Application Solutions

M80 SM Transmitter

Modbus Programmers Guide

Disclaimer:

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Despite careful checking of this manual, it is possible that an error has persisted.
We therefore kindly ask you to inform us if you find something that is at fault, so that we can correct future editions.

METTLER TOLEDO

Content

1 Project Introduction

1.1 Scope

This document describes the software specifications for the M80 SM transmitter.

1.2 Project description

M80 SM is a single-channel transmitter with Modbus interface. It supports METTLER TOLEDO 1-wire (1W) ISM® (Intelligent Sensor Management) pH, CO_2, dissolved oxygen (DO) and conductivity sensors including their measurement, calibration, and diagnostics routines.

Sensor diagnostics information includes:

DLI – Dynamic Lifetime Indicator

ACT – Adaptive Calibration Timer

TTM – Time to Maintenance

CIP (Cleaning in Place), SIP (Sterilization in Place) and Autoclaving counters

2 General Modbus Information

2.1 Documentation of the Modbus protocol

For detailed information about Modbus specifications, please refer to the following documents:
– Modbus_over_serial_line_V1_02.pdf
– Modbus_Application_Protocol_V1_1b3.pdf
These documents are available on the Modbus website: www.modbus.org
Go to tab "Technical Resources".

2.2 Modbus testing tool

On the web, there are plenty of Modbus testing tools or Modbus libraries available for C++, Python or other programming languages.
For manually accessing the M80 SM over Modbus (for instance, to predefine the Modbus address, baud rate or other items) the tool "Modbus Poll" is a feasible choice. It can be purchased at www.modbustools.com.

Alternatively for this purpose, use the METTLER TOLEDO Transmitter Configuration Box, part number 30 530 567. This is a device for connecting M80 SM transmitters to a PC / laptop running METTLER TOLEDO M80 Transmitter Configuration Tool (TCT) software. The software is available on www.mt.com/M80

Please note:
Within using "Modbus Poll", to avoid communication errors it is very important to use a delay time of at least 50ms between messages on Modbus.

There is another popular and widely used open source software for communication with Modbus devices: pre-compiled binary for Windows. No installation is required, just unzip and run. It can be downloaded from https://sourceforge.net/projects/qmodmaster/

Important:
Please note all rights and obligations for the use of open source software and read the license terms carefully before you agree.

To easily connect the M80 SM transmitter to a PC, METTLER TOLEDO offers a USB to RS485 converter. Its order number is 52 300 399.

2.3 Protocol definitions, as implemented in M80 SM

Modbus mode:	RTU
Start bits:	1
Data bits:	8
Stop bits:	1
Parity:	None
Baud rate:	4800, 9600, 19200, 38400 (default), 57600, 115200
Device address:	1 (default) to 247

The device does not implement any line polarization nor any line termination.
External line polarization and line termination is required.
Please note: The max response time for M80 SM is 500ms.

2.4 Modbus RTU function codes implemented in M80 SM

Function Code	Detail
#3	Read Holding Registers
#4	Read Input Registers
#6	Write Single Register
#16	Write Multiple Registers

For detailed description of these functions, please consult the document "Modbus_Application_Protocol_V1_1b3.pdf".
With the M80 SM, reading any register is performed by either command #3 or #4.
There is no difference in handling the information between these two commands.

2.5 Data representation

Each Modbus register contains two bytes, the data length of a command and an answer is always a multiple of two registers.
The high byte (first byte) of a register contains the last digit of a value or string, the first digit of a value or string is found on the low byte (second byte) of the last register of the register chain.
The first byte of a register always contains the higher order bits, the second byte contains the lower order bits.

Decimal values:
Integer decimal values are translated to hexadecimal numbers.
Non-integer decimal values are represented as single precision float values.
See below for examples.

For integer 16 bit values:

Example: A 16-bit value of 22'354.	
Converted to hex: 5752	
First register: Value (bytes 1, 2): 0x5752	

When using Modbus Poll select "Signed/Unsigned" to correctly interpret values.

For integer 32 bit values:
Example: A 32-bit value of 12'345'678.
Converted to hex: BC614E
First register: Higher bytes of the value (bytes 1, 2): 0x00BC
Second register: Lower bytes of the value (bytes 3, 4): 0x614E
When using Modbus Poll select "Long ABCD" to correctly interpret long values.

For float values:
The mantissa of the value is stored on the second register, its exponent in the first register.
The float data format is implemented according to IEEE754, single precision.
Example: 2.5, converted to a 32-bit float value → (Hex value 0x40200000).
First register: 0x4020
Second register: 0x0000
When using Modbus Poll select "float ABCD" to correctly interpret float values.

For ASCII-text strings:
Same data order as for integer values.
Example: Text sample: "Text". ASCII-code is: 0x54 0x65 0x78 0x74
First register: 0x5465
Second register: 0x7874

Additional information
Our usual transfer mode for Modbus is Big-Endian.

2.6 Addressing scheme

The addressing scheme of M80 SM is "Base 0" (first register number is 0).
A register offset is available on register number 0000.
Using this register offset, you can adjust the absolute starting point of the register bank to fit, for example, already existing implementations.
The register offset is unsigned with a range of 0…65535.
For instance, by setting the offset to 1, the sensor becomes "Base 1".
By default, the register offset is set to 0, thus the first user register is on number 100.

Please note: The register offset is always found on register number 0000, independent of its value. The offset affects only register numbers 0001 and up.

The register numbers given on the following pages are always relative numbers.
The absolute number of a register is calculated by adding the register offset to the relative address.

Examples:
If register offset is 999, the device address shall be read:
Relative register number of device address is 3096.
The effective absolute register number to be transmitted in the command is 4095.

2.7 Error handling

Transmission errors (corrupt telegrams) are detected by the M80 SM. Corrupt telegrams are discarded and the sensor waits for the next, correct telegram.
Errors on application layer are answered with an error message. If the answer consists of an error code, the leading bit (0x80) of the function code is set, signaling the error condition.

The following error codes are implemented in the M80 SM:

Error code in hex	Error type
0x00	No error
0x01	Illegal function code was sent to the sensor
0x02	Illegal data address (invalid register number, access denied)
0x03	Illegal data value (value out of range)
0x04	Slave device error (operation not successfully completed)
0x05	(Reserved)
0x06	Server device busy

Please note:
For single register read and write (function code #3, #4, #6), error code propriety is 0x01 > 0x02 > 0x04 > 0x06 > 0x03.
For multi-registers read and write (function code #3, #4, #16), transmitter will check each register by sequence (from small address to big address), if one of the registers encounter an error (error code priority is same as single register), the error code will be returned, and the other registers will not be checked.

2.7.1 Error code 0x01

Error code 0x01 is returned when a function code other than #3, #4, #6, #16 is sent to the sensor.

2.7.2 Error code 0x02

Error code 0x02 is returned in the following cases:

– Any attempts to send undefined registers
– Any attempts to send registers on a higher operator level then actually selected (access denied)
– When read or write registers when user level is "-".
– When data in written registers is less than or more than the required length, error code 0x02 will be returned. (See command request format in Chapter 2.8)

When writing multiple registers in one command (e.g. command #16), if one of the above four situations happen, then none of these registers will be changed.

2.7.3 Error code 0x03

Error code 0x03 is returned in the following cases:

– When writing invalid data to a register. Invalid data means any value out of the range of the specific register (value below or above limits, value not part of a list of possible values).
In such cases, the last valid data is restored on the specific Modbus register and no change is active.

– When parameter is set without the proper sensor type, such as:
1) When the DO sensor parameter (Polarization Voltage, Register 370) is set when the current sensor type is pH (register 336 is 0x0100)
2) When ISM Setup Autoclave Counter Max (register 1008) is set when current sensor type is Cond (register 336 is 0x0103)

When writing multiple registers in one command (e.g. command #16), if one of the above two situations happen, then none of these registers will be changed.

– When reading registers over 125 (>125 register numbers).
See following response command format: total data of all registers have 251 bytes, so max register numbers can be read is 251 / 2 = 125.

– When writing registers over 120 (>120 register numbers).
See following request command format: total data of all registers have 247 bytes, so max register number that can be written is 247 / 2 = 123. For reservation, the data length is limited to 120.

– If value of Register 2004 "Cal Control" is not set correctly during a calibration, then error code 0x03 (illegal data value) is returned. For example, if a calibration has already started and "Cal Control" is set to <start> again, then error code 0x03 is returned.

– If sensor is disconnected or wrong sensor is connected, then attempt to write any value to "Cal Control", the error code 0x03 is returned.

2.7.4 Error code 0x04

Error code 0x04 is typically returned when:
– Trying to log-in to a user level with a wrong password or to a non-existent user level. In these cases, the log-in fails and the operation is not successfully completed.
– Read or write registers when user level is "**" with EEPROM locked.

2.7.5 Error code 0x05

Currently not used.

2.7.6 Error code 0x06

Error code 0x06 is returned in following case:
– During a calibration, if any of Registers 2000 to 2054 (except Register 2004) are written.

Read operation of all registers works during a calibration.

2.8 Modbus frame

The following are communication examples of different Modbus frames.
For all communication examples, default values are assumed.
Slave address (Reg 3096) = 1, register Offset (Reg 0) = 0

Example 1:
Read holding Registers with Function Code 3_{dec} – query the values from register 280_{dec} within the following 8_{dec} registers, which is the part number of the M80 transmitter.

Request								
Nb of Bytes	1	1	2		2		2	
Field	Slave address	Function code	Start Address Hi	Start Address Lo	Count Hi	Count Lo	CRC16 Lo	CRC16 Hi
Hex Values	01	03	01	18	00	08	C5	F7

Response						
Nb of Bytes	1	1	1	16	2	
Field	Slave address	Function code	Number of Data bytes	Data	CRC16 Lo	CRC16 Hi
Hex Values	01	03	10	33 30 35 33 30 35 36 36 20 20 20 20 20 20 20 20	77	0C

Example:
Request: 0x 01 03 01 18 00 08 C5 F7
Response 0x 01 03 33 30 35 33 30 35 36 36 20 20 20 20 20 20 20 20 77 0C
Data as string "30530566"

Example 2:
Read holding Registers with Function Code 3_{dec} – query the values from register 320_{dec} within the following 8_{dec} registers, which is the manufacturer of the M80 transmitter.

Request								
Nb of Bytes	1	1	2		2		2	
Field	Slave address	Function code	Start Address Hi	Start Address Lo	Count Hi	Count Lo	CRC16 Lo	CRC16 Hi
Hex Values	01	03	01	40	00	08	44	24

Response						
Nb of Bytes	1	1	1	16	2	
Field	Slave address	Function code	Number of Data bytes	Data	CRC16 Lo	CRC16 Hi
Hex Values	01	03	10	4D 45 54 54 4C 45 52 20 54 4F 4C 45 44 4F 20 20	25	D0

Example:
Request: 0x 01 03 01 18 00 08 C5
Response 0x 01 03 33 30 35 33 30 35 36 36 20 20 20 20 20 20 20 20 77 0C
Data as string "METTLER TOLEDO"

Example 3:
Write multiple registers with Function Code 16_{dec} – to register starting from 3999_{dec} within the following 1_{dec} registers, data is 22354_{dec} (0x5752) which will unlock the EEPROM.

Request							
Nb of Bytes	1	1	2		2		1
Field	Slave address	Function code	Start Address Hi	Start Address Lo	Count Hi	Count Lo	Number of Data bytes
Hex Values	01	03	0F	9F	00	01	02

Request			
Nb of Bytes	2	2	
Field	Data	CRC16 Lo	CRC16 Hi
Hex Values	57 52	FB	32

Response								
Nb of Bytes	1	1	2		2		2	
Field	Slave address	Function code	Start Address Hi	Start Address Lo	Count Hi	Count Lo	CRC16 Lo	CRC16 Hi
Hex Values	01	10	0F	9F	00	01	32	F3

Example:
Request: 0x 01 10 0F 9F 00 01 02 57 52 FB 32
Response 0x 01 10 0F 9F 00 01 32 F3

Please note:
For calculating the 16 bit checksum, known as CRC16, you may find a lot examples on the Internet. There is even sample code in C/C++ or various other languages.

As can be seen in the examples above, the byte order of the checksum is opposite to that of the fields. The checksum is transferred as little-endian.

Every Modbus frame containing data has a leading field in front of the data, which represents the size of the data field in bytes. This can be seen in:
- Example 2 Response (Number of Data bytes 0x10 = 16_{dec})
- Example 3 Request (Number of Data bytes 0x02 = 2_{dec})

2.9 User levels, password protection

M80 SM transmitters have three user levels: 0, 1 and 2.
Reading registers is possible on any user level, except some specific registers used for calibration.
Writing registers of the sensor typically means changing the configuration, which also changes the behavior of the transmitter. To prevent of any unwanted configuration changes, most writing attempts are possible only on user level 2.
For all user levels, default passwords are stored in the transmitter. These passwords can be changed by the user. Changed passwords are stored in the non-volatile memory of the sensor.

User levels and default passwords of M80 SM transmitter:

User level	Code in hex	Default password in hex
0	0x03	0x00000000
1	0x0C	0x01145DEA
2	0x30	0x00F479CE

- After each power-up, the M80 SM is reset to user level 0.
- When trying to change the user level to an invalid level or using a wrong password, the sensor remains on the last valid user level, and error code 0x04 is returned.
- User level 2 can operate all registers with user level 1.
- If user level is "-", that means the register cannot be read or written. If there are read or write attempts to the register, then error code 0x02 will be returned.

Important: If a default password is changed by a user, and the new password is lost/forgotten – the transmitter may become unusable.

2.10 Writing registers, data retention

In nearly all cases, writing any registers of the M80 SM means changing the configuration of the sensor. Configuration data are stored in the non-volatile memory (EEPROM) of the sensor; therefore, the changed configuration will not get lost by a power-down of M80 SM.

2.10.1 EEPROM lock

Each time when the transmitter is being powered up, the value of register 3999 is 0, which means the EEPROM is always locked.
For persistent change of registers, M80 SM EEPROM has to be unlocked first.
To unlock M80 SM, write 0x5752 to register 3999. Otherwise, changed values will be lost after the next power cycle.
To lock M80 SM, write any values except 0x5752 to register 3999.

Note: An unlocked EEPROM becomes automatically locked after 2 minutes, and the value in register 3999 will be reset to 0. In addition, any value changed in register 3999 will be reset to 0 after 2 minutes.

