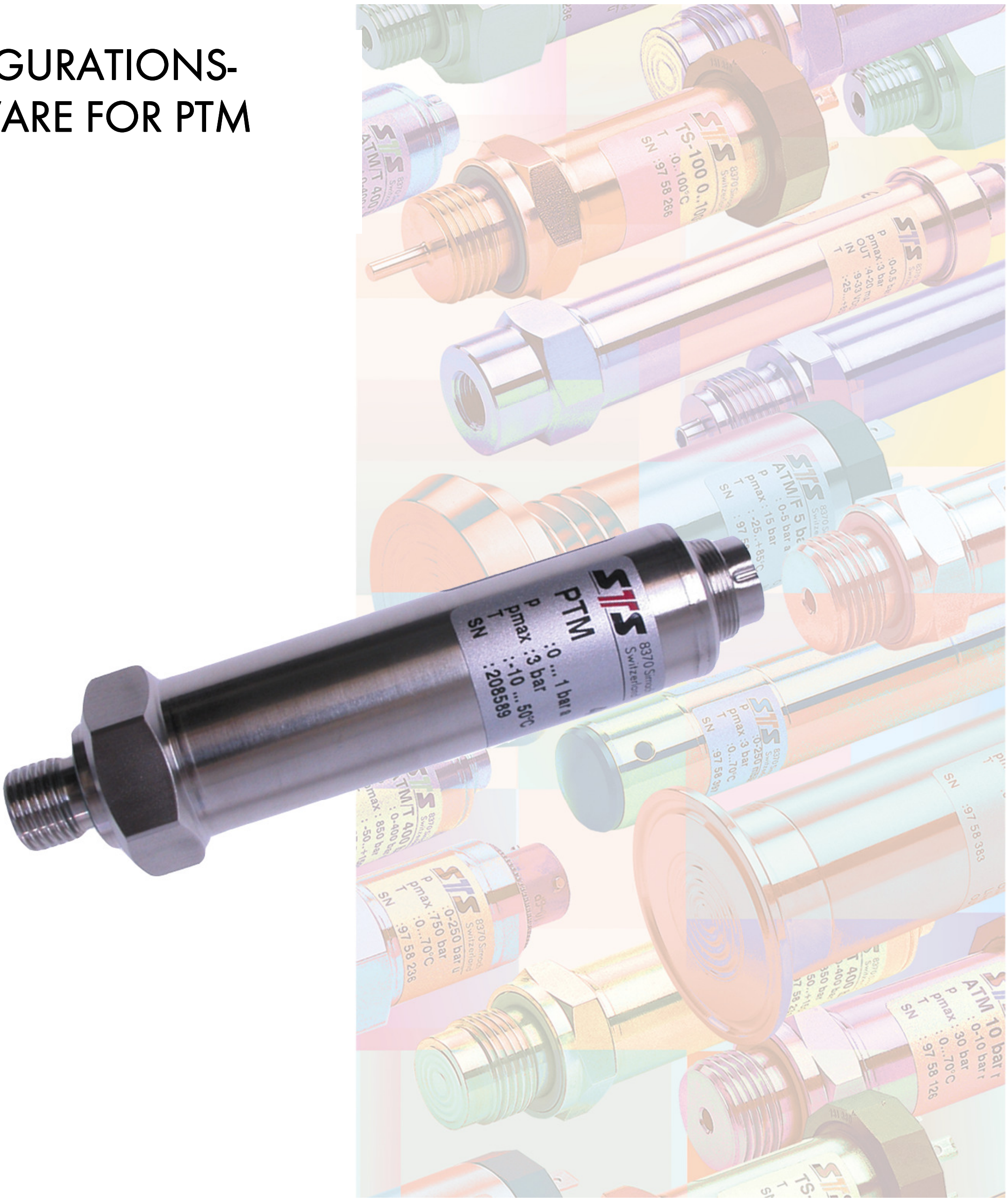
CONFIGURATIONS-SOFTWARE FOR PTM



Revision list

Version	Date	Author	Description
DEB005A	13/12/2002	RB	Created
DEB005D	03/02/2004	HU	Literature adapted; Section 1 supplemented; Section 2 - 5 re-divided and structured, partially supplemented; Section 4 new
DDB003D	19/02/2008	DH	Content revised
DDB005D	17/07/2013	MS	Content revised

Contents

Literature

[1] MODBUS over Serial Line, Specification & Implementation Guide V1.0
http://www.modbus.org → Modbus Standard Library section

[2] MODBUS Application Protocol Specification V1.1
http://www.modbus.org → Modbus Standard Library section

Conventions/Abbreviations

P	Pressure
P_{ZP}	Zero-point pressure
P_N	Nominal pressure
P_{On}	Switch point ON pressure of the relay
P_{Off}	Switch point OFF pressure of the relay
ZP	Zero point
T	Temperature
T_{NP}	Start of temperature range
T_N	End of temperature range
DW	Data word
DB	Data byte
@	at

1 PTM Transmitter Types

There are three different types of PTM transmitters. These unify the same basic functions described in Section 1.1 General and specific functions. These are listed in the following Sections 1.2 to 1.4 and shown in the block diagrams.

1.1 General

1.1.1 User scaling

It is possible to set the pressure range of the analog output, via user scaling (4 - 20 mA). The following setting ranges apply:

Pressure at 4mA: -5 - 105 %FS
Pressure at 20mA: -5 - 105 %FS

Whereby the minimum span may not be less than 25 % of the nominal range and not less than 50 mbar.

For example, for a transmitter with a nominal range of 1 bar, settings between 20% at 4mA and 80% at 20mA, or 20% at 4mA and –5% at 20mA are possible.

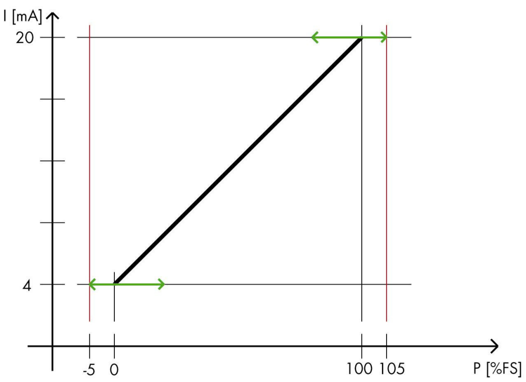


Figure 1: User scaling

The digital output is not scalable. Here the measuring range is always shown directly on 0 – 10,000 points. These are equivalent to 0 - 100 % of the measuring range.

1.1.2 Recalibration

Recalibration of the pressure measuring channel can be used to correct long-term drifts. Both the zero point (P_{NP}) and the span value (P_N) can be recalibrated. These can each be changed by +/- 5 %. The measurement of the signal by the PTM and a reference value measured in parallel are required for this purpose.

1.1.3 Temperature compensation

As a rule, the PTM transmitters have two types of temperature compensation. In the case of active temperature compensation, the thermal characteristic is measured in the furnace and the corresponding compensation data stored in the memory. Temperature compensation in sensor operation is thus determined numerically. In the case of passive temperature compensation, the thermal characteristic is compensated resistively. As this can only be used to correct linear components, this method is not quite as accurate as active compensation.

