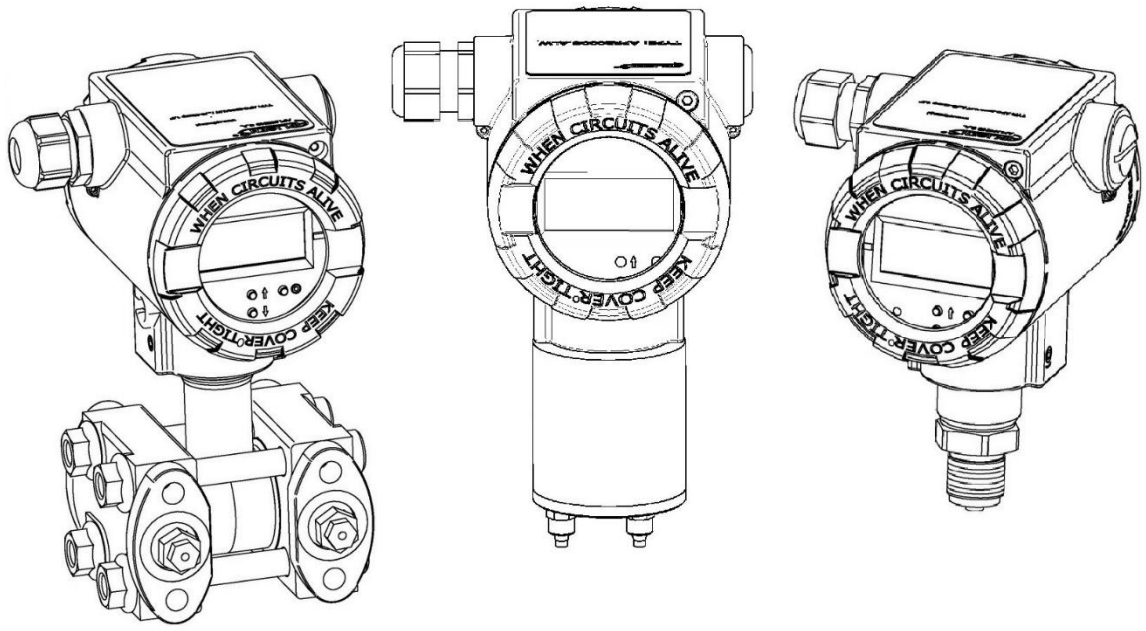
USER'S MANUAL

PRESSURE AND DIFFERENTIAL PRESSURE TRANSMITTERS

APC-2000ALM, APR-2000ALM, APR-2000ALM/G, APR-2000ALM with diaphragm seals

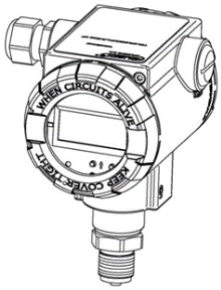


APLISENS S.A., 03-192 Warsaw, Morelowa 7 St.
tel. +48 22 814 07 77; fax +48 22 814 07 78
www.aplisens.com, e-mail: export@aplisens.com

PRODUCT CODE – see: ➔ 5.2. Transmitter identification.
The QR code or ID number identifies the transmitter and provides quick access to the following documentation on the manufacturer's website.

APC-2000ALM

ID: 0064 0002 0003 0000 0000 0000 0001 33
https://www.aplisens.pl/ID/006400020003000000000000000133



APR-2000ALM

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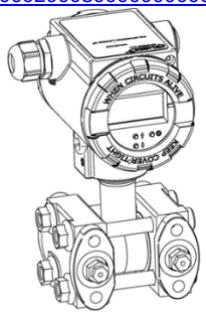

APR-2000ALM/G

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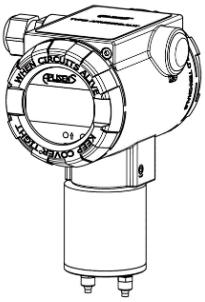
https://www.aplisens.pl/ID/006600020003000000000000000127



Symbols used

Symbol	Description
	Warning to proceed strictly in accordance with the information contained in the documentation in order to ensure the safety and full functionality of the device.
	Information particularly useful during installation and operation of the device.
	Information on disposal of used equipment.

BASIC REQUIREMENTS AND SAFE USE

The manufacturer will not be liable for damage resulting from incorrect installation, failure to maintain a suitable technical condition of the device or use of the device other than for its intended purpose.

Installation should be carried out by qualified staff having the required authorizations to install electrical and I&C equipment. The installer is responsible for performing the installation in accordance with manual as well as with the electromagnetic compatibility and safety regulations and standards applicable to the type of installation.

In systems with I&C equipment, in case of leakage, there is a danger to staff due to the medium under pressure. All safety and protection requirements must be observed during installation, operation and inspections.

If a malfunction occurs, the device should be disconnected and handed over to the manufacturer for repair.

In order to minimize the risk of malfunction and associated risks to staff, the device is not to be installed or used in particularly unfavorable conditions, where the following hazards occur:

- possible mechanical impacts, excessive shocks and vibration;
- excessive temperature fluctuation;
- water vapor condensation, dusting, icing.

Changes made to the manufacturing of products may be introduced before the paper version of the manual is updated. The up-to-date manuals are available on the manufacturer's website: www.aplisens.com.

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LIST OF TABLES

1. INTRODUCTION

1.1. Purpose of the document

The subject of manual are smart pressure transmitters **APC-2000ALM**, differential pressure transmitters **APR-2000ALM**, **APR-2000ALM/G**, **APR-2000ALM with diaphragm seals** hereinafter referred jointly to as the transmitters. The manual applies to the standard version.

The transmitters can be additionally equipped with a current regulator. Related information in the manual is preceded by the symbol "[1)]". In the absence of a controller, the variables associated with the process current are informative and current calibration operations are not applicable.

The manual contains data, tips and general recommendations for safe installation and operation of the transmitters, as well as troubleshooting in case of possible failure.

2. SAFETY

- The installation and start-up of the device and any activities related to operation shall be carried out after thorough examination of the contents of user's manual and the instructions related thereto.
- Installation and maintenance should be carried out by qualified staff having the required authorizations to install electrical and measuring devices.
- The device shall be used according to its intended purpose in line with the permissible parameters specified on the nameplate (➔ 5.2. Transmitter identification).
- The protection elements used by the manufacturer to ensure transmitter safety may be less effective if the device is operated in a manner not consistent with its intended purpose.
- Before installing or disassembling the device, it is absolutely necessary to disconnect it from the power source.
- No repairs or alterations to the transmitter electronic system are permitted. Assessment of damages and possible repair may only be performed by the manufacturer or authorized representative.
- Do not use instruments if damaged. In case of malfunction, the device must be put out of operation.

3. TRANSPORT AND STORAGE

3.1. Delivery check

After receiving the delivery, please refer to the general terms and conditions of contracts available on the manufacturer website: https://aplisens.com/ogolne_warunki_umow.html.

3.2. Transport

Transport of transmitters shall be carried out with the use of covered means of transport, in original packages with diaphragm provided with protection. The packaging shall be protected against movement and direct impact of atmospheric factors.

3.3. Storage

Transmitters shall be stored in a factory packaging, in a room without vapors and aggressive substances, protected against mechanical shock.
Allowable range of storage temperature according to the data sheet.

4. GUARANTEE

General terms and conditions of guarantee are available on the manufacturer's website: www.aplisens.com/ogolne_warunki_gwarancji.

The guarantee shall be repealed if the device is used against its intended use, failure to comply with user's manual or interference with the structure of the device.

5. IDENTYFICATION

5.1. Manufacturer's address

APLISENS S.A.
03-192 Warsaw
Morelowa 7 St.
Poland

5.2. Transmitter identification

Depending on the version of the transmitter, the nameplates may differ in the amount of information and parameters.

