Dencytee RS485 Sensors

Modbus RTU Programmer’s Manual

Firmware version:

CDOUM004

Rev.	Revision Date	Author	Change Description
00	20.12.2021	GRi	Initial version
01	23.03.2022	GRi	Update to CDOUM002
02	20.10.2023	JJ	Update to CDOUM003
03	19.07.2024	JJ	Update to CDOUM004

Table of Content

1 Modbus RTU General Information

1.1 Introduction

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

1.2 Hamilton Arc Sensors: Modbus Command Structure

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

CDOUM004

Please check the firmware version by reading register 1032.

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

1.2.1 Modbus RTU: Definitions According to Modbus IDA

The definitions in chapter 1.2 Hamilton Arc Sensors: Modbus Command Structure are an excerpt from the documents:

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

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

Attention:

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

1.2.2 Command Structure

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

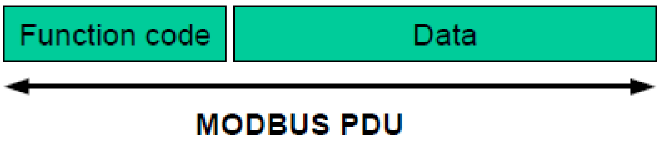


Figure 1 Modbus Protocol Data Unit

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

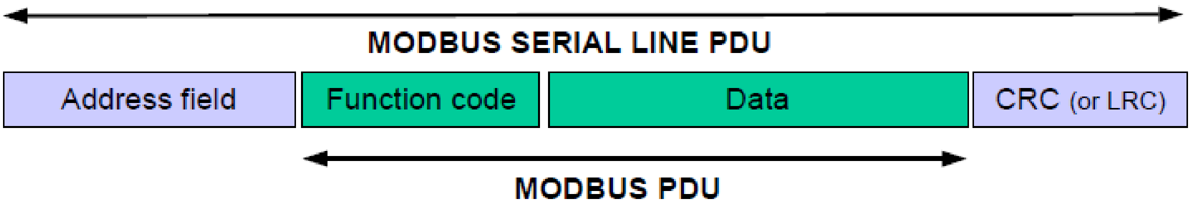


Figure 2 Modbus frame over Serial Line

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

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

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

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

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

1.2.3 Modbus RTU Transmission Mode

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

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

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

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

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

With Parity Checking

Start	1	2	3	4	5	6	7	8	Par	Stop

Figure 3 Bit sequence in RTU mode

Frame Checking Field:
Cyclical Redundancy Checking (CRC)

Frame description:

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

Figure 4 RTU Message Frame

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

1.2.4 Modbus RTU Message Framing

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

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

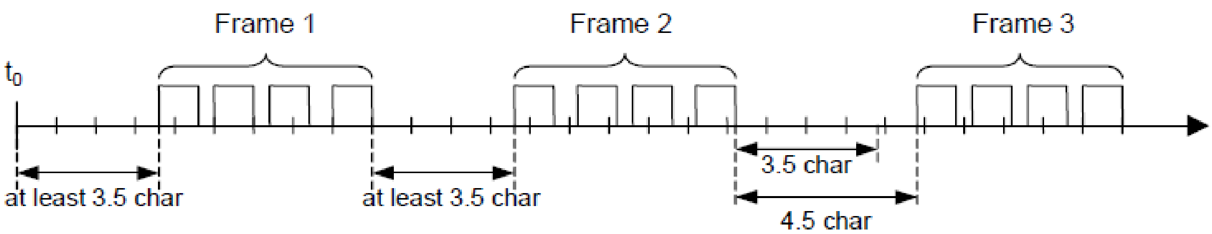


Figure 5 Valid frames with silent intervals

MODBUS message

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

Figure 6 RTU Message Frame

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

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

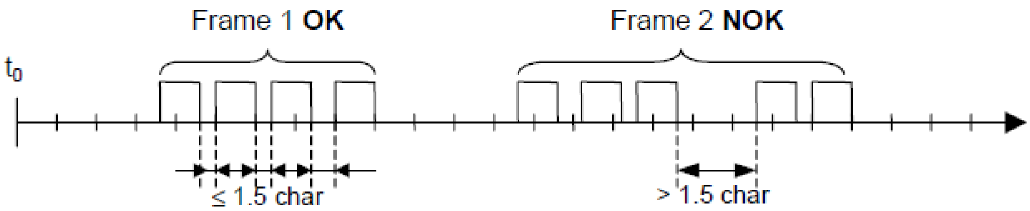


Figure 7 Data transmission of a frame

1.2.5 Modbus RTU CRC Checking

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

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

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

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

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

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

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

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

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

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

1.3 Implementation of Modbus RTU in Hamilton Arc Sensors

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

Table 1 Modbus definition for data transmission

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

The RS485 interface is configured as follows:

Table 2 RS485 definitions for Arc Sensors

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

1.4 Modbus RTU Function Codes Used for Arc Sensors

Arc Sensors use only 3 Modbus function codes:

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

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

1.4.1 Modbus function code #3: Read Holding Registers

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

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

Request

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

Response

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

*__N__ = Quantity of Registers

Error

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

Figure 8 Definition of Holding Registers

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

Figure 9 Example of reading holding registers 108 – 110. The contents of register 108 are read as the two byte values 0x022B. The contents of registers 109 and 110 are 0x0000 and 0x0064

1.4.2 Modbus function code #4: Read Input Registers

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

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

Request

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

Response

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

*__N__ = Quantity of Input Registers

Error

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

Figure 10 Definition of Input Registers

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

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

1.4.3 Modbus Function Code #16: Write Multiple Registers

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

Request

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

*__N__ = Quantity of Registers

Response

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

Error

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

Figure 12 Definition of Write Multiple Registers

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

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

1.5 Data Formats Used in Arc Sensors

1.5.1 Float

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

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

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

Example: translate the decimal value 62.85 into binary

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

62 / 2	= 31	residue 0	LSB	**0.85** * 2	= 1.70	=> 1	MSB
31 / 2	= 15	residue 1		0.70 * 2	= 1.40	=> 1	
15 / 2	= 7	residue 1		0.40 * 2	= 0.80	=> 0	
7 / 2	= 3	residue 1		0.80 * 2	= 1.60	=> 1	
3 / 2	= 1	residue 1		0.60 * 2	= 1.20	=> 1	
1 / 2	= 0	residue 1	MSB	0.20 * 2	= 0.40	=> 0	
	= **111110**			0.40 * 2	= 0.80	=> 0	LSB
					…		
					= **0.11011001100110011001100110 0**…		

62.85 = 111110.110110011001100110011001100…

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

111110**.**110110011001100110011001100… *2^**0** = 1**.**1111011011001100110011001100110… *2^**5**

Sep 3: Calculation of the dual exponent

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

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

Sep 4: Definition of the sign bit

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

Step 5: conversion into floating-point

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

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

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

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

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

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

Step 2: Calculate the decimal value

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

1.5.2 Character

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

Example: translate the ASCII-string "2076" to Hex representation

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

"2" => ASCII code table=> 0x32 Low Byte
"**0"** => ASCII code table => 0x30
"**7"** => ASCII code table => 0x37
"**6"** => ASCII code table => 0x36 High Byte

"2076" => **0x36373032**

1.5.3 Decimal

Example: translate Decimal 2227169 to Hex

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

1.6 Modbus RTU Error Messages

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

Table 4 Implemented Error-Codes

Error-Code Hex	**Status-Text**
0x00	OK
0x01	Illegal function
0x02	Illegal data address
0x03	Illegal data value
0x04	Slave device failure

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

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

2 Dencytee RS485 Commands in Modbus RTU

2.1 General

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

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

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

Attention:

When configuring and calibrating the sensor, please limit write operations to a reasonable number. More than 1'000'000 write operations will physically damage the memory of the sensor.

2.2 Operator levels and Passwords

2.2.1 Reading / Setting Operator Level

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

Table 5 Definition of operator level and default passwords

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

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

Attention:

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

2.2.2 Changing Passwords for Operator Level

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

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

2.3 Configuration of the serial RS485 Interface

Factory settings for the RS485 interface:

Table 6 RS485 factory settings

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

2.3.1 Device Address

2.3.1.1 Reading and Writing the Device Address

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

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

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

Attention:

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

2.3.1.2 Reading the Device Address Limits

The device address limits can be read in register 4098.

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

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

2.3.1.3 Broadcast

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

2.3.2 Baud Rate

2.3.2.1 Reading and Writing the Baud Rate

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

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
4102	2	Baud rate code (see Table 7)	3, 4, 16	U/A/S	S

The code for the baud rate is defined as follows:

Table 7 Code for the baud rates

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

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

Attention:

If the baud rate limits are not met when setting a new baud rate, the former baud rate stays active.
The baud rate **does not** change before the next power up.

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

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

2.3.3 Parity and Stop Bits

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

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

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

Attention:

If one of the parameter limits is not met, the old configuration stays active! Parity option (even or odd) is only available with one stop bit (max. string length of 11 bits).
The configuration **does not** change before the next power up.

2.4 Configuration of the Analog Interfaces

Note:

The Dencytee RS485 Sensor does not have any analog interfaces itself. They are provided by an Arc Wi 2G Adapter BT. But the registers to configure these interfaces are available on the sensor. That means, that these registers can be read and written with or without Arc Wi 2G Adapter BT.

2.4.1 Available Analog Interfaces

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

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

The number of analog interfaces is defined in register 4320.

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

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

2.4.2 Available Analog Interface Modes

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

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

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

Table 8 Definition of the analog interface modes

Code (Hex)	Analog Interface Mode	Description
0x00	4-20 mA inactive	Analog interface is deactivated
0x01	4-20 mA fixed	Set to a constant output value for current loop testing See 2.4.5.7 Defining a Constant Current Output for Testing
0x02	4-20 mA linear	Linear output of measurement (PMC1 / 6)

The answer is a bitwise combination (OR) of the available modes defined in Table 8.
Reg1/Reg2 and Reg3/Reg4 always return "0x03" meaning that fixed and linear mode are available.
Reg5 to Reg8 return 0. How to select or change the analog interface mode, see 2.4.4 Selection of an Analog Interface Mode.

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 to 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

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 (uint)	Modbus function code	Read access	Write access
4360	2	Analog interface mode for AO1	3, 4, 16	U/A/S	S
4488	2	Analog interface mode for AO2	3, 4, 16	U/A/S	S

For available interface modes see register 4322.

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

2.4.5 Configuration of the 4-20 mA Interface

Note:

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

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

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

Table 9 Code for selection of the primary measurement channel

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

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

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

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

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

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

2.4.5.3 Reading the Minimal and Maximal Possible Physical Output Current

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

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

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

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

2.4.5.4 Reading the Minimal and Maximal Current for Measurement Value Output

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

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

2.4.5.5 Reading the Selected Physical Unit for Analog Interface

Start register	Number of registers	Reg1 / Reg2 (uint)	Modbus function code	Read access	Write access
4376	2	Selected physical unit of AO1 (see Table 14)	3, 4	U/A/S	none
4504	2	Selected physical unit of AO2 (see Table 14)	3, 4	U/A/S	none

Read the selected unit of the selected PMC of AO1 respectively AO2. The value returned is an unsigned integer that represents the unit according to Table 14.
The physical unit for the PMC is defined in Reg. 2090 or 2410 and applies automatically for 4-20 mA output.