2.10.2 EEPROM state

There are three EEPROM states for each registers:
- A user level (0 ~ 2) with a "*", means the register value can be changed without EEPROM unlocking, the change is volatile and the change will be lost by a power-down of M80 SM.
- A user level (0 ~ 2) with a "**", means register value changes cannot be changed without EEPROM unlocking.
- A user level (0 ~ 2) without "*" and "**", means the register value cannot be stored in EEPROM and the change will be lost by a power-down of M80 SM. For example: The Salinity (register 341) and Process Pressure (register 340) are not written into the EEPROM.

2.10.3 EEPROM write cycles

Important:
The number of write cycles to an EEPROM is limited. Please make sure that you **do not** permanently use automatic write accesses to the EEPROM. The critical number of write cycles is above 500,000.

3 General Information about M80 Transmitter

The M80 SM transmitter can be used with various types of ISM sensor.

To be able to operate the M80 SM properly, it must be set to the appropriate probe.
The following probes can be used with the M80 SM:

- pH – e.g. InPro 325Xi / InPro 3100i
- CO_2 – InPro 5000i
- DO – InPro 6850i
- Conductivity – InPro 7100i

The M80 offers four measuring channels (registers 100…106), which can be occupied with the various measuring values or metadata of the probes.

In order to achieve this, the correct probe type must be set first.
This is done by setting the appropriate sensor type in register 336. See table in Chapter 4.2 Sensor types for more details.

To setup a new sensor, several steps are necessary. Please see the examples at the end of this document, in Chapter 6. Setting up the M80 SM.

After changing the sensor type in the transmitter, the four possible measuring channels are assigned by default settings, matching the selected sensor type.
For the freedom of customization, the measuring channels can be assigned to other values. For example, to frequently read special metadata of the sensors.
Registers 120 –126 may be adapted for this purpose. See Chapter Measuring Channel Units for more details.

Please make sure that the Calibration Unit in Register 2010 is also configured according to the sensor type you have selected. See table Calibration Units for more details.

4 Implemented Modbus Registers in M80 SM

4.1 M80 SM Modbus register

Except register 0000, all register addresses are relative to the offset stored in register 0000.

Example:
Register offset is set to 999. Register 3288 shall be read.
The controller must read from register 4287. Default register offset is 0.

Explanation of data types:

Data type	Description	Range
uChar8	Unsigned char 8 bit	0 255
uInt16	Unsigned integer 16 bit	0 65535
Int16	Signed integer 16 bit	–32768 32767
uInt32	Unsigned integer 32 bit	0 4294967295
Float32	Signed floating point number	3.4E-38 3.4E+38
String	ASCII encoded byte array	–

Registers sorted in ascending register number order:

Register			Access Levels			For Writable Register			Comments
Start Register	Name	Count	Read	Write	Type	Min Value	Max Value	Default Value	
0000 fix	Register Offset	1	0	2	uInt 16bit	0	65535	0	See 5.2 Modbus register offset
32	User End Firmware Version	8	0	–	String	N/A	N/A	N/A	See 4.4 User end firmware version
Measuring Value Page of attached Sensor									
98	Flag Sensor Disconnected	1	0	–	uChar 8bit	N/A	N/A	N/A	See 5.7 Diagnostic value page
99	Flag Wrong Sensor	1	0	–	uChar 8bit	N/A	N/A	N/A	
100	Primary Measuring Channel	2	0	–	Float 32bit	N/A	N/A	N/A	See 5.4.1 Measurement channel registers
102	Secondary Measuring Channel	2	0	–	Float 32bit	N/A	N/A	N/A	
104	Tertiary Measuring Channel	2	0	–	Float 32bit	N/A	N/A	N/A	
106	Quaternary Measuring Channel	2	0	–	Float 32bit	N/A	N/A	N/A	
120	Primary Measuring Channel Unit	2	0	0*	uInt 32bit	See Table 4.3 Measuring channel units		0x00010006	See Table 4.3 Measuring channel units Also see 5.4.2 Measuring channel unit registers
122	Secondary Measuring Channel Unit	2	0	0*	uInt 32bit			0x00010003	
124	Tertiary Measuring Channel Unit	2	0	0*	uInt 32bit			0x00010000	
126	Quaternary Measuring Channel Unit	2	0	0*	uInt 32bit			0x00010002	
128	Calibration Measuring Value	2	0	–	Float 32bit	N/A	N/A	NaN	See 5.4.1 Measurement channel registers
130	Calibration Unit	2	0	–	uInt 32bit	N/A	N/A	0x00010006	
Diagnostics Value Page									
200	DLI	2	0	–	Float 32bit	N/A	N/A	N/A	See 5.7 Diagnostic value page
202	ACT	2	0	–	Float 32bit	N/A	N/A	N/A	
204	TTM	2	0	–	Float 32bit	N/A	N/A	N/A	
206	CIP	1	0	–	uInt 16bit	N/A	N/A	N/A	
207	Reserved for CIP	1	0	–	uChar 8bit	0	0	0	Value is fixed to 0
208	SIP	1	0	–	uInt 16bit	N/A	N/A	N/A	See 5.7 Diagnostic value page
209	Reserved for SIP	1	0	–	uChar 8bit	0	0	0	Value is fixed to 0
210	Autoclave Counter	1	0	–	uInt 16bit	N/A	N/A	N/A	See 5.7 Diagnostic value page

Register			Access Levels			For Writable Register			Comments
Start Register	Name	Count	Read	Write	Type	Min Value	Max Value	Default Value	
218	Flag Sensor Disconnected	1	0	–	uChar 8bit	N/A	N/A	N/A	See 5.7 Diagnostic value page
219	Flag Wrong Sensor	1	0	–	uChar 8bit	N/A	N/A	N/A	
M80 SM Transmitter Information Page									
280	Part Number	8	0	–	String	N/A	N/A	"30530566"	See 5.5 Transmitter & sensor information page
312	Serial Number	8	0	–	String	N/A	N/A	N/A	See 5.5 Transmitter & sensor information page
320	Manufacturer	8	0	–	String	N/A	N/A	"METTLER TOLEDO"	
336	Sensor Type	1	0	1**	uInt 16bit	–	–	0x0100	See 4.2 Sensor type
M80 SM Sensor Parameter Page									
340	Process Pressure	1	0	1	uInt 16bit	0	O2: 16000 CO2: 9999	1013	See 5.6 Sensor parameter
341	Salinity	1	0	1/-	uInt 16bit	0	99	0	
– DO Sensor									
370	Polarization Voltage	1	0	1**	Int 16bit	–1652	1669	–674	See 5.6.1 DO sensor
Sensor Info (1)									
380	Article Number	4	0	–	String	N/A	N/A	""	See 5.5 Transmitter & sensor information page

Register			Access Levels			For Writable Register			Comments
Start Register	Name	Count	Read	Write	Type	Min Value	Max Value	Default Value	
– Cond Sensor									
390	Compensation Mode P (for Primary Measuring Channel)	1	0	1**	uChar 8bit	0x00	0x03	0x01	See 5.6.2 Cond sensor
391	Compensation Mode S (for Secondary Measuring Channel)	1	0	1**	uChar 8bit	0x00	0x03	0x01	
392	Compensation Mode T (for Tertiary Measuring Channel)	1	0	1**	uChar 8bit	0x00	0x03	0x01	
393	Compensation Mode Q (for Quaternary Measuring Channel)	1	0	1**	uChar 8bit	0x00	0x03	0x01	
394	Coefficient P (for Primary Measuring Channel)	2	0	1**	Float 32bit	0	9.99	2.0	
396	Coefficient S (for Secondary Measuring Channel)	2	0	1**	Float 32bit	0	9.99	2.0	
398	Coefficient T (for Tertiary Measuring Channel)	2	0	1**	Float 32bit	0	9.99	2.0	
400	Coefficient Q (for Quaternary Measuring Channel)	2	0	1**	Float 32bit	0	9.99	2.0	
Sensor Info (2)									
412	Serial Number	4	0	–	String	N/A	N/A	""	See 5.5 Transmitter & sensor information page
436	Sensor Name	8	0	–	String	N/A	N/A	""	See 5.5 Transmitter & sensor information page
444	Firmware Version	9	0	–	String	N/A	N/A	""	
Diagnostics Setup Page									
1000	ISM Setup CIP Counter Max	1	0	1**	uChar 8bit	0	254	100	See 5.8.1 Diagnostic reg
1002	ISM Setup CIP Temperature	1	0	1**	uChar 8bit	30	100	55	See 5.8.1 Diagnostic reg
1004	ISM Setup SIP Counter Max	1	0	1**	uChar 8bit	0	254	100	See 5.8.1 Diagnostic reg
1006	ISM Setup SIP Temperature	1	0	1**	uChar 8bit	90	130	115	See 5.8.1 Diagnostic reg

Register			Access Levels			For Writable Register			Comments
Start Register	Name	Count	Read	Write	Type	Min Value	Max Value	Default Value	
1008	ISM Setup Autoclave Counter Max	1	0	1**	uChar 8bit	0	254	0	See 5.8.1 Diagnostic reg
1020	ISM Setup Counter Code	1	0	1	uChar 8bit	0x01	0x07	0x01	See Counter Codes
1022	ISM Setup Counter Write Result Code	1	0	–	uChar 8bit	N/A	N/A	0x00	See WriteResult Code
1024	ISM Setup Counter Reset	1	–	1	uChar 8bit	0	1	0	See Counter Reset
1026	ISM Setup Counter Increment	1	–	1	uChar 8bit	0	1	0	See Counter Increment
Calibration Page									
2000	Status Calibration	2	0	–	uInt 32bit	N/A	N/A	0x01	See 5.9.2 Calibration status
2004	Control Calibration	1	0	1	uInt 16bit	0x01	0x04	0x00	See 5.9.6 Calibration control
2010	Calibration Unit	2	0	1	uInt 32bit	N/A	N/A	0x00010006	See 5.9.1 Calibration unit
2012	Calibration Method	1	0	1	uChar 8bit	N/A	N/A	0x01	See 5.9.4 Calibration method
2013	Calibration Stability	1	0	1	uChar 8bit	N/A	N/A	0x01	See 5.9.3 Calibration stability
2014	Calibration Buffer Tab	1	0	1	uInt 16bit	N/A	N/A	0x01	See 5.9.5 Calibration buffer table
2016	Calibration Point Offset	2	0	1	Float 32bit	See 5.11 Setup calibration registers for range		0.0	See 5.9.7 Calibration point
2018	Calibration Point Slope	2	0	1	Float 32bit			0.0	
2020	Calibration Point Process	2	0	1	Float 32bit			0.0	
2022	Calibration Point Point1	2	0	1	Float 32bit			0.0	
2024	Calibration Point Point2	2	0	1	Float 32bit			0.0	
2030	Calibration Pressure	1	0	1	uInt 16bit	0	16000	1013	See 5.9.8 Calibration options
2031	Calibration Salinity	1	0	1	uInt 16bit	0	99	0	
2032	Calibration Humidity	1	0	1	uChar 8bit	0	100	50	
2033	Calibration Compensation Mode	1	0	1	uChar 8bit	0x00	0x03	0x01	
2034	Calibration Coefficient	2	0	1	Float 32bit	0	9.99	2.0	

Register			Access Levels			For Writable Register			Comments
Start Register	Name	Count	Read	Write	Type	Min Value	Max Value	Default Value	
2040	Check Offset	2	0	–	Float 32bit	N/A	N/A	0.0	See 5.9.9 Calibration slope & offset
2042	Check Slope	2	0	–	Float 32bit	N/A	N/A	0.0	
2044	Offset for ORP	2	0	–	Float 32bit	N/A	N/A	0.0	
2050	Calibration Date	2	0	1	uInt 32bit	0x01012019	0x31122099	0x01012019	See 5.9.10 Calibration date & time
2052	Calibration Time	1	0	1	uInt 16bit	0x0000	0x2359	0x0101	
M80 SM Setup Page									
3096	Device Address	2	0	2*	uInt 16bit	1	247	1	See Device address
3098	Address Limit Minimum	2	0	–	uInt 16bit	N/A	N/A	1	
3100	Address Limit Maximum	2	0	–	uInt 16bit	N/A	N/A	247	
3102	Baud Rate	2	0	2*	uInt 16bit	2	7	5	See Baud rate
3104	Baud Rate Limit Minimum	2	0	–	uInt 16bit	N/A	N/A	2	
3106	Baud Rate Limit Maximum	2	0	–	uInt 16bit	N/A	N/A	7	
3108	Uart Modbus Mode	1	0	2*	uChar 8bit	0	5	0	See Modbus Mode
3288	Set User Level	4	0	0	N/A	N/A	N/A	0x0000 0x0003, 0x0000 0x0000	See Set user level and User lever code
3292	Change User Level Passwords	4	–	2*	N/A	N/A	N/A	0x0000 0x0003, 0x00A0 0xB700	See Change password
3300	Device Reboot	1	–	2	uChar 8bit	0	1	0	See 5.12 Device reboot
3999	Unlock M80 SM EEPROM	1	0	0	uInt 16bit	0x00	0xffff	0	See 2.10.1 EEPROM Lock
M80 SM Status									
6000	M80 SM Status	2	0	–	uInt 32bit	N/A	N/A	0x0000 0000	See 7.1 M80 SM status
6002	Extended Code for Status	2	0	–	uInt 32bit	N/A	N/A	0x0000 0000	See 7.2 Extended code for status

4.2 Sensor type

Sensor	Sensor Code	Comment
M80 SM 1W pH	0x0100	InPro 2XXXi and InPro 3XXXi sensors are supported
M80 SM 1W CO_2	0x0101	InPro 5000i is supported
M80 SM 1W DO	0x0102	InPro 6850i is supported
M80 SM 1W Cond	0x0103	InPro 7100i is supported

When sensor type is changed:
– Measuring Channel Unit (register 120 to 126) will be reset to default value (see 4.3 Measuring channel units) according to the sensor type.
– Diagnostics Setup Parameters (register 1000 to 1008) will be switched to the stored value of the selected sensor (see 5.8.1 Diagnostic register).

