm.

2.7.3 Calibration Procedure

2.7.3.1 Calibration at CP1 (Standard Calibration)

The ARC Sensor family 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 conductivity value and temperature over the last 3 minutes (see register 5128)
- the currently measured conductivity value fits to one of the calibration standards defined in the selected set of calibration standards
- the limits for the cell constant have to be met

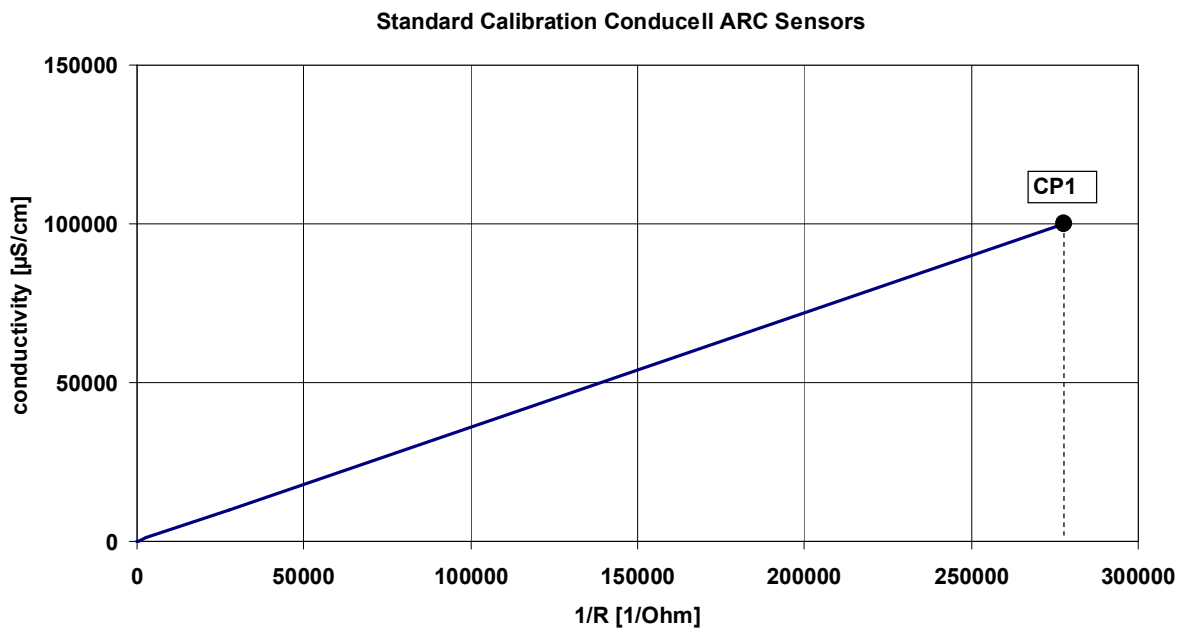


Figure 2.7.3.1.1: Standard Calibration using CP1.

CP1 defines a linear relationship between the measured conductance ($1/R$) and the conductivity of the sample. As the linear curve has no offset, the function is fully described by the slope, the so-called cell constant. This value is stored in register 5448.

Notes:

- In order to perform a standard calibration at CP1, 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 2.7.11).
- 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 conductance measured. The sensor checks the list of calibration standards that are available for automatic recognition (see chapter 2.7.11)
 - 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 1413 $\mu\text{S/cm}$ at CP1.

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 (register 9530).

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

If the sensor does find a corresponding calibration standard, the nominal conductivity value of the specific calibration standard is assigned to the currently measured electrical conductance. 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 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 conductivity value to the actual value of the calibration standard. The sensor now screens the list of calibration standards that are allowed for manual selection (register 9530). If the conductivity value entered by the operator fits in the allowed conductivity range of one of the allowed calibration standards, the entered conductivity value is assigned to the currently measured electrical conductance. 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 conductivity 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:

Step 1: Select the desired set of calibration standards (see chapter 2.7.11)

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



Attention:

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

Step 3: Choose calibration point CP1.

Step 4: Start the calibration (automatic recognition or manual selection)

The calibration is initiated at CP1 by writing to register 5162.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
5162	2	Conductivity value of the calibration standard (25°C) at CP1 (unit as defined in register 5152)	16	none	A/S

Figure 2.7.3.1.2: Definition of register 5162. You have two options to enter the conductivity value:

Automatic recognition: conductivity value=0: the sensor tries to assign the measured electrical conductance to one of the calibration standards available for automatic calibration.

Manual selection: enter the actual conductivity 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).



Attention:

It is important to enter the conductivity value of the standard at 25°C. Note the difference to calibration at CP6!

Step 5: Read the calibration status (see chapter 2.7.4)

Step 6: Check the Conducell ARC Sensor's quality indicator

Examples: (Definition of register 5158 used in these examples is given in chapter 2.7.4.1, the one for register 4872 in chapter 2.8.6)

Example to calibrate at CP1 with automatic recognition:

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

Figure 2.7.3.1.3: Example to start the calibration at CP1, setting a value of 0 for automatic recognition of the calibration standard. The sensor is immersed in a 1413 $\mu\text{S}/\text{cm}$ calibration standard.

Example to read the calibration status of CP1 (see definition in chapter 2.7.4):

Command: Calibration status CP1		Modbus address: 5158	Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value		
Format:	Hex	Hex	Float		
Value:	0x00000000	0x00000400	1.413		

Figure 2.7.3.1.4: Example to read the calibration status of CP1 after calibration with automatic recognition (0=auto) at CP1. All bits of CP1 are zero (0x00000000), indicating that the calibration was successful. The physical unit of the last calibration is mS/cm (0x0000400) and the nominal value of the assigned conductivity standard is 1.413 mS/cm (at 25°C).

Example to calibrate at CP1 with manual selection of the calibration standard:

Command: Make calibration CP1		Modbus address: 5162	Length: 2	Type: 16	Write
Parameter:	conductivity value				
Format:	Float				
Value:	1410				

Figure 2.7.3.1.5: Example to start the calibration at CP1, by means of manually selecting the calibration standard 1413 (nominal value 1413 $\mu\text{S}/\text{cm}$). The operator knows from the certificate of the specific production lot that the actual conductivity value is 1410 $\mu\text{S}/\text{cm}$.

Example to read the calibration status of CP1:

Command: Calibration status CP1		Modbus address: 5158	Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value		
Format:	Hex	Hex	Float		
Value:	0x00000000	0x00000200	1410		

Figure 2.7.3.1.6: Example to read the calibration status of CP1 after calibration CP1 at 1410 $\mu\text{S}/\text{cm}$ using manual selection. All bits of CP1 are zero (0x00000000), indicating that the calibration was successful. The physical unit of the last calibration is $\mu\text{S}/\text{cm}$ (0x0000200) and the assigned conductivity standard is 1410 $\mu\text{S}/\text{cm}$ (this is the actual value of the conductivity standard at 25°C).

