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Incyte Arc Sensors

Modbus RTU
Programmer's Manual

Firmware version:
CDCUM005

Important Notice

Rev.	Revision Date	Author	Change Description
00	25.01.2019	MIH	Initial version
01	21.06.2021	MIH	Update to CDCUM002
02	02.12.2021	CS	Update to CDCUM003
03	16.02.2022	CS	Update to CDCUM004
04	27.09.23	JJ	Update to CDCUM005

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1 Modbus RTU general information

1.1 Introduction

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

1.1 Hamilton Arc Sensors: Modbus Command Structure

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

CDCUM004

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 Incyte Arc Sensors. Before reading this manual, the operating instructions of the sensors should be read and understood.

1.1.1 Modbus RTU: Definitions According to Modbus IDA

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

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

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

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

1.1.2   Command Structure

The Modbus application protocol defines a simple **P**rotocol **D**ata **U**nit (PDU) independent of the underlying communication layers:
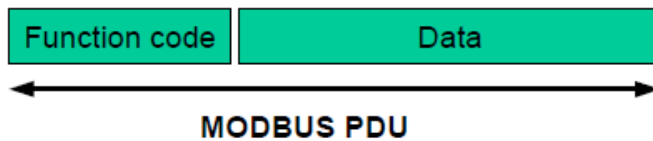
Figure 1.1.2.1: Modbus Protocol Data Unit.

The mapping of Modbus protocol on a specific bus or network introduces some additional fields on the **P**rotocol **D**ata **U**nit. The client that initiates a Modbus transaction builds the Modbus PDU, and then adds fields in order to build the appropriate communication PDU.
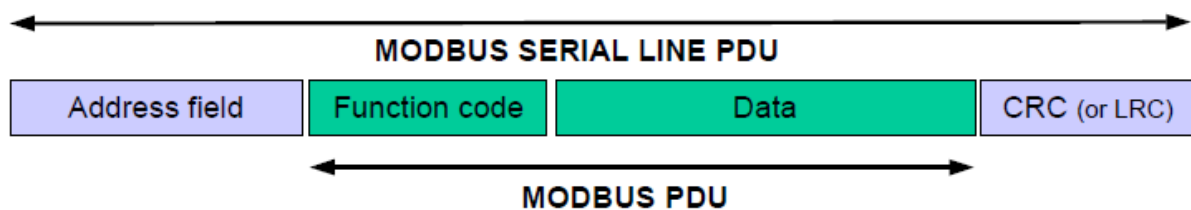
Figure 1.1.2.2: Modbus frame over Serial Line.

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

Note:
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.

1.1.3   Modbus RTU Transmission Mode

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

The format (11bits) for each byte in RTU mode is:
Coding System: 8 bit binary
Bits per Byte: 1 start bit
                        8 data bits, least significant bit sent first
                        1 bit for parity completion
                        1 stop bit

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

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

	With Parity Checking									
Start	1	2	3	4	5	6	7	8	Par	Stop
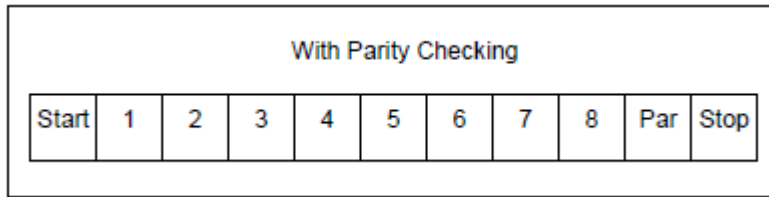
Figure 1.1.3.1: Bit sequence in RTU mode.

Frame Checking Field:
Cyclical Redundancy Checking (CRC)

Frame description:

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

Figure 1.1.3.2: RTU Message Frame.

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

1.1.4 Modbus RTU Message Framing

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

In RTU mode, message frames are separated by a silent interval of <u>at least</u> 3.5 character times.
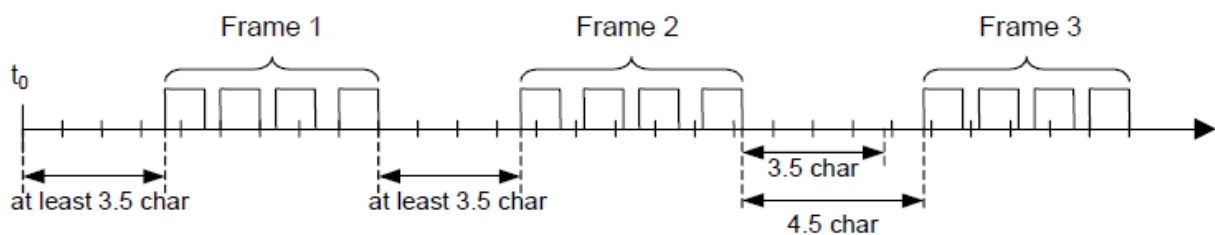
Figure 1.1.4.1: Valid frames with silent intervals.

Start	Address	Function	Data	CRC Check	End
≥ 3.5 char	8 bits	8 bits	N x 8 bits	16 bits	≥ 3.5 char
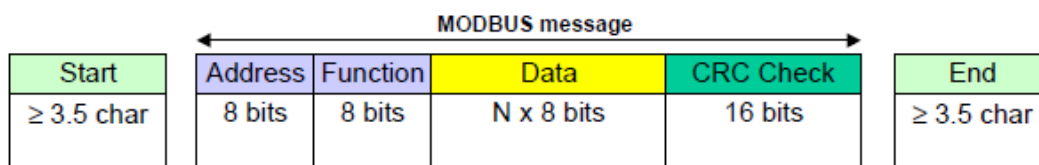
Figure 1.1.4.2: RTU Message Frame.

The entire message frame <u>must</u> be transmitted as a continuous stream of characters.

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If a silent interval of more than 1.5 character times occurs between two characters, the message frame is declared incomplete and should be discarded by the receiver.
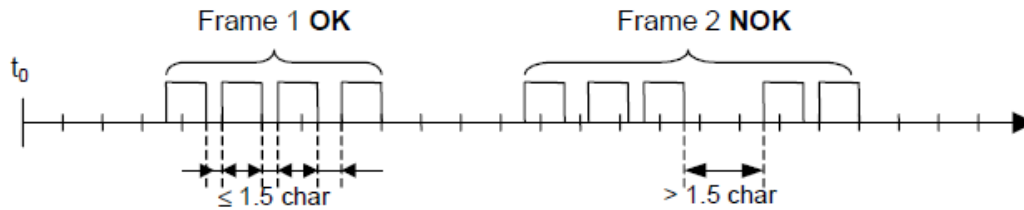
Figure 1.1.4.3: Data transmission of a frame.

1.1.5 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.

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1.2   Implementation of Modbus RTU in Hamilton Arc Sensors

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

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

Figure 1.2.1: Modbus definition for data transmission.

The RS485 interface is configured as follows:

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

Figure 1.2.2: RS485 definitions for Arc Sensors.

1.3   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).

1.3.1 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.