2.4.5.6 Defining the Measurement Values for 4 and 20 mA Output

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

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

Attention:

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

- The PMC you have mapped to AO1 / AO2 (register 4364 / 4492)
- The physical unit currently in use for the selected PMC (register 2090 for PMC1and register 2410 for PMC6.

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

Example:
Register 4364 is set to 1 (PMC1 is mapped to AO1).
Register 2090 is set to 0x00000100 (the unit "g/l" is assigned to PMC1).
Register 4378 is set to 0 and 20 (4 mA = 0 g/l, 20 mA = 20 g/l) as shown in Figure 14.
The measurement parameter 2 Offset TCD is set to 0 g/l.
The sensor reads currently a value of 10 g/l TCD, the output at the 4-20 mA accordingly is 12 mA (10 g/l).

The operator now changes the measurement parameter 2 Offset TCD to -10 g/l. Therefore, the output of AO1 increases to 20 mA (20 g/l).

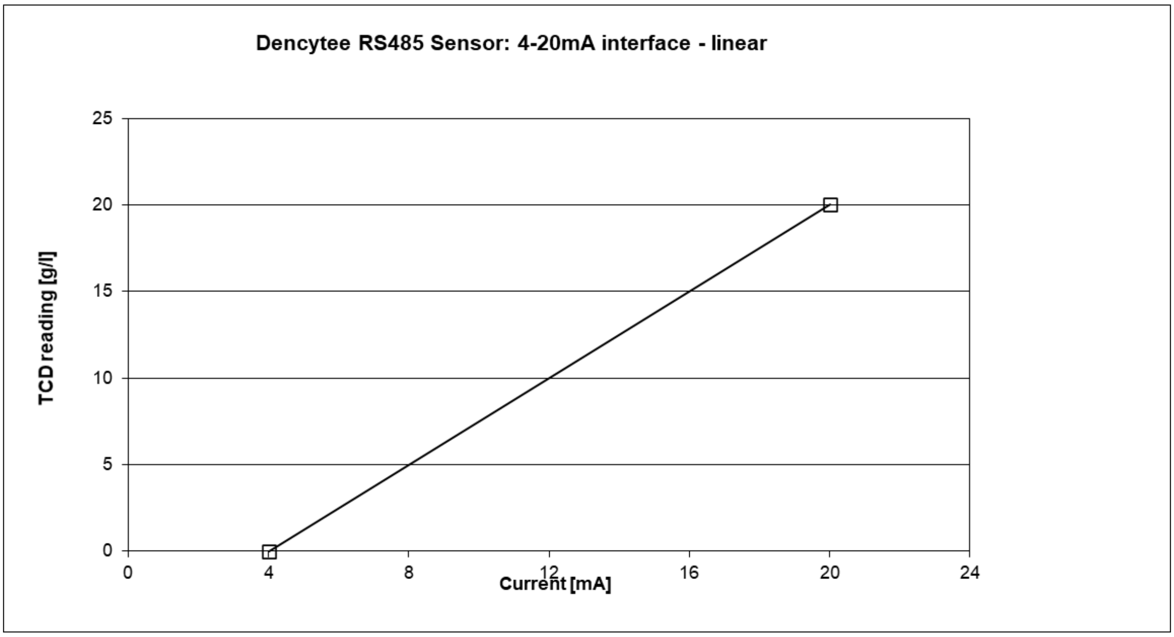


Figure 14 Example of linear 4-20mA output characteristics

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 4-20 mA fixed (0x01) (see Table 8):

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

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

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

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

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

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

Bit #	Code (hex)	Behavior of the 4-20 mA interface in case of errors and warnings
0 (LSB)	**0x000001**	**Error continuous output**
1-15	…	not available
16	**0x010000**	**Warning continuous output**
17-30	…	not available
31 (MSB)	…	not available

If the corresponding bits for the errors and warnings are not set (=0x00), the respective options are inactive.
"T exceed" is always active. What means that in case of a measurement temperature limit violation, the output current will be as the specified value.

The default settings are:

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

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

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

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

For more information about warnings, errors and temperature limits, see chapter 2.8 Correlation.

2.4.6 Reading the Internally Calculated Output Current

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

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

Attention:

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

2.5 Measurement

Note:

For more information about the measurement theory see the Dencytee RS485 Operating Instructions.

2.5.1 Definition of Measurement Channels and Physical Units

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

Table 12 Definition of PMC1 to 6 and SMC1 to 16

Bit #	Hex value	Description	Definition
0 (LSB)	**0x00000001**	**PMC1**	**TCD**
1	0x00000002	PMC2	not available
2	0x00000004	PMC3	not available
3	0x00000008	PMC4	not available
4	0x00000010	PMC5	not available
5	**0x00000020**	**PMC6**	**Temperature**
6	0x00000040	SMC1	not available
7-11	…	…	not available
12	**0x00001000**	**SMC7**	**Transmission current**
13-14	…	…	not available
15	**0x00008000**	**SMC10**	**Reflection current**
16-17	…	…	not available
18	**0x00040000**	**SMC13**	**Transmission**
19	**0x00080000**	**SMC14**	**Reflection**
20	0x00100000	SMC15	not available
21	0x00200000	SMC16	not available
22	**0x00400000**	**SMC17**	**Transmission Dark Current**
23 (MSB)	**0x00800000**	**SMC18**	**Reflection Dark Current**

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

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

Table 13 Example to read register 2048

Command: Avail. meas. channels	Modbus address: **2048**	Length: **2**	Type: **3**	Read
Parameter:	Avail. PMC and SMC			
Format:	Hex			
Value:	**0x00CC0021**			

In case of operator level U or A, the value 0x21 is returned. In other words: PMC1 and PMC6 are available to the operator U or A. In operator level S, the value 0xCC0021 is returned. In other words: PMC1, PMC6, SMC13, SMC14, SMC17 and SMC18 are available to the operator S.

The Dencytee RS485 Modbus register structure uses the following physical units.

Table 14 Definition of physical units

Bit #	Hex value	Physical unit	Start register. (8 ASCII characters, length 4 registers, Type 3, read for U/A/S)
0 (LSB)	0x00000001	none	1920
1	0x00000002	K	1924
2	0x00000004	°C	1928
3	0x00000008	°F	1932
4	0x00000010	PCV	1936
5	0x00000020	AU	1940
6	0x00000040	arb.Unit	1944
7	0x00000080	NTU	1948
8	0x00000100	g/l	1952
9	0x00000200	uS/cm	1956
10	0x00000400	mS/cm	1960
11	0x00000800	1/cm	1964
12	0x00001000	mS	1968
13	0x00002000	pF	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	CFU	2012
24	0x01000000	-	2016
25	0x02000000	Ohm	2020
26	0x04000000	%/K	2024
27	0x08000000	°	2028
28	0x10000000	e6 c/ml	2032
29	0x20000000	pF/cm	2036
30	0x40000000	kHz	2040
31 (MSB)	0x80000000	OD	2044

Table 15 Example to read the physical unit in plain text ASCII in register 1952

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

2.5.2 Primary Measurement Channel 1 (TCD)

2.5.2.1 Definition of PMC1

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

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

In register 2088, the available physical units for this channel are defined. The available physical units for PMC1: 0x00000000. The unit of PMC1 can only be changed by selecting the correlation 2.6.6 Cell Type Mode. That is why this register is empty.

Note:

The unit cannot be changed via register 2090. This can only be done via the selection of the correlation 2.6.6.

Attention:

Changing the correlation model 2.6.6 Cell Type Mode of PMC1 has also an influence on the output of the 4-20 mA analog output, as the same physical unit is active for 4-20 mA. All limits of the 4-20 mA analog output have to be redefined after changing the physical unit! See chapter 2.4.5 Configuration of the 4-20 mA Interface for more details.

2.5.2.2 Reading the measurement value of PMC1

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

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

(1) Definition of the status see chapter 2.5.10 Definition of the Measurement Status for PMC1 / PMC6. All bits set to zero means no problem.

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 Primary Measurement Channel 6 (Temperature)

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

Definition of PMC6

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

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

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

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

⚠ Attention:

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

2.5.3.1 Reading the measurement value of PMC6

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

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

(1) Value is always in the physical unit defined in register 2410/2.
(2) Definition of the status see chapter 2.5.10 Definition of the Measurement Status for PMC1 / PMC6. All bits set to zero means no problem.

Table 16 Example to read register 2410

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

Physical unit is set to °C, PMC6 is 27.42 (°C), Status is 0x00, Min allowed value is -10 °C, Max allowed value is 140 °C.

⚠ 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.

2.5.4 Secondary Measurement Channel 7 (Transmission current)

The first internal measured value is specified as transmission. This measured value is used for the selected correlation to apply the algorithm.

2.5.4.1 Definition of SMC7

Start register	Data size (registers)	Function	Data type	Modbus function code	Read access	Write access
2656	8	Description of SMC7	ASCII chars	3, 4	S	none

In register 2656, a plain text ASCII description of SMC7 is given. SMC7 is called “Trans. current”.

Start register	Data size (registers)	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
2664	6	Physical unit	Measurement value of SMC7	0	3, 4	S	none

Start reg.	Num-ber of reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Reg9 / Reg10	Modbus function code	Read access	Write access
2664	10	Selected physical unit	Measure -ment value of SMC7	0	Min allowed value	Max allowed value	3, 4	U/A/S	none

In register 2664, the unit, the measured value and the minimum and maximum value are displayed.

Attention:

The unit is fixed and cannot be changed. The unit is nA with the hex value 0x00020000.

2.5.5 Secondary Measurement Channel 10 (Reflection current)

The second internal measured value is specified as reflection current. This measured value is used for the selected correlation to apply the algorithm.

2.5.5.1 Definition of SMC10

Start register	Data size (registers)	Function	Data type	Modbus function code	Read access	Write access
2752	8	Description of SMC10	ASCII chars	3, 4	S	none

In register 2752, a plain text ASCII description of SMC10 is given. SMC10 is called “Refl. current”.

Start register	Data size (registers)	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
2760	6	Physical unit	Measurement value of SMC10	0	3, 4	S	none

Start reg.	Num-ber of reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Reg9 / Reg10	Modbus function code	Read access	Write access
2760	10	Selected physical unit	Measure -ment value of SMC10	0	Min allowed value	Max allowed value	3, 4	U/A/S	none

In register 2760, the unit, the measured value and the minimum and maximum value are displayed.

Attention:

The unit is fixed and cannot be changed. The unit is nA with the hex value 0x00020000.

2.5.6 Secondary Measurement Channel 13 (Transmission)

The first internal measured value is specified as transmission. This measured value is used for the selected correlation to apply the algorithm.

2.5.6.1 Definition of SMC13

Start register	Data size (registers)	Function	Data type	Modbus function code	Read access	Write access
2848	8	Description of SMC13	ASCII chars	3, 4	U/A/S	none

In register 2848, a plain text ASCII description of SMC13 is given. SMC13 is called "Transmission".

Start register	Data size (registers)	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
2856	6	Physical unit	Measurement value of SMC13	0	3, 4	U/A/S	none

Start reg.	Num-ber of reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Reg9 / Reg10	Modbus function code	Read access	Write access
2856	10	Selected physical unit	Measure -ment value of SMC13	0	Min allowed value	Max allowed value	3, 4	U/A/S	none

In register 2856, the unit, the measured value and the minimum and maximum value are displayed.