Table 1. Symbols occurring on the transmitter nameplate

APLISENS S.A.	Logo and name of manufacturer
CE	CE mark
CE 1453	CE mark with the number of notified body
	QR code
TYPE:	Transmitter type
Process connection:	Process connector
ID:	Transmitter model ID
P	Measurement range
Tamb	Permissible range of ambient temperature
PS	Permissible static pressure
U	Power supply voltage
	Output signal
Mat.	Material of wetted parts
Ser.- No.	Serial number
Electrical connection	Type of electrical connection
Year of production	Year of production
IP	IP protection rating
//Lower part of the nameplate//	Special version
	Note about obligation to read the manual
Aplisens S.A. ul. Morelowa 7, 03-192 Warszawa	Manufacturer address

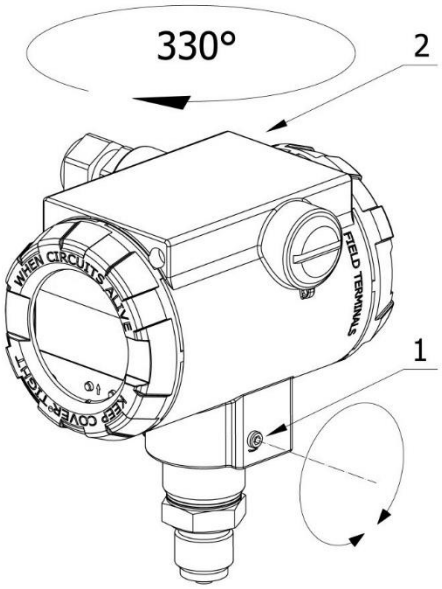
5.3. CE mark, declaration of conformity

The device has been designed to meet the highest safety standards, has been tested and has left the factory in a condition that is safe for operation. The device complies with the applicable standards and regulations listed in the EU Declaration of Conformity and has CE marking on nameplate.

6. INSTALLATION

6.1. General recommendations

During installation of transmitter on site it may be required to correct the effect of position on the measurement. This impact applies to the transmitter zero offset (➔ 6.2. Impact of mounting position on measurement). The transmitter gives the possibility of rotating the housing – to do this, loosen the screw (item 1), position the transmitter housing (item 2) as required, tighten the screw (item 1).
The transmitter body can be rotated max. by 330°.



1. Screw blocking transmitter rotation.
2. Transmitter housing.

Figure 1. Rotation of the housing

The transmitter gives the possibility of adjusting the display position to the mounting position of the body. Access to the extensions (item 2) used to rotate the display is provided after opening the front cover (item 1). The display may be rotated by an angle of 345° with a step of 15°.

1. Front cover.
2. Extensions for display rotation.
3. Local keypad buttons.
4. Housing.

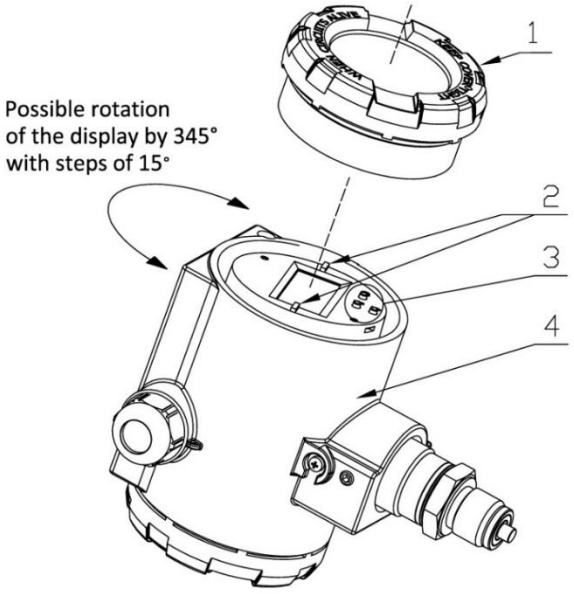


Figure 2. Change of display position and access to buttons

The method of mounting the transmitter and the configuration of impulse tubes used to feed pressure shall be based on the following conditions:

- Impulse tubes should be as short as possible and with a sufficiently large cross section, run without sharp bends.
- Impulse tubes must have a constant slope, e.g. 10 cm/m, unless they are looped.
- If the impulse tubes are installed in open air, they must be appropriately protected against freezing.
- Avoid measurement errors caused by the accumulation of condensate (in gas installations) or gas bubbles (in liquid or steam installations) in impulse lines, assembly solutions using constructions based on available engineering knowledge should be used. For gaseous medium, this may mean installing the transmitter above the pressure measuring point, and for liquids or steam below this point.
- If the measured medium contains particles, it is useful to install separators and drain valves to remove deposits.
- Keep the same liquid level or constant level difference in the impulse tubes. It is necessary to ensure the same temperature of both tubes and correct the error due to the impact of the position and filling of impulse tubes by pressure zeroing.
- Avoid installation of a measuring orifice at high points of a process system for liquids and at low points for gases.
- The configuration of impulse tubes and three- or five-way valve connection system shall be selected taking into account the measurement conditions and such functions as “pressure zeroing” of transmitters on site. In addition, it is necessary to take into account the impulse routes during degassing, dewatering and flushing.

The transmitter parts must be selected according to chemical (corrosive) properties of the process medium. Pay particular attention to the diaphragm material.

6.2. Impact of mounting position on measurement

During installation of the transmitter on site it may be required to correct the effect of the position on the measurement. This impact applies to the transmitter “zero” offset, which is related to the gravitational impact on the silicon measuring structure and is greater, the lower base measurement range of the transmitter is. It should be noted that the transmitter with ABS ranges by default do not enable zeroing operation. However, ABS range due to use of higher pressure ranges are less sensitive to impact of the mounting position.

Pressure zeroing can be performed:

- in Modbus mode using the FC 104 (0x68) function in the controller;
- using the Raport 2 software;
- using the Modbus Configurator software after switching to Configuration mode;
- using the local setpoints MENU (➔ Table 4. Structure of local setpoints MENU).

7. POWER SUPPLY

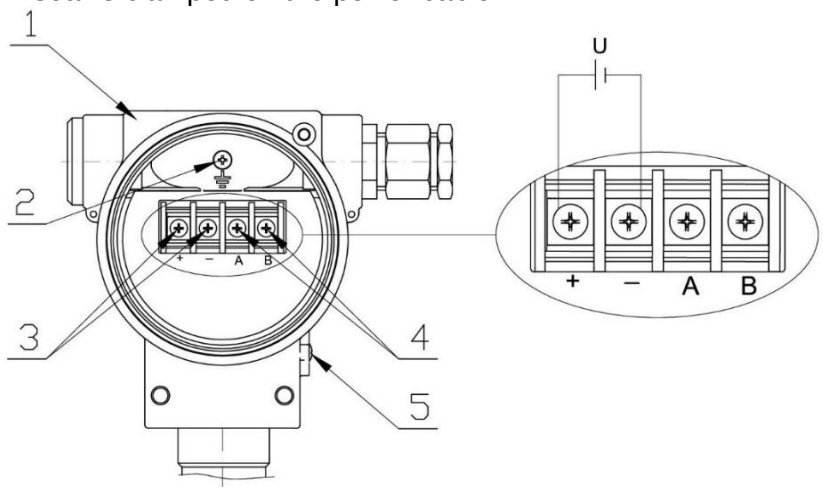
7.1. Cabling specification

Aplisens S.A. recommends using double twisted pair cable, where each pair (power supply + RS485 bus) is separately screened. The recommended external diameter of the cable for the glands sold with the product is from 5 to 10 mm. In case of using glands purchased by the customer, the outer diameter of the conductor shall be selected according to the gland specification so as to ensure tightness of the cable gland.

7.2. Cable connection to transmitter internal terminals

In order to perform correct connection of the cables, the following steps shall be performed:

- disconnect power supply;
- unscrew the rear cover of the transmitter body to access the RS485 communication bus terminals and power connector;
- pull the cable through the cable gland;
- connect the transmitter according to the ➔ Figure 3. paying attention to the polarity of the cables and their corresponding connectors and the correct tightening of the bolts fixing the conductor core to the terminal;
- tighten the rear cover of the transmitter body;
- leaving a small clearance of the cable inside the body, tighten the gland nut so that the gland seal is clamped on the power cable.



