



Description of the Communication protocol

for X-Line Pressure Transmitters from KELLER

Class.Group = 5.20

Class.Group = 5.21

Class.Group = 5.24

Version 3.7



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1 Introduction

This document describes the communications protocol for the X-Line digital pressure transmitters from KELLER Druckmesstechnik. In addition to these transmitters, other devices such as data loggers or manometers are also offered. These products are distinguished by the designation CLASS. Within this device class, the individual device groups are differentiated by the designation GROUP. All X-Line pressure transmitters bear the CLASS designation 5.

The software version number consists of following components:

Generation	Class	Group	Year	Week
Electronic circuit	Device group		SW-Version	
X1	5	20	SW-Version: release year	SW-Version: release week
X2	5	21	SW-Version: release year	SW-Version: release week
X2P	5	24	SW-Version: release year	SW-Version: release week

In this document, the software version is defined by **Class.Group-Year.Week**, e.g. 5.20-5.50.

The protocol itself is based on MODBUS, but incorporates optimised functions for the device, these functions are called Keller bus functions. However, minimum (only fct3) MODBUS RTU functionality is implemented for devices version 5.20-2.40 and newer. Full MODBUS support is provided from version 5.20-10.XX on, as well as in 5.21-XX.XX and 5.24-XX.XX.

See Appendix for an overview of the different versions.

2 Bit transfer layer (physical layer)

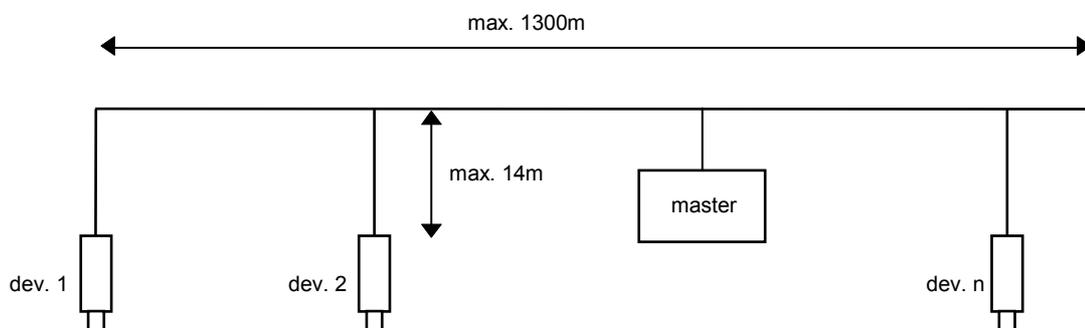
2.1 Introduction

The physical connection is provided by the RS485 serial interface. This guarantees good interference immunity and enables a flexible bus structure, i.e. several devices can be administrated as slaves by a single master. In order to minimise the scope of cabling, the RS485 is used in **half-duplex** mode. This means that 2 wires are required for communications and 2 wires for power in feed.

2.2 Characteristic

In order to operate several devices at one serial interface, they are simply all connected in parallel (RS485A, RS485B, GND and +Vcc). Before incorporating the devices into the bus, each device must be programmed with a different address.

It is possible to configure a network up to a length of 1300 metres with a maximum of 128 devices. Each riser cable may be up to 14 m in length. The employed cable should correspond to specification EIA RS485.





2.3 RS485 half-duplex details

To ensure best possible operation in an industrial environment Keller uses RS485 driver with tailored characteristics. To provide compatibility and get full advantage the bus driver of the master device has to support these specifications.

- slew rate limited In order to avoid oscillations and interference the signal slew rate is limited. This measure allows also usage of standard cables or non-standard topologies (e.g. level detectors or branch lines >> 14m). The more, termination is less critical and has not to be implemented compulsorily at the line ends, a feature important for level detectors.
- fail safe Defined signal level – even in short or open circuit case. This is very important for half-duplex operation if all devices are in reception mode – here the line is open in case that no bias resistors are implemented at the master.
- 1/8 unit load Input impedance is lower than defined by the RS485 standard, this allows connecting up to 128 devices to the bus.

Termination

Layout: between A and B at the beginning and the end of the transmission line

Value: the same as the line-impedance. Type.: 120Ohm.

In case of a fail-safe master driver (interface converter to the PC) and a noise-free environment the termination resistor are not mandatory. To reduce current peaks the resistor value can be chosen higher (1kOhm) or omitted (while transmitting the current needed for 2x120Ohm is about 50mA).

To ensure a stable communication at least one terminal resistor is necessary (mostly included in the master-RS485 driver)! One can do without a terminal resistor, if the environment is free of interference and the cable is held short (a few meters).

If the transmitter has additionally an analogue 4...20mA (two wire) output which will be used simultaneously with the serial communication, it could be useful to communicate without terminal resistor. Otherwise the analogue current signal will have heavy interferences.

The transmitters will never have a terminal resistor built in internally.

Bias-resistors

To keep up having always defined voltages one can switch pull-up respectively pull-down resistors to the transmitter: From A to +5V and from B to GND. This is necessary when such RS485 drivers are in uses which are not fail-save. This is not necessary for our products when the master is fail-safe.

Common Mode

The common-mode of the data circuit line is +12 / -7V down to GND. It is essential to keep up with this. Always connect the GND of the RS485 converter of the master with GND of the transmitter!

Definition of data circuit line assignments

signal	Designation of Keller and divers manufacturers...	Designation of the EIA Standard
inverted (-)	B	A
non-inverted (+)	A	B

Further information on RS485: <http://www.maxim-ic.com/MaximProducts/Interface/rs-485.htm>



3 Data-link layer

This section describes how data interchange is affected on this bus. The data and their check and control structures are grouped together to form messages. These constitute the smallest communication unit, i.e. only messages can be exchanged between the devices. As a half-duplex protocol is in use here, only one device can use the bus as a transmitter at any one time. All other devices are then in receive mode. The master takes the form of a PC or microcontroller, for example, and the devices are the slaves. Each message exchange takes place under the control of the master. The message contains the address for the receiving slave.

This results in the following 2 options for data interchange:

- a) Broadcasting This mode of communication enables the master to transmit a message to all slaves simultaneously. The master does not receive a reply, however, and is thus unable to check whether the message has been correctly received by every slave.
- b) Data interchange This mode of communication enables the master to communicate with a single slave. This normally involves the transmission of two messages: the master transmits a request and the slave responds to this request. Only the master is permitted to request a response. The request is received by every slave, but only the selected slave responds. The response must be received within a stipulated time, otherwise the master will assess the attempt as failed and must transmit the request again.

3.1 Transmission format for the serial interface

The data are transmitted serially via the bus. The following format applies:

- 1 start bit
- 8 data bits (the least significant bit first)
- 1 stop bit (optional 2 stop bits for *Class.Group-version 5.21-XX.XX and 5.24-XX.XX*)
- no parity (default)
- 9600 baud (default) or 115'200 Baud

This results in 10 bits (11 bits with active parity bit or 2 stop bits and 12 bits with active parity bit and 2 stop bits) per transmission byte.

3.2 Format of a message

Format of the message sent by the master

Note on the presentation of messages: Each box presents 1 data byte consisting of 8 bits, unless otherwise stated.

Each message sent by the master possesses the following format:

DevAddr	0 Function code	n byte parameters (optional)	KELLER:CRC16_H MODBUS:CRC16_L	KELLER:CRC16_L MODBUS:CRC16_H
---------	------------------------	---------------------------------	----------------------------------	----------------------------------

- **DevAddr:** Address of the device.
Address 0 is reserved for broadcasting.
Addresses 1 (default) ...249 can be used for bus mode.
Address 250 is transparent and reserved for non-bus mode. Every device can be contacted with this address.
Addresses 251...255 are reserved for subsequent developments.
- **Function code:** Function number
A function is selected and executed by the device via the function number. The function number is encoded in 7 bits. Bit 7 is always 0. The functions are described further below.
- **Parameters:** The parameters required by the function (n = 0 ... 6, according to function)
- **CRC16:** 16-bit checksum
These two check bytes serve to verify the integrity of the received data. If an error is established, the entire message will be discarded. The principle employed for CRC16 calculation is described in the appendix. The CRC16 standard is applied here.

Note: The length of a message from the master is at least 4 bytes.



Format of the message sent by the slave

A message transmitted by the slave possesses the following format:

DevAddr	X : Function code	n byte data (optional)	KELLER:CRC16_H MODBUS:CRC16_L	KELLER:CRC16_L MODBUS:CRC16_H
---------	--------------------------	------------------------	----------------------------------	----------------------------------

- DevAddr: Address of the device. This address corresponds to the address of the responding device.
- Function code:
The function number is identical to the function number sent by the master. If the most significant bit is X = 0, this indicates that the function has been executed correctly. **If bit X = 1, an exception error has occurred.**
- Data: Any data requested via the function follow here.
- CRC16: See above.

Note: A message from the slave has a minimum length of **5** bytes, and a maximum length of **10** bytes (*Class.Group-version 5.20-XX.XX*), **100** bytes (*Class.Group-version 5.21-XX.XX*) and **250** bytes (*Class.Group-version 5.24-XX.XX*).

3.3 Principle of message interchange

General rules

- An address may only be allocated to **one** device connected to the bus. If two devices on the bus have the same address, both will respond, leading to a conflict.
- Every data interchange is initiated by the master. This means that a device may only transmit data if requested to do so by the master.
- A message consists of several bytes. These bytes are transmitted **without any interruption**.

Maximal time between two bytes:

9600 baud: 1.5ms (1.5 byte length)

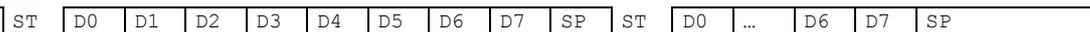
115200 baud: 0.20ms (*Class.Group-version 5.20-XX.XX*)

0.75ms (*Class.Group-version 5.21-XX.XX and 5.24-XX.XX*)

If the time between two bytes exceed the specified time, the slave ignores the received data, because of wrong message length or CRC value. In that case the answer is omitted.

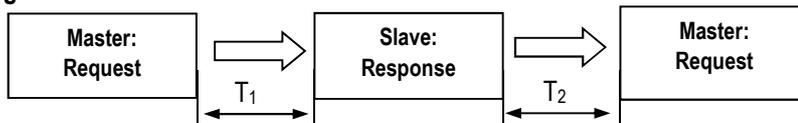
- The addressed device must respond within time T_1 , otherwise the message will be invalid.

Bit frame:



ST: start bit, D0 .. D7: 8 data bits SP: stop bit. A parity bit (if active) is inserted before the SP

Message frame:



Response times:

- T_1 : Time between receipt of inquiry and beginning of response.
 - 9600 baud: typ. 2.0ms to 6.5ms max. 100ms (*Class.Group-version 5.20-XX.XX*)**
typ. 3.5ms to 10.0ms max. 200ms* (*Class.Group-version 5.21-XX.XX*)**
typ. 3.5ms to 10.0ms max. 100ms (*Class.Group-version 5.24-XX.XX*)**
 - 115200 baud: typ. 0.7ms to 4.0ms max. 100ms (*Class.Group-version 5.20-XX.XX*)**
typ. 2.0ms to 8.0ms max. 200ms* (*Class.Group-version 5.21-XX.XX*)**
typ. 1.8ms to 10.0ms max. 100ms (*Class.Group-version 5.24-XX.XX*)**
- * with conductivity sensor, the max. T_1 time is up to 200ms (without, T_1 values are in the typical range)
- ** With Modbus communication the duration of T_1 depends on the number of register to read or write, while write takes more time than read.
- T_2 : Time to ready-to-receive state for the slave:
 - 9600 baud: min 0.5ms
 - 115200 baud: min 0.5ms



3.4 Treatment of errors

2 types of errors may occur during the interchange of messages between master and slave: transmission errors and exception errors.

Transmission errors

These errors are primarily accountable to line faults. The message format is incorrect. The following problems are possible:

- A received message is too short. → e.g. too much of time gap in frame between the bytes.
- A message is longer than the internal transmission buffer permits.
- The word length cannot be interpreted correctly.
- The CRC16 checksum is incorrect.

In these cases the slave denies the request and will therefore **not reply**. This will lead to a timeout at the master. → the request has to be repeated again.