1.1.4 Low pass filter

To suppress undesirable, rapid pressure changes to the output signal, the cut-off frequency of the low pass filter can be selected accordingly.

With the damping the rate of increase of the output signal is damped. The smaller the adjusted frequency, the larger the damping.

Cut-off frequencies of 30 Hz (default), 10 Hz, 1 Hz and 0.1 Hz are available.

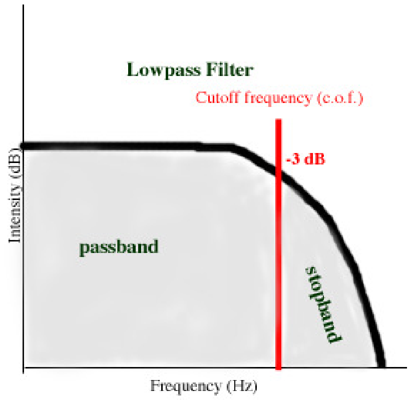


Figure 2: Damping

1.2 PTM 2-wire

1.2.1 Functions

The PTM 2-wire offers the following functions:

- User scaling of the analog pressure measuring output
- Recalibration of the pressure measuring output
- Active or passive temperature compensation
- Damping filter

The calculations of the individual parameters are indicated with the respective Modbus command.

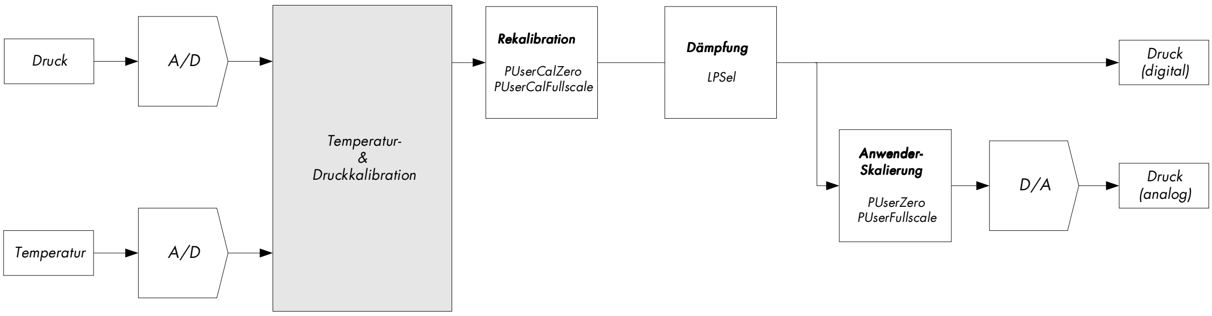


Figure 1: Signal flow diagram PTM 2-wire

1.2.2 Interface

Two types of modulation are used to communicate with the PTM 2-wire. Communication between PC and transmitter is realised via a supply voltage modulation. The transmitter responds to the PC via a current modulation. In this way, the current loop conductors are used for communication.
For the above-mentioned reasons, measurements cannot be taken of the analog output during communication. The following settings apply:

Protocol: Modbus (see Section 2) with STS Layer 7 (see Section 2)
Default address: 240 (with transmitter before February 2004: 255)
Transmission rate: 1200 baud

Data bits: 8
Parity: None
Stop bits: 2

1.3 PTM digital

1.3.1 Functions

The PTM digital offers the following functions:

- User scaling of the analog pressure measuring output
- Recalibration of the pressure measuring output
- Active or passive temperature compensation
- Damping filter
- Digital temperature output (only with active temperature compensation)
- Analog temperature output with user scaling (option with active temperature compensation)

The calculations of the individual parameters are indicated with the respective Modbus command.

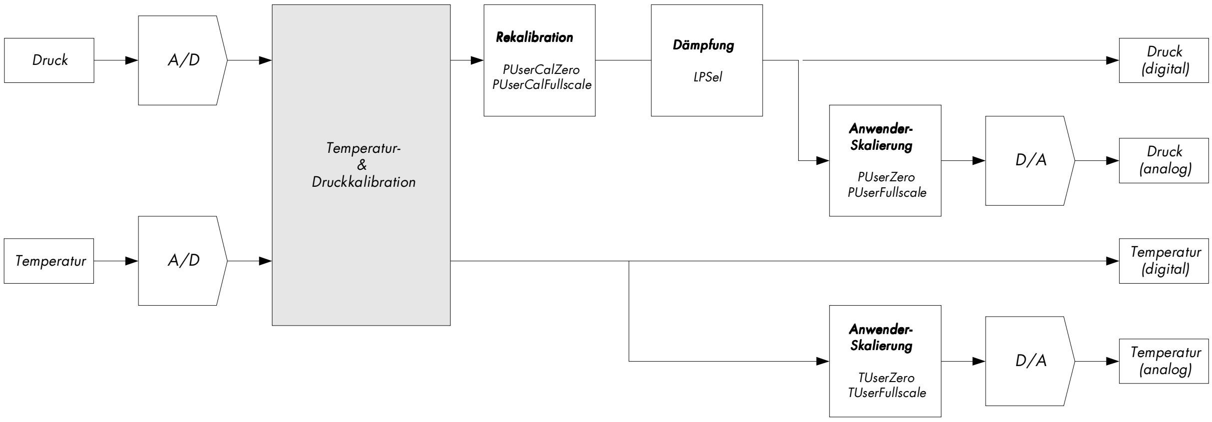


Figure 2: Signal flow diagram PTM digital

1.3.2 Interface

An RS485 interface is used to communicate with the PTM digital. The following settings apply:
Protocol: Modbus (see Section 2) with Modbus Layer 7 (see Section 4)
Default address: 240 (with transmitter before February 2004: 255)
Transmission rate: 9600 baud
Data bits: 8
Parity: None
Stop bit: 2

2 Modbus

2.1 General

The document [1] MODBUS over Serial Line describes the basics of Modbus communication, Layer 1 and 2 of the ISO/OSI layer model.

Layer 7 describes the interpretation of the data. With the PTM transmitters, two different Layer 7 logs are used. These are described in Sections 3 and 4 of this document.

2.1.1 Summary

- Modbus is a master-slave communication protocol.
- Modbus telegrams in the RTU or binary mode always begin with address (0 - 247) and a function code (Fcn-Code). Then the data bytes (DB) follow. 2 bytes with the CRC sum form the conclusion.
- The communication states (transmit/receive/cancel) are controlled via timeouts.
- The byte sequence for transmission of a data word is controlled as follows:
  Data STS Layer 7: Lo – Hi byte
  Data Modbus Layer 7: Hi – Lo byte
  CRC for both: Lo – Hi byte

2.1.2 Command structure

Command frame:

Modbus message (command or response)							
Address	Fcn Code	DW1	DW2	DW3	....	DW8	CRC
1 byte	1 byte	2 bytes	2 bytes	2 bytes		2 bytes	2 bytes

The number of data words can be seen from the definition of the respective commands. In the remainder of this document, the address and the CRC sum are not stated explicitly, but they are always part of the Modbus telegram.