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				

Figure 2.7.3.1.7: Example to read the sensor's quality indicator.

2.7.3.2 Calibration at CP6 (Product Calibration)

The product calibration is a process in order to adjust the measurement of a correctly calibrated Conducell 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 Conducell 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 Conducell ARC Sensor is still running on its prior standard calibration (CP1) while the initial measurement data for the ongoing product calibration is kept in the sensor's memory.

2. When the result of the reference analysis is available this value is assigned, at a second time point, to the former initial measurement data stored in the Conducell 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 still stored standard calibration (CP1).

If a product calibration is still active and a standard calibration (CP1) is performed the product calibration (CP6) is cancelled.

If the operator needs to overrun 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 Conducell ARC Sensor is still running on the first product calibration (old CP6) until a valid assignment has been done (new CP6).

What happens to the Conducell ARC Sensor's calibration function upon product calibration (CP6)? A product calibration has the same impact as CP1. The only difference is that the conductivity value of CP6 can be set to any desired value. CP1 is restricted to values that are defined by the set of calibration standards stored in the sensor.

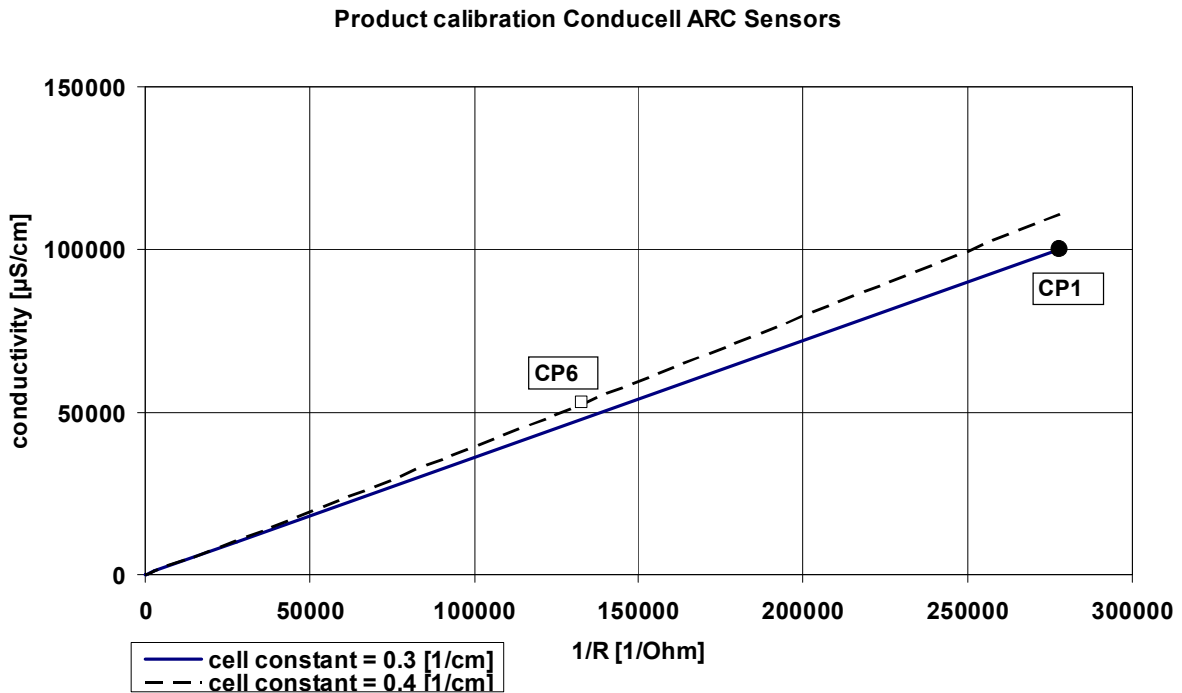


Figure 2.7.3.2.1: Effect of the product calibration CP6 on an existing standard calibration function defined by CP1.

The operator starts with a standard calibration with calibration point CP1:

CP1: conductivity value of calibration standard: 100 mS/cm

The sensor internally calculates the calibration function, using the calibration point **CP1**. The resulting calibration function, compensated to the standard temperature 25°C, is shown as a straight line. The calibration function is described by one single parameter: the cell constant. Some weeks later, the operator believes that the standard calibration function is not correct anymore. As the process is running and he is not able to perform a standard calibration under defined conditions in the lab, he decides to perform a product calibration CP6, in other words adjusting the standard calibration function to the process conditions:

CP6: conductivity value of product: 53 mS/cm

The sensor internally calculates a new cell constant. Accordingly, the slope of the calibration function is changed (dashed 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”.

Note:

The sensor's internal criteria for a successful product calibration are:

- the sensor is currently in an environment corresponding to the Conducell ARC Sensors measurement range.
- the manually assigned conductivity value does not deviate more than 70 % from the value measured prior to 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 value to the register 5340 except for assignment where the calibration value is written to register 5322 (see below).

Definition of the commands for product calibration

The commands for register 5340 are defined as follows:

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

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

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

Figure 2.7.3.2.3: Definition of register 5340

2.7.3.2.1 Product calibration: Initial measurement

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

This is achieved by writing the command 0x01 to register 5340 which performs the initial measurement and stores the corresponding measurement values in the sensor.

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

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

After successful initial measurement the corresponding calibration status (register 5318, figure 2.7.4.2.1) is "CP6 initial measurement" (0x08000000) (see figure 2.7.4.1.1).

The sensor continues measuring using the prior standard calibration.

2.7.3.2.2 Product calibration: Assignment

After successful initial measurement a correct value must be assigned to the initially stored measurement data.

This is achieved by writing the correct calibration value to register 5322.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
5322	2	Conductivity value (in the physical unit given in 5312)	16	none	A/S

Figure 2.7.3.2.2.1: Definition of register 5322

Command: CP6: Assignment		Modbus address: 5322	Length: 2	Type: 16	Write
Parameter:	Value				
Format:	Float				
Value:	1.5				

Figure 2.7.3.2.2.2: Example to assign a calibration value to the above performed initial measurement.

This is achieved by writing the correct conductivity value of 1.5 (mS/cm).

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

The calibration status (register 5318) is 0x14000000 meaning that a correct value has been assigned and that the product calibration is active (see figure 2.7.4.1.1).



Attention:

The conductivity value to be entered in register 5322 is the conductivity at the effective temperature of the measurement media, not the conductivity compensated to 25°C!