In response to a transmission error, all received data are ignored. The slave remains in receive mode while the master is required to initiate a new data interchange.

Exception errors

The message has been received correctly (no transmission error has occurred), but the transmitted function number and/or the parameters are invalid. **The slave responds with an exception error**, unless the message has been received in broadcasting mode.

The message transmitted as a response by the slave has the following format:

DevAddr	1 Function code	Exception code	KELLER: CRC16_H MODBUS: CRC16_L	KELLER: CRC16_L MODBUS: CRC16_H
---------	------------------------	----------------	------------------------------------	------------------------------------

5 types of exception errors are defined:

- illegal non-implemented function 1
- illegal data address 2
- illegal data value 3
- Slave device failure 4
- initialisation (only KELLER bus) 32

Exception error 32 occurs when the device is started up anew and initialisation has not been carried out. This happens every time the device is connected anew after a break in the power supply.



4 MODBUS communication

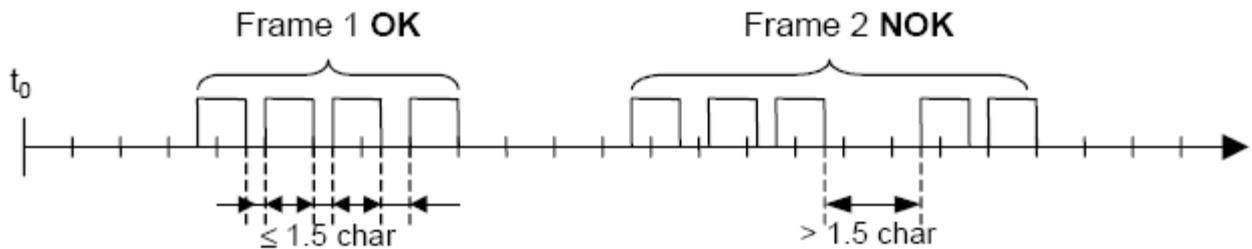
4.1 MODBUS Communication Basics

Mode: RTU Mode (ASCII is not supported)
Coding System: 8-bit binary, hexadecimal 0–9, A–F
 Two hexadecimal characters (bytes) contained in each 8-bit field of the message
Bits per Byte: 1 start bit
 8 data bits, least significant bit sent first
 No parity (default) 1 parity bit: even or odd parity (programmable)
 1 stop bit (default) 2 stop bit (programmable) (*Class.Group-version 5.21-XX.XX and 5.24-XX.XX*)
Error Check Field: 2 Byte Cyclical Redundancy Check (CRC)
Baudrate: programmable 9'600baud (default) or 115'200baud

Frame Layout:

> 3.5 char (byte) start delimiter	8 bit addr	8 bit fkt code	n x 8bit data (max n = 252)	16 bit CRC LOW / HIGH	> 3.5 char (byte) end delimiter
--------------------------------------	---------------	-------------------	-----------------------------------	-----------------------------	------------------------------------

The entire message frame must be transmitted as a continuous stream of characters. If a silent interval of more than **1.5 character times @ 9'600baud or 0.75ms @ 115'200baud** occurs between two characters, the message frame is declared incomplete and should be discarded by the receiver.



Bus Addressing:

Unicast addresses: each slave has an address between 1 (default) and 247.
Broadcast addresses: address 0 is used for broadcast frames; the slave accepts the command but must not generate an answer.
Special addresses: addresses 248 – 255 are reserved. The address 250 is used for non-bus (point-to-point) communication to address a slave with unspecified or unknown address (not MODBUS standard).

Function Code:

The 8-bit value function code describes the operation that is performed on the slave. Implemented MODBUS functions are described in the following chapter.

4.2 Using MODBUS with KELLER products

Both protocols are active. For MODBUS only a subset of the MODBUS functionality is implemented and the implemented MODBUS function codes are not used in the KELLER-protocol. Please note, that the responses are different for both protocols.

Furthermore note that for MODBUS communication NO initialization is required to be performed before any other command.

Attention: The Error Check Field byte alignment differs.

	Modbus	KELLER-Protocol
CRC-16	L:H	H:L



4.3 Description of MODBUS functions

This section describes the MODBUS functions supported by X-Line transmitters (Class.Group-version 5.20-XX.XX, 5.21-XX.XX and 5.24-XX.XX)

Overview:

- F3: Read registers on MODBUS address space
- F6: Write single register on MODBUS address space
- F8: MODBUS Echo function
- F16: Write multiple registers on MODBUS address space

Versions overview

The main differences between *Class.Group-version 5.20, 5.21 and 5.24* are, the buffer size as well as the inter frame time. The table below gives you an overview which Firmware-version supports which MODBUS functions:

Version	F3 float values 0x0000..0x000A	F3 float values 0x0100..0x0106	F3 int 16bit values 0x0010.. 0x0015	F3 int 32bit values 0x0020.. 0x002A	F3 Information & Configuration	F6	F8, F16	Data buffer size
5.20-5.50	Yes	No	Yes	No	No	No	No	10 byte
5.20-10.40	Yes	Yes	No	No	Yes	No	Yes	13 byte
5.20-12.28	Yes	Yes	Yes	Yes	Yes	Yes	Yes	13 byte
5.21-13.10 (and later)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100 byte
5.24-XX.XX	Yes	Yes	Yes	Yes	Yes	Yes	Yes	250 byte

Note: compatible for all versions to read process values (CH0..TOB2): F3 float, reg 0x0000...0x000A

4.3.1 Modbus Communication Examples

Read	addr	Request and response										received value			
P1	1	request	0x01	0x03	0x00	0x02	0x00	0x02	0x65	0xCB			0.960701bar		
		response	0x01	0x03	0x04	0x3F	0x75	0xF0	0x7B	0xE3	0xDE				
P2	1	request	0x01	0x03	0x00	0x04	0x00	0x02	0x85	0xCA			0.961042bar		
		response	0x01	0x03	0x04	0x3F	0x76	0x06	0xE0	0x15	0xD5				
TOB1	1	request	0x01	0x03	0x00	0x08	0x00	0x02	0x45	0xC9			22.719°C		
		response	0x01	0x03	0x04	0x41	0xB5	0xC0	0x79	0x6E	0x0B				
P1, TOB1	1	request	0x01	0x03	0x01	0x00	0x00	0x04	0x45	0xF5			0.960508bar 22.7637°C		
		response	0x01	0x03	0x08	0x3F	0x75	0xE3	0xD2	0x41	0xB6	0x1C		0x20	0xA0



4.3.2 Function 3: MODBUS Register Read

Read a number of subsequent registers in the MODBUS address space starting with StAdd. Note, that the data returned has to be interpreted according the definitions in “4.4 MODBUS Register Map”.

- Function is implemented in devices *Class.Group-version 5.20-2.40 and later, 5.21-XX.XX and 5.24-XX.XX.*
- A register contains 2 bytes (16 bit).
- The maximal number of registers read in one cycle is limited to:
up to 2 registers for earlier versions than *Class.Group-version 5.20-10.40*
up to 4 registers for versions *Class.Group-version 5.20-10.40 and later*
up to 40 registers for versions *Class.Group-version 5.21-XX.XX*
up to 120 registers for versions *Class.Group-version 5.24-XX.XX*
- Byte-count of the answer will be an even number (1 register = 2 bytes)
- Double sized process values (CH0, P1, P2, T, TOB1 and TOB2) must be read in one request.
- Reading float values always requires 2 data registers.
- Returns NaN (float) or ovl (integer) in case of an inactive channel or an error in the channel

Request:

DevAddr	0x03	StAdd H	StAdd L	# Reg H	# Reg L	CRC16_L	CRC16_H
---------	------	---------	---------	---------	---------	---------	---------

Response:

DevAddr	0x03	# Bytes	Data H	Data L	...	Data L	CRC16_L	CRC16_H
---------	------	---------	--------	--------	-----	--------	---------	---------

Error:

DevAddr	0x83	Error	CRC16_L	CRC16_H
---------	------	-------	---------	---------

Error codes:

- 2 Illegal data address:**
 - Wrong starting-address or wrong number of registers
 - Start-address not defined; register exceeding defined range return 0x0000
- 3 Illegal data value:**
 - Quantity of requested registers out of bound
 - Must be <= 2 for devices *Class.Group-version 5.20-2.50*
 - Must be <= 4 for devices *Class.Group-version 5.20-10.XX and later*
 - Must be <= 40 for devices *Class.Group-version 5.21-XX.XX*
 - Must be <= 120 for devices *Class.Group-version 5.24-XX.XX*

4.3.3 Function 6: MODBUS Single Register Write

This function has the same functionality as F16, but writes only 1 register.

- Function is implemented in devices *Class.Group-version 5.20-12.XX and later, and 5.21-XX.XX and 5.24-XX.XX*
- A register contains 2 bytes (16 bit).
- Use this function for single configuration steps, because the returned error is easily distinguishable from other register writes.
- Note that single register operations are not allowed in the address ranges 0x03XX and 0xFFXX and everywhere float values are addressed.

Request:

DevAddr	0x06	StAdd H	StAdd L	Data H	Data L	CRC16_L	CRC16_H
---------	------	---------	---------	--------	--------	---------	---------

Response:

DevAddr	0x06	StAdd H	StAdd L	Data H	Data L	CRC16_L	CRC16_H
---------	------	---------	---------	--------	--------	---------	---------

Error:

DevAddr	0x86	Error	CRC16_L	CRC16_H
---------	------	-------	---------	---------



Error codes:

- 2 Illegal data address**
 - address not accessible by function 6
 - Start-address not defined (for writing)
- 3 Illegal data value**
 - frame length incorrect
- 4 Slave Device Failure**
 - Attempted to write into a protected register
 - The data written is outside the defined data range

4.3.4 Function 8: MODBUS Echo Test

This function may be used to perform a quick line check. It just returns the data received.

- Function is implemented in devices *Class.Group-version 5.20-10.XX and later, 5.21-XX.XX and 5.24-XX.XX*
- Data may be any 2 byte value

Request:

DevAddr	0x08	0x00	0x00	Data H	Data L	CRC16_L	CRC16_H
---------	------	------	------	--------	--------	---------	---------

Response:

DevAddr	0x08	0x00	0x00	Data H	Data L	CRC16_L	CRC16_H
---------	------	------	------	--------	--------	---------	---------

Error:

DevAddr	0x88	Error	CRC16_L	CRC16_H
---------	------	-------	---------	---------

Error codes:

- 1 Illegal subfunction code:**
 - The subfunction code is not supported (it is not (0x00, 0x00)). *Class.Group-version 5.21-XX.XX and 5.24-XX.XX*
- 3 Illegal data value:**
 - The data following the function code was not the fixed data (0x00, 0x00). *Class.Group-version 5.20-10.XX and later*

4.3.5 Function 16: MODBUS Register WRITE

Write a number of subsequent registers on the MODBUS address space starting with StAdd.