1 – Housing.
2 – Internal ground terminal.
3 – Transmitter power terminals.
4 – Transmission line terminals RS485 A and B.
5 – External ground terminal.

Figure 3. Electrical connection to transmitter

In order to ensure the tightness of the cable gland, preventing water from getting inside the transmitter, its position should be set appropriately and the outer diameter of the conductor should be selected in accordance with the gland specification.

Internal electrical terminal connectors are suitable for conductors with the cross-section from 0,5 to 2,5 mm^2.
The internal and external electrical ground terminal of the body is suitable for conductors with cross-section from 0,5 to 5 mm^2.

Power cables may be live!
There is a risk of electric shock and/or explosion!

7.3. Transmitter supply voltage and current consumption

Due to the use of a pulse energy conversion system in the power supply stage, the current consumption is inversely proportional to the supply voltage value. The approximate relationship is presented in the table below.

Table 2. Minimum, nominal and maximum supply voltage and current consumption

Minimum supply voltage, current consumption	Nominal supply voltage, current consumption	Maximum supply voltage, current consumption
12 V DC, ~23 mA	24 V DC, ~12 mA	30 V DC, ~10 mA

Peak insulation voltage during continuous operation U_p = 1500 V.

7.4. Shielding, equipotential bonding

Optimal protection against interference is provided by the earthing of the screen on both sides (in the cabinet and device). In case of potential difference between earthing points, which may result in the flow of equalization current, the screen shall be earthed on one side – preferable at the transmitter.

7.5. Final inspection of cabling

After completing the electrical installation of the transmitter it is necessary to check the following:

- does the supply voltage measured at the transmitter terminals match the range of supply voltage specified on the transmitter nameplate?
- Is the transmitter connected according to the information given in section ➔ 7.2. Cable connection to transmitter internal terminals?
- Are all cable terminals tightened (depending on the version)?
- Are the cable gland tightened (depending on the version)?

8. SYSTEM INTEGRITY

8.1. Physical layer for RS485 data transfer

8.1.1. Introduction

The transmitter is connected to the system via RS485 serial interface. This interface guarantees high resistance to interferences and flexible bus structure, e.g. multiple Slave devices can be managed via a single Master device. An RS485 “half-duplex” mode has been implemented to reduce the number of necessary communication cables. This means that 2 communication cables are required.

8.1.2. Description

To ensure correct operation of multiple devices on one serial communication bus, appropriate device outputs (RS485A, RS485B) and outputs used to power (GND and +Vcc) should be connected in parallel to the bus. Before connecting to the bus, a unique address must be defined for each device.
A network of up to 1,200 meters with max 247 Modbus devices can be set up. Each cable branch from the bus can be up to 15 m long.
The cables should conform to EIA RS485.

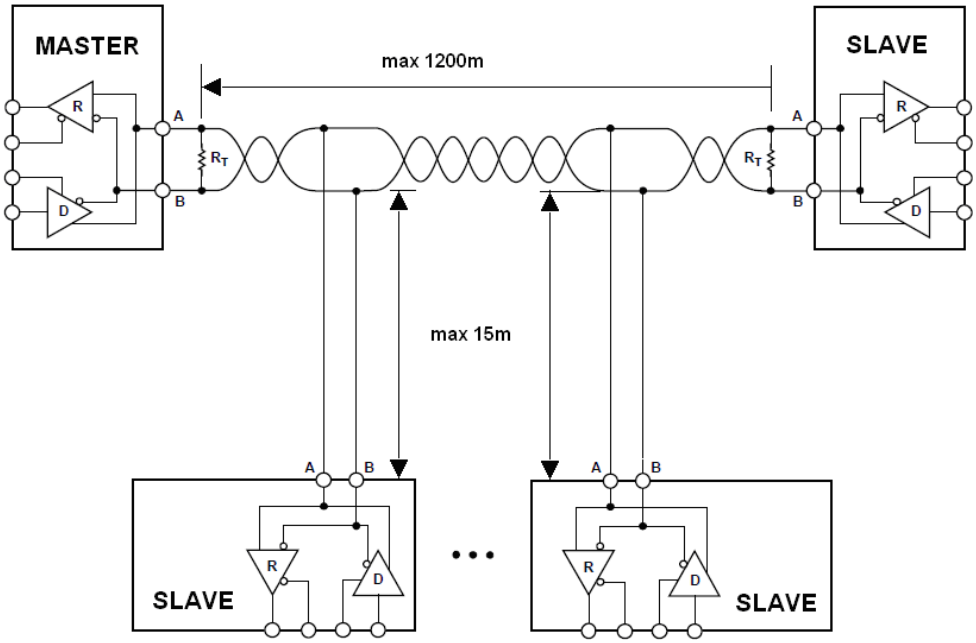


Figure 4. Example of Modbus network configuration

8.1.3. Details of RS485 “half-duplex”

To ensure the best possible efficiency in industrial environment, the transmitters from Aplisens S.A. are provided with RS485 transceivers with appropriately customized operating parameters. To provide compatibility and the best possible coworking conditions, the Master transceiver should conform to the specifications below.

8.1.3.1. Limited digital signal incremental rate

To eliminate oscillations and interferences, the output voltage slew rate of the signals from the transmitters is limited by the use of appropriate RS485 transceivers. This makes it possible to use standard cable connections and/or customized topologies (e.g. branches up to 15 m long).

8.1.3.2. “Fail safe” mode

The “fail-safe” mode means a strictly defined level of received signals – both in open bus connection and closed bus condition. It is very important in “half-duplex” mode, when all the devices connected to the bus are in receiving mode. This approach eliminates the need to use external polarization resistors. Power losses in RS485 transceivers caused by e.g. bus short-circuit, are limited by the use of thermal safety features in transmitting and receiving circuits.

8.1.3.3. 1/16 of bus load

Input impedance in RS485 transceivers used in the transmitters from Aplisens S.A., in receiving mode, is higher than the standard impedance to enable theoretical connecting up to 256 devices to the bus.

8.1.3.4. Line transmission

The terminating resistors on the RS485 bus, if it's necessary, should be connected between lines A and B at the beginning and at the end of the communication bus. When working with long transmission lines at the highest transfer rates, resistor value should correspond to cable impedance which typically is 120 Ω. With shorter bus segments and lower transfer rates, resistor with higher values, e.g. 1 kΩ, can be used to reduce current fluctuations in the transmission line (with 2 resistors of 120 Ω, the current fluctuation amplitude can be as high as ca 50 mA). At least one resistor should be used to ensure stable communication.
If a "fail-safe" device is connected to the Master bus, the electromagnetic environment in which the communication bus is located is free of interferences and the transmission line is relatively short (several meters), then the terminating resistors are not required.

The Aplisens S.A. devices described in this document are NOT equipped with terminating resistors.

8.1.3.5. Polarizing resistors

The use of polarizing resistors in order to ensuring permanently defined voltage levels on the communication bus in relation to power supply is unnecessary, because the APC(R)-2000ALM transmitters have galvanic isolation of the power supply and the RS485 communication bus transmitter/receiver, and the reference voltage of the bus, in relation to power supply, they determine internally.

8.1.3.6. Common mode voltage on RS485 bus

The APC(R)-2000ALM transmitters have galvanic isolation of the power supply, communication and measurement circuit, and the common voltage level is set internally by transmitter. No reference wire (e.g. GND) is required for communication. The supply voltages of individual APC(R)-2000ALM transmitters do not have to be equalized to the common potential.

Transmission line definitions:

Signal	Designation by APLISENS S.A. and transceiver manufactures	Designation acc. to EIA
Inverted (-)	B	A
Simple (+)	A	B

8.2. Data link layer

This subsection describes data transfer on the bus. Data and their control structures are divided into groups and make up a message. A message means the smallest communication unit and only such units can be transferred between devices. "Half-duplex" mode means that at a given point in time only one device can be in transmitting mode while the other devices must be in receiving mode. A PC or a controller is a Master device and the connected measuring or execution devices are Slave devices.