Attention:

The unit is fixed and cannot be changed. The unit is arb.Unit with the hex value 0x000040.

2.5.7 Secondary Measurement Channel 14 (Reflection)

The second internal measured value is specified as reflection. This measured value is used for the selected correlation to apply the algorithm.

2.5.7.1 Definition of SMC14

Start register	Data size (registers)	Function	Data type	Modbus function code	Read access	Write access
2880	8	Description of SMC14	ASCII chars	3, 4	U/A/S	none

In register 2880, a plain text ASCII description of SMC14 is given. SMC14 is called "Reflection".

Start register	Data size (registers)	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
2888	6	Physical unit	Measurement value of SMC14	0	3, 4	U/A/S	none

Start reg.	Num-ber of reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Reg9 / Reg10	Modbus function code	Read access	Write access
2888	10	Selected physical unit	Measure-ment value of SMC14	0	Min allowed value	Max allowed value	3, 4	U/A/S	none

In register 2888, the unit, the measured value and the minimum and maximum value are displayed.

⚠ Attention:

The unit is fixed and cannot be changed. The unit is arb.Unit with the hex value 0x000040.

2.5.8 Secondary Measurement Channel 17 (Dark Current Transmission)

The firstt internal measured value is specified as transmission. This measured value is used for the selected correlation to apply the algorithm.

2.5.8.1 Definition of SMC17

Start register	Data size (registers)	Function	Data type	Modbus function code	Read access	Write access
2976	8	Description of SMC17	ASCII chars	3, 4	S	none

In register 2976, a plain text ASCII description of SMC14 is given. SMC14 is called "Reflection".

Start register	Data size (registers)	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
2984	6	Physical unit	Measurement value of SMC17	0	3, 4	S	none

Start reg.	Num-ber of reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Reg9 / Reg10	Modbus function code	Read access	Write access
2984	10	Selected physical unit	Measure-ment value of SMC17	0	Min allowed value	Max allowed value	3, 4	S	none

In register 2984, the unit, the measured value and the minimum and maximum value are displayed.

Attention:

The unit is fixed and cannot be changed. The unit is nA with the hex value 0x00020000.

2.5.9 Secondary Measurement Channel 18 (Dark Current Transmission)

The second internal measured value is specified as reflection. This measured value is used for the selected correlation to apply the algorithm.

2.5.9.1 Definition of SMC 18

Start register	Data size (registers)	Function	Data type	Modbus function code	Read access	Write access
3008	8	Description of SMC18	ASCII chars	3, 4	S	none

In register 3008, a plain text ASCII description of SMC18 is given. SMC18 is called “Reflection”.

Start register	Data size (registers)	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
3016	6	Physical unit	Measurement value of SMC18	0	3, 4	S	none

Start reg.	Num-ber of reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Reg9 / Reg10	Modbus function code	Read access	Write access
3016	10	Selected physical unit	Measure-ment value of SMC18	0	Min allowed value	Max allowed value	3, 4	S	none

In register 3016, the unit, the measured value and the minimum and maximum value are displayed.

Attention:

The unit is fixed and cannot be changed. The unit is nA with the hex value 0x00020000.

2.5.10 Definition of the Measurement Status for PMC1 / PMC6

This is the definition of the Measurement Status for the registers 2090 (PMC1) and 2410 (PMC6):

Table 17 Definition of measurement status for Primary Measurement Channels

Bit #	Hex value	Description
0 (LSB)	0x01	Temperature out of user defined measurement temperature range (see register 4624 in chapter 2.9.1 Temperature Ranges)
1	0x02	Temperature out of operating range (see register 4608 in chapter 2.9.1 Temperature Ranges)
2	0x04	Not available
3	0x08	Warning not zero (see register 4736 chapter 2.9.3 Warnings)
4	0x10	Error not zero (see register 4800 chapter 2.9.4 Errors)

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 Table 18)	3, 4	U/A/S	none

Table 18 Bitwise definition of all parameters PA1 to PA16

Bit #	Hex value	Description	Definition
0 (LSB)	**0x0001**	**PA1**	**Factor TCD**
1	**0x0002**	**PA2**	**Offset TCD**
2	0x0004	PA3	not available
3	0x0008	PA4	not available
4-6	…	…	not available
7	0x0080	PA8	not available
8	**0x0100**	**PA9**	**Moving average**
9	0x0200	PA10	not available
10-11	…	…	not available
12	**0x1000**	**PA13**	**Meas. interval**
13-14	…	…	not available
15 (MSB)	0x8000	PA16	not available

Table 19 Example to read the available Parameters with operator level S

Command: Available parameters	Modbus address: **3072**	Length: **2**	Type: **3**	Read
Parameter:	Measurement parameters			
Format:	Hex			
Value:	**0x1103**			

The hex value 0x1102 corresponds to 0x01 (PA01) + 0x02 (PA2) + 0x100 (PA9) + 0x1000 (PA13).

Note:

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

2.6.2 PA1 Factor TCD

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

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

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

Register 3112 delivers the available units for the Factor TCD parameter. It is coded according to Table 14 Definition of physical units.The only available unit for this parameter is "none" (0x000000001).

Start reg.	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Reg7 / Reg8 (float)	Modbus function code	Read access	Write access
3114	4	Unit	Value			16	none	S
	8	Unit	Value	Minimal value	Maximal value	3, 4	U/A/S	none

Register 3114 allows reading or changing the current Factor TCD.

Unit always is 0x000000001 meaning that the Factor TCD parameter is in "none". See Table 14 *Definition of physical units*. Writing a different value to Reg1/Reg2 does not have any effect.

The offset value has a direct influence on the TCD value (PMC1). For details see 2.5.2.2 Reading the measurement value of PMC1.

Minimal value is –inf, Maximal value is +inf.

2.6.3 PA2 Offset TCD

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

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

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

Register 3144 delivers the available units for the Offset TCD parameter. It is coded according to Table 14 Definition of physical units.The only available unit for this parameter is "none" (0x000000001).

Start reg.	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Reg7 / Reg8 (float)	Modbus function code	Read access	Write access
3146	4	Unit	Value			16	none	S
	8	Unit	Value	Minimal value	Maximal value	3, 4	U/A/S	none

Register 3146 allows reading or changing the current Offset TCD.

Unit always is 0x000000001 meaning that the Offset TCD parameter is in "none". See Table 14 *Definition of physical units*. Writing a different value to Reg1/Reg2 does not have any effect.

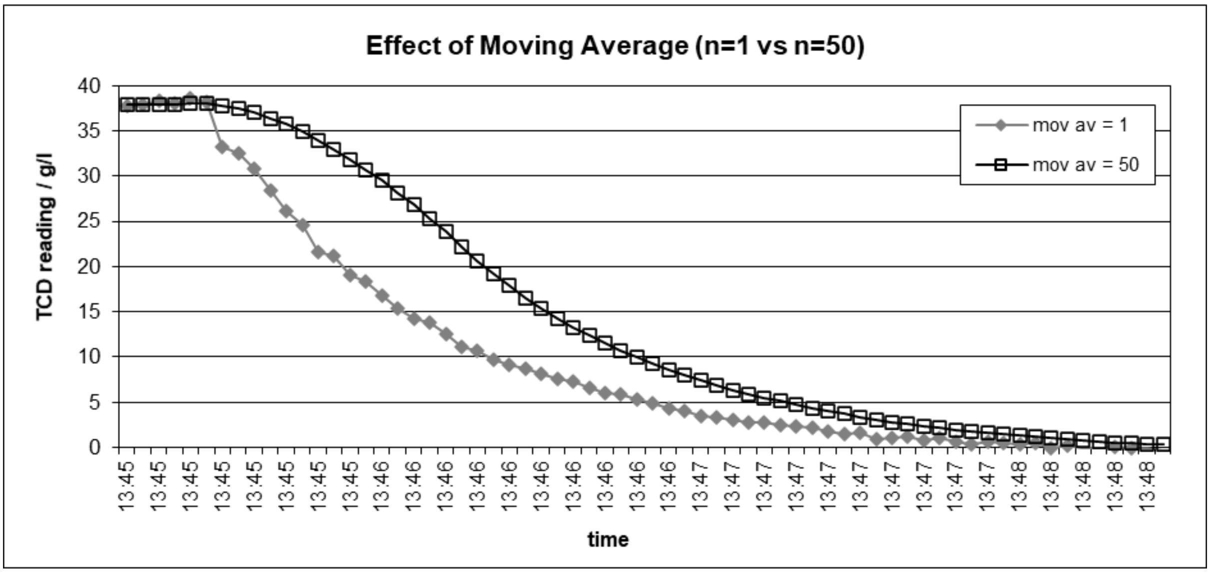
The offset value has a direct influence on the TCD value (PMC1). For details see 2.5.2.2 Reading the measurement value of PMC1.

Minimal value is –inf, Maximal value is +inf.

Attention:
Executing Mark Zero respectively Clear Zero (see 2.6.7 Mark Zero TCD) changes the offset value!

2.6.4 PA9: Moving Average

Dencytee RS485 calculates new TCD measurement values with the value defined in the measurement interval parameter One has the possibility to smoothen the TCD and Temperature reading (PMC1 and PMC6) by means of a moving average.
Figure 15 shows a comparison between no moving average (n=1) and a moving average over 50 readings at a measurement interval of 3 second.



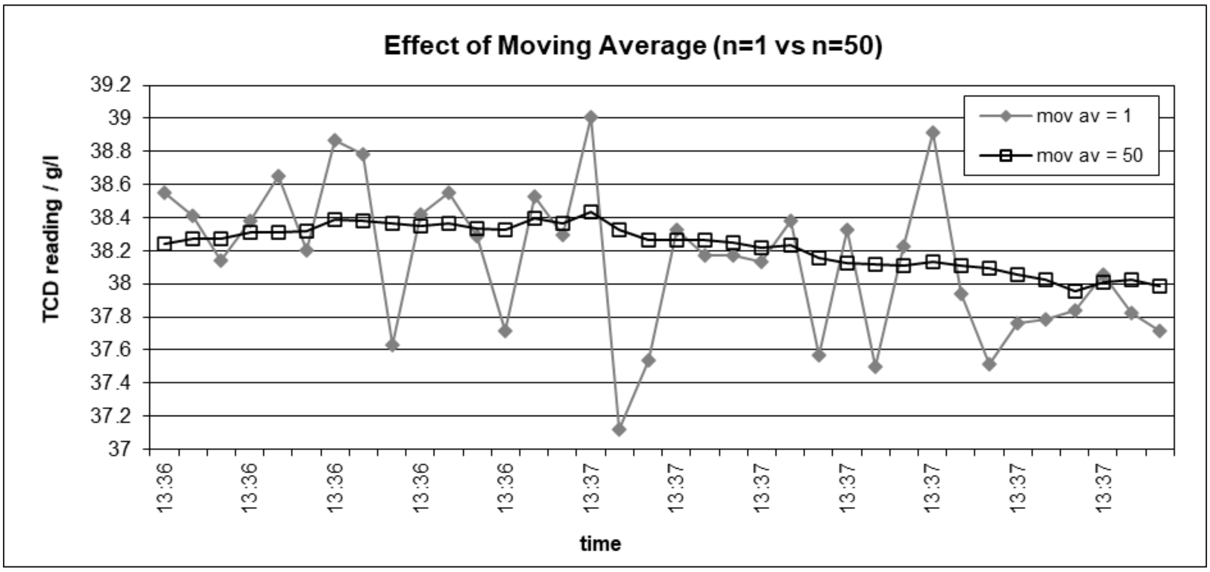


Figure 15 Comparison of the response of Dencytee RS485 to a change from 38.5 g/l to zero TCD

Using moving average, the short term signal stability can be improved; on the other hand, the response time of the sensor increases with increasing moving average. A moving average over 50 samples results in a response time of at least 50 times the measurement interval of 3 seconds.