4.3 Measuring channel units

4.3.1 Measurement unit of pH sensor

Units pH	Unit Code	Comment
DLI	0x0001'0000	
ACT	0x0001'0001	
TTM	0x0001'0002	
Temperature °C	0x0001'0003	
Temperature °F	0x0001'0004	
Temperature K	0x0001'0005	Kelvin(K) = 273.15+Celsius degree (T)
pH Value pH	0x0001'0006	
pH Value ORP	0x0001'0007	
Resistance Glass MOhms	0x0001'0008	
Resistance Reference kOhms	0x0001'0009	
pH Value mV	0x0001'000A	
pH Value V	0x0001'000B	

Measurement Channel	Default Unit	Default Unit Code
Primary Measuring Channel	pH Value pH	0x0001'0006
Secondary Measuring Channel	Temperature °C	0x0001'0003
Tertiary Measuring Channel	DLI	0x0001'0000
Quaternary Measuring Channel	ACT	0x0001'0001

Other parameters for measurement are as below (cannot be accessed in M80 SM):

pH Sensor Parameters	Value	Comment
STC	0.0	Fixed value in transmitter
Reference Temperature	25.0	Fixed value in transmitter
IP	N/A	Taken from sensor when sensor connected

4.3.2 Measurement unit of DO sensor

Units DO	Unit Code	Comment
DLI	0x0002'0000	
ACT	0x0002'0001	
TTM	0x0002'0002	
Temperature °C	0x0002'0003	
Temperature °F	0x0002'0004	
Temperature K	0x0002'0005	Kelvin (K) = 273.15+Celsius degree (T)
O_2 Part. Press. mbar	0x0002'0006	
O_2 Part. Press. hPa	0x0002'0007	
O_2 Part. Press. mmHg	0x0002'0008	
%Air Saturation	0x0002'0009	
% O_2 Concentration	0x0002'000A	
ppm Concentration	0x0002'000B	
ppb Concentration	0x0002'000C	
ppt Concentration	0x0002'000D	
DO Concentration g/l	0x0002'0010	
DO Concentration mg/l	0x0002'0011	
DO Concentration µg/l	0x0002'0012	
Process Pressure	0x0002'0013	
Amperom. Current µA	0x0002'0014	
Amperom. Current nA	0x0002'0015	

Measurement Channel	Default Unit	Default Unit Code
Primary Measuring Channel	%Air Saturation	0x0002'0009
Secondary Measuring Channel	Temperature °C	0x0002'0003
Tertiary Measuring Channel	DLI	0x0002'0000
Quaternary Measuring Channel	TTM	0x0002'0002

Other parameters for measurement are as below (cannot be accessed in M80 SM):

DO Sensor Parameters	Value	Comment
Salinity	0.0	For details, see 5.6

4.3.3 Measurement unit of CO_2 sensor

Units CO_2	Unit Code	Comment
DLI	0x0003'0000	
ACT	0x0003'0001	
TTM	0x0003'0002	
Temperature °C	0x0003'0003	
Temperature °F	0x0003'0004	
Temperature K	0x0003'0005	Kelvin(K) = 273.15+Celsius degree (T)
CO_2 Part. Press. mbar	0x0003'0006	
CO_2 Part. Press. hPa	0x0003'0007	
CO_2 Part. Press. mmHg	0x0003'0008	
% CO_2 Concentration	0x0003'0009	
CO_2 Concentration mg/l	0x0003'000A	
CO_2 UpH mV	0x0003'000C	

Measurement Channel	Default Unit	Default Unit Code
Primary Measuring Channel	CO_2 Part. Press. hPa	0x0003'0007
Secondary Measuring Channel	Temperature °C	0x0003'0003
Tertiary Measuring Channel	CO_2 UpH mV	0x0003'000C
Quaternary Measuring Channel	DLI	0x0003'0000

Other parameters for measurement are as below (cannot be accessed in M80 SM):

CO_2 Sensor Parameters	Value	Comment
HCO_3	N/A	Taken from sensor when sensor connected
Salinity	N/A	For details, see 5.6

4.3.4 Measurement unit of conductivity sensor

Units Conductivity	Unit Code	Comment
Temperature °C	0x0005'0003	
Temperature °F	0x0005'0004	
Temperature K	0x0005'0005	Kelvin(K) = 273.15+Celsius degree (T)
Resistivity Ω-cm	0x0005'0006	
Resistivity MΩ-cm	0x0005'0007	
Resistivity kΩ-cm	0x0005'0008	
Conductivity S/cm	0x0005'0009	
Conductivity mS/cm	0x0005'000A	
Conductivity uS/cm	0x0005'000B	
Conductivity nS/cm	0x0005'000C	
Conductivity S/m	0x0005'000D	
Conductivity mS/m	0x0005'000E	
Conductivity uS/m	0x0005'000F	
Conductivity nS/m	0x0005'0010	
TDS($CaCO_3$) ppm	0x0005'0011	
TDS($CaCO_3$) ppb	0x0005'0012	
TDS($CaCO_3$) ppk	0x0005'0013	
TDS(NaCl) ppm	0x0005'0014	
TDS(NaCl) ppb	0x0005'0015	
TDS(NaCl) ppk	0x0005'0016	
%H_2SO_4 Zone1	0x0005'0017	
%HCl Zone1	0x0005'0018	
%NaOH Zone1	0x0005'0019	
%NaCl	0x0005'001A	
%HNO_3 Zone1	0x0005'001B	
%H_3PO_4	0x0005'001C	

Measurement Channel	Default Unit	Default Unit Code
Primary Measuring Channel	Conductivity mS/cm	0x0005'000A
Secondary Measuring Channel	Temperature °C	0x0005'0003
Tertiary Measuring Channel	Resistivity Ω-cm	0x0005'0006
Quaternary Measuring Channel	Temperature °F	0x0005'0004

4.4 User end firmware version

This version data is implemented as 16 character ASCII strings using the following format:

#.#.##.##

The first and the second group have only one digit. The third and the fourth group have fixed two digits, the remaining space has to be filled with spaces (ASCII 0x20).

Spaces are only allowed as "trailing spaces" to fill the remainder of the field. Spaces may not be used inside the version part. In addition, padding the version numbers with zeroes is not allowed. Please see the examples below for further clarification.

The meaning of the groups is as follows:

First	*Major version number (0 – 9)* Denotes a product generation or similar.
Second	*Minor version number (0 – 9)* Denotes a version with functional changes.
Third	*Bugfix version (0 – 99)* No functional changes, just bug fixes or other corrections.
Fourth	*Build number (0 – 99)* Repository revision or build number.

4.4.1 Examples

In the following examples, space characters (ASCII 0x20) are represented by a □-symbol.
Valid versions:
0.0.00.01□□□□□□□
1.1.01.02□□□□□□□

Invalid versions:
1.□0.□0.□□□□□□□0
1.0.0.0□□□□□□□□□

5 Detailed Description of the Implemented Modbus Registers

5.1 User levels and passwords

User levels 1 or 2 can be selected by logging in with a password. The password of each access level can be changed by the user.

Set user level
To change or check the user level, write or read relative register number 3288:

Register		Register Usage		Access User Level	
Start	Count	Register 1/2	Register 3/4	Read	Write
3288	4	User Level Code	Password	0	0
Example		0x0000, 0x0030	0x00F4, 0x79CE		

The selected user level stays active until next power-down of M80 SM. After power-up, user level 0 is active. Invalid login attempts are discarded and current user level is kept.

Change passwords for user levels
To change the password of a user level, write relative register number 3292:

Register		Register Usage		Access User Level	
Start	Count	Register 1/2	Register 3/4	Read	Write
3292	4	User Level Code (hex)	Password (hex)	–	2
Example		0x0000, 0x0030	0x1905, 0x0202		

Invalid user level settings (user level code is wrong) are discarded and no password will be changed. Checking the valid passwords is performed by reading the user level.
Note: If user level code is wrong, then error code 0x03 will be returned.

5.2 Modbus register offset

By default, the Modbus register offset is defined to 0. If necessary, this offset can be changed to any number in the range of 0…65535.
To change or check the Modbus register offset, write or read absolute register number 0000:

Register		Register Usage		Access User Level	
Start	Count	Register 1/2	Datatype	Read	Write
0000	1	Modbus Register Offset	uInt16	0	2
Example		999 (hex-value on register #1: 0x03E7)	–		

5.3 Configuration of the RS485 interface

The factory settings of the RS485 interface are mentioned in Chapter 2.3 Protocol definitions, as implemented in M80 SM. The device address, as well as the baud rate and the UART Mode, can be adjusted to fit the needs of your installation.

Please verify the new settings by reading them back before powering the unit off. After the next power cycle, the settings will be in effect and if wrong, no further communication will be possible.

Device address
By default, the device address is set to 1. By reading relative registers 3098 and 3100, the valid address range can be evaluated. The device address can be changed to any number within this range by writing register 3096:

Register		**Register Usage**		**Access User Level**	
Start	Count	Register 1/2	Datatype	Read	Write
3096	2	Device Address	uInt16	0	2
3098	2	Min Address	uInt16	0	–
3100	2	Max Address	uInt16	0	–

Please note:
If the "slave address" received in the Modbus frame is not same as the "device address", then M80 SM will not respond.

Baud rate
By default, the baud rate is set to 38400. Relative registers 3104 and 3106 report the baud rate limits. The baud rate can be changed to any number within this range by writing register 3102:

Register		**Register Usage**		**Access User Level**	
Start	Count	Register 1/2	Datatype	Read	Write
3102	2	Baudrate Code (unsigned int)	uInt16	0	2
3104	2	Min. Baud rate Code (unsigned int)	uInt16	0	–
3106	2	Min. Baud rate Code (unsigned int)	uInt16	0	–

The baud rate is represented as a decimal code:

Baudrate	4800	9600	19200	**38400**	57600	115200
Code	2	3	4	**5**	6	7

Modbus Mode
By default, the mode is set to 8bit data, no parity, 1 stop bit (8, none, 1).

Register		**Register Usage**		**Access User Level**	
Start	Count	Register 1	Datatype	Read	Write
3108	1	Mode	uChar8	0	2

Possible values:

0x0000	0x0001	0x0002	0x0003	0x0004	0x0005
8,None,1	8,None,2	8,Even,1	8,Even,2	8,Odd,1	8,Odd,2

5.4 Measuring value page

5.4.1 Measuring channel registers

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
100 102 104 106	2	Readout measuring value of primary, secondary, tertiary and quaternary measuring channel from sensor. If measurement value is over range, under range or invalid, following value will be output: Over range : Inf Under range: –Inf Invalid: NaN Please see the lower limit and upper limit value of each measurement in 4.3 Measuring channel units	Float32	0	–

The measuring channel registers is available when correct sensor is connected, in following situations the output value is invalid (NaN):
– Sensor is disconnected.
– Wrong sensor is connected.

Calibration Measuring Value

Register		Register Usage		Access User Level	
Start	Count	Register 1 – 2	Datatype	Read	Write
128	2	This register is the measuring value of the "Calibration Unit" during calibration. It can be polled to get calibration value during calibration, and it cannot be written.	Float32	0	–

Note: The "Calibration Measuring Value" output is available only when calibration status is "Calibration In Progress", otherwise the "Calibration Measuring Value" is invalid (NaN).

Calibration Unit

Register		Register Usage		Access User Level	
Start	Count	Register 1 – 2	Datatype	Read	Write
130	2	This register should be same as Reg2010 "Calibration Unit", and it cannot be written.	uInt32	0	–

5.4.2 Measuring channel unit register

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
120 122 124 126	2	Setup measuring channel unit of primary, secondary, tertiary and quaternary measuring channel. uInt 32bit value see 4.3 Measuring channel units for corresponding sensor type. For persistent change of the channel unit please unlock the EEPROM fist.	uInt32	0	0

Attention: Channel unit must correspond to the attached sensor type, otherwise the error code 0x03 will be returned.

5.4.3 Sensor type register

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
336	1	Setup type of attached sensor on the M80 SM. uInt 16bit value see 4.2 Sensor type for sensor specific coding. For persistent change of the sensor type please unlock the EEPROM fist.	uInt16	0	0

5.4.4 Filter for measurement and calibration

For all measuring channel units, the filter is "None" (no averaging, no filtering for register 100, 102, 104 and 106).

For calibration measuring units, the filter is "High" (10 point moving average for register 128).

5.5 Transmitter and sensor information page

5.5.1 Transmitter information page

Part Number

Register		Register Usage		Access User Level	
Start	Count	Register 1 – 8	Datatype	Read	Write
280	8	For M80 SM, part number is "30530566". Value represented by a string.	String	0	–

For string interpretation the tool under the following link can be used:
http://www.unit-conversion.info/texttools/hexadecimal/

Serial Number

Register		Register Usage		Access User Level	
Start	Count	Register 1 – 8	Datatype	Read	Write
312	8	The SN is like "6482513".	String	0	–

Manufacturer

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
320	8	Currently is fixed to "METTLER TOLEDO".	String	0	–

Please note: for Part Number, Serial Number, and Manufacturer:
If string length does not reach max count number, the rest of the data are filled with"0x20".

5.5.2 Sensor information page

Article Number

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
380	4	It is a part number in page 0 from sensor, like "52005377"	String	0	–

Serial Number

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
412	4	It is a serial number in page 0 from sensor, like "9302271"	String	0	–

Sensor Name

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
436	8	It is sensor name in page 2 from sensor, like "InPro3253i"	String	0	–

Firmware Version

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
444	9	It is the "Sensor Firmware Version" in page 15 from sensor, like "FW 5.2.4-133"	String	0	–

Please note: for Article Number, Serial Number, Sensor Name and Firmware Version

1. If sensor is disconnected, "0x20" will be filled to this register.
2. If the wrong sensor is connected, the actual value will be returned.
3. If string length does not reach max count number, the rest of the data are filled with "0x20".

5.6 M80 SM sensor parameter page

Process Pressure

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
340	1	Unit is mbar and only for measurement. It is used for both DO and CO_2 sensors. For DO sensors, fixed value 1013 mbar is set to register 340 and it can be changed later, but it will not be saved to EEPROM, and even if reconnecting the sensor, it still keeps the last changed value. The max value is 16000 mbar. For CO_2 sensors, it is used for p_{tot} (total pressure of gas phase), fixed value 1000 mbar is set to register 340, and it can be changed later, but it will not be saved to EEPROM, and even if reconnecting the sensor, it still keeps the last changed value. The max value is 9999mbar.	uInt16	0	1

Salinity

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
341	1	It is used for DO and CO_2 sensors. For DO sensors, fixed salinity value 0.0 is set to register 341 first, and register 341 can be changed later, but it will not be saved to EEPROM. (Also see 4.3.2), and even if reconnecting the sensor, it still keep the last changed value. For CO_2 sensors, when sensor is connected, salinity value from sensor is set to register 341 first, and register 341 cannot be changed by user later, and it will not be saved to sensor. The error code 0x03 will be returned if user attempts to write any values to register 341 (see 4.3.2)	uInt16	0	1 for DO – for CO_2

Attention:

1. **If current sensor type is not CO_2 or DO (0x0101 for CO_2 or 0x0102 for DO in register 336), when "Process Pressure" or "Salinity" is written, then the parameter is not changed and error code 0x03 is returned.**
2. **If current sensor type is not CO_2 or DO (0x0101 for CO_2 or 0x0102 for DO in register 336), when "Process Pressure" or "Salinity" is read, default value (see 4.1) will be returned.**
3. **When sensor type is CO_2 but sensor is not connected. If "Salinity" is read, default value (see 4.1) will be returned.**

5.6.1 Parameter setting page – DO sensor

Polarization Voltage

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
370	1	Unit is mV. It is the polarization voltage for DO sensors. Int 16bit value It is used both for U_{meas} and U_{cal}	Int16	0	1**

Attention:

1. **If current sensor type is not DO (0x0102 for DO in register 336), when "Polarization Voltage" is written, then the parameter is not changed and error code 0x03 is returned.**
2. **If current sensor type is not DO (0x0102 for DO in register 336), when "Polarization Voltage" is read, the default value will be returned.**

5.6.2 Parameter setting page – conductivity sensor

Compensation Mode Register

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
390	1	It is the compensation mode for conductivity sensors. It is used for Primary Measuring Channel	uChar8	0	1**
391	1	It is the compensation mode for conductivity sensors. It is used for Secondary Measuring Channel	uChar8	0	1**
392	1	It is the compensation mode for conductivity sensors. It is used for Tertiary Measuring Channel	uChar8	0	1**
393	1	It is the compensation mode for conductivity sensors. It is used for Quaternary Measuring Channel	uChar8	0	1**

Compensation Mode

It only has effect on unit Ω-cm (including other unit range), S/cm (including other unit range), S/m (including other unit range), TDS NaCl and TDS $CaCO_3$.