The CRC sum is divided into individual bytes, with the low byte being transmitted first and then the high byte (see example below).

Thus: CRC = CRC hi * 256 + CRC lo

The CRC sum is formed via the address, function code and data words. If the response is faulty, no response is given.

Example: STS Layer 7 → Function code 03: Read pressure and temperature

Command

Parameter	Example (Hex)	Example (Decimal)	Description
Address	11	17	
Function code	03	03	
CRC low	2E	7470	CRC16
CRC high	1D		

Response

Parameter	Example (Hex)	Example (Decimal)	Description
Address	11	17	
Function code	03	03	
Pressure low	2E	5678	Pressure in %FS * 100 (5687 = 56.78% FS)
Pressure high	16		
Temperature low	FB	251	Temperature in %FS * 100 (251 = 2.51%FS)
Temperature high	00		
CRC low	0A	5130	CRC16
CRC high	14		

2.1.3 Example code CRC16

The CRC16 code is used as CRC sum. In order to avoid misunderstandings at this point, the C code is attached:

```
unsigned short calcCRC16 (unsigned char *data, unsigned short count)
{
 unsigned int fcs = 0xFFFFU;                /* initial Frame Check Sequence (FCS) value */
 unsigned int d, i, k;
 for (i = 0; i < count; i++)
 {
  d = (((unsigned int) (*data++)) << 0U);
  for (k = 0; k < 8; k++)
  {
   if (((fcs ^ d) & 0x0001U) == 1)
   {
    fcs = (fcs >> 1) ^ 0xA001U;    /* Generator Polynomial 0xA001U */
   }
   else
   {
    fcs = (fcs >> 1);
   }
   d >>= 1;
  }
 }
 return(fcs);
}
```

3 STS Layer 7 Protocol

3.1 General

The STS Layer 7 protocol is used for the 2-wire and PTM/GR pressure transmitters.

The digital PTM can be switched over from the Modbus Layer 7 to the STS Layer 7 protocol, whereby this switchover cannot be saved (volatile). Then the commands of the STS Layer 7 protocol are also available to the digital PTM.

With this protocol the following secondary conditions apply to the Modbus:

1. The data are transmitted as 2-byte data words (DW) i.e. the number of data bytes is always a multiple of 2.
2. The maximum number of data bytes is 16, 8 DW. The maximum telegram length, including address, function code and CRC sum, is thus 20 bytes.
3. The address 0 (broadcast) is always active for all transmitters, regardless of the address at which the transmitter is set (this contradicts the documents [1] and [2]). However, this means that the broadcast cannot be used in a network with several transmitters connected simultaneously, since otherwise the responses of the transmitters would collide.
4. The addresses 1 - 255 are permissible as possible transmitter addresses. The default is the address 240 (before February 2004: address 255).
5. The function codes are within the range of 3 - 255. This contradicts with Modbus, as they specify only codes, less than 128 are assigned and user codes are greater than the exception.

3.2 Standard commands

3.2.1 Overview of commands

The standard commands are listed below. The transmission and response lengths are stated in data bytes and include address, function code and CRC sum.

Function code	Description	2-wire	Digital	GR	Transmission length	Response length
03	Read pressure and temperature	X	X	X	4	8
04	Read relay status			X	4	8
30	Read serial number	X	X	X	4	8
31	Read firmware version number	X	X	X	4	6

Table 1: Overview of standard commands

3.2.2 Function code 03: Read pressure and temperature

Command		Response				
03		03	Pressure		Temperature	
1 Byte		1 byte	1 byte	1 byte	1 byte	1 byte

Reads the pressure. With digital output and active compensation, also the temperature. With the 2-wire and the PTM/GR transmitter, the temperature field does not contain any valid data, but the data frame remains the same. Value range: 16bit signed integer (-32,768...32,767), nominal 0...10,000 points (P_{NP}...P_N)

Pressure: Value range: 0 ... 10,000 points

Conversion:

$$P[bar] = pressure * \frac{(P_N[bar] - P_{ZP}[bar])}{10000} + P_{ZP}[bar]$$

Temperature: Value range: 0 ... 10,000 points

Conversion:

$$T[°C] = temperature * \frac{(T_N[°C] - T_{ZP}[°C])}{10000} + T_{ZP}[°C]$$

3.2.3 Function code 30: Read serial number

Command		Response				
30		30	SN1		SN2	
1 byte		1 byte	1 byte	1 byte	1 byte	1 byte

Reads the serial number.

Value range: Whole number (32bit unsigned integer) between 0 and (2^{32}-1)
Divided into 2 DW (SN1 and SN2), each of 2 bytes.

Calculation: Serial number = SN2 * 65536 + SN1

Example: SN1 = 53597
SN2 = 2 -> serial number = 184669

3.2.4 Function code 31: Read software version number

Command		Response		
31		31	Version number	
1 byte		1 byte	1 byte	1 byte

Reads the software version number.

Value range: Whole number (16bit unsigned integer) between 0 and 65,535
Calculation: Software version = version number / 100
Example: version number 202 ≡ software version 2.02

3.3 Extended commands

3.3.1 Overview of commands

The extended commands are listed below. The transmission and response lengths are quoted in data bytes and include address, function code and CRC sum.

Function code	Description	2-wire	Digital	GR	Transmission length	Response length
112	Delete user data	X	X	X	4	6
114	Set user password	X	X	X	6	6
136	Read-out user parameter 1	X	X	X	4	20
137	Read-out user parameter 2	X	X	X	4	20
138	Read-out user parameter 3	X	X	X	4	20
152	Write user parameter 1	X	X	X	20	5
153	Write user parameter 2	X	X	X	20	5
154	Write user parameter 3	X	X	X	20	5
234	Read-out factory parameter 1	X	X	X	4	20
235	Read-out factory parameter 2	X	X	X	4	20

Table 2: Overview of extended commands

3.3.2 Overview of parameters

User parameter	Function code
Address	136, 152
LPSel	136, 152
PUserZero	136, 152
PUserFullscale	136, 152
TUserZero	136, 152
TUserFullscale	136, 152
PUserCalZero	136, 152
PUserCalFullscale	136, 152
Description	137, 153
Pon1	138, 154
Poff1	138, 154
DelayOn1	138, 154
DelayOff1	138, 154
Pon2	138, 154
Poff2	138, 154
DelayOn2	138, 154
DelayOff2	138, 154

Factory parameter	Function code
PMax	234
PMin	234
TMax	234
TMin	234
SN (SN1, SN2)	235
HW_Number	235
HW_Index	235
PTyp	235
CalTyp	235

Table 3: Extended commands parameter overview

3.3.3 Function code 112: Delete parameter flash

Com-mand
112
1 byte

Response	
112	Respons e
1 byte	1 byte

Deletes the parameter flash. The password has to be sent before this command can be executed (see function code 114, Section 3.3.4

Response:	Value range:	0	Error
		1	Correct

> Note:
> Erasing data with the PTM 2-wire causes current peaks, which can interrupt communication (i.e. the response of the transmitter is interrupted). As a workaround, the application program can ignore the response and, by means of read access, ensure that the erasing process is completed successfully (with commands 136 – 138, all data words must be 65535).