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Request

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

Response

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

*N = Quantity of Registers

Error

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

Figure 1.3.1.1: Definition of Holding Registers.

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

Figure 1.3.1.2: Example of reading holding registers 108 – 110. The contents of register 108 are read as the two byte values 0x022B. The contents of registers 109 – 110 are 0x00 00 and 0x0064.

1.3.2   Modbus function code #4: Read Input Registers

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

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

Request

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

Response

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

*N = Quantity of Input Registers

Error

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

Figure 1.3.2.1: Definition of Input Registers.

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

Figure 1.3.2.2: Example of reading input register 9. The contents of input register 9 are read as the two byte value 0x000A.

1.3.3 Modbus Function Code #16: Write Multiple Registers

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

Request

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

*N = Quantity of Registers

Response

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

Error

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

Figure 1.3.3.1: Definition of Write Multiple Registers.

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

Figure 1.3.3.2: Example of writing the value 0x000A and 0x0102 to two registers starting at address 2.

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1.4   Data Formats Used in Arc Sensors

1.4.1   Float

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

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

Figure 1.4.1.1: Definition Floating point Single Precision (4 bytes resp. 2 Modbus registers).

Example: translate the decimal value 62.85 into binary

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

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

…
= **0.11011001100110011001100**…

62.85 = 111110.11011001100110011001100…

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

111110**.**11011001100110011001100… *2^**0** = 1**.**11110110110011001100110011001100… *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)

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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** $_{binary}$ = $1*2^7 + 0*2^6 + 0*2^5 + 0*2^4 + 0*2^3 + 1*2^2 + 0*2^1 + 0*2^0$

$\qquad\qquad\quad$ = 128 + 0 + 0 + 0 + 0 + 4 + 0 + 0

$\qquad\qquad\quad$ = **132**

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

Step 2: Calculate the decimal value

D $\quad$ = $(-1)^S * (1.0 + M/2^{23}) * 2^{E-127}$

$\qquad$ = $(-1)^0 * (1.0 + 8087142/2^{23}) * 2^{132-127}$

$\qquad$ = 1 * 1.964062452316284 * 32

$\qquad$ = **62.85**

1.4.2 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" $\qquad\qquad\qquad$ => **0x36373032**

1.4.3 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**	

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1.5 Modbus RTU Error Messages

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

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

Figure 1.5.1: implemented Error-Codes (see "Modbus_Application_Protocol_V1.1b" for details)

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2 Incyte Arc Sensor Commands in Modbus RTU

2.1 General

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

⚠️ Attention:

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).

2.2 Operator levels and Passwords

2.2.1 Reading / Setting Operator Level

An Incyte Arc Sensor can be operated at three different operator levels. Each operator level allows a defined access to a specific set of commands.

Abbreviation	Description	Code (hex)	Password (decimal)
U	User (lowest level)	0x03	none (any value)
A	Administrator	0x0C	18111978
S	Specialist (highest level)	0x30	16021966

Table 1: Definition of operator level and default passwords

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

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

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

⚠️ Attention:

If the password is wrong, the operator level falls back to User level U. To make sure that 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 (uint)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
4292	4	Level	New password	16	None	S

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2.3   Configuration of the serial RS485 Interface

Factory settings for the RS485 interface:

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

Table 2: RS485 factory settings

2.3.1   Device Address

2.3.1.1   Reading and Writing the Device Address

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

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

The device address can be set by S (Specialist) only, 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 (uint)	Reg3 / Reg4 (uint)	Modbus function code	Read access	Write access
4098	4	Min. device address	Max. device address	3, 4	U/A/S	none

Device address limits for Incyte Arc are:
Minimal device address: 1
Maximal device address: 32

2.3.1.3   Broadcast

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

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2.3.2 Baud Rate

2.3.2.1 Reading and Writing the Baud Rate

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

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

The code for the baud rate is defined as follows:

Baud rate	19200	38400	57600	115200
Code	4	5	6	7

Table 3: Code for the baud rates

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 change immediately after the response to the write command has been sent to the master.

2.3.2.2 Reading the Baud Rate Limits

The baud rate limits can be read in register 4104.

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

The baud rate limits for Incyte Arc are:
Minimal baud rate code: 4
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)

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 change immediately after the response to the write command has been sent to the master.

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2.4 Configuration of the Analog Interfaces

Note:

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

2.4.1 Available Analog Interfaces

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

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

The number of analog interfaces is defined in register 4320.

Start register	Number of registers	Reg1 / Reg2 (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 4: 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 / 2 / 6)

Table 4: Definition of the analog interface modes

The answer is a bitwise combination (OR) of the available modes defined in Table 4: Definition of the analog interface modes
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.

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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 Table 4: Definition of the analog interface modes

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

Code (Hex)	Primary Measurement Channel (PMC)
0x01	PMC1 (VCD)
0x02	PMC2 (Conductivity)
0x20	PMC6 (Temperature)

Table 5: Code for selection of the primary measurement channel

Reading the available Primary Measurement Channels (PMC) always return the hexadecimal value of "0x23" meaning that PMC1 (VCD), PMC2 (Conductivity) or PMC6 (Temperature) can be mapped to AO1 respectively AO2.

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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 5: Code for selection of the primary measurement channel. 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 5: Code for selection of the primary measurement channel.

The factory setting for register 4364 is "0x01" mapping PMC1 to AO1.
The factory setting for register 4492 is "0x02" mapping PMC2 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

For Incyte Arc, 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.

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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 chapter 2.5.1)	3, 4	U/A/S	none
4504	2	Selected physical unit of AO2 (see chapter 2.5.1)	3, 4	U/A/S	none

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 the *Table 10 Definition of physical units.*.
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 (see 0). 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, 2154 for PMC2, 2410 for PMC6).

⚠️ Attention:
When assigning measurement values to 4-20 mA analog output by using register 4378 / 4506, you need to consider the following:
- The PMC you have mapped to AO1 / AO2 (register 4364 / 4492)
- The physical unit currently in use for the selected PMC (register 2090 for PMC1 (VCD), 2154 for PMC2 (Cond) and register 2410 for PMC6 (temperature).
- The "Cell factor VCD" (register 3114) when PMC1 is mapped to AO1 / AO2.
- The "Offset VCD" (register 3146) when PMC1 is mapped to AO1 / AO2. Offset VCD changes as soon as "Mark Zero VCD" (register 41246) is applied.

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 0x20000000 (the unit "pF/cm" is assigned to PMC1).
Register 4378 is set to 0 and 20 (4 mA = 0pF/cm, 20 mA = 20pF/cm).