Compensation Mode	Compensation Code
None	0x0000
Standard, (default)	0x0001
Linear 25°C	0x0002
Linear 20°C	0x0003

Coefficient

Register		Register Usage		Access User Level	
Start	Count	Register 1 – 2	Datatype	Read	Write
394	2	It is the coefficient for conductivity sensors. It only takes effect for compensation Linear 25°C or Linear 20°C Unit is %/°C. It is used for Primary Measuring Channel	Float32	0	1**
396	2	It is the coefficient for conductivity sensors. It only takes effect for compensation Linear 25°C or Linear 20°C Unit is %/°C. It is used for Secondary Measuring Channel	Float32	0	1**
398	2	It is the coefficient for conductivity sensors. It only takes effect for compensation Linear 25°C or Linear 20°C Unit is %/°C. It is used for Tertiary Measuring Channel	Float32	0	1**
400	2	It is the coefficient for conductivity sensors. Float 32bit value It only takes effect for compensation Linear 25°C or Linear 20°C Unit is %/°C. It is used for Quaternary Measuring Channel	Float32	0	1**

Attention:

1. **If current sensor type is not conductivity (0x0103 for conductivity in register 336), when "Compensation Mode" or "Coefficient" is written, then the parameter is not changed and error code 0x03 is returned.**
2. **If current sensor type is not conductivity (0x0103 for conductivity in register 336), when "Compensation Mode" or "Coefficient" is read, the default value will be returned.**

5.7 Diagnostics Value Page

DLI (Dynamic Lifetime Indicator), ACT (Adaptive Calibration Timer), TTM (Time to Maintenance), CIP (Cleaning in Place), SIP (Sterilization in Place) and autoclave counters are available when correct sensor is connected. These values will be output as invalid values ("NaN" for Float 32bit or "0xFFFF" for uInt16bit) in following situation:
– Sensor is not connected.
– Wrong sensor is connected.
– The sensor does not support the diagnostic value. (For example, autoclave counter is not supported by conductivity sensors).

DLI

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
200	2	Get DLI counter value.	Float32	0	–

ACT

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
202	2	Get ACT counter value.	Float32	0	–

TTM

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
204	2	Get TTM counter value	Float32	0	–

CIP

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
206	1	Get CIP counter value.	uInt16	0	–

SIP

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
208	1	Get SIP counter value.	uInt16	0	–

Autoclave Counter

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
210	1	Get Autoclave counter value.	uInt16	0	–

Flag Sensor Disconnected

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
98	1	Get sensor connection status value. 0: means sensor is connected 1: means sensor is disconnected Function of register 98 is same as Register 218.	uChar8	0	–
218	1		uChar8	0	–

Flag Wrong Sensor

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
99	1	Get sensor recognition status value. Only when sensor is connected is this flag available like below: 0: the sensor connected is same as the sensor type in Register 336. 1: the sensor type connected is different from the sensor type in Register 336. **Please note: if sensor is disconnected, the value is default as 0.** Function of register 99 is same as Register 219	uChar8	0	–
219	1		uChar8	0	–

5.8 Diagnostics setup page

5.8.1 Diagnostic register

Each sensor type has a set of diagnostic setup values that are stored in the EEPROM.
When sensor type is changed, the diagnostic setup values will also be switched to the set of that sensor.

Set Maximum CIP Counter

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
1000	1	Setup CIP counter max.	uChar8	0	1

Set CIP Temperature

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
1002	1	Setup CIP counter temperature. Value [°C]	uChar8	0	1

Set Maximum SIP Counter

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
1004	1	Setup SIP counter max.	uChar8	0	1

Set SIP Temperature

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
1006	1	Setup SIP counter temperature. Value [°C]	uChar8	0	1

Set Maximum Autoclave Counter

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
1008	1	Setup Autoclave Counter Max. **Conductivity sensors do not have autoclave counter function. When sensor type is conductivity (Register 336 is 0x0103), if autoclave counter is written, then 0x03 is returned.**	uChar8	0	1

Attention:

1. **If sensor is not connected or wrong sensor is connected or sensor is not supported (for example, conductivity sensors do not support Maximum Autoclave Counter), when "Maximum CIP", "CIP Temperature", "Maximum SIP", "SIP Temperature" or "Maximum Autoclave Counter" is read, then "0xFFFF" is returned.**
2. **If sensor is not connected or wrong sensor is connected, when "Maximum CIP", "CIP Temperature", "Maximum SIP", "SIP Temperature" or "Maximum Autoclave Counter" is written, then error code 0x03 is returned.**

5.8.2 Manipulation of diagnostic counters

The diagnostic counters can be modified. To modify a diagnostic counter, the counter to be modified is selected by writing the desired counter code into Register 1020.

Counter codes

Available Counters	Code
SIP	0x01
CIP	0x02
Autoclaving	0x03
ACT	0x05
DLI	0x06
TTM	0x07

Setup Counter Code

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
1020	1	Setup ISM Counter Code Write wrong code except the "Available counters" will return error code 0x03.	uChar8	0	1

The status of the manipulation is shown in the ISM setup counter write result code Register 1022. This status is used for both "Counter Reset" (Register 1024) and "Counter Increment" (Register 1026). Before any manipulation, this register should be idle. The following table shows the possible status codes available for Register 1022.

Write Result Code

Status ISM Manipulations of Register 1022	Code	Comment
Idle	0x00	
Counter Reset in Progress	0x01	When current operation is not finished
Counter Reset Failed	0x02	
Counter Not Allowed For This Sensor	0x80	
Counter Reset No Sensor Present	0x81	
Counter Reset Wrong Code	0x82	
Counter Reset Busy	0x83	To start a another operation when the current operation is not finished

Please note:
When read "Write Result Code", transmitter will check if situation "Counter Not Allowed For This Sensor" or "Counter Reset No Sensor Present" exists.
If yes:

Code 0x80 or 0x81 (priority: 0x81 > 0x80) is set to transmitter.

If no:

1) If the operation "reset" or "increment" is in progress, then one of code 0x01or 0x83 is returned.
2) If the operation "reset" or "increment" is just finished, then one of the code 0x00 or 0x02 is returned, and after that the "Write Result Code" is reset to 0x00.
3) If not 1) or 2), then code 0x00 is returned.

Read Status of Counter Manipulation

Register		Register Usage	Access User Level	
Start	Count	Register 1	Read	Write
1022	1	ISM Setup Counter Write Result Code	0	–

If the counter status in Register 1022 is Idle, the counter previously selected with Register 1020 can be either reset by writing 0x01 to Register 1024 or incremented by writing 0x01 to Register 1026.

Note: Not all counters can be incremented, some can only be reset as below.

Manipulation	Sensor Type
CIP Reset	CO_2, DO, Cond
SIP Reset	CO_2, DO, Cond
DLI Reset	DO
TTM Reset	pH, CO_2, DO
Autoclave Reset	CO_2, DO
Autoclave Increment	pH, CO_2, DO

Setup counter reset

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
1024	1	ISM Setup Counter Reset 1: for starting reset process Writing other value except 1 will return error code 0x03	uChar8	–	1

Setup Counter Increment

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
1026	1	ISM Setup Counter Increment 1: for starting increment process, writing other value except 1 will return error code 0x03 **Please note, for autoclave increment:** 1. If " ISM Setup Autoclave Counter Max"(register 1008) is not 0 and only under following two conditions, then the autoclave increment operation can be done, otherwise the "Write result code" will be "Counter Not Allowed For This Sensor " if trying to increment autoclave counter. Condition 1: A new sensor is connected. Condition 2: Same sensor is reconnected with transmitter power on. 2. The autoclave counter increment can only be done once sensor is connected, otherwise the "Write result code" will be "Counter Not Allowed For This Sensor" if trying to increment autoclave counter after the first time.	uChar8	–	1

After writing a 0x01 to either Register 1024 or 1026, the writing process can be monitored when reading Register 1022 as described above.

5.9 Calibration page

The M80 SM calibration is done with a standard procedure, which remains the same for all sensors. Therefore, the procedure has to be implemented only once. Only the setup of the calibration registers will change, when another sensor is calibrated.
Below there is an example of a complete pH calibration procedure (5.10). For all other calibrations, the procedure remains the same except for the "Setup Calibration Register" setup box. This box is explained in Chapter 5.11 and following.
In addition, the meaning of errors and status registers is explained in tables after the calibration examples.

5.9.1 Calibration units

Sensor	Unit	Code
pH	pH	0x00010006
pH	ORP	0x00010007
DO	%Air	0x00020009
DO	ppm	0x0002000B
DO	ppb	0x0002000C
DO	mg/l	0x00020011
DO	µg/l	0x00020012
DO	$\%O_2$	0x0002000A
DO	mbar	0x00020006
CO_2	pH	0x0003000F
CO_2	hPa	0x00030007
CO_2	mbar	0x00030006
CO_2	mmHg	0x00030008
CO_2	$\%CO_2$	0x00030009
CO_2	mg/l	0x0003000A
Conductivity	Ω-cm	0x00050006
Conductivity	MΩ-cm	0x00050007
Conductivity	kΩ-cm	0x00050008
Conductivity	S/cm	0x00050009
Conductivity	MS/cm	0x0005000A
Conductivity	uS/cm	0x0005000B
Conductivity	nS/cm	0x0005000C

Please note:
When set to 0x0001 (Start calibration) / 0x0005 (Start calibration measurement) to Register 2004 or to get "Calibration status" value, then "Calibration unit" will be checked, see 5.9.2 for details.

5.9.2 Calibration status

Calibration status	all/RO
Idle	0x0000'0001
Calibration Done	0x0000'0002
Calibration In Progress	0x0000'0004
Calibration Ready To Check	0x0000'0008
Calibration Write Data In Progress	0x0000'0010
Calibration Wait Next Point	0x0000'0020
Spare	0x0000'0040
Calibration Not Done	0x0000'0080
No Sensor	0x0000'0100
Wrong Sensor Type	0x0000'0200
Wrong Calibration Unit	0x0000'0400
Wrong Calibration Method	0x0000'0800
Wrong Calibration Stability	0x0000'1000
Wrong Calibration Buffer	0x0000'2000
Wrong Calibration Points (out of edit range)	0x0000'4000
Stability Timeout 300s	0x0000'8000
No Calibration Data To Write	0x0001'0000
Cal Out of Limit, Continue?	0x0002'0000
Write Error	0x0004'0000
Spare	0x0008'0000
Buffer Recognize Failed	0x0010'0000
Spare	0x0020'0000
(pH)2pnt Cal Difference Between Cal Point < 60 mV	0x0040'0000
Spare	0x0080'0000
Spare	0x0100'0000
Spare	0x0200'0000
Spare	0x0400'0000
Spare	0x0800'0000
Spare	0x1000'0000
Spare	0x2000'0000
(Cond)Wrong Calibration Compensation	0x4000'0000
(Cond)Wrong Calibration Coefficient	0x8000'0000

Remark: To get calibration status according to the table below for each register to be checked, the dependent registers have to be checked first (e.g. for Register 2012, Registers 218 and 219 have to be prechecked).
Only if all dependent registers (see table below) pass the check will the register itself be checked according to its own pass-conditions. If one of the dependent registers fail, checking the register itself will not be checked, and only the error messages of the failing dependent registers will be shown.

Index	Register to check		Dependency	Pass condition	Calibration status to set	Error bit
0	218	Flag Sensor Disconnected	N/A	Value is 0	No Sensor	0x0000'0100
1	219	Flag Wrong Sensor	N/A	Value is 0	Wrong Sensor Type	0x0000'0200
2	2010	Calibration Unit	index #1	Check 5. .1 for the calibration unit supported by the specified sensors	Wrong Calibration Unit	0x0000'0400
3	2012	Calibration Method	index #1 & #2	Check 5. .4 for the calibration method supported by the specified sensors	Wrong Calibration Method	0x0000'0800
4	2013	Calibration Stability	index #1 & #2	Check 5. .3 for the calibration stability supported by the specified sensors	Wrong Calibration Stability	0x0000'1000
5	2014	Calibration Buffer Tab	index #1 & #2	Check 5. .5 for the calibration buffer table supported by the specified sensors If the sensor does not use this buffer table, it will not be checked	Wrong Calibration Buffer	0x0000'2000
6	2033	Calibration Compensation Mode	index #1 & #2	Compensation mode is "None", "Standard", "Linear 25°C" or "Linear 20°C"	(Cond)Wrong Calibration Compensation	0x4000'0000
7	2034	Calibration Coefficient	index #1 & #2 & #6	1. Only when Compensation Mode is "Linear 25°C" or "Linear 20°C" then "Calibration Coefficient" will be checked 2. Calibration Coefficient range is 0 ~9.99	(Cond)Wrong Calibration Coefficient	0x8000'0000
8	2016	Calibration Point Offset	index #1 & #2 & #3	1. For unit pH 1-point calibration, when "Calibration Buffer Tab" is not None, then this register will NOT be checked 2. The Calibration Point value is within range of "Calibration Unit", see 5. .7 for details	Wrong Calibration Points (out of edit range)	0x0000'4000
9	2018	Calibration Point Slope	index #1 & #2 & #3	1. For unit pH 1-point calibration, when "Calibration Buffer Tab" is not None, then this register will NOT be checked 2. The Calibration Point value is within range of "Calibration Unit", see 5. .7 for details	Wrong Calibration Points (out of edit range)	0x0000'4000
10	2020	Calibration Point Process	index #1 & #2 & #3	The Calibration Point value is within range of "Calibration Unit", see 5. .7 for details	Wrong Calibration Points (out of edit range)	0x0000'4000
11	2022	Calibration Point Point1	index #1 & #2 & #3	1. For unit pH 2-point calibration, when "Calibration Buffer Tab" is not None, then this register will NOT be checked 2. The Calibration Point value is within range of "Calibration Unit", see 5. .7 for details	Wrong Calibration Points (out of edit range)	0x0000'4000
12	2024	Calibration Point Point2	index #1 & #2 & #3	1. For unit pH 2-point calibration, when "Calibration Buffer Tab" is not None, then this register will NOT be checked 2. The Calibration Point value is within range of "Calibration Unit", see 5. .7 for details	Wrong Calibration Points (out of edit range)	0x0000'4000

If "Pass condition" is not reached for the checked item, then the "Error bit" will be set in the "calibration status"

Please note:
The following "Calibration status" can be shown:

1) When user is going to do a calibration, first step is to set all calibration parameters to the calibration related register (see the table below).