Note:

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

2.6.4.1 Description of PA9 (Moving Average)

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

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

2.6.4.2 Selecting the Physical Unit and Writing the Value for PA9

In register 3368, the available physical units for PA9 are defined. The only one available here is "none" (0x01). For the definition of the physical units see Table 14.

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

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

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4	Modbus function code	Read access	Write access
3370	4	Select physical unit for PA9	Value for PA9 (1-150, default: 50)	16	none	S

PA9 can take values between 1 and 150. The value of 1 does not influence the response time of the sensor, the value of 50 increases the response time 50 times the value of the measurement interval.

2.6.4.3 Reading all Values for PA9

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

Start register	Number of registers	Reg1 / Reg2	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

2.6.5 PA13: Measurement Interval

The measurement interval for the Dencytee RS485can be set between 3s and 300s (5min). The TCD measurement can also be deactivated by writing a 0 to the measurement interval register. When the interval is increased, the response time for PMC1 is slower.

Note:

When a correlation is initiated and the current measurement interval is greater than 3s or equals 0s, the measurement interval is temporarily set to 3s. The measurement interval is automatically reset to the original value 10 min after the last correlation command, or after power up. See chapter 2.8 Correlation for more details.

2.6.5.1 Description of PA13 (Measurement Interval)

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

Table 20: Definition of register 3488

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

Table 21: Example to read the description. It is "Meas. interval ".

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

2.6.5.2 Selecting the Physical Unit and Writing the Value for PA13

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

Table 22: Definition of register 3496

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

Table 23: Example to read the available physical units for PA13. The only one available here is "none" (0x01). For the definition of the physical units see chapter 2.5.1 Definition of Measurement Channels and Physical Units

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

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

Table 24: Definition of register 3496. Only one bit for the physical unit can be set and the value: 0-300.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Reg3 / Reg4	Modbus function code	Read access	Write access
3498	4	Select physical unit for PA13	Value for PA13 (0-300; default: 3)	16	none	S

Table 25: Example to set the physical unit of PA13 to “none” (0x01) and the measurement interval to 30.

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

Note:
If 1s or 2s is set as the measurement interval, it is automatically set to 3 seconds.

2.6.5.3 Reading all Values for PA13

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

Table 26: Definition of register 3498.

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

Table 27: Example to read PA13. The physical unit is 0x01 (“none”), and the measurement interval is 30 seconds.

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

Attention:
Setting PA13 to 0 deactivates TCD reading completely. Temperature readings are still active. Bit 31 of “Warning Measurement” is set which means “Measurement not running”.
The TCD value is set to an invalid value (-999) on the digital output. At the analog interface the output value goes into saturation.

2.6.6 Cell Type Mode

The Dencytee RS485 Sensor offers 10 different correlation models that define the coefficients needed to calculate PMC1. Cell Type Mode 1 to 4 (Transmission [AU], Reflection [arb.Unit], CDW Yeast [g/l] and Turbidity Std [NTU]) are fix, whereas Cell Type Mode 5 to 10 are user definable. For more information see chapter 2.8 Correlation.
The Cell Type Mode parameter (Reg. 41218, 41226 and 41228) defines the active Cell Type Mode. The different Cell Type Modes themselves are defined by the registers starting at 44454 (see chapter 2.8.5 Storage of correlations.

2.6.6.1.1 Cell Type Mode Parameter

In register 41218, a plain ASCII text description of the Cell Type Mode parameter is given:

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
41218	8	Cell Type Mode parameter	3, 4	U/A/S	none

Register 41218 returns "Cell Type Mode ".

Register 41226 delivers the available units for the Cell Type Mode parameter:

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
41226	2	Available units for Cell Type Mode parameter	3, 4	U/A/S	none

The available units are coded according to *Table 14*. For this parameter the only unit available is "none" (0x00000001).

Register 41228 allows reading or changing the currently selected Cell Type Mode:

Start register	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
41228	4	Unit	CTM			16	none	S
	8	Unit	CTM	Minimal value	Maximal value	3, 4	U/A/S	none

Unit always is 0x00000001 meaning that the Cell Type Mode parameter has no unit. See *Table 14*. Writing a different value to Reg1/Reg2 does not have any effect.

The Dencytee RS485Sensor offers 10 Cell Type Modes represented by an index of 0 to 9. Therefore, Minimal value is 0 and Maximal value is 9. If a value outside the value range is entered, either the maximum or the minimum value is taken over

CTM index (Reg3/Reg4):
- 0 = Cell Type Mode 1: Transmission [AU]
- 1 = Cell Type Mode 2: Reflection [arb. Unit]
- 2 = Cell Type Mode 3: CDW Yeast [g/l]
- 3 = Cell Type Mode 4: Turbidity Std [NTU]
- 4 = Cell Type Mode 5: User 1
- 5 = Cell Type Mode 6: User 2
- 6 = Cell Type Mode 7: User 3
- 7 = Cell Type Mode 8: User 4
- 8 = Cell Type Mode 9: User 5
- 9 = Cell Type Mode 10: User 6

Cell Type Mode 4 to 9 can be defined by the user. See chapter 2.8 Correlation.

2.6.6.2 Definition of the Cell Type Modes

Start register	Number of reg.	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
44454 + n * 54	8	Label (16 ASCII characters)				3, 4 / 3, 4, 16	U/A/S	none / S
44462 + n * 54	6	Unit (uint)	Actice Points (uint)	Status (uint)		3, 4	U/A/S	none
44468 + n * 54	6	Trans-mission CoP1 (uint)	Re-flection CoP1 (uint)	Input value CoP1 (uint)		3, 4	U/A/S	none
44474 + n * 54	6	Trans-mission CoP2 (uint)	Re-flection CoP2 (uint)	Input value CoP2 (uint)		3, 4	U/A/S	none
44480 + n * 54	6	Trans-mission CoP3 (uint)	Re-flection CoP3 (uint)	Input value CoP3 (uint)		3, 4	U/A/S	none
44486 + n * 54	6	Trans-mission CoP4 (uint)	Re-flection CoP4 (uint)	Input value CoP4 (uint)		3, 4	U/A/S	none
44492 + n * 54	6	Trans-mission CoP5 (uint)	Re-flection CoP5 (uint)	Input value CoP5 (uint)		3, 4	U/A/S	none
44498 + n * 54	6	Trans-mission CoP6 (uint)	Re-flection CoP6 (uint)	Input value CoP6 (uint)		3, 4	U/A/S	none

Definition of the Cell Type Modes (n = 0..9)

The definition of Cell Type Mode 1 starts at 44454. With an offset of 54 bytes the definition of the next Cell Type Mode is following.
Cell Type Modes 1 to 4 are read only, whereas CTM 5 to 10 can be overwritten with the mechanism for creating a new correlation.

In register 44454 + n *54, a plain ASCII text description of the Cell Type Mode is given:

n=0: Cell Type Mode 1: "Transmission   "
n=1: Cell Type Mode 2: "Reflection   "
n=2: Cell Type Mode 3: "CDW Yeast   "
n=3: Cell Type Mode 4: "Turbidity Std   "
n=4: Cell Type Mode 5: "User Correlation"
n=5: Cell Type Mode 6: "User Correlation"
n=6: Cell Type Mode 7: "User Correlation"
n=7: Cell Type Mode 8: "User Correlation"
n=8: Cell Type Mode 9: "User Correlation"
n=9: Cell Type Mode 10: "User Correlation"

2.6.7 Mark Zero TCD

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
41236	8	Mark Zero TCD	3, 4	U/A/S	none

In register 41236, a plain ASCII text description of Mark Zero TCD is given.
It returns "Mark Zero TCD   ".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
41244	2	Available units for Mark Zero	3, 4	U/A/S	none

The available units are coded according to Table 14. For this parameter the only unit available is "none" (0x00000001).

Start reg.	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
41246	4	Unit	Value			16	none	S
	8	Unit	Value	Minimal value	Maximal value	3, 4	U/A/S	none

Register 41246 allows setting the TCD measurement value to zero (Mark Zero) or to undo this settin (clear Zero). Zeroing the measurement value means that the current measurement value is saved and will be subtracted from the following measurement as an offset (see 2.6.3 PA2 Offset TCD).

Unit alswas is 0x00000001 meaning that the Cell Type Mode parameter has no unit See *Table 14.* Writing a different value to Reg1/Reg2 does not have any effect.

The zeroing functionality is controlled by the Value (Reg3/Reg4)
- 0 – Clear zero (zeroing not active)
- 1 – Mark zero (zeroing active)

Only 0 and 1 are valid Values. Therefore minimal value is 0 and maximal value is 1.

Mark zero has the effect that the offset TCD (2.6.3 PA2 Offset TCD) is set to the current TCD value, what results in a TCD value (PMC1) of zero. Clear zero sets the offset TCD back to zero.

⚠ Attention:
Zeroing the TCD value might have an influence on the output of AO1 / AO2 if PMC1 is mapped to one of it. Define the limits of the 4-20 mA current interface such that the zeroing does not lead to an unintentional behavior of the current output.

2.6.8 Inoculate

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
41290	8	Inoculation label	3, 4	U/A/S	none

In register 41290, a plain ASCII text description of the Inoculate parameter is given. It returns “Inoculate   “.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
41298	2	Available units for Inoculate	3, 4	U/A/S	none

Register 41298 delivers the available units for the Inoculate parameter. It is coded according to *Table 14*.

Start reg.	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
41300	4	Unit	Value			16	none	S
	8	Unit	Value	Minimal value	Maximal value	3, 4	U/A/S	none

Register 41300 allows marking the inoculation.

Unit always is 0x00000001 meaning that the Inoculate parameter has no unit. See*Table 14*. Writing a different value to Reg1/Reg2 does not have any effect.

The inoculate functionality is controlled by the Value (Reg3/Reg4).
0 = stop culture
1 = inoculate

Only 0 and 1 are valid Values. Therefore, Minimal value is 0 and Maximal value is 1.

The culture time (2.6.9 Culture Time) starts counting from zero when writing a 1 (inoculate) to the register 41300. Repeated writing of a 1 does not have any effect. When writing a 0 (stop culture) the culture time stops counting and is set back to zero.

2.6.9 Culture Time

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
41308	8	Culture time label	3, 4	U/A/S	none

In register 41308, a plain ASCII text description of the Inoculate parameter is given. It returns "Culture time   ".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
41316	2	Available units culture time	3, 4	U/A/S	none

Register 41316 delivers the available units for the Inoculate parameter. It is coded according to *Table 14*.

Start reg.	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
41318	8	Unit	Value	Minimal value	Maximal value	3, 4	U/A/S	none

Register 41318 is read only. It delivers the culture time in seconds. The culture time can be controlled by the inoculate command (2.6.8 Inoculate).

⚠ <u>Attention:</u>
Although Reg1/Reg2 returns 0x00000001 the unit for the culture time is second.