Messages are transferred at all times under the control of the Master device. All messages contain a Slave address. As a result two options of data transfer are available:

- **Broadcast mode**

This communication mode of the Master allows the Slave devices to receive and perform functions simultaneously, regardless of the Slave network address. In the APLISENS S.A. transmitters covered by this manual, the broadcast mode is used to make entries to the transmitters using the 101, 102, 103, 104, 105 functions. In the broadcast mode, the transmitters does not send back a telegram to acknowledge its receipt and that the function has been completed.

- **Unicast data transfer mode**

This mode enables communication between the Master device and a selected Slave device. The communication process involves sending a request message from the Master device and a response message from an appropriate Slave device. Only the Master device can send request messages. The request is received by all Slave devices connected to the bus, however, only a device with an address specified in the message sends a response. A Slave device must respond to a correctly received request message within the defined maximum time interval, otherwise the Master device recognizes that the request failed and will retry sending the message in accordance with the programmed algorithm.

8.2.1. Modbus RTU serial transmission mode

Data in the RS485 bus are transmitted serially. As described in the Modbus RTU standard (Modbus over Serial Line Specification and Implementation Guide V1.02), the following formats can be used:

- 1 start bit;
- 8 data bits (binary coding, least significant is bit sent first);
- bits for parity checking:
  - 1 bit Even (default),
  - 1 bit Odd,
  - 0 bits None (no bits for parity control).
- 1 stop bit for Even or Odd parity mode;
- 1 or 2 stop bits for None parity mode.

Characters are always sent using 10 bits (8N1) or 11 bits (8N2, 8O1, 8E1).

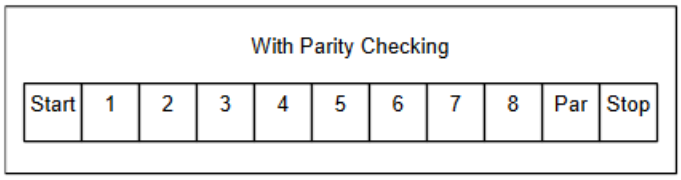


Figure 5. Bit sequence with parity checking 8E1, 8O1

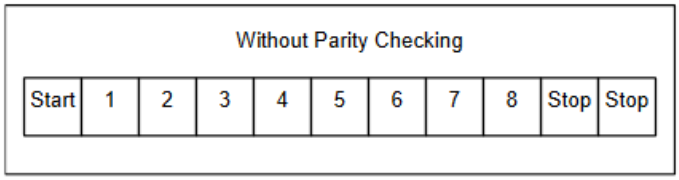


Figure 6. Bit sequence without parity checking 8N2

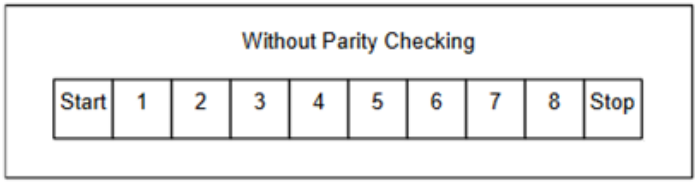


Figure 7. Bit sequence without parity checking 8N1

The 8N1 is a format outside the Modbus RTU standard (Modbus over serial line specification and implementation guide V1.02).

8.2.2. Modbus RTU message format

All Modbus RTU messages are sent in the following format:

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

Description of fields in the message:

Slave Address – network address of the Slave device. The address 0 is reserved for the broadcast in the query mode of the Master device. Slave devices, irrespective of their network address, should be able to perform the function of a write operation without sending back a response telegram in this mode.

The individual Slave devices are assigned addresses in the range of 1 … 247.
Addresses in the range 248 … 255 are reserved for future use.

0	From 1 to 247	From 248 to 255
Broadcast address	Slave individual addresses	Reserved

In one network cannot be more than one device with the same address in this range.

Function Code – a code to tell the Slave to which a request is addressed what functions are to be performed. Function codes use 7 bits (0 … 247). The oldest 8th bit is always zero when a message is sent by the Master. The same function code is returned in this field in the Slave response message. If the oldest 8th bit is zero, it means that the function was performed correctly and the data returned in the message are also correct. If the oldest 8th bit is one, it means that a function error or a device error was detected.

Data – the "Function Code", depending on the function number, can be followed by the field "Data" containing control data (Master request) or read data (Slave response). This field can contain up to 252 bytes of data. If the oldest 8th bit of the "Function code" in the Slave response is one, the data read are not entered in the field "Data" in the response message, but one byte of the field is used for sending an error code.

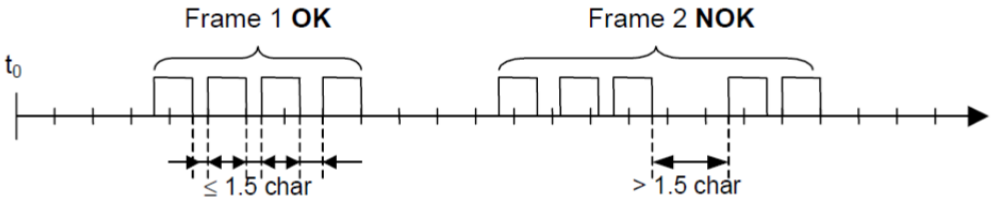
CRC – at the end of a message, there is always a field for the 2-byte control sum CRC16 sent according to the sequence "CRC Low | CRC High". The control sum is calculated as defined in appendix B to "Modbus over Serial Line Specification and Implementation Guide V1.02" available at: http://www.modbus.org/.

8.2.3. Modbus RTU message transfer rules

8.2.3.1. Primary rules

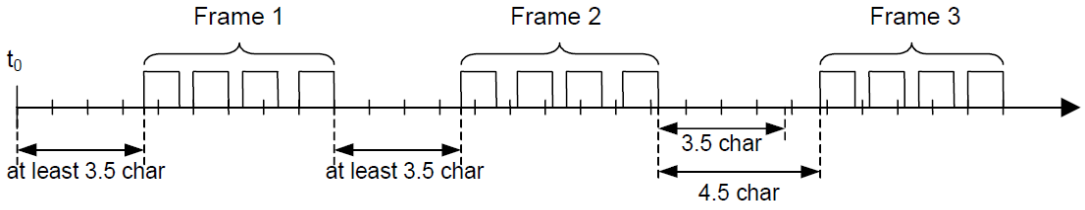
- An address in the range 1 … 247 can only be assigned to one Slave device connected to the bus. If more devices connected to the bus are assigned the same address, they will simultaneously send a response telegram, causing a conflict on the bus.
- Data transfer operations via messages are initiated at all times by the Master. This means that Slave devices can only send data-containing messages after receiving a properly addressed request message from the Master.
- A message is made up of a series of bytes. These bytes should be sent without any in-between intervals.

The maximum permissible silent interval between two successive characters must not exceed 1,5 T, where T is the time it takes to transmit one character (11 bits). If the silent interval between two successive characters exceeds 1,5 T, the message can be considered invalid and rejected by the device.



- The addressed Slave must respond within a defined silent interval, otherwise the response message will be considered invalid and rejected by the Master.

The silent interval between the request message sent by the Master and the response message sent by the Slave must not be shorter than 3,5 T, where T is the time it takes to transmit one character (11 bits). The maximum silent interval after which a Slave device responds to the Master request message depends on the function code in the request and the data load. The response time in the APLISENS S.A. transmitters described in this document should be less than 5 ms, including the most disadvantageous conditions (data load, transfer rate).



MODBUS message

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

8.2.3.2. Error handling

When messages are transferred between Master and Slave devices, two main types of errors may arise: transmission errors and Slave device errors.