2010	Calibration Unit
2012	Calibration Method
2013	Calibration Stability
2014	Calibration Buffer Tab
2016	Calibration Point Offset
2018	Calibration Point Slope
2020	Calibration Point Process
2022	Calibration Point Point1
2024	Calibration Point Point2
2030	Calibration Pressure
2031	Calibration Salinity
2032	Calibration Humidity
2033	Calibration Compensation Mode
2034	Calibration Coefficient
2040	Check Offset
2050	Calibration Date
2052	Calibration Time

Second step is to check if all calibration parameters are set correctly. Normally user will read Register 2000 (Calibration Status), if all parameters are set correctly, then value of register 2000 is 0x00000001. If one or more parameters are set incorrectly (including "No sensor" situation), the value of Register 2000 will be changed to one of the status in the following table:

Calibration status	all/RO
No Sensor	0x0000'0100
Wrong Sensor Type	0x0000'0200
Wrong Calibration Unit	0x0000'0400
Wrong Calibration Method	0x0000'0800
Wrong Calibration Stability	0x0000'1000
Wrong Calibration Buffer	0x0000'2000
Wrong Calibration Points (out of edit range)	0x0000'4000
(Cond)Wrong Calibration Compensation	0x4000'0000
(Cond)Wrong Calibration Coefficient	0x8000'0000

For example, if user wants to do a pH calibration, but sets %Air(0x00020009) as the Cal unit to Register 2010, and other registers are set correctly, then if Register 2000 is read, the value will be 0x00000400, which means wrong calibration unit is set.

2) During a calibration cycle (after set "Calibration Control" Register 2004 with "Start calibration" (0x0001) or "Start calibration measurement" (0x0005)):

If calibration is successful ("Calibrations Status" does not contain "Calibration Not one (0x00000080) in Register 2000), then one of the following codes will be set to Register 2000:

Calibration status	all/RO
Calibration Done	0x0000'0002
Calibration In Progress	0x0000'0004
Calibration Ready To Check	0x0000'0008
Calibration Write Data In Progress	0x0000'0010
Calibration Wait Next Point	0x0000'0020

If "Calibration Status" is "Calibration Not Done"(0x00000080) when read "Calibration Control" Register 2000 for the first time, one of the following codes will be set to Register 2000:

Calibration status	all/RO
No Sensor	0x0000'0100
Stability Timeout 300s	0x0000'8000
No Calibration Data to Write	0x0001'0000
Write Error	0x0004'0000
Buffer Recognize Failed	0x0010'0000
(pH)2pnt Cal Difference between Cal Point < 60 mV	0x0040'0000

Please notice: The transmitter is still in calibration status until "Calibration Control" is read out for the second time. Then code 0x00000001 is set, that means current status is idle.

5.9.3 Calibration stability (drift control, not for process calibration)

Description	Value	pH	CO2	DO	Cond
Manual	0x01				
Low	0x02	1.25 mV*	1.25 mV*	NA	NA
Medium	0x04	0.8 mV*	0.8 mV*	NA	NA
Strict	0x08	0.4 mV*	0.4 mV*	NA	NA
Auto	0x10	NA	NA	Meas. Value/ 256**	NA

* 20s stable interval within a 300s timeout
** 60s stable interval within a 300s timeout

Please note:
When set 0x0001 (Start calibration) / 0x0005 (Start calibration measurement) to Register 2004 or get "Calibration status" value, then "Calibration stability" will be checked, see 5.9.2 for details.

5.9.4 Calibration method

Method	all/RW	Comment
1-point Calibration Offset	0x01	Used for 1-point offset calibration
1-point Calibration Slope	0x02	Used for 1-point slope calibration
1-point Process Calibration Offset	0x10	Used for process offset calibration
1-point Process Calibration Slope	0x20	Used for process slope calibration
2-Point Calibration	0x30	Used for 2-point calibration

Please note:
When set 0x0001 (Start calibration) / 0x0005 (Start calibration measurement) to Register 2004 or get "Calibration status" value, then "Calibration method" will be checked, see 5.9.2 for details.

5.9.5 Calibration buffer table

The calibration buffer table is only used for pH and CO_2 sensor calibration.

Type	pH/CO_2	Comment
None	0x0001	Use register 2016/2018/2020/2022/2024 for point value
MT-9	0x0002	
MT-10	0x0004	
NIST Tech	0x0008	
NIST Std	0x0010	
HACH	0x0020	
CIBA	0x0040	
MERCK	0x0080	
WTW	0x0100	
JIS Z 8802	0x0200	

Please note:
When set 0x0001 (Start calibration) / 0x0005 (Start calibration measurement) to Register 2004 or get "Calibration status" value, then "Calibration buffer table" will be checked, see 5.9.2 for details.

5.9.6 Calibration control

Calibration Control	All / RW	Comment
Start calibration	0x0001	Used to start calibration at the beginning
Abort calibration	0x0002	Used to cancel calibration during calibration
Save calibration	0x0003	Used to save calibration data to sensor
Start calibration point2	0x0004	Used to start point2 when buffer of point2 is prepared
Start calibration measurement	0x0005	Used to begin calibration measurement. After this command, calibration measuring value (Register 128) can be read for manual calibration.

5.9.7 Calibration point

Calibration point registers are used according to calibration method, no used calibration point register will be ignored. For example, if calibration method is 2-point, then Register 2022 and 2024 are available, other calibration point registers will be ignored.
In the following registers, please enter the physical unit value of the respective buffer(s) or calibration media used.

Calibration Point Offset

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2016	2	It is only used for 1-point offset calibration.	Float32	0	1

Calibration Point Slope

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2018	2	It is only used for 1-point slope calibration	Float32	0	1

Calibration Point Process

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2020	2	It is used for both process slope and process offset calibration	Float32	0	1

Calibration Point 1

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2022	2	Calibration Point 1. It is only used for 2-point calibration	Float32	0	1

Calibration Point 2

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2024	2	Calibration Point 2. It is only used for 2-point calibration	Float32	0	1

Please note:
When set 0x0001 (Start calibration) / 0x0005 (Start calibration measurement) to Register 2004 or get "Calibration status" value, then "Calibration point" will be checked, see 5.9.2 for details.

5.9.8 Calibration options

Calibration Pressure

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2030	1	Unit is mbar It is only used for DO sensor calibration (%air or $\%O_2$). The value of register is ignored for other sensors or calibration modes. Currently, it is always used as the pressure for both 1-point and process calibrations	uInt16	0	1

Calibration Salinity

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2031	1	Unit is g/kg It is only used for DO sensor calibration. The value of register is ignored for other sensors.	uInt16	0	1

Calibration Humidity

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2032	1	Unit is % It is only used for DO sensor calibration. The value of register is ignored for other sensors.	uChar8	0	1

Calibration Compensation Mode

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2033	1	Only used for conductivity sensor calibration. The value of register is ignored for other sensors. See Compensation mode	uChar8	0	1

Calibration Coefficient

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2034	2	Unit is %/°C Only used for conductivity sensor calibration. The value of register is ignored for other sensors. See Coefficient	Float32	0	1

Please note:
Calibration Pressure, Calibration Salinity, Calibration Humidity are only checked when these registers are written.

5.9.9 Calibration slope & offset

"Check Offset", "Check Slope" and "Offset for ORP" will be output as invalid value (NaN) in following situations:
– Sensor is not connected.
– Wrong sensor is connected.

Check Offset

Register		**Register Usage**		**Access User Level**	
Start	Count	Register 1	Datatype	Read	Write
2040	2	Unit for pH sensor: pH Unit for CO_2 sensor: pH Unit for DO sensor: nA Unit for Cond sensor: Ω-cm **When in measurement mode (not in calibration):** The actual offset value from sensor is set when sensor is connected. For pH sensor, the "Check Offset" is always used for pH unit, not for ORP mV unit. **When in calibration mode:** 1. Only after calibration is done successfully (without being saved), the new calculated offset value is set. 2. It is used for both pH unit and ORP mV unit during calibration. 3. For 1-point slope or process slope pH unit calibration, a new calculated offset value is also set after calibration is done.	Float32	0	–

Check Slope

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2042	2	Unit for pH sensor: mV/pH Unit for CO2 sensor: mV/pH Unit for DO sensor: nA Unit for Cond sensor: cm^{-1} **When in measurement mode (not in calibration):** The actual offset value from sensor is set when sensor is connected. **When in calibration mode:** Only after calibration is done successfully (without being saved), the new calculated slope value is set.	Float32	0	–

Offset for ORP

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2044	2	This register is used for the offset value of mV ORP for pH sensors, user can read the offset value from it, unit is mV. **When in measurement mode (not in calibration):** The actual offset value from sensor is set when sensor is connected. **When in calibration mode:** The value of this register will not be changed. User can check the new calculated offset value from register 2040. After calibration is done successfully (without being saved), the new calculated offset value is set to this register.	Float32	0	–

5.9.10 Calibration date & time

Calibration Date

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2050	2	Format is DDMMYYYY, e.g.: 0x3009'2019 means September 30th 2019. If date is invalid, then error code 0x03 is returned. When sensor connected (except wrong sensor), the calibration date from actual calibration data will be set to this register.	uInt32	0	1

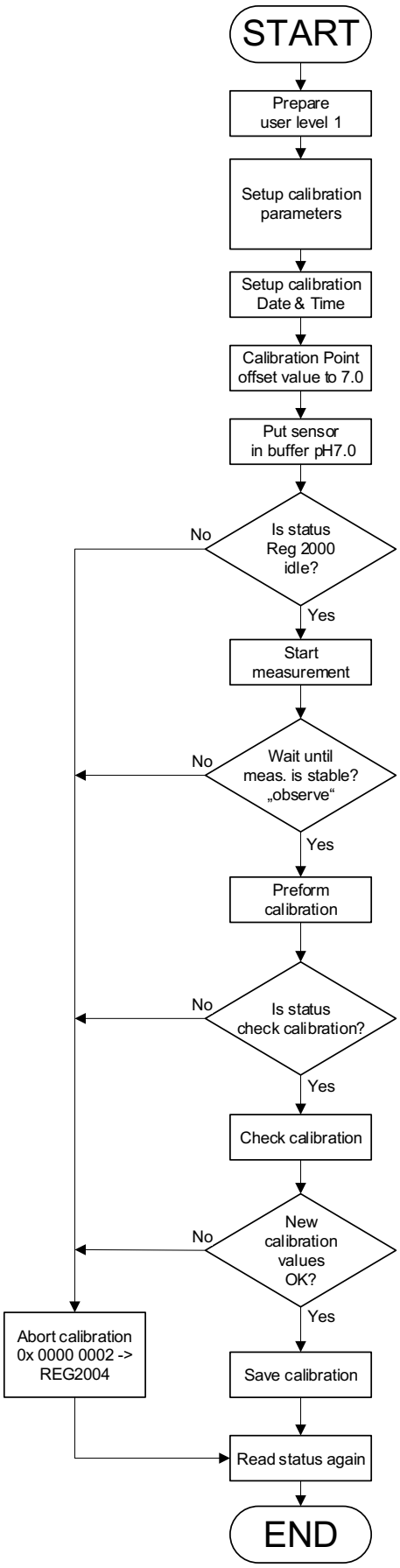
Calibration Time

Register		Register Usage		Access User Level	
Start	Count	Register 1	Datatype	Read	Write
2052	1	Format is HHMM, e.g.: 0x1530 means 15h30 If time is invalid, then error code 0x03 is returned. When sensor connected (except wrong sensor), the calibration time from actual calibration data will be set to this register.	uInt16	0	1

Please note:

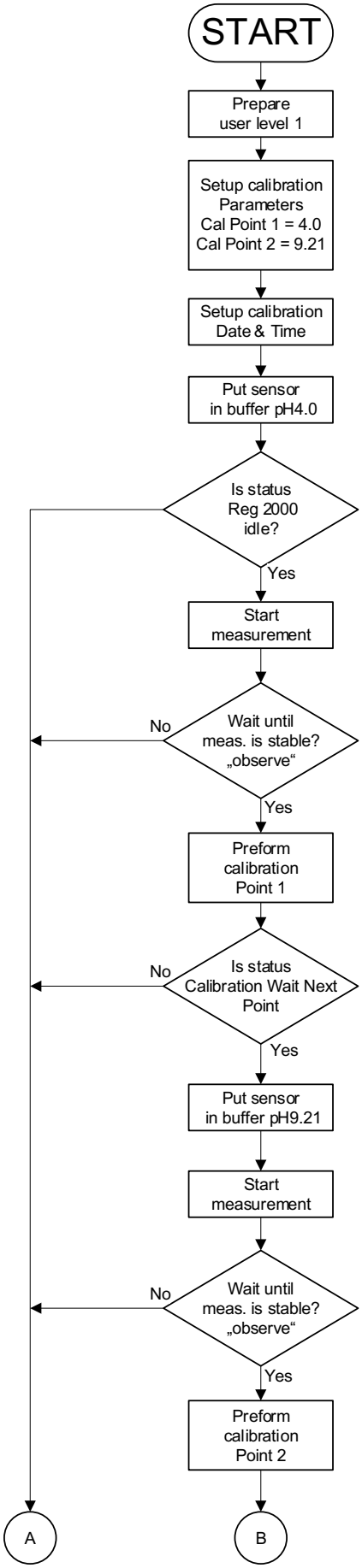
1. Calibration Date & Time are only checked when writing these registers.
2. When "Calibration Date" is set to Register 2050, if "Calibration Date" is earlier than January 1st 2019 or later than December 31st 2099, then the error code 0x03 is returned.