Minimal value is 0, maximal value is $2^{32} - 1$.

2.7 Verification

The main idea of the verification is to verify the current sensor measurement with the last standard calibration (performed by TS). For this purpose, the measured values of transmission (SMC13) and reflection current (SMC10) are compared by the software with the reference values determined during the last successful standard calibration. During verification, the transmission cap must be placed on the sensor. Then the reference value of the transmission as well as its tolerance must be read from the software and compared with the measured value (SMC13). Then this is repeated with the absorber clip, the reference value, and the tolerance of the reflection current as well as the measured value of the reflection current (SMC10). If both measured values are within the tolerances, the verification is successful, otherwise the sensor should be calibrated. This function is not executed by the sensor itself, which means that the function must be integrated into the software. No command code is required to perform the verification.

2.7.1 Verification reference and tolerance values

The reference value and the tolerance for the measurement with the transmission cap of the transmission (SMC13) are stored in register 41830:

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Modbus function code	Read access	Write access
41830	4	Reference value transmission (transmission cap)	Tolerance value transmission (transmission cap)	3, 4	U/A/S	none

Table 28 Example to read the reference and tolerance of the transmission for the verification

Command: Verification transmission	Modbus address: **41830**	Length: **4**	Type: **3**	Read
Parameter:	Reference value transmission	Tolerance value transmission		
Format:	Float	Float		
Value:	**0.8**	**0.04**		

The reference value and the tolerance for the measurement with the absorber clip of the reflection current are stored in register 41864:

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Modbus function code	Read access	Write access
41864	4	Reference value reflection current (absorber clip)	Tolerance value reflection current (absorber clip)	3, 4	U/A/S	none

Table 29 Example to read the reference and tolerance of the reflection current for the verification

Command: Verification transmission	Modbus address: **41864**	Length: **4**	Type: **3**	Read
Parameter:	Reference value reflection	Tolerance value reflection		
Format:	Float	Float		
Value:	**50000**	**2500**		

After the transmission cap/absorber clip is placed on the sensor, the transmission (SMC13) or reflection current (SMC10) should be compared to the corresponding reference values. If both are within their tolerance, the verification is successful, otherwise the sensor should be sent to the TS to perform a standard calibration.

Note:

Standard calibration can only be performed by Hamilton Technical Support (TS). The sensor must be sent back for this.

2.8 Correlation

The Dencytee RS485 Sensor contains four non-changeable default correlations, which can be selected with the parameter Cell Type Mode 2.6.6 Cell Type Mode. In addition, it is possible to create 6 further user correlations, which can then also be selected via the parameter Cell Type mode 2.6.6 Cell Type Mode. The procedure for creating a user correlation is described in this chapter.

2.8.1 Preview Correlation

2.8.1.1 Naming the preview of the correlation

The preview of the correlation can be assigned a name. If the preview is saved to the user area after successful execution 2.8.1.5.1 Creating a correlation, the name is also stored there. A maximum of 16 characters can be used as a name. The naming is executed via the following register:

Table 30 Example of naming the preview

Command: Current interface text	Modbus address: **44400** Length: **8**	Type: **3/16**	Read/Write
Parameter:	Text	Read access	Write access
Format:	Character		
Value:	**User Corr. 1**	U/A/S	S

2.8.1.2 Selection of the number of adjacent correlation points

In register 10260, the available number of Correlation Points (CoP) for Primary Measurement Channel 1 (PMC1) are defined. As shown in Table 31, six individual CoPs are theoretically possible.

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
10260	2	Available number of CoP for PMC1 (see Table 31)	3, 4	U/A/S	S

Table 31 Bitwise definition of CoP0 to CoP6

Bit #	Hex value	Description	Definition in Dencytee
0 (LSB)	0x01	CoP0	not available
1	**0x02**	**CoP1**	**Correlation Point 1**
2	**0x04**	**CoP2**	**Correlation Point 2**
3	**0x08**	**CoP3**	**Correlation Point 3**
4	**0x10**	**CoP4**	**Correlation Point 4**
5	**0x20**	**CoP5**	**Correlation Point 5**
6	**0x40**	**CoP6**	**Correlation Point 6**

Table 32 Example to read the available CoPs

Command: Available cali points	Modbus address: **10256**	Length: **2**	Type: **3**	Read
Parameter:	Points			
Format:	Hex			
Value:	**0x7E**			

The hex value 0x7E in Table 32 corresponds to 0x02 (CoP1) + 0x04 (CoP2) + 0x08 (CoP3) + 0x10 (CoP4) + 0x204 (CoP5) + 0x40 (CoP6).

The Dencytee RS485 Sensors allow 6 correlation points (CoP1 to CoP6) for the correlation. The number of active correlation points can be defined with the write command.

Hex value	Description	Definition in Dencytee
0x06	**2 Point Correlation**	**CoP1 to CoP2 are active**
0x0E	**3 Point Correlation**	**CoP1 to CoP3 are active**
0x1E	**4 Point Correlation**	**CoP1 to CoP4 are active**
0x3E	**5 Point Correlation**	**CoP1 to CoP5 are active**
0x7E	**6 Point Correlation**	**CoP1 to CoP6 are active**

If such a hex value is written to the sensor, the unselected correlation points are set to inactive. This means that the points are still available but inactive, which means that the hex value 0x7E is always displayed when register 10260 is read.

2.8.1.3 Stability criteria

When initiating the correlation at CoP1 to CoP6, the measured temperature has to be stable for at least 100 seconds. The stability criteria of the correlation are combined with the stability criteria of the standard calibration (performed by TS). With the correlation, however, only the temperature is checked since the measured signal of PMC1 is not defined with a correlation. The stability criteria are defined in register 10278:

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

Table 33 Example to read the calibration and correlation stability

Command: Read calibration and correlation stability	Modbus address: **10278**	Length: **4**	Type: **3**	Read
Parameter:	Max drift PMC1 [%/min]	Max drift temp [K/min]		
Format:	Float	Float		
Value:	**2.0**	**0.5**		

Table 34 Example to set the calibration and correlation stability

Command: Set calibration and correlation stability	Modbus address: **10278**	Length: **4**	Type: **16**	Write
Parameter:	Max drift PMC1 [%/min]	Max drift temp [K/min]		
Format:	Float	Float		
Value:	**3.0**	**0.5**		

Attention:

For the correlation only the stability of the temperature is checked

2.8.1.4 Units of correlation

The available units for the correlation are defined in register 10272

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
10272	2	Available Units of correlation	3, 4	U/A/S	none

Table 35 Example to read available correlation units

Command: Avail. Corr. Units	Modbus address: **10272**	Length: **2**	Type: **3**	Read
Parameter:	Avail. Corr. Units			
Format:	Hex			
Value:	**0x908001F0**			

According to Table 14 the available physical units for the correlation are PCV, AU, arb.Unit, NTU, g/l, CFU, e6 c/ml and OD.
In register 10274, the active physical correlation unit can be selected, by choosing one of the physical units that are defined in register 10272. Only one bit can be set.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
10274	2	Selected active physical unit for correlation	16	U/A/S	S

Table 36 Example to set the physical correlation unit to g/l (0x00000100)

Command: Correlation set unit		Modbus address: **10272**	Length: **2**	Type: **16** Write
Parameter:	Unit			
Format:	Hex			
Value:	**0x00000100**			

2.8.1.5 Correlation procedure

Table 37 Correlation points register

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Modbus function code	Read access	Write access
10314	4	Correlation command code for CoP1, see Table 38	Correlation value or dummy value (depends on command code)	16	none	A/S
11034	4	Correlation command code for CoP2, see Table 38	Correlation value or dummy value (depends on command code)	16	none	A/S
11754	4	Correlation command code for CoP3, see Table 38	Correlation value or dummy value (depends on command code)	16	none	A/S
12474	4	Correlation command code for CoP4, see Table 38	Correlation value or dummy value (depends on command code)	16	none	A/S
13194	4	Correlation command code for CoP5, see Table 38	Correlation value or dummy value (depends on command code)	16	none	A/S
13914	4	Correlation command code for CoP6, see Table 38	Correlation value or dummy value (depends on command code)	16	none	A/S

Table 38 Correlation command code

Bit #	Hex value	Description
none	0x00000000	Not valid (leads to a modbus exception)
0 (LSB)	0x00000001	
1	0x00000002	
2	0x00000004	
3	0x00000008	
4	0x00000010	Initialization of the correlation
5	0x00000020	Assignment of the input value of the correlation
6	0x00000040	Active setting of the correlation point
7	0x00000080	Not valid (leads to a modbus exception)
8	0x00000100	Inactive setting of the correlation point
9	0x00000200	Not valid (leads to a modbus exception)
10	0x00000400	Initialization of the ring buffer
11	0x00000800	Not valid (leads to a modbus exception)
3-30	…	
31 (MSB)	0x80000000	

The individual command codes are described in the chapter 2.8.1.6 Command Codes and given with an example.

2.8.1.5.1 Creating a correlation

Table 39 Initialization of the preview

<table>
<tr><td>Bit #</td><td>Hex value</td><td>Description</td></tr>
<tr><td>none</td><td>0x00000000</td><td>Delete the preview</td></tr>
<tr><td>0 (LSB)</td><td>0x00000001</td><td>Not valid (leads to a modbus exception)</td></tr>
<tr><td>1</td><td>0x00000002</td><td>Not valid (leads to a modbus exception)</td></tr>
<tr><td>2</td><td>0x00000004</td><td>Not valid (leads to a modbus exception)</td></tr>
<tr><td>3</td><td>0x00000008</td><td>Not valid (leads to a modbus exception)</td></tr>
<tr><td>4</td><td>0x00000010</td><td>Copy of user correlation 1 into the preview</td></tr>
<tr><td>5</td><td>0x00000020</td><td>Copy of user correlation 2 into the preview</td></tr>
<tr><td>6</td><td>0x00000040</td><td>Copy of user correlation 3 into the preview</td></tr>
<tr><td>7</td><td>0x00000080</td><td>Copy of user correlation 4 into the preview</td></tr>
<tr><td>8</td><td>0x00000100</td><td>Copy of user correlation 5 into the preview</td></tr>
<tr><td>9</td><td>0x00000200</td><td>Copy of user correlation 6 into the preview</td></tr>
<tr><td>9</td><td>0x00000400</td><td rowspan="3">Not valid (leads to a modbus exception)</td></tr>
<tr><td>11-30</td><td>…</td></tr>
<tr><td>31 (MSB)</td><td>0x80000000</td></tr>
</table>

2.8.1.5.2 Creating a new correlation

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
10264	2	Initialization of the preview, see Table 39	16	none	S

Table 40 Example of initializing the preview

Command: Initialization of the preview		Modbus address: **10264**	Length: **2**	Type: **16** Write
Parameter:	Command Code			
Format:	Hex			
Value:	**0x00000000**			

If a correlation is to be created from scratch, the existing correlation can be deleted in the preview. This is done with the command code 0x00000000. If this is executed, all correlation points will be reinitialized.

2.8.1.5.3 Use template of an existing correlation

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
10264	2	Initialization of the preview, see Table 39	16	none	S

Table 41 Example of initializing the preview with user correlation 1

Command: Initialization of the preview		Modbus address: **10264**	Length: **2**	Type: **16** Write
Parameter:	Command Code			
Format:	Hex			
Value:	**0x00000010**			

It is also possible to use an existing user correlation (one created by the customer at an earlier time) as a template. This is done with the command code in Table 39.