The following example shows how confusing this can be:

The sensor is measuring at 22.5°C in 0.01 M KCl solution. PA9 is 2.8 %/°C which is the correct temperature coefficient for this medium. Register 2090 (PMC1) reports 1455.7 µS/cm which is the hypothetical conductivity at 25°C calculated by the sensor. The operator is not happy with the reading and now enters the theoretical conductivity of 0.01 M KCl at 22.5°C (1315 µS/cm) as product calibration. PMC1 is now reporting 1415.3 µS/cm as the hypothetical value at 25°C. It corresponds very well to the theoretical value of 1413 µS/cm at 25°C. If the operator now sets PA4 to 0 %/°C, PMC1 reports 1317.3 µS/cm, with other words the conductivity at the effective temperature of 22.5°C.

2.7.3.2.3 Product calibration: Cancel

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

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

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

Performing this action the product calibration or any initial measurements are cancelled. 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 standard calibration.

The sensor's calibration status (register 5318) will be reading 0x00 again (see figure 2.7.4.1.1).

2.7.3.2.4 Product calibration: Restore standard calibration

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

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

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

From now on the sensor is measuring using its prior CP1 standard calibration. The sensor's calibration status (register 5318) will be reading "CP6 assigned" (0x10000000) meaning that a valid assignment for a product calibration is available in the sensor's memory (see figure 2.7.4.1.1).

2.7.3.2.5 Product calibration: Restore product calibration

If a valid but inactivated product calibration is available in the sensors memory, the calibration status is reading "CP6 assigned" (corresponding to 0x10000000, see figure 2.7.4.1.1), this stored product calibration can be restored or reactivated by writing command 0x04 to register 5340.

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

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

From now on the sensor is measuring using its prior CP6 product calibration. The sensors calibration status (register 5318) will be reading 0x14000000 (corresponding to "CP6 assigned" and "CP6 active", see figure 2.7.4.1.1) again.

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

2.7.4 Reading the Calibration Status

2.7.4.1 Reading the Calibration Status of CP1

A standard calibration is not always successful. In order to analyze what has gone wrong, the calibration status registers 5158 for CP1 can be read:

Bit #	Hex value	Definition
0 (LSB)	0x00000001	CP1: conductivity value below calibration range
1	0x00000002	CP1: conductivity value above calibration range
2	0x00000004	CP1: actual temperature reading is too low
3	0x00000008	CP1: actual temperature reading is too high
4	0x00000010	CP1: temperature reading during calibration is not stable
5	0x00000020	CP1: cell constant is too low
6	0x00000040	CP1: cell constant is too high
7	0x00000080	CP1: conductivity reading during calibration is not stable
...		not available
24	0x01000000	CP6: out of calibration range
25	0x02000000	CP6: out of range
26	0x04000000	CP6: active
27	0x08000000	CP6: initial measurement
28	0x10000000	CP6: assigned
		not available
31	0x80000000	CP1: incorrect measurement unit

Figure 2.7.4.1.1: Definition of the status for register 5158 and 5318 (see Figure 2.7.4.1.2 and 2.7.4.2.1).

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
5158	6	Status CP1 (see figure 2.7.4.1.1)	Physical unit of the last successful calibration CP1	Nominal or actual conductivity value of the calibration standard (25°C) of the last successful calibration CP1	3, 4	U/A/S	none

Figure 2.7.4.1.2: Definition of register 5158 for CP1.

Command: Calibration status CP1		Modbus address: 5158		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x00000080	0x00000200	1413			

Figure 2.7.4.1.3: Example to read the calibration status of CP1 after calibration CP1 at 0 = auto. The sensor is immersed in 84 µS /cm calibration standard. The status message is: "CP1: conductivity reading during calibration is not stable" (0x00000080). The physical unit of the last successful calibration is µS/cm (0x0200) and the last successful calibration has been performed at 1413 µS/cm.

Command: Calibration status CP1		Modbus address: 5158		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x00000000	0x00000200	84			

Figure 2.7.4.1.4: Example to read the calibration status of CP1, after having repeated the calibration of figure 2.7.4.1.3. The calibration is successful this time, and the new calibration values are reported: the physical unit of the last successful calibration is $\mu\text{S}/\text{cm}$ (0x0200) and the last successful calibration has been performed at 84 $\mu\text{S}/\text{cm}$.

(for more examples see also chapter 2.7.3.1)

2.7.4.2 Reading the Calibration Status of CP6 (Product Calibration)

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

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

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

2.7.4.2.1 Product calibration: Initial measurement

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

Command: Calibration status CP6		Modbus address: 5318		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x01000000	0x00000200	110			

Figure 2.7.4.2.1.1: Example to read the calibration status of CP6 after having performed an initial measurement at CP6 under measurement conditions outside the calibration range for CP6 (the sensor was not immersed in solution).

The status says: "CP6: out of calibration range" (0x01000000). The last successful calibration has been performed at 110 $\mu\text{S}/\text{cm}$.

The initial measurement in this case was **not** successful.

The sensor is still running on its prior standard calibration.

Calibration status after successful initial measurement:

Command: Calibration status CP6		Modbus address: 5318		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x08000000	0x00000200	110			

Figure 2.7.4.2.1.2: Example to read the calibration status of CP6 after having performed an initial measurement at CP6 under correct measurement conditions (sensor immersed in 84 $\mu\text{S}/\text{cm}$). The status says: "CP6: initial measurement" (0x08000000). The last successful calibration has been performed at 110 $\mu\text{S}/\text{cm}$. The initial measurement in this case was successful. The sensor is still running on its prior standard calibration until a valid calibration value has been assigned to this initial measurement values.

2.7.4.2.2 Product calibration: Assignment

Calibration status after invalid assignment:

Command: Calibration status CP6		Modbus address: 5318		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x0A000000	0x00000200	110			

Figure 2.7.4.2.2.1: Example to read the calibration status of CP6 after having performed a valid initial measurement at CP6 and an invalid assignment. The status says: "CP6: out of range" (0x02000000) and "CP6: initial measurement" (0x08000000). The last successful calibration has been performed at 110 $\mu\text{S}/\text{cm}$. The initial measurement in this case is still valid and available for further assignment of a product calibration value. The here performed assignment was **not** successful. The sensor remains running on its prior standard calibration.

Calibration status after valid assignment:

Command: Calibration status CP6		Modbus address: 5318		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x14000000	0x00000200	90			

Figure 2.7.4.2.2.2: Example to read the calibration status of CP6 after having performed an initial measurement at CP6 and a valid assignment to 90 $\mu\text{S}/\text{cm}$. The status says: "CP6: active" (0x04000000) and "CP6: assigned" (0x10000000). The last successful calibration corresponding to the here performed assignment has been performed at 90 $\mu\text{S}/\text{cm}$. The here performed assignment was successful. The sensor is running using a valid product calibration.

2.7.4.2.3 Product calibration: Cancel

Calibration status after cancelling an active product calibration:

Command: Calibration status CP6		Modbus address: 5318		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x00000000	0x00000200	90			

Figure 2.7.4.2.3.1: Example to read the calibration status of CP6 after having performed a cancel command at CP6.