Transmission errors, causes:

- The message received is too short due to e.g. an excessively long interval between bytes contained in the message.
- The message received is longer than allowed by the device's reception buffer due to e.g. message frame syntax improperly programmed in the controller.
- The maximum character transmission time is exceeded due to an inappropriate transfer rate.
- The control sum calculated based on the message received does not correspond to the value sent in the message in the CRC field.
- Illegal function code.
- Illegal data address.
- Illegal data load.

Slave devices do not respond to messages for which a transmission error is detected, the Master device can retry sending a request message if an invalid message receipt is detected. The respective algorithm is programmed in the Master device.

Errors in functioning of the Slave device, causes:

- Damage to the ADC converter, damage to the pressure sensor.
- Damage to the local oscillator of the microcontroller.
- Damage to RAM, FLASH, EEPROM.

Errors codes conform to "Modbus over Serial Line Specification and Implementation Guide V1.02".

8.3. Application layer, description of implemented functions

8.3.1. System functions

8.3.1.1. 0x03 (3) "Read Holding Register"

This function used to read the continuous address space of a data block. The Master sets the register start address (2 bytes) and the number of 2-byte read registers.
Registers with register addressing are accessible from addresses starting with 0x0000 or 0x9C41 (40001 dec), e.g. 1st register has the address 0x0000 or 0x9C41, 2nd has the address 0x0001 or 0x9C42, 3rd has the address 0x0002 or 0x9C43, etc.
Registers with byte addressing are accessible from addresses starting with 0x0100, e.g. 1st register has the address 0x0100, 2nd has the address 0x0102, 3rd has the address 0x0104, etc.
The data read from each register is transmitted by the Slave as 2 bytes per register, where the first byte in the sequence is more significant than the next one. When reading data from more than one register, the data from the Slave is transmitted according to the register numbering.
The registers contain data related to process variable measurements, temperatures, as well as other transmitter settings. The list of registers with addresses and description is presented in the table in section ➔ 8.3.3. Modbus register layout, registers from 0x0000 or 0x0100 or 0x9C41 (40001 dec) address.

8.3.1.2. 0x2B (43) "Read Device Identification"

Function used to read, in streaming mode, the basic transmitter identification data, including the manufacturer name, product code, software revision.
Read Device Identification | 7 bytes request, 46 bytes response |
Req: [ADD][FC][0x0E][0x01][0x00][CRC_H][CRC_L]
Resp: according to **Modbus Application Protocol Specification V1.1**

8.3.2. Manufacturer/user functions:

8.3.2.1. 0x64 (100) "Read coefficients"

Function used to read 4 bytes of coefficients.
Read Coefficients | 5 bytes request, 9 bytes response |
Req: [ADD][FC][COEFF_NUMBER][CRC_H][CRC_L]
Resp: [ADD][FC][COEFF_NUMBER][DATA0] [DATA1] [DATA2] [DATA3] [CRC_H][CRC_L]

COEFFICIENT NUMBER	NAME	DESCRIPTION OF DATA0 … DATA3
0x00	Dumping Time "s"	float IEE754 referred to PVU - Primary Variable Unit
0x01	Upper sensor limit	float IEE754 referred to PVU - Primary Variable Unit
0x02	Lower sensor limit	float IEE754 referred to PVU - Primary Variable Unit
0x03	Minimum span	float IEE754 referred to PVU - Primary Variable Unit
0x04	Upper range value	float IEE754 referred to PVU - Primary Variable Unit
0x05	Lower range value	float IEE754 referred to PVU - Primary Variable Unit
0x06	Max work temperature	float IEE754 referred to °C
0x07	Min work temperature	float IEE754 referred to °C
0x80	Auxiliary Coefficients_0	**[FIR] [ALM] [TRF] [PVU]** [FIR] – ADC integration time Filter Register 0x00 50 ms 0x01 22 ms 0x02 11 ms [ALM] – Alarm Mode (applies to 1)current output, if present) BIT0 0 = no alarm, 1 = alarm on ADC converter failures BIT1 0 = no alarm, 1 = alarm on pressure sensor failures BIT2 0 = no alarm, 1 = alarm on memory failures BIT3 0 = no alarm, 1 = alarm on oscillator failures BIT6 0 = Alarm (112,5%), 1=Alarm (-2,5%) or drive level BIT7 0 = 0,625% … 103,125% drive level of set range 1 = -1,25% … 103,125% drive level of set range [TRF] - Transfer Function Code 0x00 Linear (y=x) 0x01 Square root ($y=x^{½}$) 0x04 Special (piecewise linear) 0x05 Square ($y=x^2$) 0xF0 Manufacturer specific 1 0xF1 Manufacturer specific 2 [PVU] - Primary Variable Unit 0x01 InH2O inches of water at 68°F / 20°C 0x02 InHg inches of mercury at 0°C 0x03 FtH2O feet of water at 68°F / 20°C 0x04 mmH2O millimeters of water at 68°F / 20°C 0x05 mmHg millimeters of mercury at 0°C 0x06 psi pounds per square inch 0x07 bar bars 0x08 mbar millibars 0x09 g/cm^2 grams per square centimeter 0x0A kg/cm^2 kilograms per square centimeter 0x0B Pa pascals 0x0C kPa kilopascals 0x0D Torr torr 0x0E ATM atmospheres 0xAB mH2O4°C meters of water at 4°C 0xED MPa megapascals 0xEE inH2O4°C inches of water at 4°C 0xEF mmH2O4°C millimeters of water at 4°C
0x81	Auxiliary Coefficients_1	**[ADD][RS_mode_1][RS_mode_2][RS_mode_3]** [ADD] Modbus Address [RS_mode_1] BIT0 - 9600 bps BIT1 - 19200 bps BIT2 - 28800 bps BIT3 - 38400 bps BIT4 - 57600 bps BIT5 - 115200 bps BIT6 - n.u. BIT7 - n.u. [RS_mode_2] BIT2, BIT1, BIT0 - 011 - NONE, 2STOP

COEFFICIENT NUMBER	NAME	DESCRIPTION OF DATA0 … DATA3
		BIT2, BIT1, BIT0 - 010 - NONE, 1STOP BIT2, BIT1, BIT0 - 100 - ODD, 1STOP BIT2, BIT1, BIT0 - 000 - EVEN, 1STOP BIT3 - n.u. BIT4 - n.u. BIT5 - 1200 bps0 BIT6 - 2400 bps BIT7 - 4800 bps [RS_mode_3] n.u. **Remarks:** Only one single bit from BIT0 to BIT5 in RS_mode_1 and bits from BIT5 to BIT7 in RS_mode_2 can be in “ON” state. [n.u.] Bit not used (can be set as zero – “OFF” state)
0x82	Auxiliary Coefficients_2	**[-][-][-][WP]** [-][-][-] Not used, data negligible [WP] 0x00 Not write protected 0x01 Write protected
0x83	Auxiliary Coefficients_3	**[LOM][MIC][MDV][DPP]** [LOM] - Local Operation Mode (Local keyboard) 0x00 Enabled 0x01 Disabled [MIC] - Meter Information Configuration (Local display) 0x00 Not installed 0x01 Integral LCD [MDV] - Meter Display Variable *LCD1 Variable:* BIT0 = 0 Modbus bitrate and parity BIT0 = 1 Percent of range *LCD2 Variable:* BIT1,BIT2 = 00 Pressure BIT1,BIT2 = 01 Sensor temperature BIT1,BIT2 = 10 User conversion BIT1,BIT2 = 11 CPU temperature [DPP] - Decimal Point Position on LCD2 0x01 [•XXXXX] 0x02 [X•XXXX] 0x03 [XX•XXX] 0x04 [XXX•XX] 0x05 [XXXX•X] 0x06 [XXXXX•]
0x88	Auxiliary Coefficients_4	**[SLDC_1_H][SLDC_1_L][SLDC2_H][SLDC_2_L]** [SLDC_1_H] Most significant byte of Bus Communication Error Counter [SLDC_1_L] Least significant byte of Bus Communication Error Counter [SLDC_2_H] Most significant byte of Slave Exception Error Counter [SLDC_2_L] Least significant byte of Slave Exception Error Counter
0x89	Auxiliary Coefficients_5	**[SLDC_3_H][SLDC_3_L][SLDC_4_H][SLDC_4_L]** [SLDC_3_H] Most significant byte of Broadcast RX Mode Counter [SLDC_3_L] Least significant byte of Broadcast RX Mode Counter [SLDC_4_H] Most significant byte of CRC RX Error Counter [SLDC_4_L] Least significant byte of CRC RX Error Counter