> Note:
> Please note the procedure in Section 4.5 for writing to the memory

3.3.4 Function code 114: Password for parameter flash modifications

Command	
114	2001
1 byte	1 byte

Response	
114	Respons e
1 byte	1 byte

To delete or write the parameter flash, the password has to be transmitted first. After entering the password, erase and write operations are possible within the next 10 minutes or until the next reset.

Response	Value range:	0	Password incorrect
		1	Password correct

3.3.5 Function code 136: Read user parameter 1

Command	Response																
136	136	Address		LPSel		PUserZero		PUserFullscale		TUserZero		TUserFullscale		PUserCalZero		PUserCalFullscale	
1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.

Reads the address, damping, scaling and recalibration parameters.

Address: Value range: 1 - 255
0 is reserved for broadcast and cannot be used as address.
240 is the default value on delivery

LPSel: Description: Represents the damping set of the analog output.
Value range:
0: approx. 30 Hz, standard
1: 10 Hz
2: 1 Hz
3: 0.1 Hz

PUserZero: Description: Zero-point scaling of the analog output Pout from −5 to 105 %FS
Value range: 19,500 ... 30,500, standard: 20,000 at 0%FS
Calculation:

$$4mA\,@\,P[bar] = \frac{(PUserZero - 20000)}{10000} * (P_N[bar] - P_{ZP}[bar]) + P_{ZP}[bar]$$

PUserFullscale: Description: Full-scale scaling of the analog output Pout from −5 to 105 %FS
Value range: -500 - 10,500, standard: 10,000 at 100%FS
Calculation:

$$20mA\,@\,P[bar] = \frac{PUserFullscale}{10000} * (P_N[bar] - P_{ZP}[bar]) + P_{ZP}[bar]$$

TUserZero: Description: Zero-point scaling of the analog output Tout from −5 to 105 %FS
Value range: 19,500 - 30,500, standard: 20,000 at 0%FS
Calculation:

$$4mA\,@\,T[°C] = \frac{(TUserZero - 20000)}{10000} * (T_N[°C] - T_{ZP}[°C]) + T_{ZP}[°C]$$

TUserFullscale: Description: Full-scale scaling of the analog output Tout from −5 to 105 %FS
Value range: -500 - 10,500, standard: 10,000 at 100%FS
Calculation:

$$20mA\,@\,T[°C] = \frac{TUserFullscale}{10000} * (T_N[°C] - T_{ZP}[°C]) + T_{ZP}[°C]$$

PUserCalZero: Description: Zero-point recalibration
Value range: 19,500 - 30,500, standard: 20,000 at 0%FS
Calculation: See Section 5.1 Recalibration

PUserCalFullscale: Description: Full-scale recalibration
Value range: -500 - 10,500, standard: 10,000 at 100%FS
Calculation: See Section 5.1 Recalibration

3.3.6 Function code 137: Read user parameter 2

Com-mand	Response																
137	137	Desc1		Desc2		Desc3		Desc4		Desc5		Desc6		Desc7		Desc8	
1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.

Reads the description. The description comprises a maximum of 16 characters. The values of the individual bytes correspond to the decimal values of the ASCII table, with the low-byte of Desc1 representing the first and the high-byte of Desc8 the last character. If not all characters are required, the remaining bytes are initialised with zeros (see also function code 153).

3.3.7 Function code 234: Read factory parameter 1

Com-mand	Response																
234	234	PMax1		PMax2		PMin1		PMin2		TMax1		TMax2		TMin1		TMin2	
1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.

Reads the factory parameters of the pressure and temperature ranges.

All — Value range: Whole number (32-bit integer) between 0 and (2^{32}-1)
Divided into 2 DW, each of 2 bytes.

PMax1, PMax2 — Description: Nominal pressure of the transmitter
Calculation: PMax = PMax2 * 65536 + PMax1
If PMax > 2^{31}
PMax = (PMax2 * 65536 + PMax1) - 2^{32}

$$P_N[bar] = \frac{PMax}{100000}[bar]$$

Example: PMax1 = 54464
PMax2 = 1 -> PMax = 120000
-> P_N = 1.2 bar

PMin1, PMin2 — Description: Zero-point pressure of the transmitter
Calculation: PMin = PMin2 * 65536 + PMin1
If PMin > 2^{31}
PMin = (PMin2 * 65536 + PMin1) - 2^{32}

$$P_{NP}[bar] = \frac{PMin}{100000}[bar]$$

Example: PMin1 = 31072
PMin2 = 65534-> PMin = -100'000
-> P_{ZP} = -1 bar

TMax1, TMax2 — Description: End of the transmitter-temperature range
Calculation: TMax = TMax2 * 65536 + TMax1
If TMax > 2^{31}
TMax = (TMax2 * 65536 + Tmax1) – 2^{32}

$$T_N[°C] = \frac{TMax}{100000}[°C]$$

TMin1, TMin2 — Description: Start of the transmitter-temperature range
Calculation: TMin = TMin2 * 65536 + TMin1
If TMin > 2^{31}
TMin = (TMin2 * 65536 + TMin1) – 2^{32}

$$T_{NP}[°C] = \frac{TMin}{100000}[°C]$$

3.3.8 Function code 235: Read factory parameter 2

Command
235
1 b.

Response																
235	SN1		SN2		HW_Ver		HW_Index		PTyp		CalTyp					
1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.

Reads the factory parameters serial number, hardware version, hardware index, pressure type and calibration type.

SN1, SN2 Description: Transmitter serial number
Value range: Whole number (32-bit integer) between 0 and (2^{32}-1)
Divided into 2 DW (SN1 and SN2), each of 2 bytes.
Calculation: Serial number = SN2 * 65536 + SN1
Example: SN1 = 53597
SN2 = 2 -> serial number = 184669

HW_Ver Description: Hardware version of the transmitter print
Value range: 0 ... 9999
Representation: 6.00.xxxx.A

HW_Index Description: Hardware index of the transmitter print
Value range: 65 ... 90 (decimal ASCII values for A ... Z)
Representation: 6.00.0000.x

PTyp Description: Indicates the pressure types of the transmitter
Value range: 0: a absolute pressure
1: g relative pressure
2: sg over-pressure

CalTyp Description: Temperature calibration type
Value range: 0: passive temperature compensation
1: active temperature compensation
(For explanation of active or passive temperature compensation, see Section 1 PTM transmitter types)

3.3.9 Function code 152: Write user parameter 1

Command																
152	Address		LPSel		PUserZero		PUserFullscale		TUserZero		TUserFullscale		PUserCalZero		PUserCalFullscale	
1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.	1 b.

Response		
152	1	
1 b.	1 b.	1 b.

Writes the address, damping, scaling and recalibration parameters in the flash.

Address: Value range: 1 - 255;
0 is reserved for broadcast and cannot be used as address.