The sensor reads currently a value of 5.6pF/cm, the output at the 4-20 mA accordingly is 8.48 mA. The operator now applies "Mark Zero VCD" what sets PMC1 (VCD) to zero. Therefore, the output of AO1 reduces to 4.0 mA.
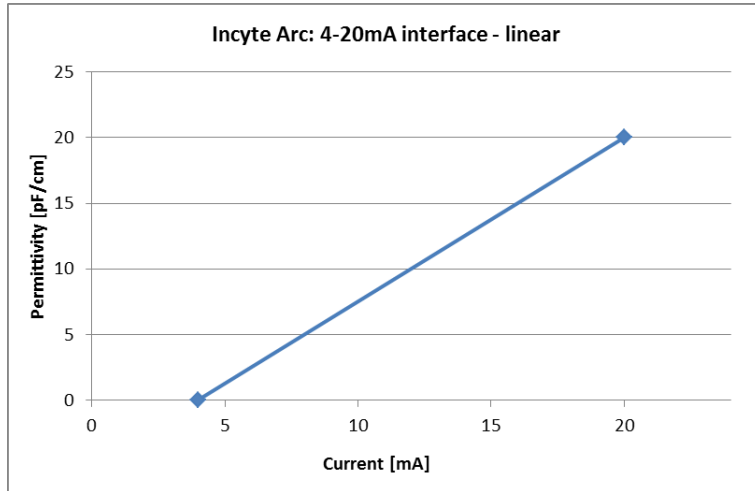

Figure 2: Example of linear 4-20mA output characteristics

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 0x01 (see 2.4.4 Selection of an Analog Interface Mode):

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

Bit #	Code (hex)	Behavior of the 4-20 mA interface in case of errors and warnings
0 (LSB)	0x000001	Error continuous output
16	0x010000	Warning continuous output

Table 6: Code for the 4-20 mA interface in case of errors and warnings

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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

Command: Error Warnings 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**

Table 7: Example: Read the settings for AO1 in case of warnings and errors.

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

For more information about warnings, errors and temperature limits, see 2.8 Sensor Status.

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:

Current outputs of Incyte Arc are provided by the Arc Wi 2G Adapter. 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 connected. This is due to compatibility to other Arc sensors.

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2.5 Measurement

ⓘ Note:

For more information about the measurement theory and the meaning of the different measurement channels see the Incyte Arc Operating Instructions (chapter: The Theory of Permittivity Measurement)

2.5.1 Definition of Measurement Channels and Physical Units

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

Bit #	Hex code	Description	Definition
0 (LSB)	**0x000001**	**PMC1**	**VCD**
1	**0x000002**	**PMC2**	**Conductivity**
2	0x000004	PMC3	not available
3	0x000008	PMC4	not available
4	0x000010	PMC5	not available
5	**0x000020**	**PMC6**	**Temperature**
6	**0x000040**	**SMC1**	**alpha**
7	**0x000080**	**SMC2**	**fc**
8	**0x000100**	**SMC3**	**delta Epsilon**
9	**0x000200**	**SMC4**	**Cole fit R2**
10	**0x000400**	**SMC5**	**Cole fit RMSE**
11	**0x000800**	**SMC6**	**Permittivity**
12	0x001000	SMC7	not available
		…	
21 (MSB)	0x200000	SMC16	not available

Table 8: Full list of PMC1 to 6 and SMC1 to 16

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

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

Example:

Command: Avail. PMC and SMC		Modbus address: **2048**	Length: **2**	Type: **3**	Read
Parameter:	Avail. PMC and SMC				
Format:	Hex				
Value:	0x0FE3				

Table 9: Example to read Reg. 2048 for Incyte Arc

In case of operator S/A/U, the value 0x0FE3 is returned. In other words, the following PMC's and SMC's are available to S/A/U: PMC1 / PMC2 / PMC6 / SMC1 / SMC2 / SMC3 / SMC4 / SMC5 / SMC6

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

Bit #	Hex code	Physical unit	Start register. (8 ASCII characters, length 4 registers, Type 3, read for U/A/S)
0 (LSB)	0x00000001	none	1920
1	0x00000002	K	1924
2	0x00000004	°C	1928
3	0x00000008	°F	1932
4	0x00000010	PCV	1936
5	0x00000020	-	1940
6	0x00000040	-	1944
7	0x00000080	-	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	-	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 10: Definition of physical units.

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

Table 11: Example to read the physical unit in plain text ASCII in register 1952

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2.5.2   Primary Measurement Channel 1 (VCD)

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 Incyte Arc is called "VCD".

In register 2088, the available physical units for this channel are defined. The available physical units for PMC1: 0xB0000110 => PCV, g/l, e6 c/ml, pF/cm and OD

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

Command: PMC1 set unit		Modbus address: **2090**	Length: **2**	Type: **16**	Write
Parameter:	Unit				
Format:	Hex				
Value:	**0x10000000**				

Table 12: Example to set the physical unit of PMC1 to e6 c/ml (0x10000000)

2.5.2.2   Reading the measurement value of PMC1

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

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

[1] Value is always in the physical unit defined in register 2090.
[2] Definition of the status see chapter 2.5.5. All bits set to zero means: no problem.

For the definition of the measurement status see chapter 2.5.5.

If no correlation model is active, the measurement value is defined as follows:

VCD = (Permittivity – Offset VCD) * Cell factor VCD

VCD	= PMC1 (Reg. 2090)
Permittivity	= SMC6 (Reg. 2632)
Offset VCD	= Reg. 3146
Cell factor VCD	= Reg. 3114

For more information about how to create and run a correlation model see the Incyte Arc Operating Instructions (Ref 10072078)

⚠ Attention:
You cannot selectively read a single register. If you want to read the measurement value, you must read the entire length of the command (10 registers) and extract the desired information.

Note:

Changing the physical unit of VCD does not affect the measurement value which is calculated according to the formula above.

2.5.3 Primary Measurement Channel 2 (Conductivity)

2.5.3.1 Definition of PMC2

Start register	Data size (registers)	Function	Data type	Modbus function code	Read access	Write access
2144	8	Description of PMC2	ASCII chars	3, 4	U/A/S	none
2152	2	Available physical units of PMC2	uint	3, 4	U/A/S	none
2154	2	Selected physical unit for PMC2	uint	16	none	S

In register 2144, a plain text ASCII description of PMC2 is given. PMC2 for Incyte Arc is called "Cond".

In register 2152, the available physical units for this channel are defined. The available physical units for PMC2: 0x00000400 => mS/cm

In register 2154, the active physical unit for this channel can be selected, by choosing one of the physical units that are defined in register 2152. For PMC2 only 0x400 (mS/cm) is available. Selecting an invalid unit code will leave the current unit unchanged.

2.5.3.2 Reading the measurement value of PMC2

Register 2154 is also used to read the measurement values of PMC2.

Start reg.	Num-ber of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (float)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (float)	Reg9 / Reg10 (float)	Modbus function code	Read access	Write access
2154	10	Selected physical unit	Measure-ment value of PMC2 [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 2152.
[2] Definition of the status see chapter 2.5.5. All bits set to zero means: no problem.

Attention:

You cannot selectively read a single register. If you want to read the measurement value, you must read the entire length of the command (10 registers) and extract the desired information.

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2.5.4 Primary Measurement Channel 6 (Temperature)

2.5.4.1 Definition of PMC6

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

In register 2400, a plain text ASCII description of PMC6 is given. PMC6 for Incyte Arc 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!