Legend:

FIR	Filter Register
ALM	Alarm Mode Code
TRF	Transfer Function Code
PVU	Primary Variable Unit

COEFFICIENT NUMBER	NAME	DESCRIPTION OF DATA0 … DATA3
WP	Write Protection	
RS_mode_1	Communication settings 1	
RS_mode_2	Communication settings 2	
RS_mode_3	Communication settings 3	
SLDC_1_H,L	Bus Communication Error Counter, a 16-bit binary counter, reset after overflow or POR	
SLDC_2_H,L	Slave Exception Error Counter, a 16-bit binary counter, reset after overflow or POR	
SLDC_3_H,L	Broadcast RX Mode Counter, a 16-bit binary counter, reset after overflow or POR	

8.3.2.2. 0x65 (101) "Write coefficients"

Function used to write 4 bytes of coefficients.
Write Coefficients | 9 bytes request, 9 bytes response |
Req: [ADD][FC][COEFF_NUMBER][DATA0][DATA1][DATA2][DATA3][CRC_H][CRC_L]
Resp: [ADD][FC][COEFF_NUMBER][DATA0][DATA1][DATA2][DATA3][CRC_H][CRC_L]

COEFFICIENT NUMBER	NAME	DESCRIPTION OF DATA0 … DATA3
0x00	Dumping Time "s"	float IEE754
0x80	Auxiliary Coefficients_0	4 bytes [-][-][-][PVU]
0x83	Auxiliary Coefficients 3	4 bytes [LOM][MIC][MDV][DPP] [LOM] - Local Operation Mode (Local keyboard) 0x00 Enabled 0x01 Disabled [MIC] - Meter Information Configuration (Local display) 0x00 Not installed 0x01 Integral LCD [MDV] - Meter Display Variable *LCD1 Variable:* BIT0 = 0 Modbus bitrate and parity BIT0 = 1 Percent of range *LCD2 Variable:* BIT1,BIT2 = 00 Pressure BIT1,BIT2 = 01 Sensor temperature BIT1,BIT2 = 10 User conversion BIT1,BIT2 = 11 CPU temperature [DPP] - Decimal Point Position on LCD2 0x01 [•XXXXX] 0x02 [X•XXXX] 0x03 [XX•XXX] 0x04 [XXX•XX] 0x05 [XXXX•X] 0x06 [XXXXX•]

Remarks:
Unicast / Broadcast mode available, no response with Broadcast Mode.
Legend:

PVU	Primary Variable Unit
[-]	Data in byte negligible, not currently used

8.3.2.3. 0x66 (102) "Set Modbus Device Address (FLASH)"

Function used to write the Modbus address in non-volatile FLASH memory.
Caution! Using the broadcast mode for this function, for more than one device connected in the network will set them to the same address and block further communication.
Set Modbus Device Address (FLASH) | 5 bytes request, 5 bytes response |
Req: [ADD][FC][new_ADD][CRC_H][CRC_L]
Resp: [ADD][FC][old_ADD]][CRC_H][CRC_L]

COEFFICIENT NAME	DESCRIPTION
new_ADD	New Modbus device address from the range 1 … 247 to be store in the FLASH memory.
old_ADD	Previous Modbus device address.

Remarks:
Unicast / Broadcast mode available, no response with Broadcast Mode. Automatically performs a HOT RESET after execution.

8.3.2.4. 0x67 (103) “Set Speed, Parity, Stop”

Function used to configure the 3 coefficients that define the Modbus communication parameters.
Set Speed, Parity, Stop | 7 bytes request, 7 bytes response |
Req: [ADD][FC][RS_mode_1][RS_mode_2][RS_mode_3][CRC_H][CRC_L]
Resp: [ADD][FC][RS_mode_1][RS_mode_2][RS_mode_3][CRC_H][CRC_L]

COEFFICIENT NAME	DESCRIPTION OF COEFFICIENTS
RS_mode_1	[RS_mode_1] BIT0 - 9600 bps BIT1 - 19200 bps BIT2 - 28800 bps BIT3 - 38400 bps BIT4 - 57600 bps BIT5 - 115200 bps BIT6 - n.u. BIT7 - n.u.
RS_mode_2	[RS_mode_2] BIT2, BIT1, BIT0 - 011 - NONE, 2STOP BIT2, BIT1, BIT0 - 010 - NONE, 1STOP BIT2, BIT1, BIT0 - 100 - ODD, 1STOP BIT2, BIT1, BIT0 - 000 - EVEN, 1STOP BIT3 - n.u. BIT4 - n.u. BIT5 - 1200 bps0 BIT6 - 2400 bps BIT7 - 4800 bps
RS_mode_3	[RS_mode_3] Data in byte negligible, currently not used for configuration
Remarks: Unicast / Broadcast mode available, no response in broadcast mode. Only one bit from BIT0 to BIT5 in RS_mode_1 and bits from BIT5 to BIT7 in RS_mode_2 can be in “ON” state. [n.u.] Bit not used (can be set as zero – “OFF” state)	

8.3.2.5. 0x68 (104) “Perform Action”

Function used to perform specific transmitter actions.
Perform Action | 5 bytes request, 5 bytes response |
Req: [ADD][FC][DATA] [CRC_H][CRC_L]
Resp: [ADD][FC][DATA] [CRC_H][CRC_L]

COEFFICIENT NAME	DESCRIPTION OF ACTION
DATA	[DATA] 0x00 – Zeroing Pressure 0xFD - Set Write Protection 0xFE - Remove Write Protection 0xFF - Hot Reset
Remarks: Unicast / Broadcast mode available, no response in broadcast mode. The reset function 0xFF may take about 2 seconds to complete.	

8.3.2.6. 0x69 (105) “Set Modbus Device Address (RAM)”

Function used to write the Modbus address in volatile RAM.
0x69 | 105 | Set Modbus Device Address (RAM) | 5 bytes request, 5 bytes response |
Req: [ADD][FC][new_ADD][CRC_H][CRC_L]
Resp: [ADD][FC][old_ADD]][CRC_H][CRC_L]

COEFFICIENT NAME	DESCRIPTION
new_ADD	New device address from the range 1 … 247 to be store in the RAM memory.
old_ADD	Previous device address.
Remarks: Unicast / Broadcast mode available, no response in broadcast mode. The new device address is valid until POWER ON RESET or HOT RESET, after their execution it returns to the address saved in the FLASH memory.	