LPSel: Description: Represents the cut-off frequency setting of the analog output.
Value range: 0:approx. 30 Hz standard
1: 10 Hz

2: 1 Hz
3: 0.1 Hz

In order to calculate PUserZero and PuserFullscale, the following should be observed:
The minimum span (P[bar] at 20mA – P[bar] at 4mA) may not be less than 25% of the nominal range and not less than 50 mbar.

PUserZero:
Description: Zero-point scaling of the analog output Pout from −5 to 105 %FS
Value range: 19,500 ... 30,500, standard: 20,000 at 0%FS
Calculation:

$$PUserZero = \frac{(P[bar]@4mA - P_{ZP}[bar])}{(P_N[bar] - P_{ZP}[bar])} * 10000 + 20000$$

PUserFullscale:
Description: Full-scale scaling of the analog output Pout from -5 to 105 %FS
Value range: -500 ... 10,500, standard: 10,000 at 100%FS
Calculation:

$$PUserFullscale = \frac{P[bar]@20mA - P_{ZP}[bar]}{(P_N[bar] - P_{ZP}[bar])} * 10000$$

In order to calculate TUserZero and TUserFullscale, the following should be observed:
the minimum span (T[°C] at 20mA – T[°C] at 4mA) may not be less than 25% of the nominal range.

TUserZero:
Description: Zero-point scaling of the analog output Tout from −5 to 105 %FS
Value range: 19,500 - 30,500, standard: 20,000 at 0%FS
Calculation:

$$TUserZero = \frac{(T[°C]@4mA - T_{ZP}[°C])}{(T_N[°C] - T_{ZP}[°C])} * 10000 + 20000$$

TUserFullscale:
Description: Full-scale scaling of the analog output Tout from -5 to 105 %FS
Value range: -500 - 10,500, standard: 10,000 at 100%FS
Calculation:

$$TUserFullscale = \frac{(T[°C]@20mA - T_{ZP}[°C])}{(T_N[°C] - T_{ZP}[°C])} * 10000$$

PUserCalZero:
Description: Zero-point recalibration
Value range: 19,500 - 30,500, standard: 20,000 at 0%FS
Calculation: See Section 5.1 Recalibration

PUserCalFullscale:
Description: Full-scale recalibration
Value range: -500 - 10,500, standard: 10,000 at 100%FS
Calculation: See Section 5.1 Recalibration

3.3.10 Function code 153: Write user parameter 2

Command																
153	Desc1		Desc2		Desc3		Desc4		Desc5		Desc6		Desc7		Desc8	
1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.

Response		
153	1	
1 B.	1 B.	1 B.

Writes the description in the flash. It comprises a maximum of 16 characters. The values of the individual bytes correspond to the decimal values of the ASCII table, with the low-byte of Desc1 representing the first and the high-byte of Desc8 representing the last character. If not all characters are required, the remaining bytes are initialised with zeros.

Example: Character string 0 – 10 mWs g

Character	ASCII (Hex)	DW (Hex)	DW (Dec)	Description
“0”	0x30	2030h	8240d	Desc1
“ ”	0x20			
“-”	0x2D	202Dh	8237d	Desc2
“ ”	0x20			
“1”	0x31	3031h	12337d	Desc3
“0”	0x30			
“ ”	0x20	6D20h	27936d	Desc4
“m”	0x6D			
“W”	0x57	7357h	29527d	Desc5
“s”	0x73			
“ ”	0x20	6720h	26400d	Desc6
“g”	0x67			
	0x00	0000h	0d	Desc7
	0x00			
	0x00	0000h	0d	Desc8
	0x00			

Procedure for writing to memory

Due to the structure of the memory, when writing the flash, the following procedure must be observed:

1. Read the user parameters (function codes 136 – 138).
2. Intermediate storage of the values in the PC.
3. Send the password (function code 114).
4. Delete the flash (function code 112).
5. If necessary, read the flash (check the deletion process) (function codes 136 – 138).
   Reading- back the parameters, they must contain the values 65535.
   → As from here the address is therefore set to an undefined value, use the address 0 to write the parameters. With it the transmitter can be addressed at any time, regardless of the address setting.
6. Compile the new user parameters.
7. Write the user parameters (function codes 152 – 154).
   All three function codes always have to be written consecutively!
   Individual parameters or lines cannot be partially overwritten!
8. Read-out the flash (check the write process) (function code 136 – 138).
   If the write process fails, continue from point 4.

4 Modbus Layer 7 Protocol

4.1 General

The Modbus Layer 7 protocol is used for the PTM and PTM/N with digital output, which is network-capable with the RS485 interface.
The document [2], MODBUS Application Protocol Specification, is to be considered the basis for this protocol.

The data are accessed with fixed function codes with an index system. For this purpose a start index (SI; read/write from which index) and the length (L; how many indices) are included. In some cases the length is also included with a byte count (BC), whereby the byte count must be calculated with the formula 2 * length.

The following secondary conditions for the Modbus apply to this protocol:

1. The parameters (data without start index, length or byte count) are transmitted as 2-byte data words (DW).
2. The maximum number of parameter bytes (data without start index, length or byte count) is 16, 8 DW. The maximum telegram length including the address, function code, start index, length, byte count and CRC sum is therefore 25 bytes (with function code 16, write multiple registers).
3. The address 0 is a broadcast address in the Modbus Layer 7 protocol, i.e. all connected transmitters carry out the command and don't respond.
4. The addresses 1 - 247 are permissible as possible transmitter addresses. The default is the address 240.
5. The start indices have always been created so that maximum blocks of eight consecutive indices result. This length can still be processed by the receiving memory of the PTM.

4.2 Standard commands

4.2.1 Overview of commands

The standard commands are listed in the following. The transmission and response lengths are specified in data bytes including the address, function code and CRC sum.

Function code	Description	2-wire	Digital	GR	Transmission length	Response length
04	Read-input registers		X		8	5 + 2*length

Table 4: Overview of standard commands

4.2.2 Function code 04: Read input register

Command				
04	Start index		Length	
1 B.	1 B.	1 B.	1 B.	1 B.

Response									
04	Byte count	DW1		DW2		.....	DWn	
1 B.	1 B.	1 B.	1 B.	1 B.	1 B.		1 B.	1 B.

The number of data words (1 to maximum of 8) is dependent of the length.
In the process, the "ByteCount" becomes the number of data bytes transmitted, or 2 * length.