- Function is implemented in devices *Class.Group-version 5.20-10.XX and later, 5.21-XX.XX and 5.24-XX.XX*
- A register contains 2 bytes (16 bit).
- The number of registers written in one cycle is limited to 2 (0x02) for *Class.Group-version 5.20-10.XX and later*
- The number of registers written in one cycle is limited to 40 (0x28) for *Class.Group-version 5.21-XX.XX*
- The number of registers written in one cycle is limited to 120 (0x78) for *Class.Group-version 5.24-XX.XX*
- Byte-count of the answer will be an even number (1 register = 2 bytes).
- Addresses above 0xFF00 are virtual command registers that simply execute a task on the slave. Please refer to chapter "4.4 MODBUS Register Map" for more information.
- Writing float values always requires 2 data registers.
- #Reg in the response declares the number of actually written registers (in case an error occurs, this amount is not the same as in the request)

**Request:**

DevAddr	0x10	StAdd H	StAdd L	# Reg H	# Reg L	# Bytes	Data H	Data L
...	Data H	Data L	CRC16 L	CRC16 H				

Response:

DevAddr	0x10	StAdd H	StAdd L	# Reg H	# Reg L	CRC16_L	CRC16_H
---------	------	---------	---------	---------	---------	---------	---------

Error:

DevAddr	0x90	Error	CRC16_L	CRC16_H
---------	------	-------	---------	---------

Error codes:

- 2 Illegal data address:**
 - Undefined starting-address or wrong number of registers
 - Start-address not defined (for writing)
- 3 Illegal data value:**
 - The amount of data is out of bound
 - Byte-count is not twice the # Reg.
- 4 Slave Device Failure:**
 - Attempted to write into a protected register
 - The data written is outside the defined data range

4.4 MODBUS Register Map**4.4.1 Process Value Ranges****4.4.1.1 Process Value Read Range (0x000x) 32bit floating point (Big Endian)**

- compatible with *Class.Group-version 5.20-5.50 and later, 5.21-XX.XX and 5.24-XX.XX*
- A Channel must be read in one cycle. Odd start address (StAdd) returns exception2
- format is float according to chapter "6.2 Floating-point format IEEE754",
 - 5.20-5.50: (2 Registers) Errors: Inactive Channel returns exception2, ovl or uvl returns exception3
 - 5.20-10.40 and later: (2 or 4 Registers) Errors: Inactive Channel returns NaN, over-/underflow is represented by +/-infinity
 - 5.21-XX.XX and 5.24-XX.XX: (up to 12 Registers) Errors: Inactive Channel returns NaN, over-/underflow is represented by +/-infinity
- corresponding functionality to Keller Bus functions F73

MODBUS StAdd (0xHILO)	Channel	Read/Write	Unit	Description
0x0000	CH0	R	---	Calculated value (customer specific format) HWord
				Calculated value (customer specific format) LWord
0x0002	P1	R	bar	Pressure of sensor1 HWord
				Pressure of sensor1 LWord
0x0004	P2	R	bar	Pressure of sensor2 HWord
				Pressure of sensor2 LWord
0x0006	T	R	°C	Temperature HWord
				Temperature LWord
0x0008	TOB1	R	°C	Temperature of sensor1 HWord
				Temperature of sensor1 LWord
0x000A	TOB2	R	°C	Temperature of sensor2 HWord
				Temperature of sensor2 LWord



4.4.1.2 Process Value Read Range (0x001x) 16bit integer

- compatible with *Class.Group-version 5.20-5.50 and later, 5.21-XX.XX and 5.24-XX.XX*, but not *5.20-10.40*
- format is 2 byte signed integer
- All values are multiplied by 100. Numeric range: +/- 32700, max. pressure +/- 327bar. (Use 32bit register for higher resolution and range.)
- Amount of registers: *version 5.20-5.50: 1Reg, version 5.20-12.28 and later: 1 ... 4Reg, version 5.21-XX.XX and 5.24-XX.XX: 1 ... 6Reg*

MODBUS StAdd (0xHILO)	Channel	Read/Write	Unit	Description
0x0010	CH0	R	1/100 --	Calculated value (customer specific format)
0x0011	P1	R	1/100 bar	Pressure of sensor1
0x0012	P2	R	1/100 bar	Pressure of sensor2
0x0013	T	R	1/100 °C	Temperature
0x0014	TOB1	R	1/100 °C	Temperature of sensor1
0x0015	TOB2	R	1/100 °C	Temperature of sensor2

Error-Handling:

Channel not active or error (NaN): value = 32767 (*version 5.50: exception2*)

Overflow or value > 327.0 : value = 32767 (*version 5.50:exception 3*)

Underflow or value < -327.0: value = -32768 (*version 5.50: exception3*)

4.4.1.3 Process Value Read Range (0x002x) 32bit integer

- compatible with *Class.Group-version 5.20-12.28 and later, 5.21-XX.XX and 5.24-XX.XX*
- A Channel must be read in one cycle. Odd start address (StAdd) returns exception2
- format is 4 byte signed integer
- Overflow returns "2147483647", an underflow "-2147483648"
- Error in a Channel or Channel not active returns "2147483647"
- Amount of Registers: *version 5.20-12.28 and later: 2 ... 4Reg, version 5.21-XX.XX and 5.24-XX.XX: 2 ... 12Reg*
- corresponding functionality to Keller Bus functions F74

MODBUS StAdd (0xHILO)	Channel	Read/Write	Unit	Description
0x0020	CH0	R	10 ⁻⁵ ---	Calculated value (customer specific format) HWord
				Calculated value (customer specific format) LWord
0x0022	P1	R	Pa (10 ⁻⁵ bar)	Pressure of sensor1 HWord
				Pressure of sensor1 LWord
0x0024	P2	R	Pa (10 ⁻⁵ bar)	Pressure of sensor2 HWord
				Pressure of sensor2 LWord
0x0026	T	R	1/100 °C	Temperature HWord
				Temperature LWord
0x0028	TOB1	R	1/100 °C	Temperature of sensor1 HWord
				Temperature of sensor1 LWord
0x002A	TOB2	R	1/100 °C	Temperature of sensor2 HWord
				Temperature of sensor2 LWord

Remark: Pressure unit is Pascal (10⁻⁵ bar) instead of bar



4.4.1.4 Process Value Read Range (0x0100) 32bit floating point

- compatible with *Class.Group-version 5.20-10.XX and later, 5.21-XX.XX and 5.24-XX.XX*
- Same as 0x0000 .. 0x000B but different mapping for accessing data in one cycle (e.g. P1 and TOB1)
- Conductivity value available with *Class.Group-version 5.21-XX.XX*
- Version 5.21-XX.XX: if Conductivity available: NaN till conductivity and T values available (start uptime!)

MODBUS StAdd (0xHILO)	Channel	Read/Write	Unit	Description
0x0100	P1	R	bar	Pressure of sensor1 [bar] HWord
				Pressure of sensor1 [bar] LWord
0x0102	TOB1	R	°C	Temperature of sensor1 [°C] HWord
				Temperature of sensor1 [°C] LWord
0x0104	P2	R	bar	Pressure of sensor2 [bar] HWord
				Pressure of sensor2 [bar] LWord
0x0106	TOB2	R	°C	Temperature of sensor2 [°C] HWord
				Temperature of sensor2 [°C] LWord
0x0108	P1	R	bar	Pressure of sensor1 [bar] HWord <i>version 5.21-XX.XX and 5.24-XX.XX</i>
				Pressure of sensor1 [bar] LWord <i>version 5.21-XX.XX and 5.24-XX.XX</i>
0x010A	T	R	°C	Temperature [°C] Hword <i>version 5.21-XX.XX and 5.24-XX.XX</i>
				Temperature [°C] Lword <i>version 5.21-XX.XX and 5.24-XX.XX</i>
0x010C	ConTc	R	mS/cm	Conductivity Temperature Compensated [mS/cm] HWord <i>version 5.21-XX.XX only</i>
				Conductivity Temperature Compensated [mS/cm] LWord <i>version 5.21-XX.XX only</i>
0x010E	ConRaw	R	mS/cm	Conductivity Raw [mS/cm] HWord <i>version 5.21-XX.XX only</i>
				Conductivity Raw [mS/cm] LWord <i>version 5.21-XX.XX only</i>



0x0209	R	P-Mode	<i>version 5.20-12.28 and later, 5.21-XX.XX and 5.24-XX.XX:</i> Type of sensor and calibration Bit 3...0 (LowNibble) P1: 0: PR (relative), 1: PA (absolute), 2: PAA (absolute), 15: not available <i>version 5.24-XX.XX only</i> Bit 7...4 (HighNibble) P2: 0: PR (relative), 1: PA (absolute), 2: PAA (absolute), 15: not available <i>version 5.24-XX.XX only</i> Earlier version: Not used (return 0x0000)
0x020A	R/W	FILT_CTRL	Filter setting for one conversion: Bit 0: Adaptive filter for P1 and P2 (on / off) ¹ Bit 1: Low pass filter for T, TOB1 and TOB2 (on / off) Bit 2...4: Over sampling ration $OSR = 2^{(8+Bit2..4)}$ <i>version 5.20-XX.XX only</i> Bit 5...6: Amount of samples per averaging: 0...3 = 1, 2, 4 or 8 values. <i>version 5.20-XX.XX only</i> Factory settings see FILTER_ORG. <i>version 5.20-XX.XX and 5.24-XX.XX</i>
0x020B	R(W)	DAC_CTRL	<i>version 5.20-XX.XX and 5.24-XX.XX</i> Analogue output: Bit 0: Milli Amperes output (4...20mA) Bit 1: Voltage output Bit 2...3: n.def only bit 4 is writable with <i>version 5.24-XX.XX</i> Bit 4 = 1: P1 is linked to the analogue output Bit 4 = 0: CH0 is linked to the analogue output Bit 5...7: n.def
0x020C	R	STATUS	Device Status
0x020D	R/W	DEV_ADDR	Device Address (default 1)
0x020E	R	Class:Group	<i>version 5.20-12.28 and later, 5.21-XX.XX and 5.24-XX.XX</i> Firmware-Version, 16Bit
0x020F	R	Year:Week	<i>version 5.20-12.28 and later, 5.21-XX.XX and 5.24-XX.XX</i> Firmware-Version, 16Bit
0x0211	R/W	ConOn	<i>version 5.21-XX.XX only</i> 0x01: Conductivity powered 0x00: Conductivity unpowered
0x0213	R/W	ConRange	<i>version 5.21-XX.XX only</i> CTD power up time: 3sec (during power up: Exception 4) 0x01: Conductivity Range 1: 0...200uS (0.2mS) 0x02: Conductivity Range 2: 0...2'000uS (2mS) 0x03: Conductivity Range 3: 0...20'000uS (20mS) 0x04: Conductivity Range 4: 0...200'000uS (200mS) (default)
0x0214	R/W	ConTempCompCoeff	<i>version 5.21-XX.XX only</i> Conductivity Temperature Compensation Method after DIN/EN 27888 0x01: Linear Temperature Compensation @ 25°C (default) 0x02: Linear Temperature Compensation @ 20°C 0x03: Non-linear Temperature Compensation (Table) @ 25°C
0x0215	R/W	ModbusInterFrameTime9k6	<i>version 5.21-16.50 and later and 5.24-XX.XX</i> minimal interframe time @ 9600Baud ModbusInterFrameTime9k6*100us = Timeout (default: 35 → 3.5ms)
0x0216	R/W	ModbusInterFrameTime115k2	<i>version 5.21-16.50 and later and 5.24-XX.XX</i> minimal interframe time @ 115200Baud ModbusInterFrameTime115k2*100us = Timeout (default: 18 → 1.8ms)
0x0223	R(W)	SPS	<i>version 5.21-XX.XX only</i> Samples per Second: 0x05: 120 SpS 0x06: 240 SpS 0x07: 480 SpS
0x0250 – 0x0257	R(W)	ASCII Serial No.	<i>version 5.21-XX.XX and 5.24-XX.XX (writable only for version 5.24-XX.XX)</i> 16 byte serial number in ASCII (option)

¹ The adaptive filter for *version 5.24-XX.XX* has only an influence on the digital output. The LP-filter has an influence on both, the digital and the analogue output.



4.4.2.1 Device Status

The **STATUS** byte contains the current status.

Bit position	.7	.6	.5	.4	.3	.2	.1	.0
Name	/STD	ERR2	TOB2	TOB1	T	P2	P1	CH0

A set **/STD** bit indicate whether the transmitter is in Power-up mode, otherwise it is in Standard mode. For *version 5.21-XX.XX*, /STD is used to indicate an error during measuring the conductivity.

A set **ERR2** bit denotes that a computation error has occurred in the calculation process for the analogue output. This occurs if the analogue signal is in saturation (depends on the scaling). *version 5.20-XX.XX and 5.24-XX.XX*

A set **CH0, P1, P2, T, TOB1, TOB2** bit indicates that a measuring or computation error has occurred in the channel concerned.

For details in error-handling see chapter **Error handling and recognition!**

4.4.2.2 Device Address

It is to be ensured that the new address is not already in use by another bus user.

Permissible addresses: 1 .. 247 (default 1). Address 250 is transparent. This means that every device, irrespective of the set address, will respond to address 250 (not MODBUS standard). Consequently, *transparent* DevAddr = 250 may only be used in stand-alone operating mode! Addresses 248 – 255 are reserved.