The status reports no messages. The last successful calibration at CP6 has been performed at 90 μ S/cm.

The sensor is running on a valid standard calibration and no product calibration is stored.

2.7.4.2.4 Product calibration: Restore standard calibration

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

Command: Calibration status CP6		Modbus address: 5318		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x10000000	0x00000200	90			

Figure 2.7.4.2.4.1: Example to read the calibration status of CP6 after having restored the standard calibration from an active product calibration (CP6).

The status says: "CP6 assigned" (0x10000000). The last successful calibration at CP6 has been performed at 90 μ S/cm.

The sensor is running on a valid standard calibration but a valid product calibration is still available in the sensor.

2.7.4.2.5 Product calibration: Restore product calibration

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

Command: Calibration status CP6		Modbus address: 5318		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x14000000	0x00000200	90			

Figure 2.7.4.2.5.1: Example to read the calibration status of CP6 after having restored an available product calibration (CP6) from an active standard calibration (CP1).

The status says: "CP6: active" (0x04000000) and "CP6: assigned" (0x10000000). The last successful calibration corresponding to the here performed assignment has been performed at 90 μ S/cm.

The sensor is running on a valid product calibration again.

2.7.5 Currently active Calibration Parameters part 1

The examples reported in chapter 2.7.5 to 2.7.8 are a result of:

- standard calibration with manual selection using calibration standard 1413 $\mu\text{S/cm}$, and defining actual value to 1416 $\mu\text{S/cm}$. Temperature during calibration is 21.08°C. The selected physical unit is $\mu\text{S/cm}$.

Command: Calibration status CP1		Modbus address: 5158		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x00000000	0x00000200	1416			

Figure 2.7.5.1: Corresponding status after standard calibration, used as example for chapter 2.7.5 to 2.7.8: Status is successful and the last successful calibration has been performed at 1416 $\mu\text{S/cm}$.

- product calibration using a measurement solution having a conductivity of 1203 $\mu\text{S/cm}$ at 22.98°C. The selected physical unit is $\mu\text{S/cm}$.

Command: Calibration status CP6		Modbus address: 5318		Length: 6	Type: 3	Read
Parameter:	Status	Unit	Value			
Format:	Hex	Hex	Float			
Value:	0x14000000	0x00000200	1203			

Figure 2.7.5.2: Corresponding status after product calibration, used as example for chapter 2.7.5 to 2.7.8: Status is saying: : "CP6: active" (0x04000000) and "CP6: assigned" (0x10000000). The last successful calibration has been performed at 1203 $\mu\text{S/cm}$.

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

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

Figure 2.7.5.3: Definition of register 5164 for CP1 and 5324 for CP6.

Command: Calibration CP1 values		Modbus address: 5164		Length: 8	Type: 3	Read
Parameter:	Unit of temperature	Temperature	Number of cali	Operating hour		
Format:	Hex	Float	Decimal	Float		
Value:	0x00000004	21.0769	28	42.09541		

Figure 2.7.5.4: Example to read the calibration values for CP1. The physical unit is °C (0x04), the temperature is 21.08 °C, the number of calibrations at CP1 is 28 and the operating hour is 42.1 h.

Command: Calibration CP6 values		Modbus address: 5324		Length: 8	Type: 3	Read
Parameter:	Unit of temperature	Temperature	Number of cali	Operating hour		
Format:	Hex	Float	Decimal	Float		
Value:	0x00000004	22.97751	13	45.16504		

Figure 2.7.5.5: Example to read the calibration values for CP6. The physical unit is °C (0x04), the temperature is 22.98 °C, the number of calibrations at CP6 is 13 and the operating hour is 45.2 h.

2.7.6 Currently active Calibration Parameters part 2

Registers 5172 (CP1) and 5332 (CP6) are not defined for Conducell ARC Sensors, as they document atmospheric pressure and salinity used for VISIFERM DO / VISIFERM DO ARC Sensors only.

2.7.7 Currently active Calibration Parameters part 3

In register 5520 and 5560 the conductivity value of the used calibration standards, the electrical resistance of the conductivity sensor and the temperature upon calibration are stored.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
5520	8	Theoretical conductivity value of the calibration standard at CP1 at effective T [$\mu\text{S}/\text{cm}$]	Electrical resistance at CP1 [Ohm]	Temp at CP1 [K]	free	3, 4	A/S	none
5560	8	Conductivity reading at initial measurement of CP6 [$\mu\text{S}/\text{cm}$]	Electrical resistance at initial measurement of CP6 [Ohm]	Temp at initial measurement of CP6 [K]	free	3, 4	A/S	none

Figure 2.7.7.1: Definition of register 5520 and 5560. Note: the interpretation of the Reg1/Reg2 is different for CP1 compared to CP6.

Command: Act calibration CP1		Modbus address: 5520		Length: 8	Type: 3	Read
Parameter:	Conductivity value of the standard [$\mu\text{S}/\text{cm}$]	Electrical resistance [Ohm]	Temp [K]	free		
Format:	Float	Float	Float	Float		
Value:	1312.969	332.7569	294.23	0		

Figure 2.7.7.2: Example to read the actual calibration values of CP1. Register 5520 reports:

- the conductivity value of the calibration standard (nominal value 1413 $\mu\text{S}/\text{cm}$), compensated to the effective temperature 294.23 K and using the actual value (actual value at 25°C set by operator: 1416 $\mu\text{S}/\text{cm}$). In this case 1312.96 $\mu\text{S}/\text{cm}$
- the resistance reading of the sensor in the moment of CP1, in this case 332.75 Ohm. Note: the cell constant reported in register 5448, determined with this CP1, is the quotient of conductivity value 1312.9 $\mu\text{S}/\text{cm}$ and the electrical resistance 332.7 Ohm.
- the temperature reading of the sensor in the moment of CP1. In this case 294.2 K

Command: Act calibration CP6		Modbus address: 5560		Length: 8	Type: 3	Read
Parameter:	Conductivity reading at initial measurement [$\mu\text{S}/\text{cm}$]	Electrical resistance [Ohm]	Temp [K]	free		
Format:	Float	Float	Float	Float		
Value:	1336.771	323.7537	296.1275	0		

Figure 2.7.7.3: Example to read the actual calibration values of CP6. Register 5560 reports:

- the conductivity reading of the sensor at the effective temperature (using the calibration settings that were active upon initial measurement of the product calibration). In this case

1336.7 $\mu\text{S}/\text{cm}$. Note: this is the conductivity reading at the effective temperature, not compensated to 25°C.

- the resistance reading of the sensor upon initial measurement of the product calibration. In this case 323.7 Ohm.
- the temperature reading of the sensor upon initial measurement of the product calibration. In this case 296.1 K.