2.5.4.2 Reading the measurement value of PMC6

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

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

[1] Value is always in the physical unit defined in register 2410.
[2] For definition of the status see chapter 2.5.5. All bits set to zero means: no problem.

Command: PMC6 read		Modbus address: **2410**		Length: **10**	Type: **3**	Read
Parameter:	Unit	Value	Status	Min limit	Max limit	
Format:	Hex	Float	Hex	Float	Float	
Value:	**0x04**	**24.35834**	**0x00**	**-20**	**140**	

Table 13: Example to read register 2410
Physical unit is set to °C (0x04), PMC6 is 24.35834 °C, Status is 0x00, Min allowed value is -20 °C, Max allowed value is 140 °C.

For definition of the measurement status see chapter 2.5.5.

⚠ Attention:
You cannot selectively read a single register. If you want to read the measurement value, you have to read the entire length of the command (10 registers) and extract the desired information.

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2.5.5 Definition of the Measurement Status for PMC1 / PMC2 / PMC6

This is the definition of the status registers read in registers 2090 (PMC1), 2154 (PMC2) and 2410 (PMC6):

Bit #	Hex code	Description
none	0x00000000	Sensor OK
0 (LSB)	0x00000001	Temperature out of measurement range (see chapter 2.8.1)
1	0x00000002	Temperature out of operating range (see chapter 2.8.1)
2	0x00000004	not used
3	0x00000008	Warning not zero (see chapter 2.8.3)
4	0x00000010	Error not zero (see chapter 2.8.4)
..		
23	0x00800000	Probe cleaning in progress

Table 14: Definition of measurement status for Primary Measurement Channels

2.5.6 Secondary Measurement Channels 1-6

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

2.5.6.1 Description of SMC

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

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

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

Description	Address	Plain Text (16 ASCII)	Description
SMC1	2464	alpha	Cole-cole Parameter: alpha
SMC2	2496	fc	Cole-cole Parameter: fc
SMC3	2528	delta Epsilon	Cole-cole Parameter: delta Epsilon
SMC4	2560	Cole fit R2	R2 of the Cole-cole fitting
SMC5	2592	Cole fit RMSE	RMSE of the Cole-cole fitting
SMC6	2624	Permittivity	Permittivity

Example:

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

Table 15: Example to read the description of SMC1 at address 2464.

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2.5.6.2 Reading the measurement value of SMC

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

Start reg.	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Modbus function code	Read access	Write access
Address	6	Physical unit	Measurement value of SMC	0	3, 4	U/A/S	none

Full list of register addresses for the measurement values of SMC1 to SMC6:

Description	Address	Text	Unit	Min value	Max value
SMC1	2472	alpha	none	0	1
SMC2	2504	fc	kHz	300	5000
SMC3	2536	delta Epsilon	pF/cm		
SMC4	2568	Cole fit R2	none	0	1
SMC5	2600	Cole fit RMSE	pF/cm		
SMC6	2632	Permittivity	pF/cm		

Reg5/Reg6 has no functionality. It always returns 0. Nevertheless, all 6 registers have to be read!

Example:

Command: SMC1 read		Modbus address: **2472**		Length: **6**	Type: **3**	Read
Parameter:	Unit	Value	Reg5/Reg6.			
Format:	Hex	Float	Float			
Value:	**0x00**	**0.95**	**0**			

Table 16: Example to read register 2472

2.5.7 Reading Scan Data

2.5.7.1 Information about Frequency Scan

Register 40988 delivers information about the frequency scan.

Start reg.	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
40988	8	Nbr of frequencies	Unit frequencies	Unit permittivity	Unit conductivity	3, 4	U/A/S	none

Nbr of frequencies: Amount of frequencies that are used for one scan. This value for Incyte Arc is 17
Unit frequencies: Unit that is used for the frequencies when reading scan values. See Table 10 Definition of physical units.
Unit permittivity: Unit that is used for the permittivity when reading scan values. See Table 10 Definition of physical units.
Unit conductivity: Unit that is used for the conductivity when reading scan values. See Table 10 Definition of physical units.

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2.5.7.2 Scan Data

Start reg.	Num-ber of reg.	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Modbus function code	Read access	Write access
Address	6	Frequency	Permittivity	Conductivity	3, 4	U/A/S	none

Address	Description
40998	Scan values at frequency 0
41004	Scan values at frequency 1
41010	Scan values at frequency 2
41016	Scan values at frequency 3
41022	Scan values at frequency 4
41028	Scan values at frequency 5
41034	Scan values at frequency 6
41040	Scan values at frequency 7
41046	Scan values at frequency 8

Address	Description
41052	Scan values at frequency 9
41058	Scan values at frequency 10
41064	Scan values at frequency 11
41070	Scan values at frequency 12
41076	Scan values at frequency 13
41082	Scan values at frequency 14
41088	Scan values at frequency 15
41094	Scan values at frequency 16

With each data set (permittivity, conductivity), the corresponding frequency is given in Reg1/Reg2.

2.5.7.3 Scan Index

The Incyte Arc sensor updates the scan data every 3 seconds. To make sure, that you do not read the same data twice, there is a scan index which is incremented as soon as new data are available.

Start register	Number of registers	Reg1 to Reg2 (uint)	Modbus function code	Read access	Write access
40996	2	Scan index	3, 4	U/A/S	none

When the sensor is powered up, the scan index is initialized to 0. After reaching $2^{32}-1$, the value rolls over to 0.

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2.6 Configuration of the Measurement

This chapter describes the configuration of the PMC's and SMC's by means of measurement parameters.

2.6.1 Measure Mode

Register 41200 contains the descriptions of the measure mode as plain text ASCII:

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
41200	8	Measure mode label	3, 4	U/A/S	none

In register 41200, a plain ASCII text description of Measure mode is given.
It returns "Measure mode   ".

Register 41208 delivers the available units for the measure mode parameter:

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
41208	2	Available units for Measure mode	3, 4	U/A/S	none

For this parameter the only unit available is "none" (0x00000001).

Register 41210 allows reading or changing the current measure mode:

Start reg.	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
41210	4	Unit	Measure mode			16	none	S
	8	Unit	Measure mode	Minimal value	Maximal value	3, 4	U/A/S	none

Unit always is 0x00000001 meaning that the measure mode parameter has no unit. See Table 10 Definition of physical units. Writing a different value to Reg1/Reg2 does not have any effect.

Reg3/Reg4 represents the measure mode of the Incyte Arc sensor.

Incyte Arc Expert:
>0 = Idle
>1 = continuous single
>2 = Dual frequency measurement (default)
>3 = do not use
>4 = Frequency Scan and Dual frequency
>5 = Frequency Scan only

When reading the register, it is 8 bytes wide with an additional minimal and maximal value. They represent the numerical range for measure mode. Minimal value always is 0. for Incyte Arc Expert, the Maximal Value is 4.
Violating the measure mode limits leads to illegal data exception!