4.4.3 Device Coefficient Range (0x03xx, 0x3xxx and 0x40xx)

- compatible with *Class.Group-version 5.20-10.XX and later, 5.21-XX.XX and 5.24-XX.XX*
- read only an even number of registers
- Writing only allowed with F16 (write cycle with more than one register)
- In most instances corresponding functionality to Keller Bus functions F30 and F31
- format is float according to chapter "6.2 Floating-point format IEEE754"

MODBUS StAdd (0xHILO)	Read/Write	Coeff-No.	Unit	DESCRIPTION
0x036A	R/W	53	bar	Threshold value of the square root function (must be > 0 if sqrt function is used) <i>version 5.20-XX.XX and 5.24-XX.XX</i>
0x0380	R/W	64	bar	Offset of pressure sensor P1, default = 0.0
0x0382	R/W	65		Gain factor of pressure sensor P1, default = 1.0
0x0384	R/W	66	bar	Offset of pressure sensor P2, default = 0.0
0x0386	R/W	67		Gain factor of pressure sensor P2, default = 1.0
0x0388	R/W	68	bar	Offset of analogue output <i>version 5.20-XX.XX and 5.24-XX.XX</i>
0x038A	R/W	69		Gain factor of analogue output <i>version 5.20-XX.XX and 5.24-XX.XX</i>
0x038C	R/W	70		Offset of CH0, default = 0.0 <i>version 5.20-XX.XX and 5.24-XX.XX</i>
0x038E	R/W	71		Gain factor of CH0, default = 1.0 <i>version 5.20-XX.XX and 5.24-XX.XX</i>
0x0390	R/W	72	°C	Offset of temperature T <i>version 5.21-XX.XX and 5.24-XX.XX</i>
0x0394	R/W	74	°C	Offset of temperature TOB1 <i>version 5.21-XX.XX and 5.24-XX.XX</i>
0x0398	R/W	76	°C	Offset of temperature TOB2 <i>version 5.21-XX.XX and 5.24-XX.XX</i>
0x03A0	R	80	bar	Minimum pressure of sensor P1
0x03A2	R	81	bar	Maximum pressure of sensor P1
0x03A4	R	82	bar	Minimum pressure of sensor P2
0x03A6	R	83	bar	Maximum pressure of sensor P2
0x03A8	R	84	°C	Minimum temperature of temperature sensor
0x03AA	R	85	°C	Maximum temperature of temperature sensor
0x03AC	R	86	°C	Minimum temperature of sensor P1
0x03AE	R	87	°C	Maximum temperature of sensor P1
0x03B0	R	88	°C	Minimum temperature of sensor P2
0x03B2	R	89	°C	Maximum temperature of sensor P2
0x03B4	R	90		Minimum value of channel CH0
0x03B6	R	91		Maximum value of channel CH0
0x03B8	R	92	bar	Pressure for minimum analogue signal ¹ <i>version 5.20-XX.XX and 5.24-XX.XX</i>
0x03BA	R	93	bar	Pressure for maximum analogue signal ¹ <i>version 5.20-XX.XX and 5.24-XX.XX</i>
0x03BC	R	94	mA, V	Minimum analogue signal ^{1,2} <i>version 5.20-XX.XX and 5.24-XX.XX</i>
0x03BE	R	95	mA, V	Maximum analogue signal ^{1,2} <i>version 5.20-XX.XX and 5.24-XX.XX</i>
0x03D0	R		%FS	CH0_Accuracy <i>version 5.24-XX.XX only</i>
0x03D2	R		%FS	P1_Accuracy <i>version 5.24-XX.XX only</i>
0x03D4	R		%FS	P2_Accuracy <i>version 5.24-XX.XX only</i>
0x03D6	R		%FS	T_PT1000_Accuracy <i>version 5.24-XX.XX only</i>
0x03D8	R		%FS	TOB1_Accuracy <i>version 5.24-XX.XX only</i>
0x03DA	R		%FS	TOB2_Accuracy <i>version 5.24-XX.XX only</i>
0x03E0	R/W	121		Gain Conductivity Range 1 <i>version 5.21-XX.XX only</i>
0x03E2	R/W	122		Gain Conductivity Range 2 <i>version 5.21-XX.XX only</i>
0x03E4	R/W	123		Gain Conductivity Range 3 <i>version 5.21-XX.XX only</i>
0x03E6	R/W	124		Gain Conductivity Range 4 <i>version 5.21-XX.XX only</i>
0x03EA	R/W	126	1/°C	Conductivity Temperature Coefficient (default 0.022-> water) <i>version 5.21-XX.XX only</i>
0x03EC	R	127		Conductivity Cell Constant (default 1.00) <i>version 5.21-XX.XX only</i>
0x03F0	R			CH0_SPS <i>version 5.24-XX.XX only</i>
0x03F2	R			P1_SPS <i>version 5.24-XX.XX only</i>
0x03F4	R			P2_SPS <i>version 5.24-XX.XX only</i>
0x03F6	R			T_PT1000_SPS <i>version 5.24-XX.XX only</i>
0x03F8	R			TOB1_SPS <i>version 5.24-XX.XX only</i>
0x03FA	R			TOB2_SPS <i>version 5.24-XX.XX only</i>
0x3000 – 0x301F	R/W	-		Coeff for CH0 straight line curve fitting of P1 <i>version 5.24-XX.XX only</i>
0x3200 – 0x3217	R/W	100		(12 • float) free coefficients for customer use <i>version 5.24-XX.XX only</i>
0x4070 – 0x408F	R		Hz	Table of digital cut-off frequencies for LP-filter ³ <i>version 5.24-XX.XX only</i>

¹ Required for scaling the analogue output (see below)



² The information for Addr. 0x3BC and Addr. 0x3BE may be in mA or V, according to whether the device possesses a voltage output or a current output (see DAC_CTRL).

³ Table of cut-off frequencies (see explanation below)

4.4.3.1 Scaling of channels CH0, P1 and P2

CH0, P1 and P2 are linearly scalable with zero point and gain factor: **Value = gain factor * value + offset**

Standard values: Offset = 0.0, gain factor = 1.0

T, TOB1 and TOB2 are only scalable with zero point. Standard value: Offset = 0.0

It is also possible to influence the offset values via device operation command.

The gain factor should be used **for calibration purposes only**, and not to alter pressure units. The latter operation should always be carried out by the master! In order to represent other pressure units via the analogue output, the unit conversion must be taken into account when scaling the analogue output.

4.4.3.2 Scaling the analogue output

The analogue output on the X-Line pressure transmitters can be programmed via the interface. As the two routes *sensor-signal* → *digital transformation and digital value* → *analogue signal* are calibrated independently at the factory, the analogue output can be set to different pressures or pressure units **without** requiring recalibration. For this purpose, KELLER offers the free CCS30 software, which provides a convenient means of carrying out this scaling with a PC.

To programme the scaling of the analogue output yourself, proceed as follows:

Device configuration range enables you to ascertain whether the device possesses an analogue output (DAC_CTRL). The coefficients required for calculation can be read out of device coefficient range (Pressure for minimum/maximum analogue signal; Offset/Gain of analogue output). A new scaling can be programmed by changing certain device coefficients.

Read-out of pressure range for the analogue output:

The following coefficients (K[MODBUS StAdd.]) must be read out using function 3 in order to calculate the lower and upper limit of the analogue output:

$$A = (K[0x3B8] - K[0x388]) / K[0x38A]$$

$$B = (K[0x3BA] - K[0x388]) / K[0x38A]$$

Setting a new pressure range for the analogue output:

K[0x388] and K[0x38A] must be calculated and written into the device using function 16:

$$K[0x388] = K[0x3B8] - ((K[0x3BA] - K[0x3B8]) / (B - A)) * A$$

$$K[0x38A] = (K[0x3BA] - K[0x3B8]) / (B - A)$$

Whereby:

K[x] : Coefficient with the corresponding Modbus start address [x]

A : Pressure in bar at which the Minimum analogue signal K[0x3BC] is to be output

B : Pressure in bar at which the Maximum analogue signal K[0x3BE] is to be output

Other pressure units are to be converted into bar.



4.4.3.3 Cut-off frequencies for LP-Filter

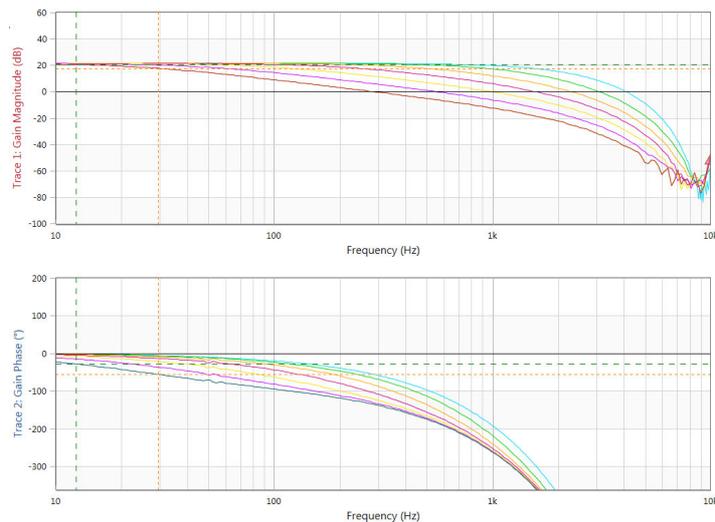
The cut-off frequencies are dependent on the hardware and are programmed during calibration process. All values are in the unit Hz and formatted as float.

Device configuration range enables you to ascertain if the LP-Filter is turned on and on what position it is (LP_FILTER high nibble). The coefficients required for information can be read out of device coefficient range (table of digital cut-off frequencies for LP-filter). A new cut-off frequency can be programmed by changing device configuration LP_FILTER value.

The first value in the table of digital cut-off frequencies (MODBUS StAdd 0x4070) corresponds with the LP_FILTER register value (high nibble) 0x0X (LP-Filter switched off). The second value in the table (MODBUS StAdd 0x4072) corresponds with the LP_FILTER register value 0x1X ...

LP_FILTER value	MODBUS StAdd cut-off frequency						
0x0X	0x4070	0x4X	0x4078	0x8X	0x4080	0xCX	0x4088
0x1X	0x4072	0x5X	0x407A	0x9X	0x4082	0xDX	0x408A
0x2X	0x4074	0x6X	0x407C	0AX	0x4084	0EX	0x408C
0x3X	0x4076	0x7X	0x407E	0BX	0x4086	0FX	0x408E

Example: frequency response of different LP-filter configurations:



4.4.4 Device Custom Range (0x03C0 and 0x40xx)

- format is unsigned integer and ASCII as described in format

MODBUS StAdd (0xHILO)	Read/Write	Coeff. No.	format	DESCRIPTION
0x03C0	R	99	U32	Calibration date: Reg 0: High: Day, Low: Month Reg 1: Year <i>version 5.24-XX.XX only</i>
0x4000	R/W		U16	Calibration date: Year <i>version 5.24-XX.XX only</i>
0x4001	R/W		U16	Calibration date: High Month, Low: Day <i>version 5.24-XX.XX only</i>
0x4010 – 0x402F	R		ASCII	Product No. (Abacus No.) <i>version 5.24-XX.XX only</i>
0x4030 – 0x404F	R		ASCII	Product Name <i>version 5.24-XX.XX only</i>
0x4050 – 0x406F	R		ASCII	Product Text <i>version 5.24-XX.XX only</i>



4.4.5 Device Operation Command List

- compatible with *Class.Group-version 5.20-10.XX and later, 5.21-XX.XX and 5.24-XX.XX*
- Writing only allowed with F16 (write cycle with 2 registers)
- Only one command per request
- This address range is NOT readable
- corresponding functionality to Keller Bus function F95
- Some bytes of the message are fixed, see following frame layout:

Request:

DevAddr	0x10	StAddr H	StAddr L	0x00	0x02	0x04	B3	B2
---------	------	----------	----------	------	------	------	----	----

B1	B0	CRC16 L	CRC16 H
----	----	---------	---------

Response:

DevAddr	0x10	StAddr H	StAddr L	0x00	0x02	CRC16_L	CRC16_H
---------	------	----------	----------	------	------	---------	---------