2.7.8 Currently active Calibration Parameters part 4

Register 5448 documents the cell constant which is defined by CP1 or CP6 calibration.

Start register	Number of registers	Reg1 / Reg2 (Float)	Reg3 / Reg4 (Float)	Reg5 / Reg6 (Float)	Modbus function code	Read access	Write access
5448	6	Offset resistance [Ohm]	Cell constant of the active calibration [1/cm]	Reference temperature [K]	3, 4	U/A/S	none

Figure 2.7.8.1: Definition of register 5448.

Command: Calculated cali values		Modbus address: 5448		Length: 6	Type: 3	Read
Parameter:	Offset resistance [Ohm]	Cell constant [1/cm]	Ref temp [K]			
Format:	Float	Float	Float			
Value:	0	0.4327845	298.15			

Figure 2.7.8.2: Example to read register 5448: offset resistance is always 0; cell constant is 0.433 1/cm; reference temperature is 298.15 K (=25°C).

Note: the cell constant is determined either by CP1 or CP6.

2.7.9 Special Commands for Calibration with VISICAL

The VISICAL calibration device allows calibration of Conducell ARC Sensors at CP1. The Conducell ARC Sensor's associated calibration parameters for CP1 are those predefined and stored in the corresponding register of the sensor.

Register 5164 defines the conductivity value for CP1 which is only valid for use with VISICAL. The same calibration limits for the conductivity value are used as for standard calibration at CP1 (register 5152).



Attention:

- It is not possible to perform a product calibration using VISICAL.
- Physical unit is fixed to $\mu\text{S/cm}$ by definition.
- Only the LOW button has any significance for VISICAL.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
5180	2	conductivity value at CP1 [$\mu\text{S/cm}$] (default: 1413)	3, 4, 16	U/A/S	S

Figure 2.7.9.1: Definition of register 5180 for CP1.

Command: VISICAL CP1		Modbus address: 5180		Length: 2	Type: 3	Read
Parameter:	Value [$\mu\text{S/cm}$]					
Format:	Float					
Value:	1413					

Figure 2.7.9.2: Example to read the conductivity value valid for CP1. It is 1413. Accordingly, the next time when a calibration is started using VISICAL at LOW, a calibration with manual selection is performed, using the calibration standard at 1413 $\mu\text{S/cm}$. The operator has to make sure that - within the selected set of calibration standards - a standard at 1413 $\mu\text{S/cm}$ is selected for manual selection.

Command: VISICAL CP1		Modbus address: 5180		Length: 2	Type: 16	Write
Parameter:	Value [$\mu\text{S/cm}$]					
Format:	Float					
Value:	84					

Figure 2.7.9.3: Example to set the VISICAL calibration value for CP1 to 84 $\mu\text{S/cm}$.



Attention:

- Pressing VISICAL's HIGH button when in use with Conducell ARC Sensors will not have any consequences.

2.7.10 Calibration Standards

2.7.10.1 Available Sets of Calibration Standards

Conducell 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.

In register 9472 the available sets of calibration standards are defined.

Start register	Number of registers	Reg1 / Reg2 (Bit, see Figure 2.7.10.1.2)	Modbus function code	Read access	Write access
9472	2	Available calibration standard sets	3, 4	U/A/S	none

Figure 2.7.10.1.1: Definition of register 9472.

Bit #	Hex value	Description	Definition
0 (LSB)	0x00000001	Set 1	HAMILTON
1	0x00000002	Set 2	REAGECON
2	0x00000004	Set 3	KCI solutions
3	0x00000008	Set 4	not available
4	0x00000010	Set 5	not available
5	0x00000020	Set 6	not available

Figure 2.7.10.1.2: Definition of available sets of calibration standards.

Command: Available cali sets	Modbus address: 9472	Length: 2	Type: 3	Read
Parameter: Calibration sets				
Format: Hex				
Value: 0x00000007				

Figure 2.7.10.1.3: Example to read the available calibration sets: Set 1 (0x00000001) + set 2 (0x00000002) + set 3 (0x00000004), in total 0x00000007.

In register 9474 the selected set of calibration standards is defined.

Start register	Number of registers	Reg1 / Reg2 (Bit, see Figure 2.7.10.1.2)	Modbus function code	Read access	Write access
9474	2	Selected set of calibration standard	3, 4	U/A/S	S

Figure 2.7.10.1.4: Definition of register 9474. Only one bit can be set.

Command: Selected set of cal stand.	Modbus address: 9474	Length: 2	Type: 3	Read
Parameter: Calibration set				
Format: Hex				
Value: 0x00000001				

Figure 2.7.10.1.5: Example to read the selected set of calibration standards. Set 1 (HAMILTON) (0x00000001) is active.

Command: Select set of cal stand.	Modbus address: 9474	Length: 2	Type: 16	Write
Parameter: Calibration set				
Format: Hex				
Value: 0x04				

Figure 2.7.10.1.6: Example to set the calibration standard set to "KCI solutions" (0x04).

2.7.10.2 Definitions for Individual Sets of Calibration Standards

Once the operator has selected a set of calibration standards (register 9474) the register 9504 and following give all information on the selected set of calibration standards.

Start register	Number of registers	Reg1 ... Reg8 (16 ASCII characters)	Modbus function code	Read access	Write access
9504	8	Manufacturer of the selected set	3, 4	U/A/S	none
9512	8	Info 1 of the selected set	3, 4	U/A/S	none
9520	8	Info 2 of the selected set	3, 4	U/A/S	none

Figure 2.7.10.2.1: Definition of registers 9504 to 9520.

Command: manufacturer of set		Modbus address: 9504	Length: 8	Type: 3	Read
Parameter:	Text				
Format:	Character				
Value:	HAMILTON				

Figure 2.7.10.2.2: Example to read the description (in this case, the set 0x01 is selected)

Within one set of calibration standards, a maximum of 12 calibration standards are available. In the following registers, the details of each calibration standard is given:

Start register	Description
9536	Nominal value and tolerance of calibration standard 1
9552	Nominal value and tolerance of calibration standard 2
9568	Nominal value and tolerance of calibration standard 3
9584	Nominal value and tolerance of calibration standard 4
9600	Nominal value and tolerance of calibration standard 5
9616	Nominal value and tolerance of calibration standard 6
9632	Nominal value and tolerance of calibration standard 7
9648	Nominal value and tolerance of calibration standard 8
9664	Nominal value and tolerance of calibration standard 9
9680	Nominal value and tolerance of calibration standard 10
9696	Nominal value and tolerance of calibration standard 11
9712	Nominal value and tolerance of calibration standard 12

Figure 2.7.10.2.3: Definition for the register range from 9536 until 9720.