Idle: The sensor switches off the measurement and reduces the power consumption to a minimum of less than 500mW. Communication and configuration via Modbus is still possible.

Dual frequency measurement: The sensor measures Permittivity (SMC6), Conductivity (PMC2) and Temperature (PMC6). Permittivity is measured using the two frequencies (fc and fhigh) defined by the

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Cell Type Mode. Out of this value VCD (PMC1) is calculated. The correlation is given by the Cell factor (see 2.6.4 Cell Factor VCD). In this mode, the sampling rate is 1 Sample per Second.

Frequency Scan only: In this mode, the sensor is measuring a Permittivity spectrum at 17 different frequencies. For more information see 2.5.7 Reading Scan Data. Furthermore, Conductivity (PMC2), Temperature (PMC6), as well as alpha (SMC1), fc (SMC2), delta Epsilon (SMC3), R2 (SMC4) and RMSE (SMC5) are available. VCD (PMC1) and Permittivity (SMC6) will be zero. In this mode, the sampling rate is 1 Sample per 3 Seconds. Running a correlation model is possible.

Frequency Scan + Dual frequency: This is a combination of the two measure modes Frequency scan and Dual frequency measurement. Therefore, all above mentioned measurement channels are available. The sampling rate is 1 Sample per 3 Seconds. Running a correlation model is possible.

⚠ Attention:
ArcAir only uses measure mode 2 and 4. If you connect your sensor to ArcAir while mode 0 or 5 is selected, some values might be missing on the User Interface or in the log file!

ℹ Note:
For more information about the measurement theory see the Incyte Arc Operating Instructions (chapter: *The Theory of Permittivity Measurement*)
For more information about how to create a correlation model with the ArcAir Data Modeling Software see the Incyte Arc Operating Instructions (Ref 10072078)

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2.6.2 Cell Type Mode

The Incyte Arc Sensor offers 6 different Cell Type Modes which define the measurement frequencies and the filtering for the Dual Frequency Measurement Mode. Cell Type Mode 1 to 3 (Animal, Yeast and Bacteria) are fix, whereas Cell Type Mode 4 to 6 are user definable.
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 41648.

2.6.2.1 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 label	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 10 Definition of physical units. 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 10 Definition of physical units. Writing a different value to Reg1/Reg2 does not have any effect.

The Incyte Arc Sensor offers 6 Cell Type Modes represented by an index of 0 to 5. Therefore, Minimal value is 0 and Maximal value is 5. Writing an invalid index to the CTM register will leave the selection unchanged!

CTM index (Reg3/Reg4):
  0 = Cell Type Mode 1: Animal
  1 = Cell Type Mode 2: Yeast
  2 = Cell Type Mode 3: Bacteria
  3 = Cell Type Mode 4: User 1
  4 = Cell Type Mode 5: User 2
  5 = Cell Type Mode 6: User 3

Cell Type Mode 4 to 6 can be defined by the user. See 2.6.2.2 Definition of the Cell Type Modes.

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2.6.2.2 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
41648 + n * 24	8	Label (16 ASCII characters)				3, 4 / 3, 4, 16	U/A/S	none / S
41656 + n * 24	8	Index fmeas (uint)	Index fhigh (uint)	Index min (uint)	Index max (uint)	3, 4 / 3, 4, 16	U/A/S	none / S
41664 + n * 24	6	Moving avg (uint)	Moving avg min (uint)	Moving avg max (uint)		3, 4 / 3, 4, 16	U/A/S	none / S

Definition of the Cell Type Modes (n = 0..5)

The definition of Cell Type Mode 1 starts at 41648. With an offset of 24 bytes the definition of the next Cell Type Mode is following.
Cell Type Modes 1 to 3 are read only, whereas CTM 4 to 6 are writeable as well for operator level S.

In register 41648 + n *24, a plain ASCII text description of the Cell Type Mode is given:
    n=0: Cell Type Mode 1: "Animal"
    n=1: Cell Type Mode 2: "Yeast"
    n=2: Cell Type Mode 3: "Bacteria"
    n=3: Cell Type Mode 4: "User 1"
    n=4: Cell Type Mode 5: "User 2"
    n=5: Cell Type Mode 6: "User 3"

Register 41656 + n *24, define the measure frequencies (fmeas, fhigh) for the Dual Frequency Measurement Mode.
The frequencies are defined by an index:

Index	Frequency [kHz]
0	300.1
1	373.8
2	465.7
3	579.8
4	720.0
5	896.4
6	999.5
7	1117.7
8	1392.3
9	1729.3

Index	Frequency [kHz]
10	2002.7
11	2155.3
12	2689.3
13	3347.3
14	4158.0
15	5187.9
16	6446.8
17	8029.9
18	9994.5

Index min is 0, Index max is 18. Writing values out of range will automatically be corrected to within the borders.

Note:
For more information about the measurement theory and the meaning of the different frequencies see the Incyte Arc Operating Instructions (chapter: The Theory of Permittivity Measurement)

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Using moving average (register 41664 + n * 24), the short-term signal stability can be improved; on the other hand, the response time of the sensor increases with increasing moving average.
Reg1/Reg2 defines the amount of filter tabs (moving average elements). The filter time delay (response time) is defined by this number and the sampling time of the sensor which is 3 seconds. With a Minimal value of 1 and a Maximal value of 128 filter times between 3 and 384 seconds are possible.

Writing values lower than 1 or higher than 128 will automatically be corrected to the closest valid value!

⚠ <u>Attention:</u>
When changing the moving average in the cell type mode tab of ArcAir, not only the moving average of the Dual Frequency Measurement but also the moving average of the Frequency Scan Measurement (see 2.6.8) is changed. Both parameters are set to the same value.

ArcAir allows the following settings:
- None: Moving average = 1
- Low: Moving average = 32
- Medium: Moving average = 64
- High: Moving average = 128

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2.6.3 Mark Zero VCD

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

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

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 10 Definition of physical units.* 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 41228 allows setting the VCD measurement value to zero (Mark Zero) or to undo this setting (Clear Zero). Zeroing the measurement value means that the current measurement value is saved and will be subtracted from the following measurements as an offset (see 2.6.5 Offset VCD)

Unit always is 0x00000001 meaning that the Cell Type Mode parameter has no unit. See Table 10 Definition of physical units. 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 VCD (2.6.5 Offset VCD) is set to the current Permittivity value, what results in a VCD value (PMC1) of zero. Clear zero sets the offset VCD back to zero.

⚠ Attention:
Zeroing the VCD 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.

2.6.4 Cell Factor VCD

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

In register 3104, a plain ASCII text description of Cell factor VCD is given.
It returns "Cell factor VCD ".

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

Register 3112 delivers the available units for the Cell factor VCD parameter. It is coded according to Table 10 Definition of physical units.

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 Cell factor VCD.

Unit always is 0x00000001 meaning that the Cell factor VCD parameter has no unit. See Table 10 Definition of physical units. Writing a different value to Reg1/Reg2 does not have any effect.

The Cell factor VCD Value (Reg3/Reg4) defines the correlation between the measured Permittivity (SMC 6) and the VCD value (PMC1).