MODBUS StAddr (0xHILO)	Read/Write	Reg. Name	DESCRIPTION
0xFF00	W	Set Zero P1	The zero point value from P1 (Coeff-No. 64) is calculated, that the current measured value equals the floating point number specified.
0xFF02	W	Reset Zero P1	Zero Point Value from P1 is set to default (Coeff-No. 64 = 0.0)
0xFF04	W	Set Zero P2	The zero point value from P2 (Coeff-No. 66) is calculated, that the current measured value equals the floating point number specified.
0xFF06	W	Reset Zero P2	Zero Point Value from P2 is set to default (Coeff-No. 66 = 0.0)
0xFF08	-	-	
0xFF0A	-	-	
0xFF0C	W	Set Zero CH0	The zero point value from CH0 (Coeff-No. 70) is calculated, that the current measured value equals the floating point number specified. <i>version 5.20-XX and 5.24-XX.XX</i>
0xFF0E	W	Reset Zero CH0	Zero Point Value from CH0 is set to default (Coeff-No. 70 = 0.0) <i>version 5.20-XX and 5.24-XX.XX</i>
0xFF10	W	Set Zero T	The zero point value from T is calculated, that the current measured value equals the floating point number specified. <i>version 5.21-XX.XX and 5.24-XX.XX</i>
0xFF12	W	Reset Zero T	Zero Point Value from T is set to default (Coeff-No. 72 = 0.0) <i>version 5.21-XX.XX and 5.24-XX.XX</i>
0xFF14	W	Set Zero TOB1	The zero point value from TOB1 is calculated, that the current measured value equals the floating point number specified. <i>version 5.21-XX.XX and 5.24-XX.XX</i>
0xFF16	W	Reset Zero TOB1	Zero Point Value from TOB1 is set to default (Coeff-No. 74 = 0.0) <i>version 5.21-XX.XX and 5.24-XX.XX</i>
0xFF18	W	Set Zero TOB2	The zero point value from TOB2 is calculated, that the current measured value equals the floating point number specified. <i>version 5.21-XX.XX and 5.24-XX.XX</i>
0xFF1A	W	Reset Zero TOB2	Zero Point Value from TOB2 is set to default (Coeff-No. 76 = 0.0) <i>version 5.21-XX.XX and 5.24-XX.XX</i>



5 Description of Keller bus functions

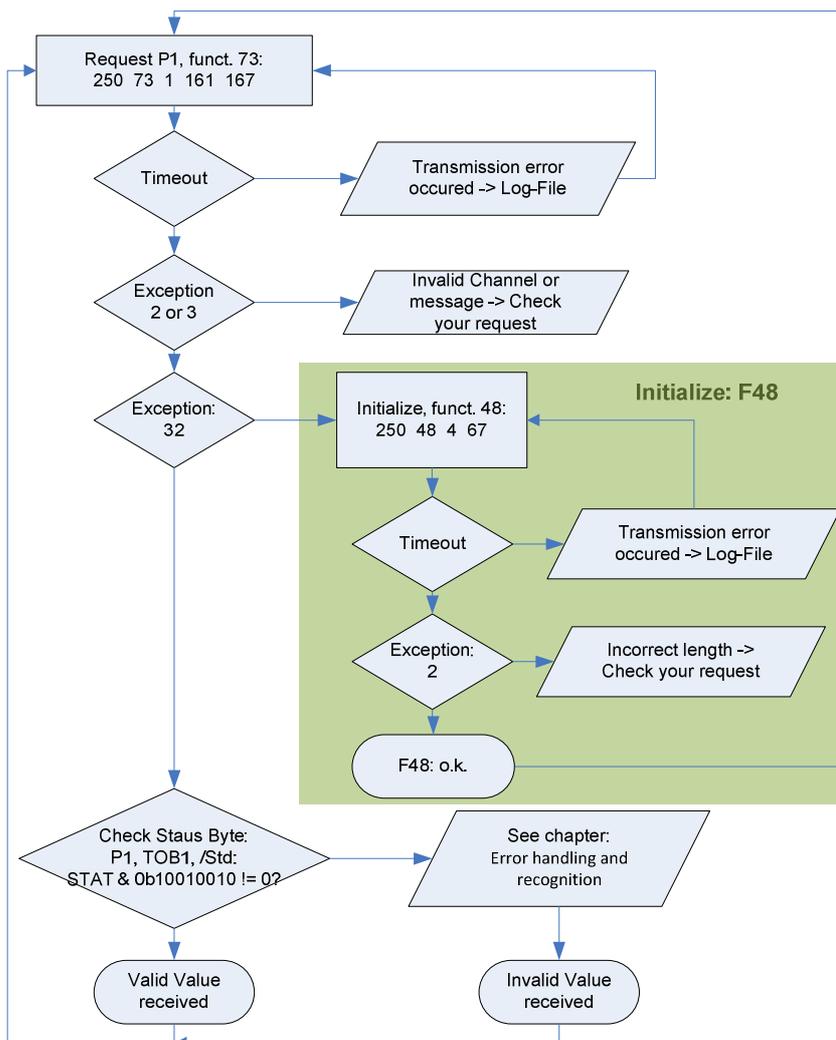
This section describes the functions of the bus protocol for X-Line transmitters (Class.Group-version 5.20-XX.XX, 5.21-XX.XX and 5.24-XX.XX) using the Keller bus functions (not MODBUS).

Note that all numbers are shown as decimal (not as hex, contradictory to what was described in the MODBUS-chapters)!

Overview:

- F30: Read out calibration (scaling) and information floating-point values
- F31: Write calibration floating-point values
- F32: Read out configurations
- F33: Write configurations
- F48: Initialise devices, whereby the device ID is returned**
- F66: Write bus address
- F69: Read out serial number
- F73: Read out current pressure and temperature values in floating-point format**
- F74: Read out current pressure and temperature values in integer format
- F95: Zeroing functions

5.1 Example: read pressure value with exception handling



A simple example for reading out a pressure value.

Because only one transmitter is connected, the „transparent“ address 250 is used.

To read out pressure functions 73 and 48 are necessary. When the slave replies with error no. 32 (device just recently started up, power on), then this has to be confirmed with function 48. This is helpful to detect current supply interruptions (on the power supply circuit).

Enhancement:

During start-up the device group can be checked via function F48 to ensure that this version is supported.

Further information is available:

- F30: pressure and temperature range
- F69 serial number



Some examples:

	address	request	response	received value
Read P1	250	250 73 1 161 167	250 73 63 109 186 172 0 26 27	0.9286296 bar
	1	1 73 1 80 214	1 73 63 109 177 83 0 231 97	0.9284870 bar
Read P2	1	1 73 2 81 150	1 73 63 109 178 242 0 119 232	0.9285117 bar
Read TOB1	250	250 73 4 162 103	250 73 65 201 184 0 0 224 204	25.21484 °C
	1	1 73 4 83 22	1 73 65 202 81 128 0 95 54	25.28979 °C
Initialize	1	1 48 52 0	1 48 5 20 12 28 13 1 84 134	version 5.20-12.28
		1 48 52 0	1 48 5 21 17 50 100 1 161 243	version 5.21-17.50
		1 48 52 0	1 48 5 24 20 46 255 1 90 116	version 5.24-20.46

5.2 Coefficients

Calibration values

The calibration values can be read and written.

No.	Read / Write	Description of coefficient	Unit
53	R/W	Threshold value of the square root function, (must be >0 if sqrt is used) <i>version 5.20-XX.XX and 5.24-XX.XX</i>	bar
64	R/W	Offset of pressure sensor P1, default 0.0	bar
65	R/W	Gain factor of pressure sensor P1, default 1.0	
66	R/W	Offset of pressure sensor P2, default 0.0	bar
67	R/W	Gain factor of pressure sensor P2, default 1.0	
68	R/W	Offset of analogue output <i>version 5.20-XX.XX and 5.24-XX.XX</i>	bar
69	R/W	Gain factor of analogue output <i>version 5.20-XX.XX and 5.24-XX.XX</i>	
70	R/W	Offset of CH0, default 0.0 <i>version 5.20-XX.XX and 5.24-XX.XX</i>	
71	R/W	Gain factor of CH0, default 1.0 <i>version 5.20-XX.XX and 5.24-XX.XX</i>	
72	R/W	Offset of temperature sensor T <i>version 5.21-XX.XX and 5.24-XX.XX</i>	°C
74	R/W	Offset of temperature sensor TOB1 <i>version 5.21-XX.XX and 5.24-XX.XX</i>	°C
76	R/W	Offset of temperature sensor TOB2 <i>version 5.21-XX.XX and 5.24-XX.XX</i>	°C
72	R/W	Upper threshold value for switching output 1 ¹ <i>version 5.20-XX.XX only</i>	
73	R/W	Lower threshold for switching output 1 ¹ <i>version 5.20-XX.XX only</i>	
78	R/W	Upper threshold value for switching output 2 ¹ <i>version 5.20-XX.XX only</i>	
79	R/W	Lower threshold for switching output 2 ¹ <i>version 5.20-XX.XX only</i>	
121	R/W	Gain Conductivity Range 1 <i>version 5.21-XX.XX only</i>	
122	R/W	Gain Conductivity Range 2 <i>version 5.21-XX.XX only</i>	
123	R/W	Gain Conductivity Range 3 <i>version 5.21-XX.XX only</i>	
124	R/W	Gain Conductivity Range 4 <i>version 5.21-XX.XX only</i>	
126	R/W	Conductivity Temperature Coefficient (default 0.022-> water) <i>version 5.21-XX.XX only</i>	
127	R/W	Conductivity Cell Constant (default 1.00) <i>version 5.21-XX.XX only</i>	
100... 111	R/W	free coefficients for customer use	
140... 156	R/W	Coeff for CH0 straight line curve fitting of P1 <i>version 5.24-XX.XX only</i>	

¹ no longer supported for *version 5.20-10.XX and newer*.

Information values

The information values are readable only.

The information for No. 94 and 95 may be in mA or V, according to whether the device possesses a voltage output or a current output (see DAC_CTRL function 33).

No.	Read / Write	Description of the coefficient	Unit
80	R	Minimum pressure of sensor P1	bar
81	R	Maximum pressure of sensor P1	bar
82	R	Minimum pressure of sensor P2	bar
83	R	Maximum pressure of sensor P2	bar
84	R	Minimum temperature of temperature sensor	°C
85	R	Maximum temperature of temperature sensor	°C
86	R	Minimum temperature of sensor P1	°C
87	R	Maximum temperature of sensor P1	°C



88	R	Minimum temperature of sensor P2	°C
89	R	Maximum temperature of sensor P2	°C
90	R	Minimum value of channel CH0	
91	R	Maximum value of channel CH0	
92	R	Pressure for minimum analogue signal * <i>version 5.20-XX.XX and 5.24-XX.XX</i>	bar
93	R	Pressure for maximum analogue signal * <i>version 5.20-XX.XX and 5.24-XX.XX</i>	bar
94	R	Minimum analogue signal ¹ <i>version 5.20-XX.XX and 5.24-XX.XX</i>	mA , V
95	R	Maximum analogue signal ¹ <i>version 5.20-XX.XX and 5.24-XX.XX</i>	mA , V
99	R	Calibration date: B3:day B2:month B1:B0:year	
120	R	Conductivity hardware version and firmware version (C.G/Y.W) <i>version 5.21-16.50 and later only</i>	-

¹ Required for scaling the analogue output (see below)

Scaling of channels CH0, P1 and P2

CH0, P1 and P2 are linearly scalable with zero point and gain factor: **Value = gain factor * value + offset**

Standard values: Offset = 0.0, gain factor = 1.0

T, TOB1 and TOB2 are only scalable with zero point. Standard value: Offset = 0.0

It is also possible to influence the offset values via function 95 (see function 95).

The gain factor should be used **for calibration purposes only**, and not to alter pressure units. The latter operation should always be carried out by the master! In order to represent other pressure units via the analogue output, the unit conversion must be taken into account when scaling the analogue output.

Scaling the analogue output

The analogue output on the X-Line pressure transmitters can be programmed via the interface. As the two routes *sensor-signal* → *digital transformation and digital value* → *analogue signal* are calibrated independently at the factory, the analogue output can be set to different pressures or pressure units **without** requiring recalibration. For this purpose, KELLER offers the free CCS30 software, which provides a convenient means of carrying out this scaling with a PC.