Attention:

Only user correlations and no default correlations can be used as templates. If there are no user correlations, this function cannot be executed.

2.8.1.6 Command Codes

2.8.1.6.1 Initialization ring buffer

Table 42 Example of initialization of the ring buffer for correlations point 1

Command: Initialization of the ringbuffer for CoP1		Modbus address: **10314**	Length: **4**	Type: **16** Write
Parameter:	Command Code	Dummy Value		
Format:	Hex	Hex		
Value:	**0x00000400**	**0x00000000**		

Since the stability of the signal cannot be checked in a correlation (air bubbles, stirring rate, etc.), a mean/median filter is applied over the measured signal. To activate this filter, the command code 0x00000400 is written in the desired CoP. This fills the ring buffer with 32 values. At the initialization 2.8.1.6.2 Initialization ring buffer the content of the ring buffer is deleted and must be reinitialized at the next point.

2.8.1.6.2 Initialization correlation point

Table 43 Example of initializing the preview for correlations point 1

Command: Initialization of CoP1		Modbus address: **10314**	Length: **4**	Type: **16** Write
Parameter:	Command Code	Dummy Value		
Format:	Hex	Hex		
Value:	**0x00000010**	**0x00000000**		

After initializing the ring buffer, you have to wait 100 seconds until the ring buffer has the desired 32 values. After this waiting time the correlation point can be initialized, whereby all necessary measuring values, which are specified in 2.8.2 Available correlation parameters, are stored.

Note:

When a correlation is initiated and the current measurement interval is greater than 3s or equals 0s, the measurement interval is temporarily set to 3s. The measurement interval is automatically reset to the original value 10 min after the last correlation command, or after power up.

2.8.1.6.3 Assigning the offline value

Table 44 Example of assigning the input value for correlations point 1

Command: Assignment of CoP1		Modbus address: **10314**	Length: **4**	Type: **16** Write
Parameter:	Command Code	Input Value		
Format:	Hex	float		
Value:	**0x00000020**	**0.432**		

After the correlation point has been initialized, the offline value determined externally can be assigned to the particular point.

2.8.1.6.4 Switching the correlation point active/inactive

Table 45 Example to inactivate the correlation point 1

Command: Inactivation of CoP1		Modbus address: **10314**	Length: **4**	Type: **16** Write
Parameter:	Command Code	Dummy Value		
Format:	Hex	Hex		
Value:	**0x00000040**	**0x00000000**		

There is also a possibility to make correlation points inactive, which will cause the point to be ignored when creating a correlation.

Table 46 Example to activate the correlation point 1

Command: Activation of CoP1		Modbus address: **10314**	Length: **4**	Type: **16** Write
Parameter:	Command Code	Dummy Value		
Format:	Hex	Hex		
Value:	**0x00000100**	**0x00000000**		

This inactivation of a point can be undone with the command code 0x000040.

2.8.1.7 Status correlation point preview

Table 47 Correlation points status register

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Modbus function code	Read access	Write access
10312	4	Correlation Status for CoP1, see Table 48	Correlation value	3, 4	U/A/S	none
11032	4	Correlation Status for CoP2, see Table 48	Correlation value	3, 4	U/A/S	none
11752	4	Correlation Status for CoP3, see Table 48	Correlation value	3, 4	U/A/S	none
12472	4	Correlation Status for CoP4, see Table 48	Correlation value	3, 4	U/A/S	none
13192	4	Correlation Status for CoP5, see Table 48	Correlation value	3, 4	U/A/S	none
13912	4	Correlation Status for CoP6, see Table 48	Correlation value	3, 4	U/A/S	none

Table 48 Meaning Status bits of the correlation points

Bit #	Hex value	Definition
None	0x00000000	Not available
0 (LSB)	0x00000001	Not available
1-14	…	Not available
15	0x00008000	Out of range
16-18	…	Not available
19	0x00080000	Temperature too high
20	0x00100000	Temperature too low
21	0x00200000	Drift temperature
22	0x00400000	Not available
23	0x00800000	Invalid input value
24	0x01000000	Reflection too low
25-27	…	Not available
28	0x10000000	Correlation Point active
29	0x20000000	Correlation Point initialized
30	0x40000000	Correlation Point assigned
31	0x80000000	Not available

Attention:

In the status of point 1 to point 5, the status of the standard calibration (performed by TS) and the status of the correlation are indicated. Bit 0 to bit 13 is reserved for the standard calibration Bit 14 to bit 31 is reserved for the correlation.

2.8.2 Available correlation parameters

The available correlation parameters are defined in the following registers:

Table 49 Bitmask of available correlation parameters.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
10326	2	Bitmask of the available correlation parameters for correlation point 1, see Table 50.	3, 4	U/A/S	none
11046	2	Bitmask of the available correlation parameters for correlation point 2, see Table 50.	3, 4	U/A/S	none
11766	2	Bitmask of the available correlation parameters for correlation point 3, see Table 50.	3, 4	U/A/S	none
12486	2	Bitmask of the available correlation parameters for correlation point 4, see Table 50.	3, 4	U/A/S	none
13206	2	Bitmask of the available correlation parameters for correlation point 5, see Table 50.	3, 4	U/A/S	none
13926	2	Bitmask of the available correlation parameters for correlation point 6, see Table 50.	3, 4	U/A/S	none

Table 50 Bitwise definition of available correlation parameters.

Bit #	Hex value	Definition
0 (LSB)	0x00000001	not available
1	0x00000002	Calibration parameter index 2
2	0x00000004	Calibration parameter index 3
3-9	…	Not available
10	0x00000010	Calibration parameter index 11
11	0x00000020	Calibration parameter index 12
12-31	…	Not available

Table 51 Example to read available correlation parameters for Correlation Point 1

Command: Avail. Cali. Param. for Correlation Point 1		Modbus address: **10326**	Length: **2**	Type: **3** Read
Format:	Hex			
Value:	**0x00000C06**			

Table 52 Description of the available correlation parameters

Calibration parameter index#	Definition
2	The assigned correlation value is stored within parameter index 2.
3	At the time of a valid initialization of a correlation point, the current temperature value is stored within parameter index 3.
11	At the time of a valid initialization of a correlation point, the current transmission value is stored within correlation parameter index 11.
12	At the time of a valid initialization of a correlation point, the current reflection value is stored within correlation parameter index 12.

2.8.2.1.1 Description of the parameters

The value and unit of the available correlation preview parameter for all correlation points, can be read out via the following register:

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4 (fix)	Reg5 / Reg6	Calibration Parameter Index and description,	Modbus function code	Read access	Write access
10374 + (CoPx -1) *720	6	Not relevant	Unit	Value	2	3, 4	U/A/S	none
10412 + (CoPx -1) *720	6	Not relevant	Unit	Value	3	3, 4	U/A/S	none
10662 + (CoPx -1) *720	6	Not relevant	Unit	Value	11	3, 4	U/A/S	none
10694+ (CoPx -1) *720	6	Not relevant	Unit	Value	12	3, 4	U/A/S	none

The description of correlation parameter 2, 3, 11 and 12, can be read out via the following register:

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Calibration Parameter Index and description	Modbus function code	Read access	Write access
10360 + (CoPx -1) *720	8	Assigned value	2	3, 4	U/A/S	none
10392 + (CoPx -1) *720	8	Temperature	3	3, 4	U/A/S	none
10648 + (CoPx -1) *720	8	Transmission	11	3, 4	U/A/S	none
10680+ (CoPx -1) *720	8	Reflection	12	3, 4	U/A/S	none

Note:

Up to 22 parameters are reserved. The Dencytee RS485 sensor, on the other hand, only needs four. The available parameters are specified with the bit mask in Table 49. The base address is 10328 + (CoPx - 1) * 720 for the naming and 10342 + (CoPx - 1) * 720 for the values.

Table 53 Example to read the unit "none" and Assigned value of correlation point 1

Command: Corr. Parameter 2	Modbus address: **10374**	Length: **6**	Type: **3**	Read
Parameter:	Corr. Par.2 - Not relevant	Corr. Par.2 - Unit	Corr. Par.2 - Value	
Format:	Hex	Hex	Float	
Value:	**0x00000000**	**0x00000100**	**0.23**	

Table 54 Example to read the description of parameter 2 of correlation point 1

Command: Current interface text	Modbus address: **10360**	Length: **8**	Type: **3**	Read
Parameter:	Text			
Format:	Character			
Value:	**Assigned value**			

2.8.3 Saving the preview to the desired user space

After the correlation is fully initialized and assigned in the preview, it can be saved to a user area.On the whole, the sensor provides space for six correlations created by the user. The memory space for the default correlations cannot be overwritten. This memory function is executed with register 10266 with the command codes specified in Table 55.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
10266	2	Saving the preview to the user space/ correlation status	16	U/A/S	S

Table 55 Command codes for saving the preview of the correlation to the desired user space

Bit #	Hex value	Description
none	0x00000000	Delete the preview
0 (LSB)	0x00000001	Not valid (leads to a modbus exception) Reserved for default correlation 1
1	0x00000002	Not valid (leads to a modbus exception) Reserved for default correlation 2
2	0x00000004	Not valid (leads to a modbus exception) Reserved for default correlation 3
3	0x00000008	Not valid (leads to a modbus exception) Reserved for default correlation 4
4	0x00000010	Saving the preview in user space 1
5	0x00000020	Saving the preview in user space 2
6	0x00000040	Saving the preview in user space 3
7	0x00000080	Saving the preview in user space 4
8	0x00000100	Saving the preview in user space 5
9	0x00000200	Saving the preview in user space 6
9	0x00000400	Not valid (leads to a modbus exception)
11-30	…	
31 (MSB)	0x80000000	

As an example, the correlation is placed in user area 1. This is done as follows:

Table 56 Example of saving the preview in user space 1

Command: Initialization of the preview		Modbus address: **10266**	Length: **2**	Type: **16** Write
Parameter:	Command Code			
Format:	Hex			
Value:	**0x00000010**			

Only at this moment the individual points can be considered together. It is checked whether the units of the individual points are identical, whether the states of the individual points are OK, whether the offline input values and the measured values are monotonous, whether all offline values are assigned and whether enough points are active.

To check if everything has worked correctly, the status must be read. This is defined as a read function of register 10266. This is described in detail in 2.8.4 Correlation Status.

2.8.4 Correlation Status

In addition to saving the preview to the desired user area, register 10266 contains the correlation status as a read function. The meaning of the status bits is described in Table 58.

Table 57 Reading the correlation status

Command: Initialization of the preview		Modbus address: **10266**	Length: **2**	Type: **16** Write
Parameter:	Command Code			
Format:	Hex			
Value:	**0x00000000**			

Table 58 Meaning Status bits of the correlation

Bit #	Hex value	Definition
None	0x00000000	Correlation successful
0 (LSB)	0x00000001	Units of correlation points not identical
1	0x00000002	Subordinate status of the individual points not ok
2	0x00000004	Assigned offline values not monotonously increasing
3	0x00000008	Not all offline values are assigned
4	0x00000010	Sensor measured values not monotonous
5	0x00000020	Too less correlation points active
6	0x00000040	No valid correlation

Note:

Status bit 6 is only used to indicate whether a correlation is present in the user area. When saving the preview to a user area, this bit is never set.