VCD = (Permittivity – Offset VCD) * Cell factor VCD

VCD   = PMC1 (Reg. 2090)
Permittivity   = SMC6 (Reg. 2632)
Offset VCD   = Reg. 3146
Cell factor VCD = Reg. 3114

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

⚠ <u>Attention:</u>
Changing the cell factor might have an influence on the output of AO1 / AO2 if PMC1 is mapped to one of it. All limits of the 4-20 mA current interface have to be redefined after changing the cell factor!

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2.6.5 Offset VCD

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

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

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

Register 3144 delivers the available units for the Offset VCD parameter. It is coded according to Table 10 Definition of physical units. The only available unit for this parameter is "pF/cm" (0x20000000).

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 VCD.

Unit always is 0x20000000 meaning that the Cell factor VCD parameter is in "pF/cm". See Table 10 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 VCD 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 (2.6.3 Mark Zero VCD) changes the offset value!

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2.6.6 Mark Zero Frequency Scan

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
41254	8	Mark Zero Scan label	3, 4	U/A/S	none

In register 41254, a plain ASCII text description of Mark Zero Scan is given.
It returns "Mark Zero Scan ".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
41262	2	Available units for Mark Zero Scan	3, 4	U/A/S	none

Register 41262 delivers the available units for the Mark Zero Scan parameter. It is coded according to Table 10.

Start reg.	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
41264	4	Unit	Value			16	none	S
	8	Unit	Value	Minimal value	Maximal value	3, 4	U/A/S	none

Register 41264 allows setting the Scan measurement values to zero (Mark Zero) or to undo this setting (Clear Zero). Zeroing the measurement values means that all the current measurement values (at each single frequency) are saved and will be subtracted from the following measurement values as an offset.

Unit always is 0x00000001 meaning that the Mark Zero Scan parameter has no unit. See Table 10. 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 values (2.6.7 Offset Frequency Scan) are set to the current scan values (2.5.7.2 Scan Data), what results in a spectrum with all Zeros. Clear zero sets the offset values back to zero.
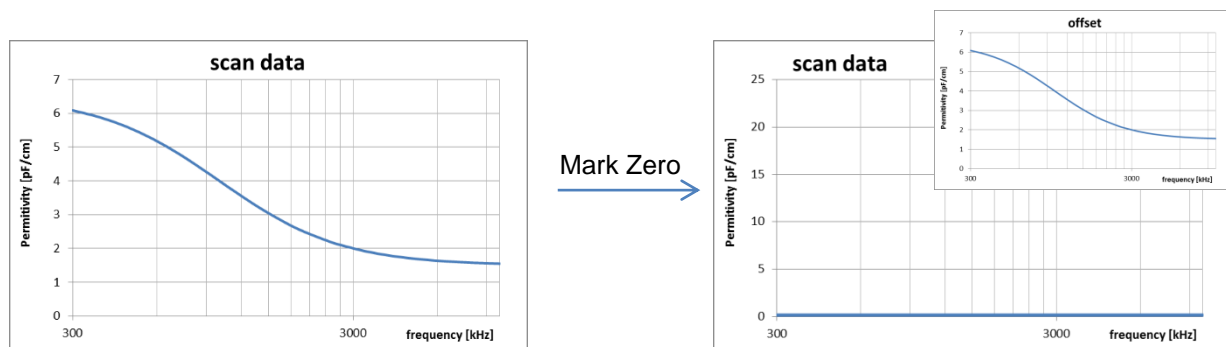

Figure 3: Effect of Mark Zero

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2.6.7 Offset Frequency Scan

Start register	Number of registers	Reg1 / Reg2 (float)	Modbus function code	Read access	Write access
41868 + 2*n	2	Permittivity offset at Frequency n	3, 4, 16	U/A/S	S

The registers starting from 41868 deliver the offset values of the frequency scan data. These values are in pF/cm and represent the permittivity at the time when Mark Zero was applied. n is in the range of 0 to 16. The corresponding frequencies can be read through the scan data registers (2.5.7.2 Scan Data)

Note: Use the Mark Zero functionality (2.6.6 Mark Zero Frequency Scan) to write the scan offset values!

2.6.8 Moving Average Frequency Scan

Start register	Number of registers	Reg1 to Reg8 16 ASCII characters	Modbus function code	Read access	Write access
41272	8	Moving average Scan label	3, 4	U/A/S	none

In register 41272, a plain ASCII text description of Moving average Scan is given.
It returns "Mov avg Scan".

Start register	Number of registers	Reg1 / Reg2 (bitwise defined)	Modbus function code	Read access	Write access
41280	2	Available units for Moving average Scan	3, 4	U/A/S	none

Register 41280 delivers the available units for the Moving average Scan parameter. It is coded according to Table 10.

Start reg.	Number of reg.	Reg1 / Reg2 (uint)	Reg3 / Reg4 (uint)	Reg5 / Reg6 (uint)	Reg7 / Reg8 (uint)	Modbus function code	Read access	Write access
41282	4	Unit	Value			16	none	S
	8	Unit	Value	Minimal value	Maximal value	3, 4	U/A/S	none

Register 41282 allows reading or changing the amount of measurement points used for the averaging of the scan data.

Unit always is 0x00000001 meaning that the Moving average Scan parameter has no unit. See Table 10. Writing a different value to Reg1/Reg2 does not have any effect.

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.
Reg3/Reg4 defines the amount of filter tabs (moving average elements). The filter time delay (response time) is defined by this number and the sampling time of the sensor which is 3 seconds. With a Minimal value of 1 and a Maximal value of 128 filter times between 3 and 384 seconds are possible.

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Moving average is applied to every single frequency of the scan data.

Writing values lower than 1 or higher than 128 will automatically be corrected to the closest valid value!

Note:
When using ArcAir, the moving average of the Frequency Scan Measurement is set to the same value than the moving average of the Dual Frequency Measurement (see 2.6.2.2). This value can be changed in the cell type mode tab of ArcAir,

ArcAir allows the following settings:
- None: Moving average = 1
- Low: Moving average = 32
- Medium: Moving average = 64
- High: Moving average = 128

2.6.9 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 10: Definition of physical units.
.

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 10: Definition of physical units.
. 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.

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The culture time (2.6.10 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.

2.6.10 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 41290, 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 10.

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 (2.6.9 Inoculate).

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

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

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2.7 Sensor Cleaning

This chapter describes the electrochemical cleaning of the electrodes and not CIP or SIP cycles. For CIP and SIP see 2.8.5 Definition of SIP and CIP.

The Incyte Arc Sensor offers auto or manual cleaning. The auto cleaning consists of periodic cleaning events. As soon as auto cleaning is activated, the cleaning event takes place periodically with the defined repetition rate. In the manual cleaning mode however, the cleaning event takes place only once as soon as it is started.