To programme the scaling of the analogue output yourself, proceed as follows:

Function 32 enables you to ascertain whether the device possesses an analogue output. The coefficients required for calculation can be read out using function 30. A new scaling can be programmed using function 31.

Read-out of pressure range for the analogue output:

The following coefficients (K[No.]) must be read out using function 30 in order to calculate the lower and upper limit of the analogue output:

$$A = (K[92] - K[68]) / K[69]$$

$$B = (K[93] - K[68]) / K[69]$$

Setting a new pressure range for the analogue output:

K[68] and K[69] must be calculated and written into the device using function 31:

$$K[68] = K[92] - ((K[93] - K[92]) / (B - A)) * A$$

$$K[69] = (K[93] - K[92]) / (B - A)$$

Whereby:

K[x] : Coefficient with the corresponding number [x] → see function 30

A: Pressure in bar at which the signal K[94] is to be output

B: Pressure in bar at which the signal K[95] is to be output

Other pressure units are to be converted into bar.



5.2.1 Function 30: Read Coefficients

Request:

DevAddr	30	No.	CRC16_H	CRC16_L
---------	----	-----	---------	---------

Response:

DevAddr	30	B3	B2	B1	B0	CRC16_H	CRC16_L
---------	----	----	----	----	----	---------	---------

Exception errors:

- 2** version 5.20: if No. > 111
version 5.21: if No. > 127
version 5.24: if No. > 156
- 3** if message length incorrect
- 32** if device is not yet initialised

Note:

Every coefficient can be read in IEEE754 format (floating-point format 4-byte B0 ... B3) via this function.
→ Information on IEEE754: see appendix.

5.2.2 Function 31: Write Coefficients

Request:

DevAddr	31	No.	B3	B2	B1	B0	CRC16_H	CRC16_L
---------	----	-----	----	----	----	----	---------	---------

Response:

DevAddr	31	0	CRC16_H	CRC16_L
---------	----	---	---------	---------

Exception errors:

- 2** If write access is not allowed
- 3** If message length is incorrect
- 4** If error in saving of new coefficients *version 5.21-XX.XX only*
- 32** If device has not yet been initialised

Note:

Information on scaling of the channels: See functions 73 and 95. Information on which channels are active: See function 32 CFG_P, CFG_T and CFG_CH0.



5.3 Configurations

With functions 32 and 33 one can read and write some configuration of the device. These functions provide a single byte access.
Description:

Nr.	Name	Description	Read	Write
0	CFG_P	Active pressure channels (high priority): Bit 1: P1 Bit 2: P2	✓	✗
1	CFG_T	Active Temperature channels (low priority): Bit 3: T (Temperature sensor) Bit 4: TOB1 (Temperature of pressure sensor P1) Bit 5: TOB2 (Temperature of pressure sensor P2) Bit 7 Con (Conductivity sensor) <i>version 5.21-XX.XX only</i>	✓	✗
2	CFG_CH0	<i>version 5.20-XX.XX and 5.24-XX.XX</i> Configuration of CH0 (Calculated channel): Byte value (decimal) 0: inactive 1: Difference P1 – P2 2: Difference P2 – P1 3: Square root calculation sqrt(P1), set coefficient Nr. 53 > 0 4: Square root calculation sqrt(P2), set coefficient Nr. 53 > 0 5: Square root calculation sqrt(P1 – P2), set coefficient Nr. 53 > 0 6: Square root calculation sqrt(P2 – P1), set coefficient Nr. 53 > 0 11: Absolute value abs(P1) 12: Absolute value abs(P1 – P2) 13: Line pressure compensated differential pressure (only at factory, add. parameters) 14: straight line curve fitting of P1 (only if P2 is not active, <i>5.20-12.24 and earlier</i>) 15: temperature measured by PT1000	✓	✓ Device has to be restarted (power Off/On). Please note that for some settings there are more configurations needed
3	CNT_T	Temperature measurement interval in seconds. <i>version 5.20-XX.XX only</i>	✓	✓
4	CNT_TCOMP LP-FILTER	Value of Bit 0 ... 3 (LowNibble): CNT_TCOMP <i>version 5.20-XX.XX only</i> After CNT_T * CNT_TCOMP seconds a temperature compensation will be performed. Value of Bit 4 ... 7 (HighNibble): Low pass filter* for P1 and P2. <i>LowpassFilter = [B7...B4]</i> The formula for the low pass filter is given as: $P_{n+1} = \frac{(2^{LowpassFilter} - 1) \cdot P_{n-1} + P_n}{2^{LowpassFilter}}$ where: P _{n+1} : new filtered value P _n : actual measured value P _{n-1} : old filtered value	✓	✓
7	FILTER	Filter setting for one conversion: Bit 0: Adaptive filter for P1 and P2 (on / off) ¹ Bit 1: Low pass filter for T, TOB1 and TOB2 (on / off) Bit 2.. 4: Over sampling ration OSR = 2 ^{^(8+Bit 2...4)} <i>version 5.20-XX.XX only</i> Bit 5.. 6: Amount of samples per averaging: 0..3 = 1, 2, 4 or 8 values <i>version 5.20-XX.XX only</i> Factory settings see FILTER_ORG. <i>version 5.20-XX.XX only</i>	✓	✓
9	DAC	<i>version 5.20-XX.XX and 5.24-XX.XX</i> Analogue output: Bit 0: milli Amperes output (4 .. 20mA) Bit 1: Voltage output Bit 4 = 1: P1 is linked to the analogue output Bit 4 = 0: CH0 is linked to the analogue output Scaling see function 30/31	✓	(✓ : Bit4) <i>version 5.20-10.40 and earlier and 5.24-XX.XX</i> Change of bit 4 allowed to link the analogue output either to CH0 or P1
10	UART	UART settings: Bit 0 .. 3: Baud rate Baud rate Value = 0: 9'600baud Baud rate Value = 1: 115'200baud Bit 4: Parity selection. 0: no Parity, 1: Parity enable Bit 5: Parity mode. 0: odd parity, 1: even parity Bit 6: Stop bit. 0: 1 Stop bit, 1: 2 Stop bits <i>version 5.21-XX and 5.24-XX</i>	✓	✓ <i>version 5.20-XX-XX:</i> restart Device <i>version 5.21-XX.XX and 5.24-XX.XX:</i> generates a restart → reinitialise!



11	FILTER_bck	Factory setting for filter value. <i>version 5.20-XX.XX and 5.24-XX.XX</i>	✓	✗
12	STAT	Status of the measurement. See function 73 for details.	✓	✗
13	DEV_ADDR	Device address. Range: 1 ... 255 (default 1)	✓	✓
14	P-Mode	<i>version 5.20-12.XX and later, 5.21-XX.XX and 5.24-XX.XX</i> Type of sensor and calibration. Bit 0 ... 3 (LowNibble) P1: 0: PR (relative), 1: PA (absolute), 2: PAA (absolute) 15: not available (<i>version 5.24-XX.XX only</i>) Bit 4 ... 7 (HighNibble) P2: 0: PR (relative), 1: PA (absolute), 2: PAA (absolute) 15: not available (<i>version 5.24-XX.XX only</i>)	✓	✗
15	SPS	<i>version 5.21-17.10 and later</i> Samples per Second: 0x05: 120 SpS 0x06: 240 SpS 0x07: 480 SpS	✓	✓ <i>version 5.21-XX.XX</i>
20	SDI-12	<i>version 5.21-14.XX and later only</i> Switch to SDI-12 Mode 0x99	✗	✓
25	ModbusInterFrameTime9k6	<i>version 5.21-16.50 and later and 5.24-XX.XX</i> Minimal interframe time @ 9600Baud ModbusInterFrameTime9k6*100us = Timeout (default: 35 → 35ms)	✓	✓
26	ModbusInterFrameTime115k2	<i>version 5.21-16.50 and later and 5.24-XX.XX</i> Minimal interframe time @ 115200Baud ModbusInterFrameTime115k2*100us = Timeout (default: 18 → 1.8ms)	✓	✓
28	ConOn	<i>version 5.21-XX.XX only</i> 0x01: Conductivity powered 0x00: Conductivity unpowered	✓	✓
31	ConRange	<i>version 5.21-XX.XX only</i> 0x01: Conductivity Range 1: 0...200uS (0.2mS) 0x02: Conductivity Range 2: 0...2'000uS (2mS) 0x03: Conductivity Range 3: 0...20'000uS (20mS) 0x04: Conductivity Range 4: 0...200'000uS (200mS) (default)	✓	✓
32	ConTempCompMode	Conductivity <i>Temperature Compensation Method after DIN/EN 27 888</i> <i>version 5.21-XX.XX only</i> 0x01: Linear Temperature Compensation @ 25°C (default) 0x02: Linear Temperature Compensation @ 20°C 0x03: Non-linear Temperature Compensation (Table)@ 25°C	✓	✓
33	SDI-12_available	<i>version 5.21-13-35 and 5.21-14.35 and later only</i> 0x01: Switch to SDI-12 possible 0x00: SDI-12 Wire not available	✓	✗

¹ The adaptive filter for *version 5.24-XX.XX* has only an influence on the digital output. The LP-filter has an influence on both, the digital and the analogue output.

5.3.1 Function 32: Read configuration

Request:

DevAddr	32	No.	CRC16_H	CRC16_L
---------	----	-----	---------	---------

Response:

DevAddr	32	Data	CRC16_H	CRC16_L
---------	----	------	---------	---------

Exception errors:

- 2** If No. is not available
- 3** If message length is incorrect
- 32** If device has not yet been initialised



5.3.2 Function 33: Write configuration

Request:

DevAddr	33	No.	Data	CRC16_H	CRC16_L
---------	----	-----	------	---------	---------

Response:

DevAddr	33	0	CRC16_H	CRC16_L
---------	----	---	---------	---------

Exception errors:

- 2 If write access is not allowed
- 3 If message length is incorrect
- 4 If error in saving of new configuration values *version 5.21-XX.XX only*
- 32 If device has not yet been initialised

5.4 Function 48 : Initialise and release

Request:

DevAddr	48	CRC16_H	CRC16_L
---------	----	---------	---------

Response:

DevAddr	48	Class	Group	Year	Week	BUF	STAT	CRC16_H	CRC16_L
---------	----	-------	-------	------	------	-----	------	---------	---------

Exception error:

- 3 If message length is incorrect

Note:

Each time the device is switched on by applying the supply voltage or after a break in the power supply, the device must be initialised via this function. Calling a different function will lead to **exception error 32**.

The following information is returned:

Class	Device ID code
5:	X-Line digital pressure transmitter (33, 35, 36, 39)
Group	Subdivision within a device class
1:	X-Line transmitter from 1999 or later
20:	X-Line transmitter from 2002 or later
21:	X-Line transmitter version X2
24:	X-Line transmitter version X2P
	The differences between these devices are defined in italics in the functions.
Year, Week	Firmware version
BUF	Length of the internal receive buffer
STAT	Status information
0:	Device addressed for first time after switching on.
1:	Device was already initialised



5.5 Function 66 : Write and read new device address

Request:

DevAddr	66	NewAddr	CRC16_H	CRC16_L
---------	----	---------	---------	---------

Response:

DevAddr	66	ActAddr	CRC16_H	CRC16_L
---------	----	---------	---------	---------

Exception error:

- 3 If message length is incorrect or value not allowed
- 4 If error in saving of new address value *version 5.21-XX.XX*
- 32 If device is not yet initialised

Note:

This function programmes the device addresses to NewAddr. The address is returned in ActAddr as confirmation. It is to be ensured that the new address NewAddr is not already in use by another bus user.

Permissible addresses: 1 .. 255. Address 250 is transparent. This means that every device, irrespective of the set address, will respond to address 250. Consequently, *transparent* DevAddr = 250 may only be used in stand-alone operating mode!

For the purpose of **reading the device address** when the address is not known, for example, the value 250 is transferred as DevAddr and the value 0 is transferred as NewAddr. The current address is then returned in response.

5.6 Function 69 : Read serial number

Request:

DevAddr	69	CRC16_H	CRC16_L
---------	----	---------	---------

Response:

DevAddr	69	SN3	SN2	SN1	SN0	CRC16_H	CRC16_L
---------	----	-----	-----	-----	-----	---------	---------

Exception errors:

- 3 If message length is incorrect
- 32 If device is not yet initialised.