4.2.3 Start index overview

The parameters can be read out in function of code 04 under the following start index:

User parameter	Start index	Access
Measured pressure value	0	r
Measured temperature value	1	r
Software version	7	r

Table 5: Start index overview of standard commands

Access r: read only

4.2.4 Start index 0: Measured pressure value

Pressure Value range: 0 - 10,000 points

Conversion: $$P[bar] = pressure[points] * \frac{(P_N[bar] - P_{NP}[bar])}{10000} + P_{NP}[bar]$$

Value range: 16bit signed integer (-32,768...32,767), nominal 0...10,000 points (P_{NP}...P_N)

4.2.5 Start index 1: Measured temperature value

Temperature Value range: 0 - 10,000 points

Conversion: $$T[°C] = temperature[points] * \frac{(T_N[°C] - T_{NP}[°C])}{10000} + T_{NP}[°C]$$

Value range: 16bit signed integer (-32,768...32,767), nominal 0...10,000 points (P_{NP}...P_N)

Example transmission code (in hex format) for a sensor with the address 240_{10} or $F0_{16}$:
T_{NP} = -10°C, T_N = 50°C

F0	04	00	01	00	01	75	2B
Address	Function code	Start index		Length		CRC	
(byte)	(byte)	high byte	low byte	high byte	low byte	low byte	high byte

Data transfer sequence →

Example answer (in hex format) for a sensor with the address 240_{10} or $F0_{16}$:

F0	04	02	15	EF	8B	F9
Address	Function code	ByteCount	Temperature [points]		CRC	
(byte)	(byte)	(byte)	high byte	low byte	low byte	high byte

Data transfer sequence

Example conversion: $T = 5615 * \frac{(50-(-10))}{10000} + (-10) = 23.69°C$

4.2.6 Start index 7: Software version

Version Value range: Whole number (16bit unsigned integer) between 0 and 65,535

Calculation: Software version = Versions number / 100

Example: Versions number 202 ≡ Software version 2.02

4.3 Extended commands

4.3.1 Command overview

The extended commands are listed in the following. The transmission and response length are specified in data bytes including the address, function code and CRC sum.

Function code	Description	2-wire	Digital	GR	Transmission length	Response length
03	Read holding registers		X		8	5 + 2*length
16	Write multiple registers		X		9 + 2*length	8

Table 6: Overview of extended commands

4.3.2 Function code 03: Read holding register

Command				
03	Start index		Length	
1 B.	1 B.	1 B.	1 B.	1 B.

Response								
03	Byte count	DW1		DW2		.....	DWn	
1 B.	1 B.	1 B.	1 B.	1 B.	1 B.		1 B.	1 B.

The number of data words (1 to a maximum of 8) is dependent on the length.
In the process, the byte count becomes the number of data bytes transmitted, or 2 * length.

4.3.3 Function code 16: Write multiple register

Command										
16	Start index		Length		BC	DW1		.....	DWn	
1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.	1 B.		1 B.	1 B.

Response				
16	Start index		Length	
1 B.	1 B.	1 B.	1 B.	1 B.

The number of data words (1 to a maximum of 8) is dependent on the length.
In the process, the byte count becomes the number of data bytes to be transmitted, or 2 * length.

4.3.4 Start index overview

The parameters can be read or written with the two function codes 03 and 16 under the following start index:

User parameter	**Start index**	**Access**
Command set for Layer 7	0	rw
Set user password	2	w
Set user password + delete data	4	w
Address	20	rw
LPSel	21	rw
PUserZero	22	rw
PUserFullscale	23	rw
TUserZero	24	rw
TUserFullscale	25	rw

Factory parameter	**Start index**	**Access**
PMax	200 + 201	r
PMin	202 + 203	r
TMax	204 + 205	r
TMin	206 + 207	r
SN (SN1, SN2)	210 + 211	r
HW_Number	212	r
HW_Index	213	r
PTyp	214	r
CalTyp	215	r

PUserCalZero	26	rw			
PUserCalFullscale	27	rw			
Description (two characters each)	30 -37	rw			

Table 7: Start index overview of expanded commands

Access r: read only
w: write only
rw: read and write

4.3.5 Start index 0: Layer 7 command set

Reads or sets the command set to be used on the Layer 7 level.

Command set Value range: 0 Modbus Layer 7 command set
1 STS Layer 7 command set

Following start-up, the digital transmitter is always in the Modbus Layer 7 command set. The ModBus STS Layer 7 command settings cannot be saved; it is in a volatile state. This reset will be made during a reset.

Important: In the STS Layer 7 command settings the two function codes 03 and 16 have also been implemented after Modbus Layer 7 command settings. As a result, a transmitter can also be reset to the Modbus Layer 7 command settings.

4.3.6 Start index 2: Password for parameter flash modifications

To enable deleting or writing of the parameter flash, the password must be transmitted first. After the password is entered, delete and write operations are possible within the next 10 minutes in each case until the next reset.

This command only has a write access!

The password is: 2001

4.3.7 Start index 4: Write and delete password for parameter flash modifications

To enable deleting or writing of the parameter flash, the password must be transmitted first. After the password has been entered, deleting and writing operations are possible within the next 10 minutes each time until the next reset. At the same time, the parameter flash is also immediately deleted with this command and after it will be ready for write access.

This command only has a write access!

The password is: 2001

4.3.8 Start index 20: Address

Address Description: Device address of Modbus protocol
Value range: 1 - 247
0 is reserved for broadcast and is not permissible as an address.
240 is the default value on delivery.

4.3.9 Start index 21: Low pass filter

LPSel: Description: Represents the damping settings of the analog pressure output.
Value range: 0:approx. 30 Hz Standard

1: 10 Hz
2: 1 Hz
3: 0.1 Hz

4.3.10 Start index 22: Pressure zero-point scaling of analog output

PUserZero

Description: Zero-point scaling for analog output Pout from−5 to 105 %FS
Value range: 19,500 - 30,500, Standard: 20,000 at 0%FS
read:

$$4mA\ @\ P[bar] = \frac{(PUserZero - 20000)}{10000} * (P_N[bar] - P_{ZP}[bar]) + P_{ZP}[bar]$$

write:

$$PUserZero = \frac{(P[bar]\ @\ 4mA - P_{ZP}[bar])}{(P_N[bar] - P_{ZP}[bar])} * 10000 + 20000$$

4.3.11 Start index 23: Pressure of full-scale scaling of analog output

PUserFullscale

Description: Full-scale scaling for analog output Pout from -5 to 105 %FS
Value range: -500 - 10,500, Standard: 10,000 at 100%FS
read:

$$20mA\ @\ P[bar] = \frac{PUserFullscale}{10000} * (P_N[bar] - P_{ZP}[bar]) + P_{ZP}[bar]$$

write:

$$PUserFullscale = \frac{P[bar]\ @\ 20mA - P_{ZP}[bar]}{(P_N[bar] - P_{ZP}[bar])} * 10000$$

4.3.12 Start index 24: Temperature of zero-point scaling of analog output

TUserZero

Description: Zero-point scaling for analog output Tout from −5 to 105 %FS
Value range: 19,500 - 30,500, Standard: 20,000 at 0%FS
read:

$$4mA\ @\ T[°C] = \frac{(TUserZero - 20000)}{10000} * (T_N[°C] - T_{ZP}[°C]) + T_{ZP}[°C]$$

write:

$$TUserZero = \frac{(T[°C]\ @\ 4mA - T_{ZP}[°C])}{(T_N[°C] - T_{ZP}[°C])} * 10000 + 20000$$