2.7.1 Defining a Cleaning Event
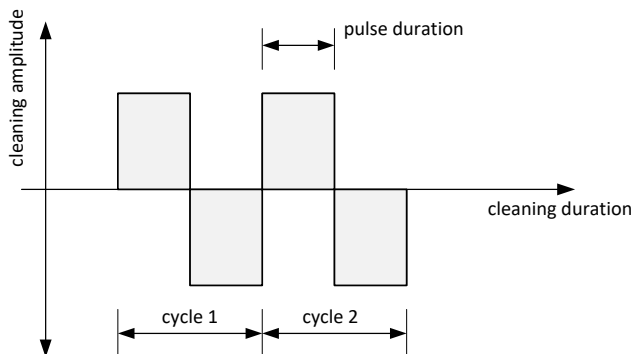
Figure 4: Definition of a cleaning event

Start Reg	Number of registers	Reg 1 + Reg 2	Reg 3 + Reg 4	Read access	Write access
41508	4	Nbr of cycles (uint)	Pulse duration [s] (uint)	U/A/S	S

i Note:

ArcAir defines a short and a long cleaning. These cleanings are defined as follows:
- short: cycles = 1, duration = 5
- long: cycles = 10, duration = 5

2.7.2 Autocleaning

Start Reg	Number of registers	Reg 1 + Reg 2	Read access	Write access
41512	2	Repetition rate [min] (uint)	U/A/S	S
41514	2	Activate autocleaning (uint)	U/A/S	S

Write a 1 to register 41514 to activate the autocleaning. Write a 0 to deactivate it.

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2.7.3 Manual Cleaning

Start Reg	Number of registers	Reg 1 + Reg 2	Read access	Write access
41516	2	Start manual cleaning cycle (uint)	none	S
41516	2	Manual cleaning status (uint)	U/A/S	none

Write a 1 to register 41516 to activate the manual cleaning event.

Reading the register 41516 delivers the cleaning status which can be as following:
      0: no action
      1: manual cleaning running
      2: cleaning not started; conductivity too low

i Note:
Cleaning status 2 (conductivity too low) stays active until the register 41516 is written again. Therefore it is possible to write a 0 to the register just to update the cleaning status.

! Attention:
A manual cleaning event cannot be deactivated or stopped!

2.8   Sensor Status

2.8.1   Temperature Ranges

In registers 4608 and 4612 two different temperature ranges are defined:
- Operation – outside of this range, the sensor should not be operated at all!
- Measurement – in this range the sensor works properly within the specification.
  Outside of this range the sensor still allows Modbus communication, but as soon as the specified temperature range (ambient and/or medium) is exceeded, the permittivity and conductivity measurement is switched off. In this case the last value of measurement will be frozen.

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

The unit of the temperatures is according to the selected unit of PMC6 (see 2.5.4.1 Definition of PMC6).

If one of this ranges is exceeded the measurement status will be set accordingly (see 2.5.5 Definition of the Measurement Status for PMC1 / PMC2 / PMC6)

For Incyte Arc the ranges are as follows:
- Operating temperature: -20 .. +140°C
- Measurement temperature: 0 .. +60°C

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2.8.2 Operating Hours, Counters and System Time

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

In register 4676 are stored:
- total operating hours
- operating hours above max measurement temperature (see chapter 2.8.1)
- the operating hours above max operating temperature (see chapter 2.8.1)

In register 4682 are stored:
- number of power ups
- number of watchdog resets
- Heartbeat: counts repetitively from 0 to 19 in a 1 second cycle.

In register 4688 are stored:
- number of sterilizations in place (SIP) (see chapter 2.8.5)
- number of cleanings in place (CIP) (see chapter 2.8.5)

In register 4692 is stored:
- number of autoclavings.

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

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

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2.8.3 Warnings

A "Warning" is a notification message which still allows further functioning of the system. This message alerts the operator of a possible problem that could lead to uncertain results.
It is reported by the PMC (2.5.5 Definition of the Measurement Status for PMC1 / PMC2 / PMC6) if a warning is active or not. Therefore, it is not necessary to poll the Warnings register!

2.8.3.1 Currently Active Warnings

The currently active warnings are stored in register 4736. For the definition of the warnings see 2.8.3.2.

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

2.8.3.2 Definition of Warnings

Bit #	Hex	Description
none	0x00000000	OK
5	0x00000020	Out of calibration range: lower limit
6	0x00000040	Out of calibration range: upper limit
8	0x00000100	SNR too high
12	0x00001000	Measurement off, because of over temperature
13	0x00002000	Measurement off, because of too weak power supply
22	0x00400000	Scan fitting poor input data (R2)
25	0x02000000	T below lower limit
26	0x04000000	T above upper limit
28	0x10000000	Too many sterilization cycles

Table 17: Definition of warnings "measurement".

Bit #	Hex	Description
		not available

Table 18: Definition of warnings "calibration". None is defined.

Bit #	Hex	Description
		not available

Table 19: Definition of warnings "interface". None is defined.

Bit #	Hex	Description
none	0x00000000	OK
0	0x00000001	Sensor supply voltage too low
1	0x00000002	Sensor supply voltage too high
21	0x00200000	Recording memory full

Table 20: Definition of warnings "hardware".

2.8.4 Errors

An "Error" message indicates a serious problem of the sensor which does not allow further proper functioning of the sensor. This problem must be solved.
It is reported by the PMC (2.5.5 Definition of the Measurement Status for PMC1 / PMC2 / PMC6) if an error is active or not. Therefore, it is not necessary to poll the Errors register!

2.8.4.1 Currently Active Errors

The currently active errors are stored in register 4800. For the definition of the errors see chapter 2.8.4.2.

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

2.8.4.2 Definition of Errors

Bit #	Hex	Description
none	0x0000000	OK
25	0x2000000	Temperature sensor defective

Table 21: Definition of errors "measurement".

Bit #	Hex	Description
		not available

Table 22: Definition of errors "calibration". None is defined.

Bit #	Hex	Description
		not available

Table 23: Definition of errors "interface". None is defined.

Bit #	Hex	Description
none	0x0000000	OK
2	0x0000004	Temperature reading far below min
3	0x0000008	Temperature reading far below max
22	0x0040000	Internal error (I2C, EEPROM)
24	0x0100000	Internal error (I2C)
25	0x0200000	Internal error (Sync error)
26	0x0400000	Internal error (Stack overflow)

Table 24: Definition of errors "hardware".

If an internal error occurs, reset the sensor and try again.

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2.8.5 Definition of SIP and CIP

Incyte Arc Sensors are counting special cleaning events such as sterilizations or cleaning cycles by means of tracking typical temperature profiles (see chapter 2.8.2).