5.9.11 Examples of calibration work flow



Example:
pH -Sensor / Method Offset / Stability manual
observe Date 25.10.2019 : 09h:51m

User Level Code	0x 0000 000C	->	REG 3288
User Level Password	0x 0114 5DEA	->	REG 3290
Unit	0x 0001 0006	->	REG 2010
Method	0x 0001	->	REG 2012
Stability	0x 0001	->	REG 2013
Buffer Tab	0x 0001	->	REG 2014
Offset	0x 0001	->	REG 2014
Date	0x 2510 2019	->	REG 2050
Time	0x 0951	->	REG 2052
Offset	0x 40E0 0000	->	REG 2016
Status Calibration	%actual value"	<-	REG 2000
Measurement	0x 0000 0005	->	REG 2004
Calib. Meas. Value	%actual value"	<-	REG 128
Measurement	0x 0000 0001	->	REG 2004
Status Calibration	%actual value"	<-	REG 2000
Check Offset	%actual value"	<-	REG 2040
Check Slope	%actual value"	<-	REG 2042
Save	0x 0000 0003	->	REG 2004
Status Calibration	%actual value"	<-	REG 2000



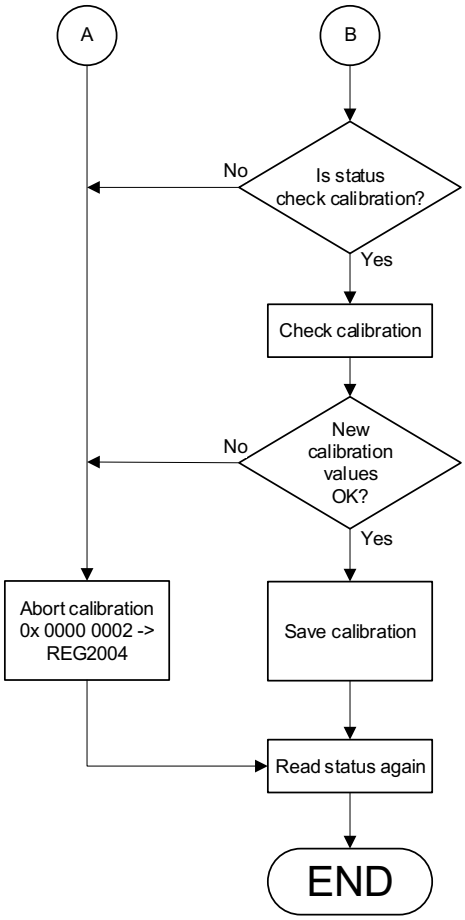
Example:
pH -Sensor / Method 2-Point / Stability manual obs.
Date 28.10.2019 : 11h:15m

User Level Code	0x 0000 000C	->	REG 3288
User Level PW	0x 0114 5DEA	->	REG 3290

Unit	0x 0001 0006	->	REG 2010
Method	0x 0030	->	REG 2012
Stability	0x 0001	->	REG 2013
Buffer Tab	0x 0001	->	REG 2014
Cal Point 1	0x 4080 0000	->	REG 2022
Cal Point 2	0x 4113 5C29	->	REG 2024

Date	0x 2810 2019	->	REG 2050
Time	0x 1115	->	REG 2052

Status Calibration	„actual value“	<-	REG 2000
Measurement	0x 0000 0005	->	REG 2004
Calib. Meas. Value	„actual value“	<-	REG 128
Measurement	0x 0000 0001	->	REG 2004
Status Calibration	„actual value“	<-	REG 2000
Measurement	0x 0000 0005	->	REG 2004
Calib. Meas. Value	„actual value“	<-	REG 128
Measurement	0x 0000 0004	->	REG 2004



Status Calibration	„actual value“	<-	REG 2000
Check Offset	„actual value“	<-	REG 2040
Check Slope	„actual value“	<-	REG 2042
Save	0x 0000 0003	->	REG 2004
Status Calibration	„actual value“	<-	REG 2000

5.10 Complete calibration example of a pH sensor

Please note:

- **When calibration is finished or canceled by user, calibration status is either "Calibration Done", "Calibration Not Done" or other error message. Please read the Cal status register (Register 2000) again to make sure the Cal status is reset to 0x01 (Idle). Otherwise, the transmitter is still in calibration status and no register values can be written to it. The error code 0x06 will be returned if attempts to write register values to the transmitter are made in this situation.**
- **When starting a calibration (Start calibration measurement (0x0005) or Start calibration (0x0001)), if "Calibration Date" (Register 2050) or "Calibration Time" (Register 2052) is not valid ("Calibration Date" is early than January 1st 2019 or later than December 31st 2099), then "Calibration Date" and "Calibration Time" will be reset to default value.**
- If value of "Cal Control" Is not set correctly during a calibration, the error code 0x03 (illegal data value) is returned, see condition below:
  1. Start calibration (0x0001) can be sent when calibration status is "Idle", or when calibration status is "Calibration In Progress" (after send "Start calibration measurement (0x0005)).
  2. Abort calibration(0x0002) can be sent when calibration status is not "Calibration Write Data In Progress"
  3. Save calibration(0x0003) can be sent when calibration status is "Calibration Ready To Check"
  4. Start calibration point2(0x0004) can be send when calibration status is "Calibration Wait Next Point" or "Calibration In Progress"(after sending "Start calibration measurement" (0x0005))
  5. Start calibration measurement (0x0005) can be sent when calibration status is "Idle" or "Calibration Wait Next Point"
- When cal status is "0x01" (Idle), after reading cal status register (Register 2000), transmitter will check all calibration parameter and set error code if some parameters are not correct.
- Only when cal status is 0x01 (Idle) can a new calibration be started.
- Cal status "Idle" and "Calibration Not Done" can be set with other cal status (from 0x00000100 to 0x80000000).
- After abort calibration (0x0002), calibration status is reset to "Idle".
- During calibration (calibration status is not "Idle" or "Calibration Done" or "Calibration Not Done"), if sensor is disconnected, then calibration will not be done, but cal status will be "Calibration Done" together with "No sensor 0x0000'0100".
- During calibration (calibration status is not "Idle"), user can only write to Register 2004. If user attempts to write to other registers, then error code 0x06 (Server Device Busy) will be returned. The read operation still works during a calibration.
- User name saved in TEDs of sensor is "M80-SM".

5.11 Setup calibration registers

5.11.1 Setup calibration registers for cal pH sensor pH

The table describes the same values as in the tables in Chapter 5.9 Calibration page.

Setup Calibration Registers:

Item	Value	Modbus Register #	Unit/Command
Calibration Unit	0x0001'0006	2010	pH
Calibration Method			
Offset	0x01	2012	
Slope	0x02	2012	Range
Process Offset	0x10	2012	–2…16 pH
Process Slope	0x20	2012	
2-Point	0x30	2012	
Calibration Stability			
Manual	0x01	2013	1.25 mV
Low	0x02*	2013	0.8 mV
Medium	0x04*	2013	0.4 mV
Strict	0x08*	2013	
Calibration Buffer Tab	0x0001		
None	(None: use Reg 2016/ 2018/2020/ 2022/ 2024)	2014	—
		2014	See Calibration Buffer Tab below
All the rest	0x0002 – 0x0200		
Calibration Point			
Offset	7.0 pH	2016	Insert actual value as floating point number
Slope	4.0 pH	2018	
Process	7.51 pH	2020	
Point1	7.0 pH	2022	
Point2	4.0 pH	2024	
Calibration			
Pressure	none	2030	—
Humidity	none	2032	
Salinity	none	2031	
Calibration			
Date	0x2809'2019	2050	Date 28.09.2019
Time	0x1733	2052	Time 17h33

* pH criteria: 20s interval within 300s

Example:
Calibration of a pH sensor pH, offset calibration, manual stability, buffer tab none, 7.00 pH offset, on September 28th 2019, 15h30
Write the following values to the registers:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001'0006	Unit is pH	2010	2	Calibration Unit
0x0001	1-point calibration offset	2012	1	Calibration Method
0x0001	Stability is manual	2013	1	Calibration Stability
0x0001	Buffer tab is none	2014	1	Calibration Buffer Tab
7.0 (IEEE float)	pH 7.0	2016	2	Calibration Point Offset
0x2809'2019	28.09.2019	2050	2	Calibration Date
0x1530	15h:30min	2052	1	Calibration Time

After this setup, start the calibration by sending:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001	Start calibration	2004	1	Control calibration

Please note:

For "Slope" and "Process Slope" calibration:

Calibration point 1 (pH value and voltage value) is taken from the last Offset-Calibration in TEDs.

Calibration point 2 (pH value and voltage value) is the current measurement or point value (from Register 2018 or Register 2020)

If pH value of calibration point 1 is same as that of point 2 or if difference of voltage between two calibration points is less than 60mV, then calibration is not done.

Other calibration not done conditions are the same as for 1-point offset calibration.

For "Slope" calibration, the cal point 1 response time is set as 0, the cal point 2 response time is $t_{leave\ calibration} - t_{entry\ calibration}$.

5.11.2 Setup calibration registers for cal pH sensor mV ORP

This table describes the same values of the box Setup Calibration Registers in
5. Setup Calibration Registers:

Item	Value	Modbus Register #	Unit/Command
Calibration Unit	0x0001'0007	2010	mV ORP
Calibration Method Offset Process Offset	0x01 0x10	2012 2012	Range –1500 mV…1500 mV
Calibration Stability Manual	0x01	2013	
Calibration Buffer Tab None	0x0001	2014	—
Calibration Point Offset Process	–15.5 mV +45.3 mV	2016 2020	Insert actual value as floating point number
Calibration Pressure Humidity Salinity	none none none	2030 2032 2031	———
Calibration Date Time	0x2809'2019 0x1733	2050 2052	Date 28.09.2019 Time 17h33

Example:
Calibration of a pH sensor mV, process offset calibration, manual stability, buffer tab none, +45.3 mV process offset, on September 28th 2019, 15h30
Write the following values to the registers:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001'0007	Unit is ORP	2010	2	Calibration Unit
0x0010	1-point process calibration offset	2012	1	Calibration Method
0x0001	Stability is manual	2013	1	Calibration Stability
0x0001	Buffer tab is none	2014	1	Calibration Buffer Tab
45.3 (IEEE float)	Process value 45.3	2020	2	Calibration Point Process
0x2809'2019	28.09.2019	2050	2	Calibration Date
0x1530	15h:30min	2052	1	Calibration Time

After this setup, start the calibration by sending:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001	Start calibration	2004	1	Control calibration

5.11.3 Setup calibration registers for cal DO sensor %air

This table describes the same values of the box Setup Calibration Registers in
5. Setup Calibration Registers:

Item	Value	Modbus Register #	Unit/Command
Calibration Unit	0x0002'0009	2010	%Air
Calibration Method Offset Slope Process Offset Process Slope	 0x01 0x02 0x10 0x20	 2012 2012 2012 2012	Range 0…5%Air 5…500%Air 0…5%Air 5…500%Air
Calibration Stability Manual Auto	 0x01** 0x10*	 2013 2013	 Manual Auto
Calibration Buffer Tab None	 0x0001	 2014	 —
Calibration Point Offset Slope Process	 3.0% Air 100.0% Air 21.2% Air	 2016 2018 2020	Insert actual value as floating point number
Calibration Pressure Humidity Salinity	 1013 50 none	 2030 2032 2031	 1013 mbar 50% —
Calibration Date Time	0x2809'2019 0x1733	2050 2052	Date 28.09.2019 Time 17h33

* DO criteria: 60s interval within 300s: | nA_max – nA_min | <= nA_act / 256 (only for 1-point slope)
** For 1-point offset calibration method, only "Manual" can be set.

If Calibration Method is Process Offset or Process Slope, stability should be Manual and Humidity is always 100% in liquid. This means Register 2032 will be force set as 100 when calibration is started.

Example:
Calibration of a DO sensor %air, offset calibration, manual stability, 3% offset, pressure 1008 mbar, humidity 45%, on September 28th 2019, 15h30
Write the following values to the registers:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0002'0009	Unit is %air	2010	2	Calibration Unit
0x0001	1-point calibration offset	2012	1	Calibration Method
0x0001	Stability is manual	2013	1	Calibration Stability
0x0001	Buffer tab is none	2014	1	Calibration Buffer Tab
3.0 (IEEE float)	Offset value 3.0	2016	2	Calibration Point Offset
0x2809'2019	28.09.2019	2050	2	Calibration Date
0x1530	15h:30min	2052	1	Calibration Time

After this setup, start the calibration by sending:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001	Start calibration	2004	1	Control calibration

5.11.4 Setup calibration registers for cal DO sensor ppm, ppb, mg/l, µg/l

This table describes the same values of the box Setup Calibration Registers in
5. Setup Calibration Registers:

Item	Value	Modbus Register #	Unit/Command
Calibration Unit	0x0002'000B 0x0002'000C 0x0002'0011 0x0002'0012	2010 2010 2010 2010	ppm ppb mg/l µg/l
Calibration Method Offset Slope Process Offset Process Slope	 0x01 0x02 0x10 0x20	 2012 2012 2012 2012	Range For 1-point offset and process offset cal, the range is: 0…0.5ppm and 0…0.5 mg/l For 1-point slope and process slope cal, the range is: 0.5…70 ppm and 0.5…70 mg/l
Calibration Stability Manual Auto	 0x01** 0x10*	 2013 2013	 Manual Auto
Calibration Buffer Tab None	 0x0001	 2014	——
Calibration Point Offset Slope Process	0.5 ppm 65.0 mg/l 55.6 mg/l	2016 2018 2020	Insert actual value as floating point number
Calibration Pressure Humidity Salinity	1013 50 10 g/kg	2030 2032 2031	1013 mbar —— 10 g/kg
Calibration Date Time	0x2809'2019 0x1733	2050 2052	Date 28.09.2019 Time 17h33

* DO criteria: 60s interval within 300s: | nA_max – nA_min | <= nA_act : 256 (only for 1-point slope)
** For 1-point offset calibration method, only "Manual" can be set.

If Calibration Method is Process Offset or Process Slope, stability should be Manual and Humidity is always 100% in liquid. This means Register 2032 will be force set as 100 when calibration is started.