Start register	Number of registers	Reg1 / Reg2 (Float)	Reg3 / Reg4 (Float)	Reg5 / Reg6 (Float)	Reg7 / Reg8 (Float)	Modbus function code	Read access	Write access
9536, 9552, ...	8	Calibr. standard nominal value [µS/cm]	Tolerance of nominal value (±) [µS/cm]	Value to be measured nominally [µS/cm]	Tolerance of value to be measured (±) [µS/cm]	3, 4	U/A/S	none

Figure 2.7.10.2.4: Definition for registers 9536 until 9720.

Command: Read standard 4		Modbus address: 9648	Length: 8	Type: 3	Read
Parameter:	Nominal value [µS/cm]	Tolerance (±) [µS/cm]	Value to be measured nominally [µS/cm]	Tolerance of value to be measured (±) [µS/cm]	
Format:	Float	Float	Float	Float	
Value:	1413	14.13	1413	700	

Figure 2.7.10.2.5: Example to read the values for calibration standard 8 within the "HAMILTON" set.

This standard has a nominal value of 1413 ± 14.13 µS/cm until expiry date as defined by HAMILTON. During standard calibration, either with automatic recognition or with manual selection, the sensor accepts a window of conductivity readings between 713 and 2113 µS/cm (1413 ± 700 µS/cm) to be assigned to this standard. The decision is made using the currently active cell constant. Note: make sure that calibration standards selected for automatic calibration do not exhibit overlapping acceptance windows!

Register 9528 defines for the selected set of calibration standards:

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

Start register	Number of registers	Reg1 / Reg2 (Bit, see figure 2.7.10.2.8)	Modbus function code	Read access	Write access
9528	2	Availability of the 12 cal. standards	3, 4	U/A/S	none

Figure 2.7.10.2.6: Definition of register 9528

Command: Available standards		Modbus address: 9528	Length: 2	Type: 3	Read
Parameter:	Standard fields				
Format:	Hex				
Value:	0x03FF03FF				

Figure 2.7.10.2.7: Example to read the information of register 9528. For the definition of the bits, see Figure 2.7.10.2.8. The value 0x0FFF0FFF says that (for the selected set of calibration standards):

- calibration standards 1-10 are available for manual calibration
- all 12 calibration standards 1-10 are available for automatic recognition.

Bit	Hex code	Index of Calibration Standard within the selected set	Calibration type
0 (LSB)	0x00000001	1	manual selection
1	0x00000002	2	manual selection
2	0x00000004	3	manual selection
3	0x00000008	4	manual selection
4	0x00000010	5	manual selection
5	0x00000020	6	manual selection
6	0x00000040	7	manual selection
7	0x00000080	8	manual selection
8	0x00000100	9	manual selection
9	0x00000200	10	manual selection
10	0x00000400	11	manual selection
11	0x00000800	12	manual selection
12-15		not available	
16	0x00010000	1	automatic recognition
17	0x00020000	2	automatic recognition
18	0x00040000	3	automatic recognition
19	0x00080000	4	automatic recognition
20	0x00100000	5	automatic recognition
21	0x00200000	6	automatic recognition
22	0x00400000	7	automatic recognition
23	0x00800000	8	automatic recognition
24	0x01000000	9	automatic recognition
25	0x02000000	10	automatic recognition
26	0x04000000	11	automatic recognition
27	0x08000000	12	automatic recognition
28-31		not available	

Figure 2.7.10.2.8: Availability / Selection for the 12 calibration standards within one given set.

Bit 0-11 define availability of standards 1-12 for manual calibration.

Bit 16-27 define availability of standards 1-12 for automatic recognition

Register 9528: the corresponding calibration standard is available if bit is set

Register 9530: the corresponding calibration standard is selected if bit is set

By means of register 9530, the specialist can define for each available calibration standard if the specific standard is available.

Start register	Number of registers	Reg1 / Reg2 (Bit, see figure 2.7.10.2.8)	Modbus function code	Read access	Write access
9530	2	Selected standard fields	3, 4	U/A/S	S

Figure 2.7.10.2.9: Selected calibration standards within one given set.

Command:	Selected standard fields	Modbus address:	9530	Length:	2	Type:	3	Read
Parameter:	Standard fields							
Format:	Hex							
Value:	0x038F03FF							

Figure 2.7.10.2.10: Example to read the selected calibration standards. The value 0x038F03FF says that:

- calibration standards 1-10 are selected for manual selection
- calibration standards 1, 2, 3, 4, 8, 9 and 10 are selected for automatic recognition

Command:	Selected standard fields	Modbus address:	9530	Length:	2	Type:	16	Write
Parameter:	Standard fields							
Format:	Hex							
Value:	0x030C03FF							

Figure 2.7.10.2.11: Example to set the calibration standards 1-10 for manual calibration and calibration standards 3, 4, 9 and 10 for automatic recognition.



Attention:

Note: make sure that calibration standards selected for automatic calibration do not exhibit overlapping acceptance windows (see figure 2.7.10.2.5) !

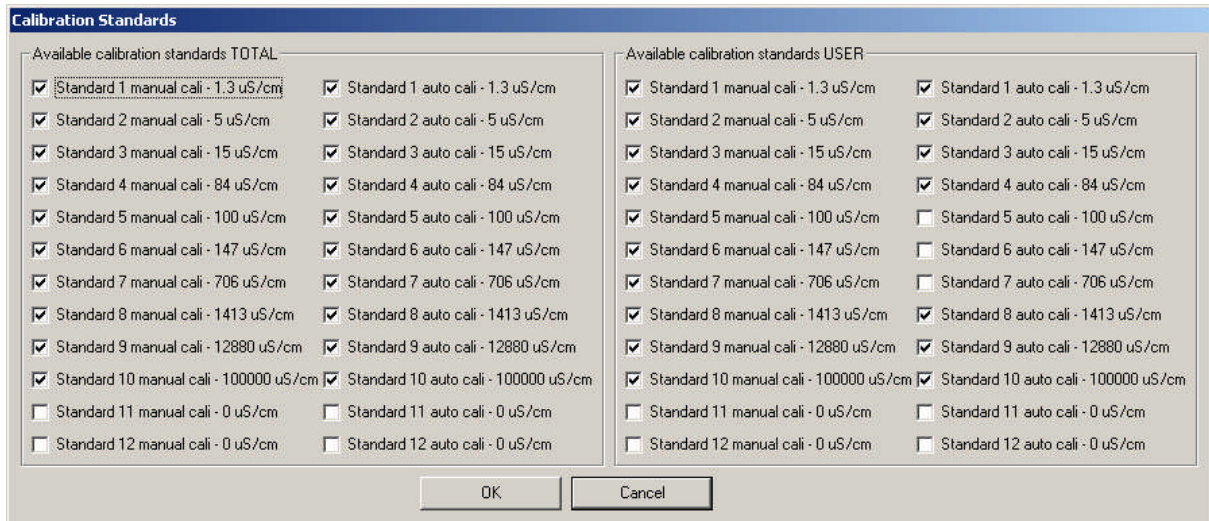


Figure 2.7.10.2.12: Illustration from the ARC Sensor Configurator software tool for registers 9528 and 9530. For this example, the HAMILTON set of calibration standard is selected.