Note:

The serial number is allocated at the factory. It consists of 4 bytes unsigned integer and is calculated as follows:

$$SN = 256^3 * SN3 + 256^2 * SN2 + 256 * SN1 + SN0$$

**5.7 Function 73 : Read value of a channel (floating point)****Request:**

DevAddr	73	CH	CRC16_H	CRC16_L
---------	----	----	---------	---------

Response:

DevAddr	73	B3	B2	B1	B0	STAT	CRC16_H	CRC16_L
---------	----	----	----	----	----	------	---------	---------

Exception errors:

- 2** version 5.20-XX.XX: if no. > 5
version 5.21-XX.XX: if no. > 11
version 5.24-XX.XX: if no. > 5
- 3** If message length is incorrect
- 32** If device is not yet initialised

Note:

A device can measure up to five signals (channels):

version 5.20-XX.XX and 5.24-XX.XX:

Two independent pressure sensors P1 and P2, as well as the temperatures of these pressure sensors TOB1 and TOB2 and an additional temperature sensor T. The temperatures of the pressure sensors (TOB1, TOB2) are required for temperature compensation of the pressure signal.

version 5.21-XX.XX:

One pressure sensor P1, as well as the temperatures of pressure sensors TOB1 and an additional temperature sensor T. Optional a conductivity sensor is available and ConTc and ConRaw can be measured as well. The temperature of the pressure sensor (TOB1) is required for temperature compensation of the pressure signal.

Please use function 32 to get the information about the active channels.

CH0 is a calculated channel whose mode of functioning is defined in function 32 / 33.

On a standard pressure transmitter, only channels P1 and TOB1 are available.

The measured value is returned in IEEE754 format (4-byte B0 ... B3).

CH	Name	Description	Unit
0	CH0	Calculated channel (see function 32,33 <i>version 5.20-XX.XX and 5.24-XX.XX only</i>)	*
1	P1	Pressure from pressure sensor 1	bar
2	P2	Pressure from pressure sensor 2	bar
3	T	Additional temperature sensor	°C
4	TOB1	Temperature of pressure sensor 1	°C
5	TOB2	Temperature of pressure sensor 2	°C
10	ConTc	Conductivity Temperature Compensated <i>version 5.21-XX.XX only</i>	mS/cm
11	ConRaw	Conductivity Raw Value <i>version 5.21-XX.XX only</i>	mS/cm

* Dependent on definition in function 32.

The **STAT** byte contains the current status.

Bit position	.7	.6	.5	.4	.3	.2	.1	.0
Name	/STD	ERR2	TOB2	TOB1	T	P2	P1	CH0

A set **/STD** bit indicate whether the transmitter is in Power-up mode, otherwise it is in Standard mode. For *version 5.21-XX.XX*, /STD is used to indicate an error during measuring the conductivity.

A set **ERR2** bit denotes that a computation error has occurred in the calculation process for the analogue output. This occurs if the analogue Signal is in saturation (depends on the scaling). *version 5.20-XX.XX and 5.24-XX.XX*

A set **CH0, P1, P2, T, TOB1, TOB2** bit indicates that a measuring or computation error has occurred in the channel concerned.

For details in error-handling see chapter **Error handling and recognition!**



5.8 Function 74 : Read value of a channel (32bit integer)

Request:

DevAddr	74	CH	CRC16_H	CRC16_L
---------	----	----	---------	---------

Response:

DevAddr	74	B3	B2	B1	B0	STAT	CRC16_H	CRC16_L
---------	----	----	----	----	----	------	---------	---------

Exception errors:

- 2 5.20-XX.XX: if no. > 5
5.21-XX.XX: if no. > 11
5.24-XX.XX: if no. > 5
- 3 If message length is incorrect
- 4 *version 5.20-5.50 and earlier:* If a channel is in overflow/underflow/inactive state or the data is invalid. For newer versions: overflow/underflow/inactive state is showed by value. See Chapter 6.3
- 32 If device has not yet been initialised

Note:

Same as function 73, but values as 4-byte integer (long) B0 ... B3, where B3 is MSByte. The resolution is reduced to 0.01mbar.

Signed Integer: $\pm 2'000'000'000$

Unit: CH0: CH0 *10⁻⁵
P1 and P2: Pascal (1Pa = 10⁻⁵ bar).
T, TOB1 and TOB2: 0.01°C
ConTC and ConRaw are not available with F74

Status-Byte (STAT): See function 73.

For details in error-handling see chapter **Error handling and recognition!**

5.9 Function 95 : Commands for setting the zero point

Requests:

Request a:

DevAddr	95	CMD	CRC16_H	CRC16_L
---------	----	-----	---------	---------

Request b with set point:

DevAddr	95	CMD	B3	B2	B1	B0	CRC16_H	CRC16_L
---------	----	-----	----	----	----	----	---------	---------

where B3:B0: Floating-point number IEEE754 format (4-byte B0 ... B3) for the set point.

Response:

DevAddr	95	0	CRC16_H	CRC16_L
---------	----	---	---------	---------

Exception errors:

- 1 If in Power-up mode
If data value is incorrect (NaN, INF, NINF) *version 5.21-XX.XX only*
- 2 If CMD invalid
- 3 If message length incorrect
- 4 If error in saving of new calibration values *version 5.21-XX.XX only*
- 32 If device is not yet initialised

**Note:**

The following actions can be carried out with this function:

CMD	Meaning
0	Set zero point of P1
1	Reset zero point of P1 to standard value
2	Set zero point of P2
3	Reset zero point of P2 to standard value
4	--
5	--
6	Set zero point of CH0 <i>version 5.20-XX.XX and 5.24-XX.XX</i>
7	Reset zero point of CH0 to standard values <i>version 5.20-XX.XX and 5.24-XX.XX</i>
8	Set zero point of T <i>version 5.21-XX.XX and 5.24-XX.XX</i>
9	Reset zero point of T to standard value <i>version 5.21-XX.XX and 5.24-XX.XX</i>
10	Set zero point of TOB1 <i>version 5.21-XX.XX and 5.24-XX.XX</i>
11	Reset zero point of TOB1 to standard value <i>version 5.21-XX.XX and 5.24-XX.XX</i>
12	Set zero point of TOB2 <i>version 5.21-XX.XX and 5.24-XX.XX</i>
13	Reset zero point of TOB2 to standard value <i>version 5.21-XX.XX and 5.24-XX.XX</i>

CMD 0, 2, 6, 8, 10, 12:

Zero point values for pressure channels P1, P2 and the calculated channel CH0 and T, TOB1, TOB2. These values can also be read via function 30 and written via function 31.

Request a: The zero point is calculated such that the current measured value = 0.0.

Request b: The zero point is calculated such that the current measured value equals the set point (B3:B0).

CMD 1, 3, 7, 9, 11, 13: Reset zero point to factory setting

The zero point values are reset to 0.0.

5.10 Function 100 : Read configuration**Request:**

DevAddr	100	Index	CRC16_H	CRC16_L
---------	-----	-------	---------	---------

Response:

DevAddr	100	PARA0	PARA1	PARA2	PARA3	PARA4	CRC16_H	CRC16_L
---------	-----	-------	-------	-------	-------	-------	---------	---------

Exception errors:

- 2 If index > 8
- 3 If message length is incorrect
- 32 If device is not yet initialised

Note:

This function supplies the information about the configuration of the device. [Please use Function 32 instead of this function](#) for devices of *Class.Group-version 5.20-5.24 and earlier*. With function 32/33 you have access to a single parameter instead of all five parameters.

Index	Para0	Para1	Para2	Para3	Para4
0		UART	FILTER_ORG		
2	CFG_P	CFG_T	CFG_CH0 *	CNT_T	High Nibble Low Nibble* LP-Filter CNT_TCOMP
3			FILTER		DAC *

*: Not for *Class.Group-version 5.21-XX.XX*

For details see description in function 32 / 33. For change the configuration use function 33.



6 Appendix

6.1 Interface converter

The serial RS232 interface or the USB interface can be used for connection to a PC. KELLER offers converters for this purpose. Various other products are commercially available, however. The following requirements apply when working with KELLER software:

- The converter must control transmit / receive switch-over automatically.
- KELLER converters feature a hardware echo, i.e. the transmitted message is received again immediately as an echo. This echo is required by some KELLER software programmes.

6.2 Floating-point format IEEE754

As data transmission is effected byte-wise (8-bit data), the floating-point values are represented as follows:
 B0: Bit 0...7; B1: Bit 8...15, B2: Bit 16...23, B3: Bit 24...31

Representation in accordance with IEEE754:

B3 DATA H (Reg. 0)	B2 DATA L (Reg. 0)	B1 DATA H (Reg. 1)	B0 DATA L (Reg. 1)	
b01000001 (0x41)	b00101001 (0x29)	b00000010 (0x02)	b11011110 (0xDE)	Valid Number
b01111111 (0x7F)	b10000000 (0x80)	b00000000 (0x00)	b00000000 (0x00)	∞ / Overflow
b11111111 (0xFF)	b10000000 (0x80)	b00000000 (0x00)	b00000000 (0x00)	-∞ / Underflow
bx11111111 (0xFF)	b11111111 (0xFF)	b11111111 (0xFF)	b11111111 (0xFF)	Not a Number

1 bit Sign + 8 bit Exponent + 23 bit Mantis = 32 bit

Calculation of the value transmitted:

$$V = (-1)^S \cdot (1.0 + \frac{M}{2^{23}}) \cdot 2^{E-127}$$

$$0 = 0$$

$$10000010 = 130$$

$$01010010000001011011110 = 2687710$$

$$-10 * (1.0 + \frac{2687710}{8388608}) * 2^{130-127} = 10.5631999969482421875$$

These values directly show the value in the requested unit [bar] or [°C] (for version 5.21-XX.XX: if conductivity sensor available [mS]).

$$\Rightarrow 10.5632 \text{ bar}$$

Usage of Keller software:

If you use the DLL which is available from KELLER, you do not need to carry out conversion, as this is encapsulated in the DLL. If you wish to address the devices directly, however, you must convert the individual bytes into a floating-point value.

To obtain a floating-point value from the individual bytes, proceed as follows:

1. Define data structure in which an array of 4 bytes and a 32-bit floating-point value is defined at the same memory location.
2. Write the bytes into the byte array.
3. Read out the floating-point value.

You do not need to carry out any actions, therefore, as the computer attends to interpretation. Some microcontrollers have a different data structure for floating-point values. In such cases, adaptation is necessary.



6.3 Error handling and recognition

The electronic unit can read five signals: pressure values from two pressure sensors (**P1**, **P2**), temperature values from both of these pressure sensors (**TOB1**, **TOB2**) and temperature value from one additional temperature sensor (**T**). Additionally, out of these values, other values can be calculated (**CH0**). These values are described as **channels** in this documentation.

To check if the channels are active one may use function F32 (or MODBUS addresses 0x0204-0x0206) (refer to according chapter).

Additional: *version 5.21-XX.XX* is available with a conductivity sensor. It provides three values: Conductivity temperature compensated (**ConTc**), conductivity raw (**ConRaw**) as well as the temperature (**T**).

Measuring range

The signals are being measured with an analogue to digital converter (ADC). The measuring range is limited upwards and downwards.

For the pressure signals P1 and P2 the limitation is depending on the compensated pressure range, which can be read out with function 30 (as well as MODBUS function 3 [range 0x03xx] from *version 5.20-10.XX and later, 5.21-XX.XX and 5.24-XX.XX*).

Readable range: (pressure range minimum – 10%) up to (pressure range maximum + 10%)

Is the pressure below or above this range, then the bit in the Status-Byte will be set. The measured value itself is no longer valid when the Status-Bit is set. It is set to +Inf or -Inf.

Dependencies

P1 and P2 are temperature-compensated and therefore they are depending on temperature. Channel CH0 is always depending on P1 and / or P2 and on a temperature channel. Is there a fault in one of these dependencies so the depending channel will follow accordingly.

What is new in version 5.20-10.40 and later, 5.21-XX.XX and 5.24-XX.XX

Version **5.20-10.40** (available end of 2010) and later will display additionally to the Status-Bit also an error in the value itself.

The format follows the special indications according to floating point arithmetic: **NaN**, **+Inf** (ovl), **-Inf** (ufl). See chapter floating-point Format IEEE754.