8.3.3. Modbus register layout, registers from 0x0000 or 0x0100 or 0x9C41 (40001 dec) address

Address (hex)	Purpose	Notes	Format	Bytes (2 bytes per register)
0x0000 0x0100 0x9C41	**Percent of range**	Percentage of the set range control	IEEE754	4 bytes (2 registers)
0x0002 0x0104 0x9C43	**Pressure of sensor 1**	Pressure or level process variable	IEEE754	4 bytes (2 registers)
0x0004 0x0108 0x9C45	**Pressure of sensor 2**	Constant 0 of the selected unit	IEEE754	4 bytes (2 registers)
0x0006 0x010C 0x9C47	**Temperature of sensor 1**	Temperature process variable in ºC	IEEE754	4 bytes (2 registers)
0x0008 0x0110 0x9C49	**Processor temperature**	CPU (main processor) temperature process variable in ºC	IEEE754	4 bytes (2 registers)
0x000A 0x0114 0x9C4B	**Temperature of sensor 2**	Constant 0ºC	IEEE754	4 bytes (2 registers)
0x000C 0x0118 0x9C4D	**User specific**	Scaled value of the percentage of the set range control	IEEE754	4 bytes (2 registers)
0x000E 0x011C 0x9C4F	**[1)]Current Loop**	Process variable of the 4 … 20 mA current loop	IEEE754	4 bytes (2 registers)
0x0010 0x0120 0x9C51	**Percent of range**	1/100 % of the set range control	Signed 16-bit int	2 bytes (1 register)
0x0011 0x0122 0x9C52	**Pressure of sensor 1**	Integer, 1/100 of the pressure or level unit	Signed 16-bit int	2 bytes (1 register)
0x0012 0x0124 0x9C53	**Pressure of sensor 2**	Value 0 1/100 of the selected unit	Signed 16-bit int	2 bytes (1 register)
0x0013 0x0126 0x9C54	**Temperature of sensor 1**	Integer, 1/100 ºC	Signed 16-bit int	2 bytes (1 register)
0x0014 0x0128 0x9C55	**Processor temperature**	Integer, 1/100 ºC	Signed 16-bit int	2 bytes (1 register)
0x0015 0x012A 0x9C56	**Temperature of sensor 2**	Value 0 1/100 in ºC	Signed 16-bit int	2 bytes (1 register)
0x0016 0x012C 0x9C57	**Pressure or Level unit**	Pressure or level unit	Unsigned 16-bit int	2 bytes (1 register)
0x0017 0x012E 0x9C58	----------	----------	----------	2 bytes (1 register)
0x0018 0x0130 0x9C59	**Upper sensor limit**	Upper limit of the basic range	IEEE754	4 bytes (2 registers)
0x001A 0x0134 0x9C5B	**Lower sensor limit**	Lower limit of the basic range	IEEE754	4 bytes (2 registers)
0x001C 0x0138 0x9C5D	**Damping value**	Seconds (s)	IEEE754	4 bytes (2 registers)
0x001E 0x013C 0x9C5F	**Response delay value**	Milliseconds (ms)	Unsigned 16-bit int	2 bytes (1 register)
0x001F 0x013E 0x9C60	**Modbus address**	1 … 247	Unsigned 8-bit int	2 bytes (1 register)
0x0020 0x0140 0x9C61	**Identity register**		Unsigned 8-bit int	6 bytes (3 registers)
0x0023 0x0146 0x9C64	**Status register**		8-bit flags	2 bytes (1 register)

Fields shaded in grey are not active in the specified models.

8.3.3.1. Example 1 of the request message with the function 0x03 for 3 different addresses fields, reading the IEEE754 process variable stored in 2 registers

Master request and slave response, sensor 1 pressure value read.

Request message							
Slave address	Function	Parameters				Slave address	Slave address
		Starting address in register (H)	Starting address in register (L)	Number of registers to be read (H)	Number of registers to be read (L)		
0x01	**0x03**	**0x00**	**0x02**	**0x00**	**0x02**	**0x65**	**0xCB**
0x01	**0x03**	**0x01**	**0x04**	**0x00**	**0x02**	**0x84**	**0x36**
0x01	**0x03**	**0x9C**	**0x43**	**0x00**	**0x02**	**0x1B**	**0x8F**
Response message							
Slave address	Function	Parameters				Slave address	Slave address
		Number of data bytes	Data value (sensor 1 pressure in IEEE754 format), hexadecimal numbers				
0x01	**0x03**	**0x04**	**40 5F D1 BC**			**0x82**	**0x00**

8.3.3.2. Example 2 of the request message with the function 0x03 for 3 different addresses fields, reading all registers

Master request and slave response, total accessible address space read .

Request message							
Slave address	Function	Parameters				CRC(L)	CRC(H)
		Starting address in register (H)	Starting address in register (L)	Number of registers to be read (H)	Number of registers to be read (L)		
0x01	**0x03**	**0x00**	**0x00**	**0x00**	**0x24**	**0x45**	**0xD1**
0x01	**0x03**	**0x01**	**0x00**	**0x00**	**0x24**	**0x44**	**0x2D**
0x01	**0x03**	**0x9C**	**0x41**	**0x00**	**0x24**	**0x3B**	**0x95**
Response message							
Slave address	Function	Parameters				CRC(L)	CRC(H)
		Number of data bytes	Memory content in registers read, hexadecimal numbers				
0x01	**0x03**	**0x48**	**00 00 00 00 40 5F F8 DD 00 00 00 00 41 C8 00 00 41 C8 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 5E 00 00 09 C4 09 C4 00 00 00 0C 00 00 42 C8 00 01 00 00 00 00 00 00 00 00 00 00 00 01 00 BC 7D 00 00 01 00 00**			**0x97**	**0xCE**

8.3.3.3. Received data based on example 2, assigned to the relevant registers

0x0000, 0x0100, 0x9C41	**Percent of range**	IEEE754	**40 5F F8 DD**	4 bytes (2 registers)
0x0002, 0x0104, 0x9C43	**Pressure of sensor 1**	IEEE754	**40 5F F8 DD**	4 bytes (2 registers)
0x0004, 0x0108, 0x9C45	**Pressure of sensor 2**	IEEE754	**00 00 00 00**	4 bytes (2 registers)
0x0006, 0x010C, 0x9C47	**Temperature of sensor 1**	IEEE754	**41 C8 00 00**	4 bytes (2 registers)
0x0008, 0x0110, 0x9C49	**Processor temperature**	IEEE754	**41 C8 00 00**	4 bytes (2 registers)
0x000A, 0x0114, 0x9C4B	**Temperature of sensor 2**	IEEE754	**00 00 00 00**	4 bytes (2 registers)
0x000C, 0x0118, 0x9C4D	**Users specific**	IEEE754	**00 00 00 00**	4 bytes (2 registers)
0x000E, 0x011C, 0x9C4F	**[1)]Current Loop**	IEEE754	**00 00 00 00**	4 bytes (2 registers)
0x0010, 0x0120, 0x9C51	**Percent of range**	Signed 16-bit int	**01 5E**	2 bytes (1 register)
0x0011, 0x0122, 0x9C52	**Pressure of sensor 1**	Signed 16-bit int	**01 5E**	2 bytes (1 register)
0x0012, 0x0124, 0x9C53	**Pressure of sensor 2**	Signed 16-bit int	**00 00**	2 bytes (1 register)
0x0013, 0x0126, 0x9C54	**Temperature of sensor 1**	Signed 16-bit int	**09 C4**	2 bytes (1 register)
0x0014, 0x0128, 0x9C55	**Processor temperature**	Signed 16-bit int	**09 C4**	2 bytes (1 register)
0x0015, 0x012A, 0x9C56	**Temperature of sensor 2**	Signed 16-bit int	**00 00**	2 bytes (1 register)
0x0016, 0x012C, 0x9C57	**Pressure or Level unit**	Unsigned 16-bit int	**00 0C**	2 bytes (1 register)
0x0017, 0x012E, 0x9C58	**----------**	----------	**00 00**	2 bytes (1 register)
0x0018, 0x0130, 0x9C59	**Upper sensor limit**	IEEE754	**42 C8 00 01**	4 bytes (2 registers)
0x001A, 0x0134, 0x9C5B	**Lower sensor limit**	IEEE754	**00 00 00 00**	4 bytes (2 registers)
0x001C, 0x0138, 0x9C5D	**Damping value**	IEEE754	**00 00 00 00**	4 bytes (2 registers)
0x001E, 0x013C, 0x9C5F	**Response delay value**	Unsigned 16-bit int	**00 06**	2 bytes (1 register)
0x001F, 0x013E, 0x9C60	**Modbus address**	Unsigned 8-bit int	**00 01**	2 bytes (1 register)
0x0020, 0x0140, 0x9C61	**Identity register**	Unsigned 8-bit int	**00 BC 7D 00 00 01**	6 bytes (3 registers)
0x0023, 0x0146, 0x9C64	**Status register**	8-bit flags	**00 00**	2 bytes (1 register)
Fields shaded in grey are not active in the specified models.				