On the left half of the figure, the availability of the calibration standards 1-12 is shown, as defined in register 9528. In the left column, the availability for manual calibration is shown (calibration standards 1-10). In the right column, the availability for automatic recognition is given (calibration standards 1-10 as well).

On the right half of the figure, the individual selection defined by the specialist is shown as read from register 9530. In the left column, the selection for manual selection is shown (calibration standards 1-10). In the right column the selection for automatic recognition is given (calibration standards 1, 2, 3, 4, 8, 9 and 10).

Manufacturer	Availability for manual selection (left) and automatic recognition (right)																								
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Figure 2.7.10.2.13: default definitions in register 9528 for all 3 sets of calibration standards available in Conducell ARC Sensors.

2.8 Sensor Status

2.8.1 Temperature Ranges

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

- Operation – in this range the sensor will work properly (current output, Modbus communication), except the measurement, which is stopped until the temperature is back in the measurement range. In this case the last value of measurement will be frozen and sent to analog interfaces.
- Measurement – in this range the sensor is able to measure.
- Calibration – in this range the sensor can be calibrated.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Modbus function code	Read access	Write access
4608	4	Operating temperature min [°C]	Operating temperature max [°C]	3, 4	U/A/S	none
4612	4	Measurement temperature min [°C]	Measurement temperature max [°C]	3, 4	U/A/S	none
4616	4	Calibration temperature min [°C]	Calibration temperature max [°C]	3, 4	U/A/S	none

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

Command: Operating T range		Modbus address: 4608		Length: 4	Type: 3	Read
Parameter:	Operating T min [°C]	Operating T max [°C]				
Format:	Float	Float				
Value:	-20	130				

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

Command: Measurement T range		Modbus address: 4612		Length: 4	Type: 3	Read
Parameter:	Measurement T min [°C]	Measurement T max [°C]				
Format:	Float	Float				
Value:	-20	130				

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

Command: Calibration T range		Modbus address: 4616		Length: 4	Type: 3	Read
Parameter:	Calibration T min [°C]	Calibration T max [°C]				
Format:	Float	Float				
Value:	5	50				

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

2.8.2 Operating Hours and Counters

In register 4676 are given:

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

In register 4682 are stored:

- number of power ups
- number of watchdog resets
- number of writing cycles to the sensor's flash memory

In register 4688 are given:

- number of sterilizations in place (SIP) (see chapter 2.8.5)
- number of cleanings in place (CIP) (see chapter 2.8.5)

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg3 / Reg4	Modbus function code	Read access	Write access
4676	6	Operating hours [h]	Operating hours above max measurement temperature [h]	Operating hours above max operating temperature [h]	3, 4	U/A/S	none
4682	6	Number of Power ups	Number of Watchdog resets	Number of Writing cycles to flash memory	3, 4	U/A/S	none
4688	4	Number of SIP cycles	Number of CIP cycles	-	3, 4	U/A/S	none

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

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

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

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

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

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

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

2.8.3 Warnings

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

2.8.3.1 Currently Active Warnings

The currently active warnings are stored in register 4736.

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

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

Command: Active warning		Modbus address: 4736		Length: 8	Type: 3	Read
Parameter:	W Measurement	W Calibration	W Interface	W Hardware		
Format:	Hex	Hex	Hex	Hex		
Value:	0x00	0x00	0x00	0x00		

Figure 2.8.3.1.2: Example to read the currently active warnings.

2.8.3.2 History of Warnings

The history of warnings is not implemented in Conducell ARC Sensors.

2.8.3.3 Definition of Warnings

Bit #	Hex	Description
		not available

Figure 2.8.3.3.1: Definition of warnings “measurement”. None is defined.

Bit #	Hex	Description
0 (LSB)	0x0001	PMC1 (conductivity) calibration recommended
1	0x0002	PMC1 (conductivity) last calibration not successful

Figure 2.8.3.3.2: Definition of warnings “calibration”.

Bit #	Hex	Description
		not available

Figure 2.8.3.3.3: Definition of warnings “interface”. None is defined.

Bit #	Hex	Description
		not available

Figure 2.8.3.3.4: Definition of warnings “hardware”. None is defined.

2.8.4 Errors

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

2.8.4.1 Currently Active Errors

The currently active errors are stored in register 4800.

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

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

Command: Active errors		Modbus address: 4800		Length: 8	Type: 3	Read
Parameter:	E Measurement	E Calibration	E Interface	E Hardware		
Format:	Hex	Hex	Hex	Hex		
Value:	0x00	0x00	0x00	0x00	0x00	

Figure 2.8.4.1.2: Example to read the currently active errors.

2.8.4.2 History of Errors

The history of errors is not implemented in Conducell ARC Sensors.

2.8.4.3 Definition of Errors

Bit #	Hex	Description
		not available
10	0x0000400	Resistance 4 electrodes too high
11	0x0000800	Resistance 4 electrodes too low
12	0x0001000	Resistance 2 electrodes too high
13	0x0002000	Resistance 2 electrodes too low
		not available
25	0x2000000	Temperature sensor defective

Figure 2.8.4.3.1: Definition of errors "measurement".

Bit #	Hex	Description
1	0x0000002	Sensor failure (Quality value < 15%)

Figure 2.8.4.3.2: Definition of errors "calibration".

Bit #	Hex	Description
		not available

Figure 2.8.4.3.3: Definition of errors "interface". None is defined.

Bit #	Hex	Description
		not available
24	0x1000000	Internal communication error (between front-end and user-end)

Figure 2.8.4.3.4: Definition of errors "hardware".

2.8.5 Reading Definition of SIP and CIP

Conducell ARC Sensor are counting special cleaning events such as sterilizations or cleaning cycles by means of tracking typical temperature profiles (see chapter 2.8.2).