	CH0	P1 / P2	TOB1 / TOB2
NaN	Dependency error (P1, P2 = NaN or +/-Inf)	+/-Inf in compensating T-channel	-
+Inf	-	ADC value out of range (Overflow)	ADC value out of range (Overflow) or T > 300 °C
-Inf	-	ADC value out of range (Underflow)	ADC value out of range (Underflow) or T < - 70°C
0.000	Sqrt: (p < Pcutoff)	-	-

The values NaN, +Inf and -Inf are defined in the IEEE754 standard and are described in chapter Floating-point format IEEE754.

NaN is also shown, when the requested channel is not active. In this case, the Status-Bit is not set.

Special Integer Values (F74, F3):

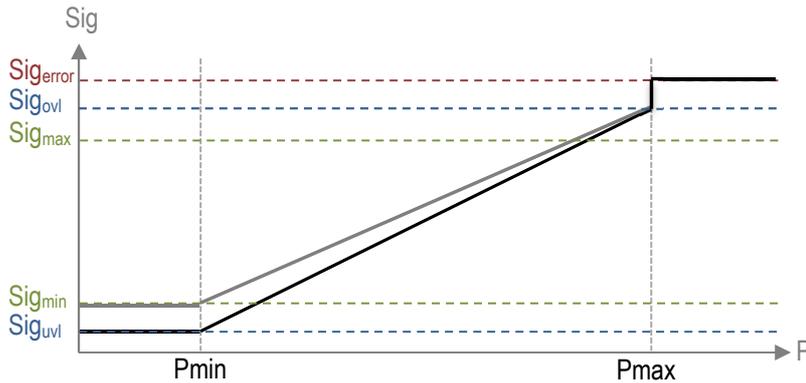
	32bit signed integer	16bit signed integer
NaN, +Inf	2147483647 (0x7FFFFFFF)	32767 (0x7FFF)
-Inf	-2147483648 (0x80000000)	-32768 (0x8000)



6.3.1 Analogue Output

The analogue output has to transfer the error states described in the former chapter and therefore additional analogue states were introduced. The graph below shows the transfer function between pressure (in this example the analogue output is a function of P – however it could also be some other mathematical function using CH0). The black line (grey for LV version) shows the transfer function for a positive DAC-gain. The $\text{Sig}_{\text{error}}$ is independent of any scaling function and represents an internal error state (source has NaN, see table above).

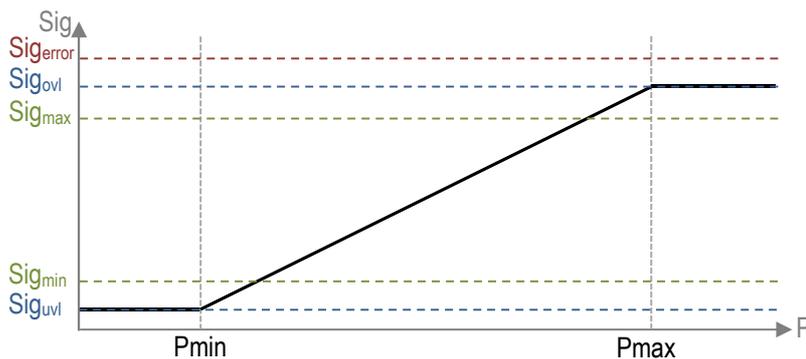
Version 5.24



The following table shows possible analogue values for different hardware types *version 5.24*:

	0 – 10V	0 - 5V	0 - 2.5V	0.1 - 2.5V (LV)	4-20mA	Digital representative
$\text{Sig}_{\text{error}}$	11.6V	5.8V	2.9V	2.88V	22.56mA	NaN
Sig_{ovl}	11V	5.5V	2.75V	2.74V	21.6mA	+Inf
Sig_{max}	10V	5V	2.5V	2.5V	20mA	value
Sig_{min}	0V	0V	0V	0.1V	4mA	value
Sig_{ovl}	-1V	-0.5V	-0.25V	<0.1V	3.6mA	-Inf

Version 5.20



The following table shows possible analogue values for different hardware types *version 5.20*:

	0 – 10V, (0 – 5V)	0 - 2.5V	4-20mA	Digital representative
$\text{Sig}_{\text{error}}$	11.6V	2.9V	22.5mA	NaN
Sig_{ovl}	11V	2.75V	21.8mA	+Inf
Sig_{max}	10V	2.5V	20mA	value
Sig_{min}	0V	0V	4mA	value
Sig_{ovl}	-1V	-0.3V	3.3mA	-Inf



6.4 Calculation of the CRC16 checksum

The checksum can either be calculated or derived from a table.

Here is an example of CRC16 calculation in C:

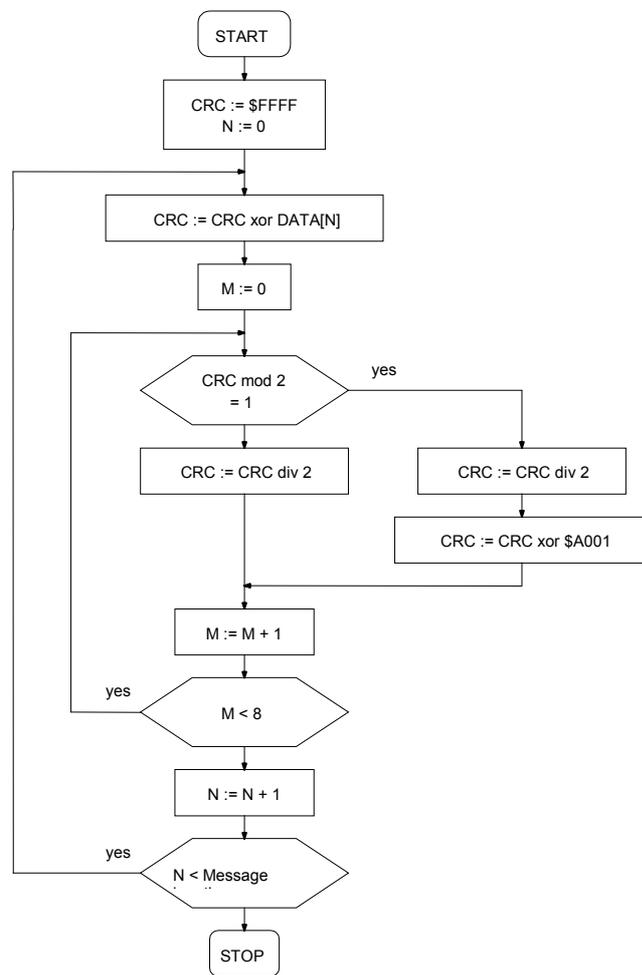
```

////////////////////////////////////
// CRC-16 calculation in C
//
// Calculation of CRC-16 checksum over an amount of bytes in the serial buffer.
// The calculation is done without the 2byte from crcl6 (receive-mode).
// SC_Buffer[]: Byte-Buffer for the serial interface. Type: unsigned char (8bit)
// SC_Amount : Amount of Bytes which should be transmitted or are received (without CRC16)
//
////////////////////////////////////
void CalcCRC16(unsigned char* CRC_H, unsigned char* CRC_L)
{
  // locals
  unsigned int Crc;
  unsigned char n, m, x;

  // initialisation
  Crc= 0xFFFF;
  m= SC_Amount;
  x= 0;

  // loop over all bits
  while(m>0)
  {
    Crc^= SC_Buffer[x];
    for(n=0; n<8; n++)
    {
      if(Crc&1)
      {
        Crc>>= 1;
        Crc^= 0xA001;
      }
      else
        Crc>>= 1;
    }
    m--;
    x++;
  }
  // result
  *CRC_H= (Crc>>8)&0xFF;
  *CRC_L= Crc&0xFF;
}
}

```



This results in the following calculation for function 48 with device address 250: CRC16_H= 4, CRC16_L= 67.

Examples showing use based on a table are to be found in the MODBUS documentation at:

<http://www.modbus.org>



6.5 Changes

- **Document version 2.1**, 19. October 2005: New function 32 and 33 for device *Class.Group -Year.Week 5.24* and earlier, F75: cancelled.
- **Document version 2.2**, 16. August 2006:
Description for function 32/33 revised. Function 101 added. Formula for scaling of the analogue output corrected.
- **Document version 3.0**, 20. December 2010:
Added Modbus (chapter 4) support for *Class.Group-version 5.20-10.XX*
Modbus Implementation of Functions (3,6,8 and 16) with support of all functions covered by the Keller Bus protocol.
Added chapter error handling and recognition
Modified chapter "Floating-point format IEEE754"
- **Document version 3.1**, 14. August 2012:
Added changes of *Class.Group-version 5.20-12.28*
- **Document version 3.2**, 12. August 2013:
New device family Class.Group-version 5.21-XX.XX added.
- **Document version 3.3**, 1. November 2014:
Commands for Conductivity Sensor added in Class.Group-version 5.21-XX.XX.
- **Document version 3.4**, 1. April 2016:
New commands for Conductivity Sensor added in Class.Group-version 5.21-XX.XX.
- **Document version 3.5**, 27. January 2017:
Default added for Baudrate and Bus Address
- **Document version 3.7**, 20. November 2020:
New device family Class.Group-version 5.24-XX.XX added

An overview of the released versions for *Class.Group 5.20-XX.XX*:

Version Year.Week	Date of production	Major changes
2.40	2002..2003	Base version
3.50	2003 .. 2006	- CH0: add option Line pressure compensation
5.50	2006 .. 2010	- Hardware redesign to increase robustness under EMC - add Low pass Filter and adaptive Filter for pressure channels - Switch2 option cancelled - only two temperature channels possible: TOB1 and TOB2 or T - sqrt calculation without scaling factor - add function F32 and F33 for configuration access known issue: CRC of exception code using MODBUS F3 is wrong
10.40	2011...2012	- Improved error handling: see error handling and recognition - Switch option: cancelled - CH0: Curve fitting added (CFG_CH0= 14), SF6 calculation: cancelled (CFG_CH0=7..10) MODBUS protocol: - CRC16 in case of an exception corrected - F3: access to all registers as in the KELLER protocol (Information and config values) - Serial buffer increased from 10 to 13Bytes → readout of 2 values possible in one task - F6, F8, F16 added: Configuration and calibration also with MODBUS known issue: - MODBUS F3 0x0010 ..0x001A: not usable - CH0 scale (Coeff 70 and 71) must be default (Nr.70 = 0.00, Nr. 71 = 1.00)
12.28	Aug. 2012..	- CH0 scaling: corrected - MODBUS F3: 0x020E, 0x020F: Read firmware version added Int 16Bit values 0x0010 .. 0x0015 compatible with <i>version 5.20-5.50</i> 0x0020 .. 0x002A: integer 32bit for process values added

**An overview of the released versions for Class.Group 5.21-XX.XX:**

Main differences between Group 20 and the new added Group 21.

- Group 21 has no analogue output only digital communication
- Group 21 has a SDI-12 communication interface and is able to work as SDI-12 device
- Group 21 has a higher ADC resolution for pressure and temperature channel
- Group 21 has a larger buffer size for RS485 communication.

Version Year.Week	Date of production	Major revision
13.33	August 2013	Base version
13.35	August 2013	Implementation of HW identification
14.35	August 2014	Implementation of the conductivity sensor
15.45	November 2015	Adaption of threshold values of conductivity
16.40	October 2016	Implementation of adjustable Modbus RTU timeout and adaption to new conductivity sensor version
17.10	Mai 2017	General implementation for ADC speed (SPS)
17.50	December 2017 ...	Bug fixes

An overview of the released versions for Class.Group 5.24-XX.XX:

Main differences between Group 20 / 21 and the new added Group 24.

- Group 24 has a higher ADC resolution for pressure and temperature channel
- Group 24 has a higher bandwidth for pressure and temperature
- Group 24 has a larger buffer size for RS485 communication
- Group 24 has different options for digital communication protocols

Version Year.Week	Date of production	Major revision
20.XX	November 2020 ...	Base version

6.6 Support

We are pleased to offer you support in implementing the protocol. Use our free PC-software CCS30 for communication and configuration. Also divers for LabView, C#, etc. are available on our website: <http://www.keller-druck.com>

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