Example:
Calibration of a DO sensor mg/l, offset calibration, auto stability, 0.48 mg/l offset, pressure 1018 mbar, salinity 10 g/kg, on September 28th 2019, 15h30
Write the following values to the registers:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0002'0011	Unit is mg/l	2010	2	Calibration Unit
0x0001	1-point calibration offset	2012	1	Calibration Method
0x0010	Stability is auto	2013	1	Calibration Stability
0x0001	Buffer tab is none	2014	1	Calibration Buffer Tab
0.48 (IEEE float)	Offset value 0.48 mg/l	2016	2	Calibration Point Offset
0x3F8	Calibration pressure 1018 mbar	2030	1	Calibration Pressure
0x000A	Calibration salinity 10g/kg	2031	1	Calibration Salinity
0x2809'2019	28.09.2019	2050	2	Calibration Date
0x1530	15h:30min	2052	1	Calibration Time

After this setup, start the calibration by sending:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001	Start calibration	2004	1	Control calibration

5.11.5 Setup calibration registers for cal DO sensor %O_2

This table describes the same values of the box Setup Calibration Registers in
5. Setup Calibration Registers:

Item	Value	Modbus Register #	Unit/Command
Calibration Unit	0x0002'000A	2010	%O_2
Calibration Method Offset Slope Process Offset Process Slope	 0x01 0x02 0x10 0x20	 2012 2012 2012 2012	Range 0…1.05%O_2 1.05…100%O_2 0…1.05%O_2 1.05…100%O_2
Calibration Stability Manual Auto	 0x01** 0x10*	 2013 2013	Manual Auto
Calibration Buffer Tab None	0x0001	2014	—
Calibration Point Offset Slope Process	 0.75%O_2 95.7%O_2 21.2%O_2	 2016 2018 2020	Insert actual value as floating point number
Calibration Pressure Humidity Salinity	 1013 50 none	 2030 2032 2031	 1013 mbar 50% —
Calibration Date Time	0x2809'2019 0x1733	2050 2052	Date 28.09.2019 Time 17h33

* DO criteria: 60s interval within 300s: | nA_max – nA_min | <= nA_act : 256 (only for 1-point slope)
** For 1-point offset calibration method, only "Manual" can be set.

If Calibration Method is Process Offset or Process Slope, stability should be Manual and Humidity is always 100% in liquid. This means Register 2032 will be force set as 100 when calibration is started.

Example:
Calibration of a DO sensor % O_2, slope calibration, manual stability, 99.2% O_2 slope, pressure 1001 mbar, humidity 47%, on September 28th 2019, 15h30
Write the following values to the registers:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0002'000A	Unit is $\%O_2$	2010	2	Calibration Unit
0x0002	1-point calibration slope	2012	1	Calibration Method
0x0001	Stability is manual	2013	1	Calibration Stability
0x0001	Buffer tab is none	2014	1	Calibration Buffer Tab
99.2 (IEEE float)	Slope value 99.2% O_2l	2018	2	Calibration Point Slope
0x3F9	Calibration pressure is 1001 mbar	2030	1	Calibration Pressure
0x002F	Calibration humidity is 47%	2032	1	Calibration Humidity
0x2809'2019	28.09.2019	2050	2	Calibration Date
0x1530	15h:30min	2052	1	Calibration Time

After this setup, start the calibration by sending:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001	Start calibration	2004	1	Control calibration

5.11.6 Setup Calibration Registers for cal DO sensor mbar

This table describes the same values of the box Setup Calibration Registers in
5. Setup Calibration Registers:

Item	Value	Modbus Register #	Unit/Command
Calibration Unit	0x0002'0006	2010	mbar
Calibration Method Offset Slope Process Offset Process Slope	 0x01 0x02 0x10 0x20	 2012 2012 2012 2012	 Range 0…2000 mbar
Calibration Stability Manual Auto	 0x01** 0x10*	 2013 2013	 Manual Auto
Calibration Buffer Tab None	 0x0001	 2014	 —
Calibration Point Offset Slope Process	 15.0 mbar 625.0 mbar 320.0 mbar	 2016 2018 2020	 Insert actual value as floating point number
Calibration Pressure Humidity Salinity	 1013 none none	 2030 2032 2031	 1013 mbar —
Calibration Date Time	0x2809'2019 0x1733	2050 2052	Date 28.09.2019 Time 17h33

* DO criteria: 60s interval within 300s: | nA_max – nA_min | <= nA_act : 256 (only for 1-point slope)
** For 1-point offset calibration method, only "Manual" can be set.

If Calibration Method is Process Offset or Process Slope, stability should be Manual and Humidity is always set 100% in liquid. This means Register 2032 will be force set as 100 when calibration is started.

Example:
Calibration of a DO sensor mbar, slope calibration, manual stability, 625.0 mbar slope, pressure 1001 mbar, on September 28th 2019, 15h30
Write the following values to the registers:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0002'0006	Unit is mbar	2010	2	Calibration Unit
0x0002	1-point calibration slope	2012	1	Calibration Method
0x0001	Stability is manual	2013	1	Calibration Stability
0x0001	Buffer tab is none	2014	1	Calibration Buffer Tab
625.0 (IEEE float)	Slope value 625.0 mbar	2018	2	Calibration Point Slope
0x3F9	Calibration pressure is 1001 mbar	2030	1	Calibration Pressure
0x2809'2019	28.09.2019	2050	2	Calibration Date
0x1530	15h:30min	2052	1	Calibration Time

After this setup, start the calibration by sending:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001	Start calibration	2004	1	Control calibration

5.11.7 Setup calibration registers for cal CO_2 sensor pH

This table describes the same values of the box Setup Calibration Registers in 5. Setup Calibration Registers:

Item	Value	Modbus Register #	Unit/Command
Calibration Unit	0x0003'000F	2010	pH
Calibration Method Offset Slope 2-Point	 0x01 0x02 0x30	 2012 2012 2012	Range –2…16 pH –2…16 pH –2…16 pH
Calibration Stability Manual Low Med Strict	 0x01 0x02* 0x04* 0x08*	 2013 2013 2013 2013	Manual 1.25 mV 0.8 mV 0.4 mV
Calibration Buffer Tab None MT-9	0x0001 (none use Reg 2016/ 2018 /2022/2024) 0x0002 – 0x0200	 2014 2014	— Select MT-9 Buffer
Calibration Point Offset Slope Point1 Point2	 7.0 4.0 7.0 4.0	2016 2018 2022 2024	Insert actual value as floating point number
Calibration Pressure Humidity Salinity	 none none none	2030 2032 2031	—
Calibration Date Time	0x2809'2019 0x1733	2050 2052	Date 28.09.2019 Time 17h33

* pH criteria: 20s interval within 300s

Example:
Calibration of a CO_2 sensor pH, offset calibration, manual stability, buffer tab none, 7.02 pH offset, on September 28th 2019, 15h30
Write the following values to the registers:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0003'000F	Unit is pH	2010	2	Calibration Unit
0x0001	1-point calibration offset	2012	1	Calibration Method
0x0001	Stability is manual	2013	1	Calibration Stability
0x0001	Buffer tab is none	2014	1	Calibration Buffer Tab
7.02 (IEEE float)	Offset value 7.02 pH	2016	2	Calibration Point Offset
0x2809'2019	28.09.2019	2050	2	Calibration Date
0x1530	15h:30min	2052	1	Calibration Time

After this setup, start the calibration by sending:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001	Start calibration	2004	1	Control calibration

Please note:
For "Slope" calibration:
- Calibration point 1 (pH value and voltage value) is taken from the last Offset-Calibration in TEDs, The cal point 1 response time is set as 0.
- Calibration point 2 (pH value and voltage value) is the current measurement or point value (from Register 2018 or Register 2020), the cal point 2 response time is $t_{leave\ calibration} - t_{entry\ calibration}$.

If pH value of calibration point 1 is same as that of point 2 or if difference of voltage between two calibration points is less than 60mV, then calibration is not done.
Other calibration not done conditions are the same as for 1-point offset calibration.
The cal point 1 response time is set as 0, the cal point 2 response time is $t_{leave\ calibration} - t_{entry\ calibration}$.

5.11.8 Setup calibration registers for cal CO_2 sensor hPa, mbar, mmHg, %CO_2, mg/l

This table describes the same values of the box Setup Calibration Registers in
5. Setup Calibration Registers:

Item	Value	Modbus Register #	Unit/Command
Calibration Unit	0x0003'0007 0x0003'0006 0x0003'0008 0x0003'0009 0x0003'000A	2010 2010 2010 2010 2010	hPa mbar mmHg %CO_2 mg/l
Calibration Method Process Offset	0x10	2012	Range 0…2000 hPa 0…2000 mbar 0…1500 mmHg 0…200%CO_2 0…5000mg/l
Calibration Stability Manual	0x01	2013	Manual
Calibration Buffer Tab None	0x0001	2014	—
Calibration Point Process Offset	120.0 hPa	2020	Insert actual value as floating point number
Calibration Pressure Humidity Salinity	none* none none	2030 2032 2031	—
Calibration Date Time	0x2809'2019 0x1733	2050 2052	Date 28.09.2019 Time 17h33

* For a CO_2 process calibration, the process pressure Modbus Register 340 has to be correct.

Example:
Calibration of a CO_2 sensor $\%CO_2$, process offset calibration, manual stability, buffer tab none, 190.5$\%CO_2$, process pressure 1013 mbar, on September 30th 2019, 15h30
Write the following values to the registers:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0003'0009	Unit is $\%CO_2$	2010	2	Calibration Unit
0x0010	1-point calibration process	2012	1	Calibration Method
0x0001	Stability is manual	2013	1	Calibration Stability
0x0001	Buffer tab is none	2014	1	Calibration Buffer Tab
190.5 (IEEE float)	Process value is 190.5$\%CO_2$	2020	2	Calibration Point Process
0x03F5	Process pressure is 1013 mbar	340	1	Process Pressure ($\%CO_2$ only)
0x2809'2019	28.09.2019	2050	2	Calibration Date
0x1530	15h:30min	2052	1	Calibration Time

After this setup, start the calibration by sending:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001	Start calibration	2004	1	Control calibration

5.11.9 Setup calibration registers for cal conductivity sensor Ω-cm, MΩ-cm, kΩ-cm

This table describes the same values of the box Setup Calibration Registers in
5. Setup Calibration Registers:

Item	Value	Modbus Register #	Unit/Command
Calibration Unit	0x0005′0006 0x0005′0007 0x0005′0008	2010 2010 2010	Ω-cm MΩ-cm kΩ-cm
Calibration Method Slope Process Slope 2-Point	 0x02 0x20 0x30	 2012 2012 2012	 Range 0…9999MΩ-cm
Calibration Stability Manual	0x01	2013	Manual
Calibration Buffer Tab None	0x0001	2014	—
Calibration Point Slope Process Point1 Point2	 3379 3380 3379 3380	 2018 2020 2022 2024	 Insert actual value as floating point number
Calibration Pressure Humidity Salinity	 none none none	 2030 2032 2031	 —
Calibration Date Time	0x3009′2019 0x1730	2050 2052	Date 30.09.2019 Time 15h30
Calibration Compensation Calibration Coefficient	 0x0003 2.0	 2033 2034	Linear 25 °C %/°C

Example:
Calibration of a conductivity sensor Ω-cm, process slope calibration, manual, 3380 Ω-cm process cal, Linear 25 °C, 2.0%/°C on September 28th 2019, 15h30
Write the following values to the registers:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0005'0006	Unit is Ω-cm	2010	2	Calibration Unit
0x0020	1-point process calibration slope	2012	1	Calibration Method
0x0001	Stability is manual	2013	1	Calibration Stability
0x0001	Buffer tab is none	2014	1	Calibration Buffer Tab
3380.0 (IEEE float)	Process slope value is 3380.0 Ω-cm	2020	2	Calibration Point Process
0x0002	Compensation mode is linear 25°C	2033	1	Calibration Compensation Mode
2.0 (IEEE float)	Cal. coefficient is 2.0%/°C	2034	2	Calibration Coefficient
0x2809'2019	28.09.2019	2050	2	Calibration Date
0x1530	15h:30min	2052	1	Calibration Time

After this setup, start the calibration by sending:

Data to Write (hex)	Description of Data	Start Register dec	Register Count dec	Description of Register
0x0001	Start calibration	2004	1	Control calibration

5.11.10 Setup calibration registers for cal conductivity sensor S/cm, mS/cm, µS/cm, nS/cm

This table describes the same values of the box Setup Calibration Registers in
5. Setup Calibration Registers:

Item	Value	Modbus Register #	Unit/Command
Calibration Unit	0x0005′0009 0x0005′000A 0x0005′000B 0x0005′000C	2010 2010 2010 2010	S/cm mS/cm µS/cm nS/cm
Calibration Method Slope Process Slope 2-Point	 0x02 0x20 0x30	 2012 2012 2012	 Range 0…999 S/cm
Calibration Stability Manual	0x01	2013	Manual
Calibration Buffer Tab None	0x0001	2014	—
Calibration Point Slope Process Point1 Point2	 296 296 296 297	 2018 2020 2022 2024	 Insert actual value as floating point number
Calibration Pressure Humidity Salinity	 none none none	 2030 2032 2031	 —
Calibration Date Time	 0x3009′2019 0x1730	 2050 2052	 Date 30.09.2019 Time 15h30
Calibration Compensation Calibration Coefficient	 0x0003 2.0	 2033 2034	 Linear 25 °C %/°C

Example:
Calibration of a conductivity sensor µS/cm, process slope calibration, manual, 296 µS/-cm process cal, Linear 25 °C, 2.0%/°C on September 28th 2019, 15h30
Write the following values to the registers:

Data to Write (hex)	Description of Data	Start Rregister dec	Register Count dec	Description of Register
0x0005'000B	Unit is µS/cm	2010	2	Calibration Unit
0x0020	1-point Process Calibration Slope	2012	1	Calibration Method
0x0001	Stability is manual	2013	1	Calibration Stability
0x0001	Buffer Tab is none	2014	1	Calibration Buffer Tab
296.0 (IEEE float)	Process Slope Value is 296.0 µS/cm	2020	2	Calibration Point Process
0x0002	Compensation Mode is linear 25°C	2033	1	Calibration Compensation Mode
2.0 (IEEE float)	Cal. Coefficient is 2.0%/°C	2034	2	Calibration Coefficient
0x2809'2019	28.09.2019	2050	2	Calibration Date
0x1530	15h:30min	2052	1	Calibration Time

After this setup, start the calibration by sending:

Data to write (hex)	Description of Data	Start register dec	Register Count dec	Description of Register
0x0001	Start calibration	2004	1	Control calibration

5.12 Device Reboot

By default, the device reboot register 3300 is defined to 0.