4.3.13 Start index 25: Temperature of full-scale scaling for analog output

TUserFullscale

Description: Full-scale scaling for analog output Tout from −5 to 105 %FS
Value range: -500 - 10,500, Standard: 10,000 at 100%FS
read:

$$20mA\ @\ T[°C] = \frac{TUserFullscale}{10000} * (T_N[°C] - T_{ZP}[°C]) + T_{ZP}[°C]$$

write:

$$TUserFullscale = \frac{(T[°C]\ @\ 20mA - T_{ZP}[°C])}{(T_N[°C] - T_{ZP}[°C])} * 10000$$

4.3.14 Start index 26: Pressure of zero-point recalibration

PUserCalZero

Description: Zero-point recalibration
Value range: 19,500 - 30,500, Standard: 20,000 at 0%FS

Calculation: see Section 5.2 Recalibration

4.3.15 Start index 27: Pressure of full-scale recalibration

PUserCalFullscale	Description:	Full-scale recalibration
	Value range:	-500 - 10,500, Standard: 10,000 at 100%FS
	Calculation:	see Section 5.2 Recalibration

4.3.16 Start index 30 - 37: Device description

The description consists of a maximum of 16 characters. The values of the individual bytes are equivalent to the decimal values of the ASCII table, whereby the low byte of Desc1 represents the first and the high byte of Desc8 the last character. If not all characters are required, then the remaining bytes are initialised with zeros.

Example: character string 0 – 10 mWc g

Character	ASCII (Hex)	DW (Hex)	DW (Dec)	Description
"0"	0x30	2030h	8240d	Desc1
" "	0x20			
"-"	0x2D	202Dh	8237d	Desc2
" "	0x20			
"1"	0x31	3031h	12337d	Desc3
"0"	0x30			
" "	0x20	6D20h	27936d	Desc4
"m"	0x6D			
"W"	0x57	7357h	29527d	Desc5
"s"	0x73			
" "	0x20	6720h	26400d	Desc6
"g"	0x67			

	0x00	0000h	0d	Desc7
	0x00			
	0x00	0000h	0d	Desc8
	0x00			

4.3.17 Start index 200+201: Nominal pressure

Data type signed long

PMax1, PMax2 Description: Nominal pressure

Calculation: PMax = PMax2 * 65536 + PMax1

If PMax > 2^{31}

PMax = (PMax2 * 65536 + PMax1) - 2^{32}

$$P_N[bar] = \frac{PMax}{100000}[bar]$$

Example: PMax1 = 54464

PMax2 = 1 -> PMax = 120,000

-> P_N = 1.2 bar

4.3.18 Start index 202+203: Zero-point pressure

Data type signed long

PMin1, PMin2 Description: Zero-point pressure

Calculation: PMin = PMin2 * 65536 + PMin1

If PMin > 2^{31}

PMin = (PMin2 * 65536 + PMin1) - 2^{32}

$$P_{NP}[bar] = \frac{PMin}{100000}[bar]$$

Example: PMin1 = 31072

PMin2 = 65534-> PMin = -100,000

-> P_{NP} = -1 bar

4.3.19 Start index 204+205: End of temperature range

Data type signed long

TMax1, TMax2 Description: End of temperature range

Calculation: TMax = TMax2 * 65536 + TMax1

If TMax > 2^{31}

TMax = (TMax2 * 65536 + Tmax1) – 2^{32}

$$T_N[°C] = \frac{TMax}{100000}[°C]$$

4.3.20 Start index 206+207: Start of temperature range

Data type	signed long	
TMin1, TMin2	Description:	Start of temperature range
	Calculation:	TMin = TMin2 * 65536 + TMin1
		If TMin > 2^{31}
		TMin = (TMin2 * 65536 + TMin1) − 2^{32}
		$T_{NP}[°C] = \frac{TMin}{100000}[°C]$

4.3.21 Start index 210+211: Serial number

Data type	unsigned long	
SN1, SN2	Description:	Transmitter serial number
	Value range:	Whole number (32bit integer) between 0 and (2^{32}-1)
		Divided into 2 DW (SN1 and SN2) of 2 bytes each.
	Calculation:	Serial number = SN2 * 65536 + SN1
		Example: SN1 = 53597
		SN2 = 2 -> Serial number = 184669

4.3.22 Start index 212: Hardware version

HW_Ver	Description:	Hardware version of the PCB
	Value range:	0 - 9999
	Format:	6.00.xxxx.A

4.3.23 Start index 213: Hardware index

HW_Index	Description:	Hardware index of the PCB
	Value range:	65 - 90 (ASCII values decimal for A - Z)
	Format:	6.00.0000.x

4.3.24 Start index 214: Pressure type

PTyp	Description:	Indicates pressure types		
	Value range:	0:	a	Absolute pressure
		1:	g	Relative pressure
		2:	sg	Overpressure

4.3.25 Start index 215: Temperature calibration type

CalTyp	Description:	Temperature calibration type
	Value range:	0: Passive temperature compensation
		1: Active temperature compensation
		(For explanation, see Section 1 PTM transmitter types)

4.4 Handling exceptions

4.4.1 General

In the Modbus Layer 7 protocol, faulty transmission of a node, will be responded with an exception. However, faulty does not mean:

- Incorrect device address
- Faulty CRC sum

In these cases no response may be transmitted.

The exception response is characterised by the fact that the function code has been increased by 128. For example, for a function code 03, the response in the case of an exception is received with the function code 131.

4.4.2 Exception response

Command				
xx	......		......	
1 B.	1 B.	1 B.	1 B.	1 B.

Response	
xx + 128	Exception code
1 B.	1 B.

As described above, the function code is increased by 128 during the response. With the exception code, an error in the receiver can be find out.

4.4.3 Exception codes

Here the following exception codes are possible:

Exception code	Fault description
1	The function code used in the command is not supported by the device.
2	a) The start index used in the command is not supported by the device. b) The length used in the command is too large for this start index.
3	The length used in the command is 0.
4	a) There are not enough rights present to an index used in the command (write/read). b) The value range of the data to be written has been violated.

Table 8: Exception codes

4.5 Procedure when writing to memory

Due to the memory structure, it is necessary when writing the flash to comply with the following procedure:

1. Read the user parameters (function code 03, start index 20 + 30, per length 8)
2. Temporary storage of the values in the PC
3. Writing the password and deleting the flash (function code 16, start index 4, length 1)
   After the flash is deleted, the address is set with the default to 240 (0xF0) until it is reset with the first write access to the start index 20, see Point 6.
   As a result, the address 240 should only be used when only one transmitter is in the network. As soon as several transmitters are connected in the network, then no transmitter should be operated on the permanent address 240, as otherwise collisions can occur on the bus during parameterisation!
4. If necessary read the flash. (checking the delete process) (function code 03, start index 20 + 30, per length 8)
   When reading back, the parameter must contain the values 65535.
5. Putting together the new user parameters
6. Writing the user parameters (function code 16, start index 20 + 30, per length 8)
   It must be observed that the start index 20 is to be written first so that the address is reset. From here the correct address can then be used further.
   All three index blocks must always be written consecutively!
   Individual parameters or partial lines cannot be overwritten!
7. Reading out of the flash (checking the write process) (function code 03, start index 20 + 30, per length 8)
   If the write process fails, continue from Point 3.