2.8.5 Storage of correlations

To have an overview of the individual correlations, the components can be read via Modbus. In a block is the name, the unit, the bit mask of the active correlation points, the correlation status, as also the input values and measured values of the respective correlation points.

Table 59 Modbus addresses of the individual components of a correlation

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Reg7 / Reg8	Modbus function code	Read access	Write access
44454 + (n -1) *54	8	Correlation Name				3, 4, 16	U/A/S	S
44462 + (n -1) *54	6	Unit	Bit mask available Corr. Points	Corr. Status		3, 4	U/A/S	S for n > 4
44468 + (n -1) *54	6	Value Trans-mission CoP1	Value Reflection CoP1	Input value CoP1		3, 4	U/A/S	S for n > 4
44474 + (n -1) *54	6	Value Trans-mission CoP2	Value Reflection CoP2	Input value CoP2		3, 4	U/A/S	S for n > 4
44480 + (n -1) *54	6	Value Trans-mission CoP3	Value Reflection CoP3	Input value CoP3		3, 4	U/A/S	S for n > 4
44486 + (n -1) *54	6	Value Trans-mission CoP4	Value Reflection CoP4	Input value CoP4		3, 4	U/A/S	S for n > 4
44492+ (n -1) *54	6	Value Trans-mission CoP5	Value Reflection CoP5	Input value CoP5		3, 4	U/A/S	S for n > 4
44498+ (n -1) *54	6	Value Trans-mission CoP6	Value Reflection CoP6	Input value CoP6		3, 4	U/A/S	S for n > 4

Note:

n = 1-4 contain the information of the default correlations. n = 5-10 contain the information of the user correlations. An empty user area is marked in the status with the status bit 6.

2.8.6 Delete existing correlations

Existing correlations can be overwritten using the process described in 2.8.3 Saving the preview to the desired user space. There is also the possibility to delete existing correlations. This is done with the same Modbus register that is used for copying an existing correlation to the preview 2.8.1.5.3 Use template of an existing correlation. The command codes are different. This is done with the same Modbus register that is used to copy an existing correlation to the preview. The command codes are different. When deleting a correlation, the bitmask is ored with 0x10000000 Table 61.

Start register	Number of registers	Reg1 / Reg2	Modbus function code	Read access	Write access
10264	2	Delete existing correlations	16	U/A/S	S

Table 60 Example delete user correlation 1

Command: Correlation set unit		Modbus address: **10262**	Length: **2**	Type: **16** Write
Parameter:	Unit			
Format:	Hex			
Value:	**0x10000010**			

Table 61 Command codes for deleting user correlations

Bit #	Hex value	Description
4	0x10000010	Deleting the user correlation 1
5	0x10000020	Deleting the user correlation 2
6	0x10000040	Deleting the user correlation 3
7	0x10000080	Deleting the user correlation 4
8	0x10000100	Deleting the user correlation 5
9	0x10000200	Deleting the user correlation 6

Note:

Only the user correlations can be deleted. If a try is made to delete a default correlation, a Modbus exception is returned.

2.9 Sensor Status

2.9.1 Temperature Ranges

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

- Operation – is the maximum temperature range to which the sensor can be exposed to during operation and storage. If the current temperature is out of
- Measurement – is the maximum allowable range where TCD measurement is possible.
- Calibration – in this range the sensor can be calibrated.
- User defined Measurement – the specialist (operator level S) can adjust the range in which TCD reading is active. The user defined measurement temperature range is a sub range of the measurement temperature range.

Note:

When performing a correlation, the user defined measurement temperature range is temporarily set to the values of the measurement temperature range from register 4612. After 10 minutes after the last correlation command or after a power up, the user defined measurement temperature range in register 4624 is reset to the values the user has defined.

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

Table 62 Example to read the operating temperature values min and max

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:	**-10**	**140**		

Table 63 Example to read the measurement 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:	**0**	**80**		

Table 64 Example to read the calibration 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**		

Table 65 Example set the user defined measurement temperature

Command: User measurement T		Modbus address: **4624**	Length: **4**	Type: **16** Write
Parameter:	User measurement T min [°C]*	User measurement T max [°C]*		
Format:	Float	Float		
Value:	**0**	**80**		

Note:

Temperature reading is active at any time, regardless of the current temperature.
*The unit of the temperatures is according to the selected unit of PMC6 (see 2.5.3 Primary Measurement Channel 6 (Temperature))

2.9.2 Operating Hours, Counters and System Time

In register 4676 are stored:

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

In register 4682 are stored:

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

In register 4688 are stored:

- number of sterilization in place (SIP) (see chapter 2.9.8 Reading Definition of SIP and CIP)
- number of cleaning in place (CIP) (see chapter 2.9.8 Reading Definition of SIP and CIP)

In register 4692 is stored

- number of autoclavings

Note:

The register 4692 has no effect for the sensor and is only for the user to trace the record for himself.

In register 8232 is stored

- system time counter.

Note:

When the sensor is powered up, the system time is set to 0. A value between 0 and 2^{32} can be written into this register. From this value, the sensor increments this value every second.
We recommend to use as base date the so-called UNIX timestamp (hint: www.epochconverter.com) which starts at 1st of January 1970 GMT. When a calibration is performed the system time value will be copied to the register 10488 for CoP1, 11208 for CoP2 and 104088 for CoP6 (after the action "initial measurement"). With this copied value, the absolute time of calibration can be recovered, even if the sensor has powered down in the meantime.
Be sure to update this register if needed after every power up of the sensor.

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

Table 66 Example to read the operating hours

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**	

Table 67 Example to read Power ups and Watchdog

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**	

Table 68 Example to read SIP and CIP cycles

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

Table 69 Example to read the number of autoclavings

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

Table 70 Example to write the number of autoclavings

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

Table 71 Example to write the system time into the sensor

Command: System Time		Modbus address: **8232**	Length: **2**	Type: **16** Write
Parameter:	System Time			
Format:	Decimal			
Value:	**1614147385**			

Table 72 Example to read the system time

Command: System Time		Modbus address: **8232**	Length: **2**	Type: **3** Read
Parameter:	System Time			
Format:	Decimal			
Value:	**1614178800**			

Note:

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

2.9.3 Warnings

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

2.9.3.1 Currently Active Warnings

The currently active warnings are stored in register 4736.

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

Table 73 Example to read the active warnings

Command: Warning active	Modbus address: **4736**	Length: **8**	Type: **3**	Read
Parameter:	W Measurement	W Calibration	W Interface	W Hardware
Format:	Hex	Hex	Hex	Hex
Value:	**0x00000000**	**0x00000000**	**0x00000000**	**0x00000000**

2.9.3.2 Definition of Warnings

Table 74 Definition of warnings "measurement"

Bit #	Hex code	Description
0 (LSB)	0x00000001	TCD reading below lower limit
	The TCD reading is too low. Make a new correlation.	
1	0x00000002	TCD reading above upper limit
	The TCD reading is too high. Make a new correlation.	
25	0x02000000	T reading below lower limit
	The temperature is below the user defined measurement temperature range (see register 4624). If outside this range, the sensor will not perform TCD readings.	
26	0x04000000	T reading above upper limit
	The temperature is above the user defined measurement temperature range (see register 4624). If outside this range, the sensor will not perform TCD readings.	
31	0x80000000	Measurement not running
	Causes that trigger this warning: 1.) Sensor operating voltage range is not between 10-27 VDC or 2.) The temperature measurement is outside the user defined temperature range. 3.) The measurement is switched off via the parameter measurement interval.	

Table 75 Definition of warnings "calibration"

Bit #	Hex code	Description
0 (LSB)	0x00000001	TCD calibration recommended
	Send to HAM Technical Support (TS) for standard calibration	

Table 76 Definition of warnings "interface"

Bit #	Hex code	Description
		Not available

Table 77 Definition of warnings "hardware"

Bit #	Hex code	Description
0 (LSB)	0x00000001	Sensor supply voltage too low
	The sensor supply voltage is below 10V. Please check your power supply.	
1	0x00000002	Sensor supply voltage too high
	The sensor supply voltage is above 27V. Please check your power supply.	
9	0x00000200	Replace sensor recommended
	The Sensor Quality Indicator is below 40%. The quality of the sensor is sufficient for reliable measurement, but replacement of the sensor will be needed in near future.	
10	0x00000400	Sensor deviation high
	If the sensor signal deviates more than 20% during calibration.	

2.9.4 Errors

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

2.9.4.1 Currently Active Errors

The currently active errors are stored in register 4800.

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

Table 78 Example to read the active errors

Command: Errors current	Modbus address: **4800**	Length: **8**	Type: **3**	Read
Parameter:	E Measurement	E Calibration	E Interface	E Hardware
Format:	Hex	Hex	Hex	Hex
Value:	**0x00000000**	**0x00000000**	**0x00000000**	**0x00000000**

2.9.4.2 Definition of Errors

Table 79 Definition of errors "measurement"

Bit #	Hex code	Description
0 (LSB)	0x00000001	TCD reading failure
	TCD algorithm error	
25	0x02000000	T sensor defective
	The internal temperature sensor is defective.	

Table 80 Definition of errors "calibration"

Bit #	Hex code	Description
		Not available

Table 81 Definition of errors "interface"

Bit #	Hex code	Description
		Not available

Table 82 Definition of errors “hardware”

<table>
<tr><th>Bit #</th><th>Hex code</th><th>Description</th></tr>
<tr><td rowspan="2">2</td><td>0x00000004</td><td>Temperature reading far below min</td></tr>
<tr><td colspan="2">The measured temperature is below the operation temperature (Reg. 4608)</td></tr>
<tr><td rowspan="2">3</td><td>0x00000008</td><td>Temperature reading far above max</td></tr>
<tr><td colspan="2">The measured temperature is above the operation temperature (Reg. 4608)</td></tr>
<tr><td rowspan="2">9</td><td>0x00000200</td><td>Sensor Defective</td></tr>
<tr><td colspan="2">Sensor is defective or Sensor Quality Indicator is below 10%. The quality of the sensor is not sufficient for reliable measurement. Sensor needs to be replaced.</td></tr>
<tr><td rowspan="2">10</td><td>0x00000400</td><td>Sensor deviation too high</td></tr>
<tr><td colspan="2">If the sensor signal deviates more than 40% during calibration.</td></tr>
<tr><td rowspan="2">11</td><td>0x00000800</td><td>Negative dark current</td></tr>
<tr><td colspan="2">If the dark current is too low.</td></tr>
<tr><td rowspan="2">12</td><td>0x00001000</td><td>Reflection current too low</td></tr>
<tr><td colspan="2">If the reflection current is too low.</td></tr>
<tr><td rowspan="2">22</td><td>0x00400000</td><td>EEPROM comm. (I2C) error Userend</td></tr>
<tr><td colspan="2">EEPROM communication error
Reset the sensor and try again</td></tr>
<tr><td rowspan="2">24</td><td>0x01000000</td><td>Internal communication (I2C) failure Userend</td></tr>
<tr><td colspan="2">Internal I2C communication error
Reset the sensor and try again</td></tr>
<tr><td rowspan="2">25</td><td>0x02000000</td><td>Internal communication failure (frontend)</td></tr>
<tr><td colspan="2">No communication between Frontend and Userend.
Reset the sensor and try again</td></tr>
<tr><td rowspan="2">26</td><td>0x04000000</td><td>Stackoverflow</td></tr>
<tr><td colspan="2">Internal memory failure
Reset the sensor and try again</td></tr>
</table>

2.9.5 Measurement values - Exceeds Temperature range, and TCD measurement errors

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

Category	Hex Code	Description
Measurement Warning	0x02000000	T reading below lower limit **OR**
	0x04000000	T reading above upper limit **AND**
	0x80000000	Measurement not running

In case that the current measurement temperature exceeds the operating temperature range, following error / warning bits has to be set:

Category	Hex Code	Description
Hardware Error	0x00000004	Temperature reading far below min **OR**
	0x00000008	Temperature reading far above max **AND**
Measurement Error	0x00000001	TCD reading failure

The measurement output values for these cases are defined in Table 83.