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

CIP temperature min: 80 °C   CIP temperature max: 100 °C   CIP time min: 30 minutes
SIP temperature min: 120 °C   SIP temperature max: 140 °C   SIP time min: 30 minutes
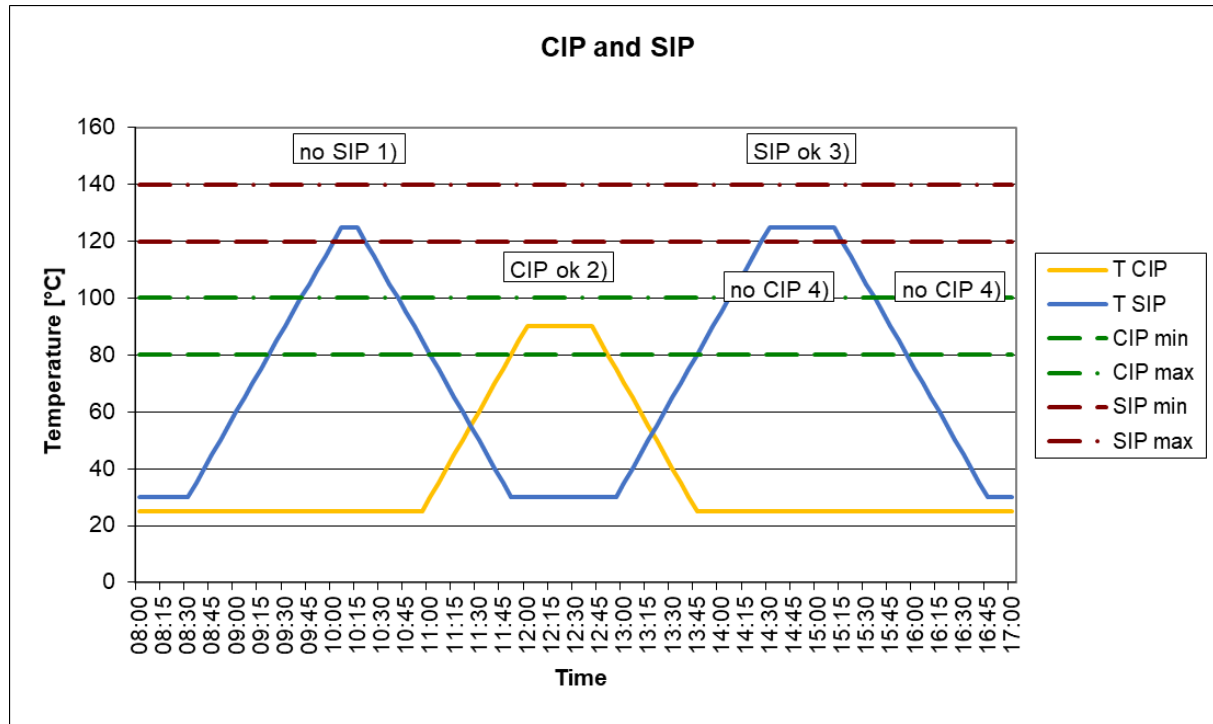
Figure 5: Definition of CIP and SIP cycles
   1) no SIP-cycle counted, because time too short <30 minutes.
   2) CIP-cycle counted, because time >30 minutes and in CIP temperature range.
   3) SIP-cycle counted, because time >30 minutes and in SIP temperature range.
   4) no CIP-cycle counted, because of reaching the SIP-min limit.

Start register	Number of registers	Reg1 / Reg2 (float)	Reg3 / Reg4 (float)	Reg5 / Reg6 (float)	Reg7 / Reg8	Modbus function code	Read access	Write access
4988	8	SIP Temperature min	SIP Temperature max	SIP Process time min [min]	Empty	3, 4	U/A/S	S
4996	8	CIP Temperature min	CIP Temperature 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 2.5.4.1 Definition of PMC6).

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2.8.6 Reading the Sensor's Quality Indicator

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

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

The sensor's quality indicator is influenced by:
- Conductivity
- Warnings
- Errors

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2.9   Sensor Identification and Information

2.9.1   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	FW Date	2022-02-16	3, 4	U/A/S	none
1032	8	FW	CDCUM005	3, 4	U/A/S	none
1040	8	BL Date	2017-09-18	3, 4	U/A/S	none
1048	8	BL	BL5UX001	3, 4	U/A/S	none
1056	8	Userend PN	243892/00	3, 4	U/A/S	none
1064	8	Userend SN	1234	3, 4	U/A/S	none
1072	8	not available	not available	3, 4	U/A/S	none
1080	8	not available	not available	3, 4	U/A/S	none
1088	8	not available	not available	3, 4	U/A/S	none
1096	8	not available	not available	3, 4	U/A/S	none
1104	8	not available	not available	3, 4	U/A/S	none
1112	8	not available	not available	3, 4	U/A/S	none
1120	8	not available	not available	3, 4	U/A/S	none
1128	8	not available	not available	3, 4	U/A/S	none
1136	8	not available	not available	3, 4	U/A/S	none
1144	8	not available	not available	3, 4	U/A/S	none

Due to compatibility reason to other ARC sensors, register 1088 – 1144 are readable. They return ASCII "not available" and have no further meaning.

2.9.2   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	243950/00	3, 4	U/A/S	none
1288	8	Sensor name	Incyte	3, 4	U/A/S	none
1296	8	Sensor Lot	3214567	3, 4	U/A/S	none
1304	8	Sensor Lot date	2010-04-30	3, 4	U/A/S	none
1312	8	Sensor SN	0001001	3, 4	U/A/S	none
1320	8	Manufacturer part 1	HAMILTON Bonaduz	3, 4	U/A/S	none
1328	8	Manufacturer part 2	AG Switzerland	3, 4	U/A/S	none
1336	8	Sensor type	Arc CDC Sensor	3, 4	U/A/S	none
1344	8	Power supply	22-26V 1.5W	3, 4	U/A/S	none
1352	8	Pressure range	0 ... 12 bar	3, 4	U/A/S	none
1360	8	Sensor ID	243950-0001001	3, 4	U/A/S	none
1368	8	a-length	120	3, 4	U/A/S	none
1376	8	(space holder)	not available	3, 4	U/A/S	none
1384	8	Electrical connection	VP 8.0	3, 4	U/A/S	none
1392	8	Process connection	PG 13.5	3, 4	U/A/S	none
1400	8	Sensing material	Pt	3, 4	U/A/S	none

2.9.3 Free User Memory Space

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

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Example of content	Modbus function code	Read access	Write access
1536	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1544	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1552	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1560	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1568	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1576	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1584	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1592	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1600	8	Measuring point	243950-0001001	3, 4, 16	U/A/S	S
1608	8	Free user space S	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1616	8	Free user space S	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1624	8	Free user space S	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1632	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1640	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1648	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1656	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1664	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1672	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1680	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1688	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1696	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1704	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1712	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1720	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1728	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1736	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1744	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1752	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none

An important register is 1600, as it is the description of the measuring point. This information is used by ArcAir in order 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.

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2.10 System Commands

2.10.1 Restore Factory Settings

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

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

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3 Appendix

3.1 List of tables

3.2 List of figures

3.3 Abbreviations

A   Operator level: Administrator
AO   Analog Output Interface
PMC   Primary Measurement Channel
S   Operator level: Specialist (highest level)
SMC   Secondary Measurement Channel
U   Operator level: User (lowest level)
VCD   Viable Cell Density

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