5 Procedure and Calculations

5.1 Recalibration

The sensors are factory calibrated. Due to the long-term drifts, however, zero-point and full-scale errors can occur. As a result of recalibration, it is possible, to a certain extent, to compensate both. Recalibration is only recommended if there is a pressure reference which is five times more accurate than the sensor. Furthermore, it should be noted that the sensor position can be crucial for calibration. The transmitters are calibrated at room temperature in a vertical position with the pressure sensor downwards.

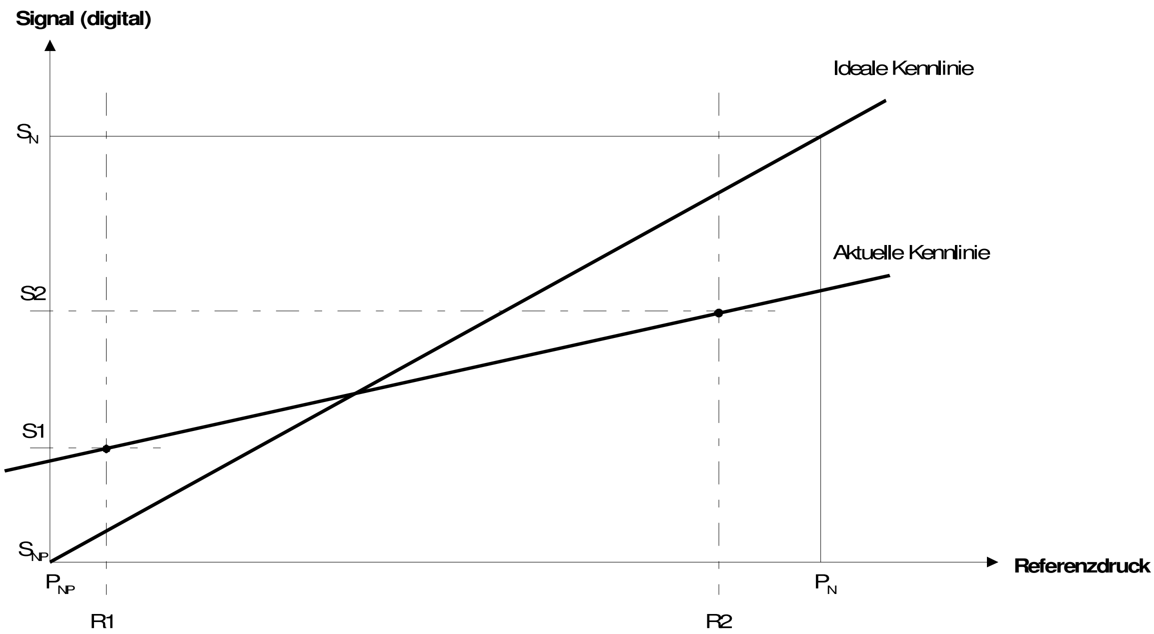


Figure 5: Calculating the recalibration

Abbreviation	Description	Value range	Unit
P_{ZP}	Zero-point pressure of the transmitter	Fixed according to specification	[Unit]
P_N	Nominal pressure of the transmitter	Fixed according to specification	[Unit]
R1	Reference pressure in the range from -5 ... 10 %FS	Reference measurement	[Unit]
R2	Reference pressure in the range from 90 ... 105 %FS	Reference measurement	[Unit]
S_{ZP}	Digital pressure signal with transmitter at zero-point pressure	0	[Digits]
S_N	Digital pressure signal with transmitter at nominal pressure	10000	[Digits]
S1	Digital pressure signal at R1	PTM measurement -500 ... 10500	[Digits]
S2	Digital pressure signal at R2	PTM measurement 500 ... 10500	[Digits]

Table 4: Recalibration signals

5.1.2 STS Layer 7 protocol

Values S1 and S2 can be read with function code 03 (see Section 3.2.2). It is important that reference pressure values R1 and R2 are determined at the same time as S1 and S2. PuserCalFullscale and PuserCalZero can be read with function code 136 (see Section 3.3.5) and are described with function code 152 (see Section 3.3.10).

5.1.3 Modbus Layer protocol

Values S1 and S2 can be read with function code 04 and start index 0 (see Section 4.2.2). It is important that reference pressure values R1 and R2 are determined at the same time as S1 and S2. PuserCalFullscale and PuserCalZero can be read with function code 03 (see 3.2.2) and start index 26 and 27 (see Section 4.3.14/15) and are described with function code 16 (see 4.3.3) and start index 26 and 27 (see Section 4.3.14/15).

5.1.4 Calculation

The calculation to recalibrate the PTM transmitters is as follows:

Calculate current (cur) increase in PTM:

$$G_{PTM} = \frac{10000}{(PUserCalFullscale_{cur} - (PUserCalZero_{cur} - 20000))}$$

Offset: In the case of a pure offset recalibration: $G = \frac{(S_N - S1)}{(P_N - R1)}$

In the case of an offset and full-scale recalibration: $G = \frac{(S2 - S1)}{(R2 - R1)}$

It thus follows that:

$$PUserCalZero_{new} = PUserCalZero_{cur} + \frac{(S1 - (R1 - P_{ZP}) * G)}{G_{PTM}}$$

Full-scale: If a pure full-scale recalibration is performed: $G = \frac{(S2 - S_{ZP})}{(R2 - P_{ZP})}$

If an offset and full-scale recalibration is performed: $G = \frac{(S2 - S1)}{(R2 - R1)}$

It thus follows that:

$$PUserCalFullscale_{cur} = PUserCalFullscale_{cur} - \frac{(S_N - S2 - (P_N - R2) * G)}{G_{PTM}}$$

5.2 Unit conversions

5.2.1 Pressure units

The following gives the conversion factors for converting any unit into bar.

Unit	Conversion factor
bar	1
ft H2O	0.02989
ft WC	0.02989
hPa	0.001
inHG	0.03386
inH2O	0.00249
inWG	0.00249
kg*/cm2	0.98067
kPa	0.01
kp/cm2	0.98067
lbf/in2	0.06895
mbar	0.001
mCE	0.09807
mFC	0.07993

Unit	Conversion factor
mFG	0.09464
mH2O	0.09807
mmHg	0.00133
mmH2O	0.0001
mmWC	0.0001
mmWG	0.0001
mmWS	0.0001
MPa	10
mWC	0.09807
mWG	0.09807
mWS	0.09807
Pa	0.00001
psi	0.06895

Table 5: Pressure units

5.2.2 Temperature units

Kelvin -> degrees Celsius:

$T[°C] = T[K] - 273.15$

Degrees Celsius -> Kelvin:

$T[K] = T[°C] + 273.15$

Degrees Fahrenheit -> degrees Celsius:

$T[°C] = 5/9 * T[F] - 160/9$

Degrees Celsius -> degrees Fahrenheit:

$T[°F] = 9/5 * T[°C] + 32$