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

CIP temperature min: 80 °C CIP temperature max: 100 °C CIP time min: 30 minutes
 SIP temperature min: 120 °C SIP temperature max: 130 °C SIP time min: 30 minutes

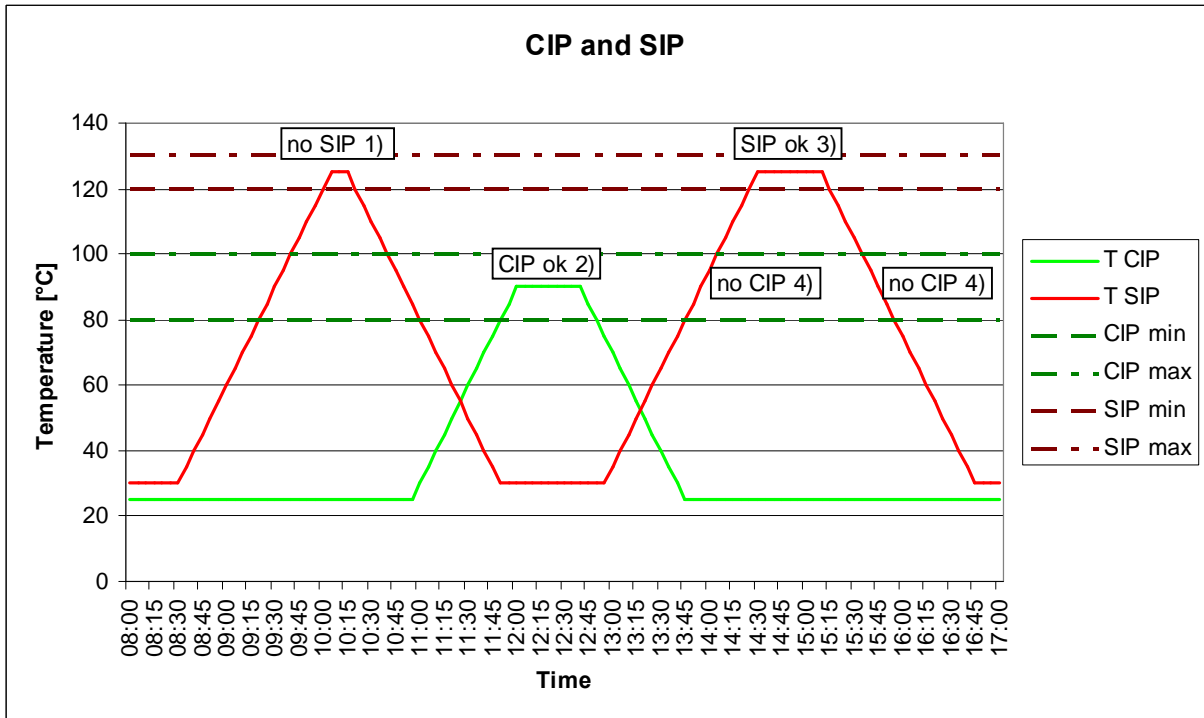


Figure 2.8.5.1: Definition of CIP and SIP cycles.

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

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

Figure 2.8.5.2: Definition of register 4988 and 4996.

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

Figure 2.8.5.3: Example to write the SIP definitions.

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

Figure 2.8.5.4: Example to read the SIP definitions.

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

Figure 2.8.5.5: Example to write the CIP definitions.

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

Figure 2.8.5.6: Example to read the CIP definitions.

2.8.6 Reading the Sensor's Quality Indicator

In register 4872 the sensor quality (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

Figure 2.8.6.1: Definition of register 4872.

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

Figure 2.8.6.2: Example to read the sensor's quality indicator.

The sensor's quality indicator is influenced by:

- Cell constant
- Errors

2.9 Sensor Identification and Information

2.9.1 General Information

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

Start register	Number of registers	Reg1 ... Reg8 (16 ASCII characters)	Example of content	Modbus function code	Read access	Write access
1024	8	Userend FW Date	2010-04-28	3, 4	U/A/S	none
1032	8	Userend FW	CONUM011	3, 4	U/A/S	none
1040	8	Userend BL Date	2009-09-18	3, 4	U/A/S	none
1048	8	Userend BL	BL0UX012	3, 4	U/A/S	none
1056	8	Userend P/N	242822/01	3, 4	U/A/S	none
1064	8	Userend S/N	not available	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	2009-09-16	3, 4	U/A/S	none
1096	8	Frontend FW	CONF010	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 P/N	242825/00	3, 4	U/A/S	none
1128	8	Frontend S/N	not available	3, 4	U/A/S	none
1136	8	Frontend (space holder)	not available	3, 4	U/A/S	none
1144	8	Frontend (space holder)	not available	3, 4	U/A/S	none

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

Command: Userend Firmware		Modbus address: 1032		Length: 8	Type: 3	Read
Parameter:	Text					
Format:	Character					
Value:	EPHUM011					

Figure 2.9.1.2: Example to read register 1032.

2.9.2 Sensor Identification

Start register	Number of registers	Reg1 ... Reg8 (16 ASCII characters)	Example of content	Modbus function code	Read access	Write access
1280	8	Part number	242159/01	3, 4	U/A/S	none
1288	8	Sensor name	Conducell 4USF	3, 4	U/A/S	none
1296	8	Work order number	3214567	3, 4	U/A/S	none
1304	8	Work order date	2010-04-30	3, 4	U/A/S	none
1312	8	Serial number	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.Con Sensor	3, 4	U/A/S	none
1344	8	Power supply	007..030V 0150mW	3, 4	U/A/S	none
1352	8	Pressure range	0 ... 20 bar	3, 4	U/A/S	none
1360	8	Sensor ID	242159-0001001	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	1.4435	3, 4	U/A/S	none

Figure 2.9.2.1: Definition of registers containing sensor identification.

Command:	Serial number	Modbus address:	1312	Length:	8	Type:	3	Read
Parameter:	Text							
Format:	Character							
Value:	0001001							

Figure 2.9.2.2: Example to read register 1312.

2.9.3 Free User Memory Space

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

Start register	Number of registers	Reg1 ... Reg8 (16 ASCII characters)	Example of content	Modbus function code	Read access	Write access
1536	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1544	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1552	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1560	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1568	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1576	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1584	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1592	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1600	8	Measuring point	242159-0001001	3, 4, 16	U/A/S	S
1608	8	Free user space S	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1616	8	Free user space S	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1624	8	Free user space S	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1632	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1640	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1648	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1656	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1664	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1672	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1680	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1688	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1696	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1704	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1712	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1720	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1728	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1736	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1744	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1752	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none

Figure 2.9.3.1: Definition of registers containing user information.

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



Attention:

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

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

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

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

Figure 2.9.3.3: Example to read the register 1568 (written in figure 2.9.1.6).

2.10 System Commands

2.10.1 Recall Sensor's Factory Settings

Using register 8192 you can recall the sensor manufacturer values (interfaces, calibration data and passwords), except the SIP and CIP data which remain unchanged. By sending the recall value "732255", all configuration values will be set to default.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
8192	2	Recall by value 732255	16	none	S

Figure 2.10.1.1: Definition of register 8192.

Command: Recall		Modbus address: 8192	Length: 2	Type: 16	Write
Parameter:	Recall				
Format:	Decimal				
Value:	732255				

Figure 2.10.1.2: Example to write the restore command.

3 Abbreviations

AO	Analog Output Interface
CP	Calibration Point
ECS	Electrochemical Sensor Interface
PMC	Primary Measurement Channel
SMC	Secondary Measurement Channel



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