Table 83 Measurement values (PMCs) in case of exceeding the user defined- or operating temperature range

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

2.9.6 Measurement values – no TCD measurement within the frontend is running

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

Category	Hex Code	Description
Hardware Warning	0x00000001	Sensor supply voltage too low **OR**
	0x00000002	Sensor supply voltage too high **AND**
Measurement Warning	0x80000000	Measurement not running

In case the frontend measurement is not running, following warning bit is set:

Category	Hex Code	Description
Measurement Warning	0x80000000	Measurement not running

The measurement output values for this cases, are defined in Table 84.

Table 84 Measurement values (PMCs) in case no communication within the frontend is running

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

2.9.7 Measurement values – Hardware errors

The measurement output values for this cases, are defined in Table 85.

Table 85 Measurement values (PMCs) in case Hardware errors

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

2.9.8 Reading Definition of SIP and CIP

The Dencytee RS485 Sensor is counting special cleaning events such as sterilizations or cleaning cycles by means of tracking typical temperature profiles (see chapter 2.9.2 Operating Hours, Counters and System Time).

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

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

CIP / SIP time maximum values: 180 min

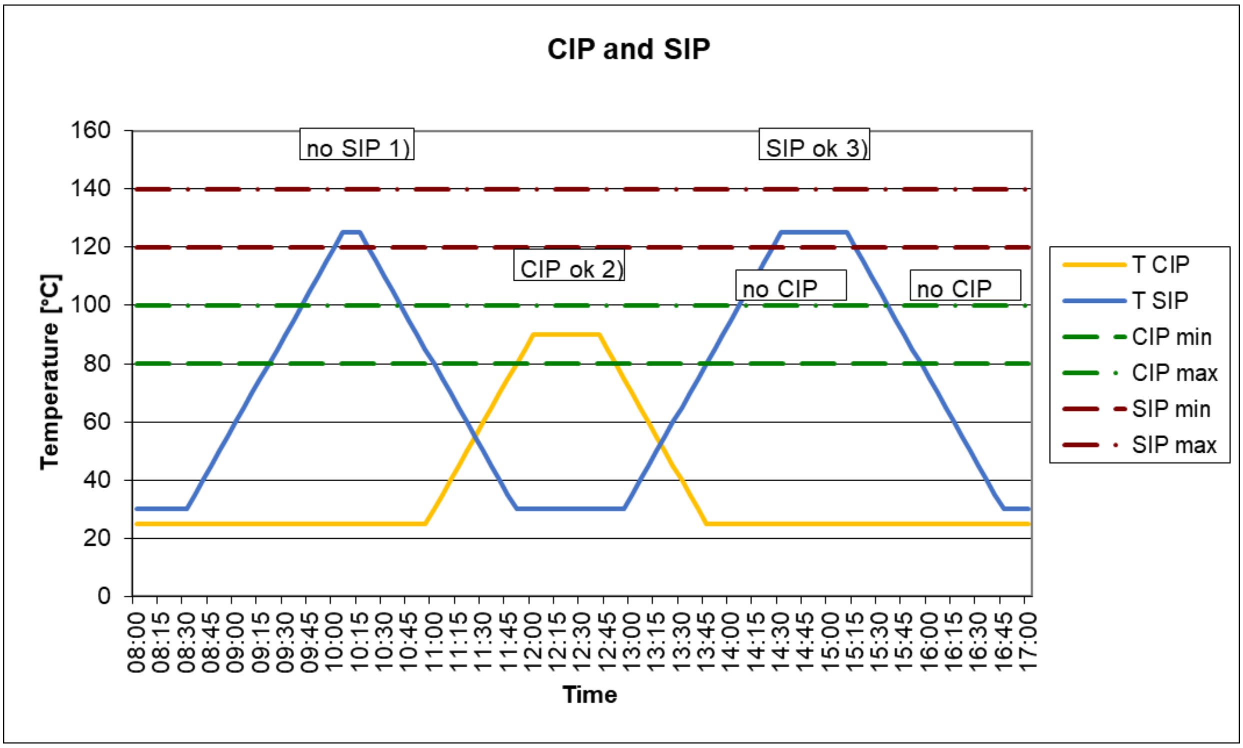


Figure 16 Definition of CIP and SIP cycles

Explanation of Figure 16:

1) no SIP-cycle counted, because time in defined SIP temperature range too short (less than 30 minutes).
2) CIP-cycle counted, because time greater than 30 minutes and in CIP temperature range.
3) SIP-cycle counted, because time greater than 30 minutes and in SIP temperature range.
4) no CIP-cycle counted, because above CIP max temperature.

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

The unit of the temperatures is according to the selected unit of PMC6 (see 2.5.3 Primary Measurement Channel 6 (Temperature))

2.9.9 Quality Indicator

2.9.9.1 Reading the Sensor Quality Indicator

In register 5472 with a command length of 2, the sensor quality (0-100%) is given in 10% percent steps. Hamilton recommends the replacement of the sensor at a value less than 40 % (see Table 77).

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

Table 86 Example to read the Sensor Quality Indicator with a command length of 2

Command: Sensor cap quality	Modbus address: **5472**	Length: **2**	Type: **3**	Read
Parameter:	Sensor quality [%]			
Format:	Float			
Value:	**100**			

2.9.9.2 Reading the Measurement Quality Indicator

In register 5472 with a command length of 6, the sensor quality (0-100%) in 10% percent steps and the measurement quality is given.

Start register	Number of registers	Reg1 / Reg2	Reg3 / Reg4	Reg5 / Reg6	Modbus function code	Read access	Write access
5472	6	Sensor quality [%]	Not used	Measurement quality, see Table 87	3, 4	U/A/S	none

Table 87 Definition of measurement quality values

Value	Description
100	Good sensor quality (no actions)
50	Poor sensor quality (maintenance required)
0	Bad sensor quality (sensor defective)

Table 88 Example to read the sensor- and measurement quality with a command length of 6

Command: Measurement quality	Modbus address: **5472**	Length: **6**	Type: **3**	Read
Parameter:	Sensor quality [%]	Not used	Measurement quality	
Format:	Float	Float	Float	
Value:	**100**	**-999**	**100**	

2.10 Sensor Identification and Information

2.10.1 General Information

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

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Example of content	Modbus function code	Read access	Write access
1024	8	Userend FW Date	2024-07-19	3, 4	U/A/S	none
1032	8	Userend FW	CDOUM004	3, 4	U/A/S	none
1040	8	Userend BL Date	2018-05-07	3, 4	U/A/S	none
1048	8	Userend BL	BL5UX001	3, 4	U/A/S	none
1056	8	Userend Ref	10075122/00	3, 4	U/A/S	none
1064	8	Userend SN	9999	3, 4	U/A/S	none
1072	8	Userend (space holder)	not available	3, 4	U/A/S	none
1080	8	Userend (space holder)	not available	3, 4	U/A/S	none
1088	8	Frontend FW Date	2021-11-22	3, 4	U/A/S	none
1096	8	Frontend FW	CDOFJ001	3, 4	U/A/S	none
1104	8	Frontend BL Date	not available	3, 4	U/A/S	none
1112	8	Frontend BL	not available	3, 4	U/A/S	none
1120	8	Frontend Ref	237680/00	3, 4	U/A/S	none
1128	8	Frontend SN	9999	3, 4	U/A/S	none
1136	8	Frontend (space holder)	not available	3, 4	U/A/S	none
1144	8	Frontend (space holder)	not available	3, 4	U/A/S	none

2.10.2 Sensor Identification

Definition of registers containing sensor identification:

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Example of content	Modbus function code	Read access	Write access
1280	8	Sensor Ref	10064919-11/00	3, 4	U/A/S	none
1288	8	Sensor name	Dencytee RS485	3, 4	U/A/S	none
1296	8	Sensor Lot	1354271	3, 4	U/A/S	none
1304	8	Sensor Lot date	2021-03-16	3, 4	U/A/S	none
1312	8	Sensor SN	2076	3, 4	U/A/S	none
1320	8	Manufacturer part 1	HAMILTON Bonaduz	3, 4	U/A/S	none
1328	8	Manufacturer part 2	AG Switzerland	3, 4	U/A/S	none
1336	8	Sensor type	ARC TCD Sensor	3, 4	U/A/S	none
1344	8	Power supply	10 - 27V 1.5W	3, 4	U/A/S	none
1352	8	Pressure range	10..12000mbar	3, 4	U/A/S	none
1360	8	Sensor ID	1006491911-2076	3, 4	U/A/S	none
1368	8	a-length	120	3, 4	U/A/S	none
1376	8	Sensor technology state	TS2.00	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	NIR optics	3, 4	U/A/S	none

2.10.3 Free User Memory Space

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

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Example of content	Modbus function code	Read access	Write access
1536	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1544	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1552	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1560	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1568	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1576	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1584	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1592	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1600	8	Measuring Point	10064919-11-2076	3, 4, 16	U/A/S	S
1608	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1616	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1624	8	Userspace	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1632	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1640	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1648	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1656	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1664	8	ext. OEM Sensor Name	*FREE_USERSPACE*	3, 4	U/A/S	none
1672	8	ext. OEM PartNumber	*FREE_USERSPACE*	3, 4	U/A/S	none
1680	8	ext. OEM Customer 1	*FREE_USERSPACE*	3, 4	U/A/S	none
1688	8	ext. OEM Customer 2	*FREE_USERSPACE*	3, 4	U/A/S	none
1696	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1704	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1712	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1720	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1728	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1736	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1744	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none
1752	8	Userspace	*FREE_USERSPACE*	3, 4	U/A/S	none

An important register is 1600, as it is the description of the measuring point. The information of this register is to identify individual sensors.

Attention:

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

2.11 System Commands

2.11.1 Restore Factory Settings

Using register 8192 you can recall the sensor manufacturer values (interfaces, passwords etc), except the SIP and CIP data, calibration data and correlation data which remain unchanged. By sending the recall value “911”, all configuration values will be set to default.

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

3 Appendix

3.1 List of tables

3.2 List of figures

Abbreviations

AO	Analog Output Interface
AU	Absorbance Unit
CDW	Cell Dry Weight
CIP	Cleaning In Place
CoP	Correlation Point
CRC	Cyclical Redundancy Checking
IDA	Interface for distributed automation
LSB	Least Significant Bit
MC	Measurement Channel
MSB	Most Significant Bit
OD	Optical Density
PA	Parameter
PDU	Protocol Data Unit
PMC	Primary Measurement Channel
RTU	Remote Terminal Unit
SMC	Secondary Measurement Channel
SIP	Sterilization In Place
TCD	Total Cell Density
TS	Technical Support

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