Register		Register Usage	Access User Level	
Start	Count	Register 1	Read	Write
3300	1	After writing 0x01 to register 3300, after the response is sent, then M80 SM will reboot automatically, reboot progress will take about 10 seconds. The error code 0x03 will be returned if user attempt to write any other values except 0x01.	–	2

6 Setting up the M80 SM

6.1 Setting up the M80 SM for a 1W pH sensor

Example:
Set up M80 SM for a pH sensor, select pH/°C for primary and secondary measuring channel, observe Dynamic Lifetime Indicator (DLI) and Time To Maintenance (TTM) on the tertiary and quaternary measuring channel.
Write the following values to the registers:

Data to write (hex)	Description of Data	Start register dec	Register Count dec	Description of Register
0x5752	EEPROM unlock password	3999	1	Unlock M80 SM EEPROM
0x0000'000C	User code level 1	3288	2	User Level
0x0114'5DEA	User level 1 password	3290	2	User Level Password
0x0100	Sensor type = pH	336	1	Sensor Type
0x0001'0006	Prim. channel unit = pH	120	2	Prim. Measure Channel Unit
0x0001'0003	Sec. channel unit = °C	122	2	Sec. Measure Channel Unit
0x0001'0000	Ter. channel unit = DLI	124	2	Ter. Measure Channel Unit
0x0001'0002	Quar. channel unit = TTM	126	2	Quar. Measure Channel Unit

Read register 100/102/104/106 for float value of primary, secondary, tertiary and quaternary measuring channel.

6.2 Setting up the M80 SM for a 1W DO sensor

Example:
Set up M80 SM for a DO sensor, select mbar/°C for primary and secondary measuring channel, observe Dynamic Lifetime Indicator (DLI) and Time To Maintenance (TTM) on the tertiary and quaternary measuring channel.
Write the following values to the registers:

Data to write (hex)	Description of Data	Start register dec	Register Count dec	Description of Register
0x5752	EEPROM unlock password	3999	1	Unlock M80 SM EEPROM
0x0000'000C	User code level 1	3288	2	User Level
0x0114'5DEA	User level 1 password	3290	2	User Level Password
0x0102	Sensor type = 1W DO	336	1	Sensor Type
0x0002'0006	Prim. channel unit = mbar	120	2	Prim. Measure Channel Unit
0x0002'0003	Sec. channel unit = °C	122	2	Sec. Measure Channel Unit
0x0002'0000	Ter. channel unit = DLI	124	2	Ter. Measure Channel Unit
0x0002'0002	Quar. channel unit = TTM	126	2	Quar. Measure Channel Unit

Read register 100/102/104/106 for float value of primary, secondary, tertiary and quaternary measuring channel.

6.3 Setting up the M80 SM for a 1W CO_2 sensor

Example:
Set up M80 SM for a CO_2 sensor, select mbar/°C for primary and secondary measuring channel, observe Dynamic Lifetime Indicator (DLI) and Time To Maintenance (TTM) on the tertiary and quaternary measuring channel.
Write the following values to the registers:

Data to write (hex)	Description of Data	Start register dec	Register Count dec	Description of Register
0x5752	EEPROM unlock password	3999	1	Unlock M80 SM EEPROM
0x0000'000C	User code level 1	3288	2	User Level
0x0114'5DEA	User level 1 password	3290	2	User Level Password
0x0101	Sensor type = 1W CO_2	336	1	Sensor Type
0x0003'0006	Prim. channel unit = mbar	120	2	Prim. Measure Channel Unit
0x0003'0003	Sec. channel unit = °C	122	2	Sec. Measure Channel Unit
0x0003'0000	Ter. channel unit = DLI	124	2	Ter. Measure Channel Unit
0x0003'0002	Quar. channel unit = TTM	126	2	Quar. Measure Channel Unit

Read register 100/102/104/106 for float value of primary, secondary, tertiary and quaternary measuring channel.

6.4 Setting up the M80 SM for a 1W Conductivity sensor

Example:
Set up M80 SM for a Cond sensor, select S/cm / °C for primary and secondary measuring channel, observe Ω-cm and °F on the tertiary and quaternary measuring channel.
Write the following values to the registers:

Data to write (hex)	Description of Data	Start register dec	Register Count dec	Description of Register
0x5752	EEPROM unlock password	3999	1	Unlock M80 SM EEPROM
0x0000'000C	User code level 1	3288	2	User Level
0x0114'5DEA	User level 1 password	3290	2	User Level Password
0x0103	Sensor type = 1W Cond	336	1	Sensor Type
0x0005'0003	Prim. channel unit = S/cm	120	2	Prim. Measure Channel Unit
0x0005'0004	Sec. channel unit = °C	122	2	Sec. Measure Channel Unit
0x0005'0005	Ter. channel unit = Ω-cm	124	2	Ter. Measure Channel Unit
0x0005'0006	Quar. channel unit = °F	126	2	Quar. Measure Channel Unit

Read register 100/102/104/106 for float value of primary, secondary, tertiary and quaternary measuring channel.

7 M80 SM Status

7.1 M80 SM status

If M80 SM encounter an unrecoverable error during initialization progress, it will not response to any read/write command (like #3, #4, #6 & #16), but user can only use #3 command to read register 6000 to get the detail status for it.

Please note:
The following communication setting will be used as below ONLY when error happened during initialization progress:
Modbus address: 0x01
Modbus baud rate: 38400
Modbus Mode: 8, No, 1

If M80 SM encounter an error (such as EEPROM read/ write error) during running, it will still running normally, and user can still read the register 6000 to see the status.

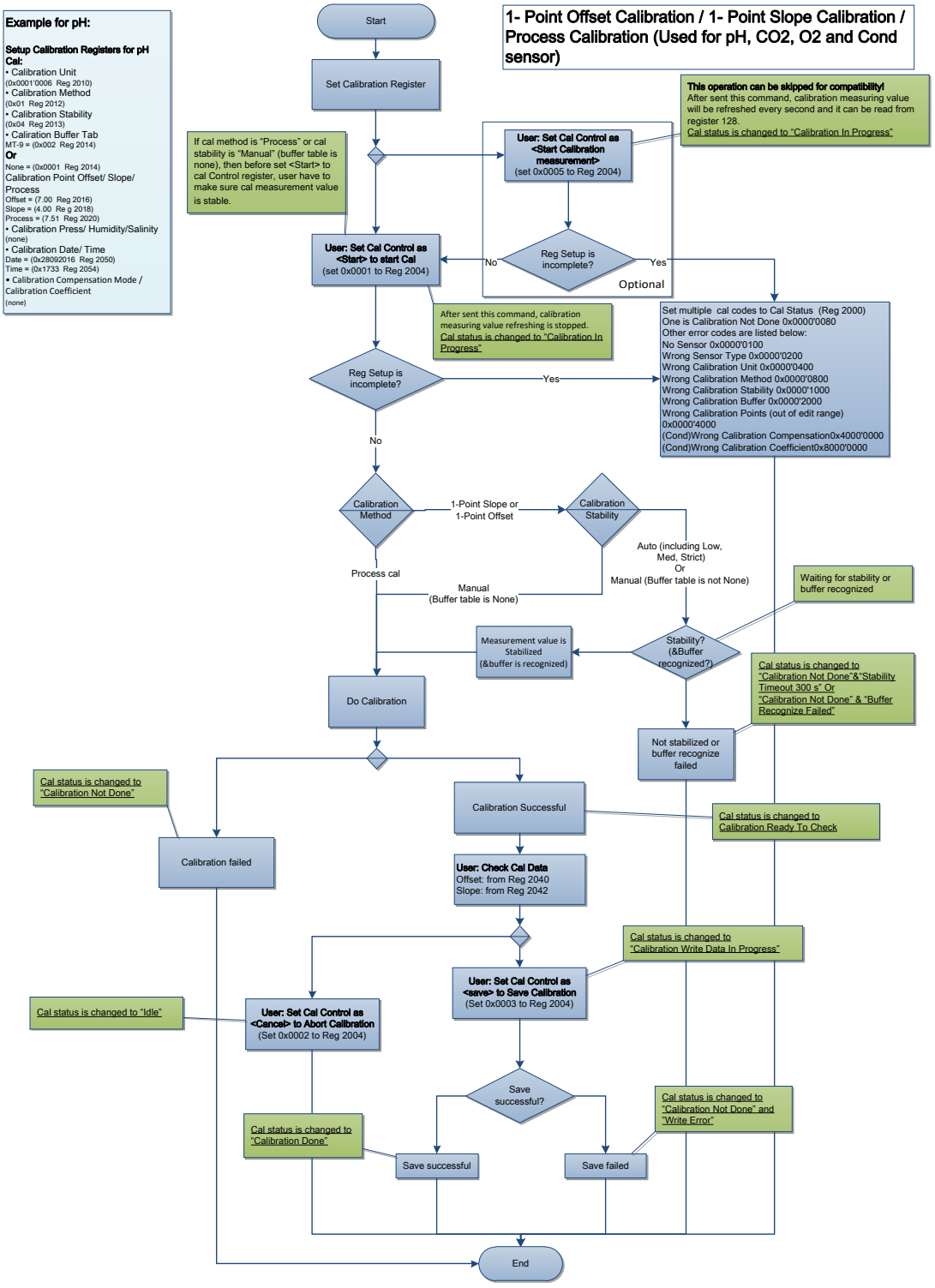
M80 SM detail status	all/RO	Comment
Configuration data initial error	0x0000'0001	Error in initial
EEPROM read or write initial error 1	0x0000'0002	Error in initial
EEPROM read or write initial error 2	0x0000'0004	Error in initial
EEPROM read or write initial error 3	0x0000'0008	Error in initial
EEPROM read or write initial error 4	0x0000'0010	Error in initial
EEPROM read or write initial error 5	0x0000'0020	Error in initial
EEPROM read or write initial error 6	0x0000'0040	Error in initial
EEPROM read or write initial error 7	0x0000'0080	Error in initial
EEPROM read or write running error	0x0000'0100	Error in normal running
Reserved	0x0000'0200	
Reserved	0x0000'0400	
Reserved	0x0000'0800	
Reserved	0x0000'1000	
Reserved	0x0000'2000	
Reserved	0x0000'4000	
Reserved	0x0000'8000	
Reserved	0x0001'0000	
Reserved	0x0002'0000	
Reserved	0x0004'0000	
Reserved	0x0008'0000	
Reserved	0x0010'0000	
Reserved	0x0020'0000	
Reserved	0x0040'0000	
Reserved	0x0080'0000	
Reserved	0x0100'0000	
Reserved	0x0200'0000	
Reserved	0x0400'0000	
Reserved	0x0800'0000	
Reserved	0x1000'0000	
Reserved	0x2000'0000	
Reserved	0x4000'0000	
Reserved	0x8000'0000	

7.2 Extended code for status

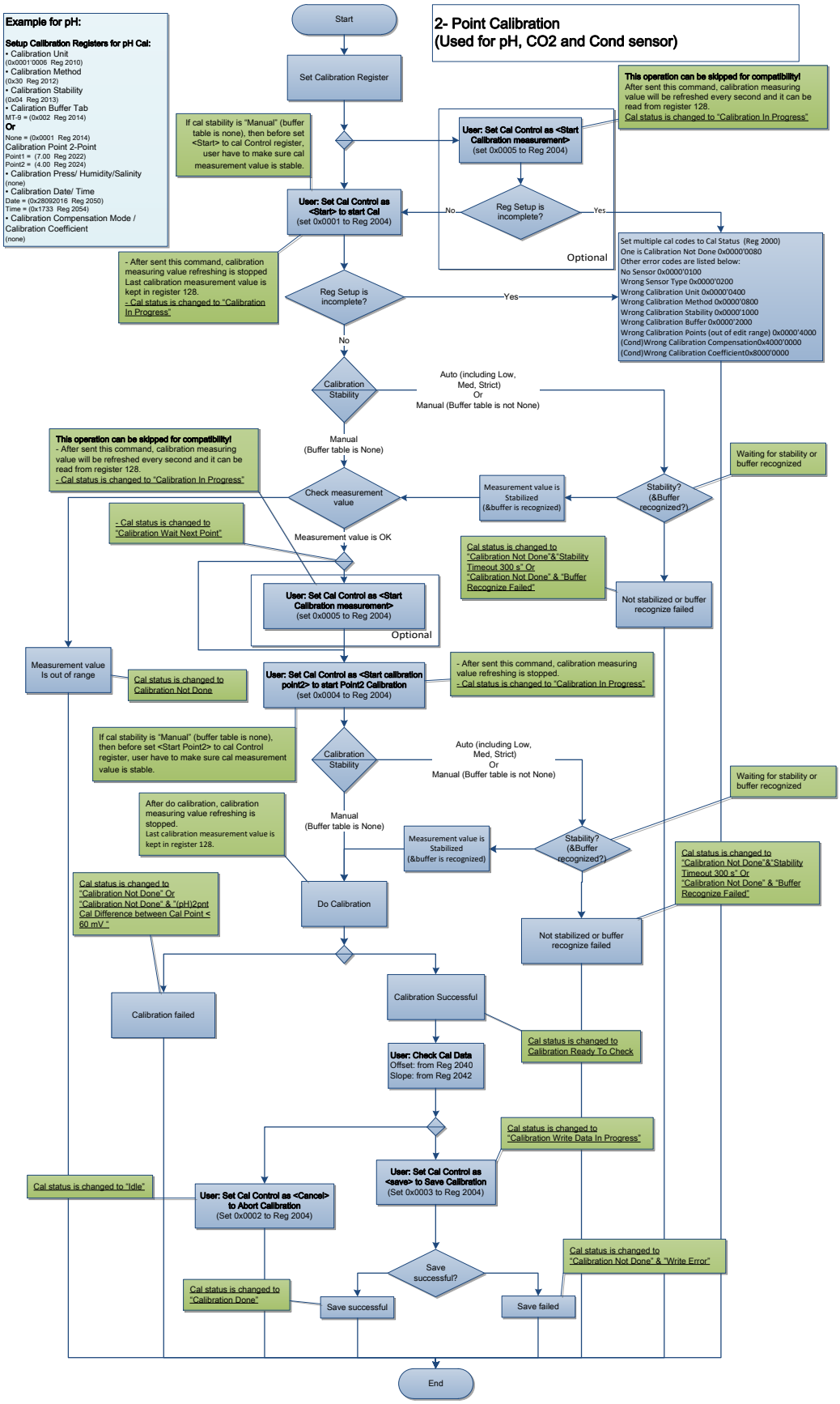
If M80 SM encounter an unrecoverable error during initialization process and the detailed status is "EEPROM read or write initial error 5 (0x0000'0020)"(Also see that in 7.1), then an extended code will be set into register 6002 (such as F5 0B 03 0A).

8 Appendix

8.1 Complete calibration example of a pH sensor



8.2 Complete calibration example of a pH sensor



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