8.3.4. Data from registers readable using function 03

8.3.4.1. Register 0x0000 or 0x0100 or 0x9C41, percentage of the set range

0x0000, 0x0100, 0x9C41	**Percent of range**	Percentage of the set range control	IEEE754	4 bytes (2 registers)

This is the percentage control value of the set range. For example: if the set range is 0 … 100 kPa, and the currently read pressure value is 50 kPa, the control value is 50%. The advantage of the set range is that the user can define its span by setting the start and end values contained within the basic pressure/level range. You can program mathematical operations on a part of the measuring range or use that part of the measuring range to display your own values in custom units. This value can be used to perform additional mathematical operations on it in the controller working with the transmitter. It can also be converted by the transmitter, depending on the settings, by means of a quadratic, root or linear multi-section function and read from the register in this form using the **0x03 (3) Read Holding Register** function. This can be used, for example, to measure the flow on Venturi tubes or to calculate volumes in tanks of any shapes. The scaled user value in user units is available as a digital readout via Modbus protocol and/or displayed on the local LCD display. For operation of the LCD display including calibration and the unit displayed, see ➔ 9.1. Local LCD display.

8.3.4.2. Register 0x0002 or 0x0104 or 0x9C43, pressure of sensor 1

0x0002, 0x0104, 0x9C43	**Pressure of sensor 1**	Pressure or level process variable	IEEE754	4 bytes (2 registers)

Basic process variable (pressure or level) standardized for the selected physical unit. This value is sent in 4-byte floating point format conforming to IEEE754. The maximum readable pressure or level range is between values 1 and 2 defined as:

1. [Lower sensor limit – 0.5 x (Upper sensor limit – Lower sensor limit)];
2. [0.5 x (Upper sensor limit – Lower sensor limit) + Upper sensor limit].

If the lower sensor limit is designated Pd and the upper sensor limit is designated Pg, then the transmitter's maximum possible processing range can be described as:
P= [Pd -0,5x(Pg-Pd) … Pg+0,5x(Pg-Pd)]

Example:
A pressure transmitter that Pd=0 kPa, Pg=100 kPa will process pressure in the range of -50 kPa to +150 kPa. If the pressure continues to increase beyond the permissible range, the read value will not change.

8.3.4.3. Register 0x0004 or 0x0108 or 0x9C45, pressure of sensor 2

0x0004, 0x0108, 0x9C45	**Pressure of sensor 2**	Constant 0 of the selected unit	IEEE754	4 bytes (2 registers)

Standby register. Data to be read are always zero.

8.3.4.4. Register 0x0006 or 0x010C or 0x9C47, temperature of sensor 1

0x0006, 0x010C, 0x9C47	**Temperature of sensor 1**	Sensor 1 temperature process variable in ºC	IEEE754	4 bytes (2 registers)

Value of the temperature process variable in ºC read from the transmitter's measuring head. This value corresponds to the temperature of the measuring sensor and an approximated temperature of the medium (depending on the application).

8.3.4.5. Register 0x0008 or 0x0110 or 0x9C49, CPU temperature (main processor)

0x0008, 0x0110, 0x9C49	**Processor temperature**	CPU (main processor) temperature process variable in ºC	IEEE754	4 bytes (2 registers)

Value of the temperature process variable in ºC read from the microcontroller temperature sensor. This value corresponds to the approximated temperature of the transmitter electronics board.

8.3.4.6. Register 0x000A or 0x0114 or 0x9C4B, temperature of sensor 2

0x000A, 0x0114, 0x9C4B	**Temperature of sensor 2**	Constant 0ºC	IEEE754	4 bytes (2 registers)

Standby register. Data to be read are always zero.

8.3.4.7. Register 0x000C or 0x0118 or 0x9C4D, user specific

0x000C, 0x0118, 0x9C4D	**User specific**	Process variable of the percentage of the set range control scaled by user	IEEE754	4 bytes (2 registers)

This is the control value of the set range expressed as a percentage, additionally scaled by parameters entered by the user. Due to it, you can read the currently displayed value related to the pressure / hydrostatic level from the registers, scaled to any units of mass, volume, flow, etc.

8.3.4.8. Register 0x000E or 0x011C or 0x9C4F, [1)]current loop

0x000E, 0x011C, 0x9C4F	**[1)]Current Loop**	Process variable of the 4 … 20 mA current loop	IEEE754	4 bytes (2 registers)

This is the value of the [1)]current loop process variable of the transmitter with a 4 … 20 mA output. Data can be used, for example, to control Modbus converters with a 4 … 20 mA current output simulating this type of transmitter.

8.3.4.9. Register 0x0010 or 0x0120 or 0x9C51, percentage of set range control

0x0010, 0x0120, 0x9C51	**Percent of range**	1/100% of the set range control	Signed 16-bit int	2 bytes (1 register)

Those data have been described in Register 1. With this index, it occurs as a 16-bit integer version with a sign.

8.3.4.10. Register 0x0011 or 0x0122 or 0x9C52, pressure of sensor 1 – binary format, integer and sign

0x0011, 0x0122, 0x9C52	**Pressure of sensor 1**	Integer, 1/100 of the pressure or level unit	Signed 16-bit int	2 bytes (1 register)

Value of the primary process variable (pressure) standardized for the selected physical unit of pressure (or level). This value is an integer sent in binary format scaled as a value 100 times greater than the value of the sensor 1 pressure process variable.

The measuring range for a scaled integer, including its sign, is in the range of -32767 to 32767 units. If this range is exceeded, a false value will be read. In case of pressure reading in binary format "Signed 16-bit int", the basic unit should be selected so that 100 times the pressure value does not exceed the above range.

8.3.4.11. Register 0x0012 or 0x0124 or 0x9C53, pressure of sensor 2 – binary format, integer and sign

0x0012, 0x0124, 0x9C53	**Pressure of sensor 2**	Value 01/100 of the selected unit	Signed 16-bit int	2 bytes (1 register)

Standby register. Data to be read are always zero.

8.3.4.12. Register 0x0013 or 0x0126 or 0x9C54, temperature of sensor 2 – binary format, integer and sign

0x0013, 0x0126, 0x9C54	**Temperature of sensor 1**	Integer,1/100ºC	Signed 16-bit int	2 bytes (1 register)

Value of the temperature process variable in ºC read from the transmitter's measuring head. This value is an integer sent in binary format scaled as a value 100 times greater than the value of the sensor 1 temperature process variable. This value corresponds to the temperature of the measuring sensor and an approximated temperature of the medium (depending on the application).

8.3.4.13. Register 0x0014 or 0x0128 or 0x9C55, CPU (main processor) temperature– binary format, integer and sign

0x0002, 0x0104, 0x9C43	**Processor temperature**	Integer,1/100ºC	Signed 16-bit int	2 bytes (1 register)

Value of the temperature process variable in ºC read from the transmitter's CPU. This value is an integer sent in binary format scaled as a value 100 times greater than the value of the CPU temperature process variable. This value correspond to the temperature of the transmitter's electronic circuits.

8.3.4.14. Register 0x0015 or 0x012A or 0x9C56, temperature of sensor 2– binary format, integer and sign

0x0015, 0x012A, 0x9C56	**Temperature of sensor 2**	Signed 16-bit int	**00 00**	2 bytes (1 register)

Standby register. Data to be read are always zero.

8.3.4.15. Register 0x0016 or 0x012C or 0x9C57, pressure or level unit

0x0016, 0x012C, 0x9C57	**Pressure or Level unit**	Pressure or level unit	Unsigned 16-bit int	2 bytes (1 register)

Binary value corresponding to the pressure or level unit. The table below shows the units used.

Unit	Value (dec/hex)	Unit	Value (dec/hex)
atm	14dec / 0x0E	mbar	8dec / 0x08
bar	7dec / 0x07	mmH2O in 4°C	239dec / 0xEF
FtH2O	3dec / 0x03	mmH2O	4dec / 0x04
g/cm²	9dec / 0x09	mH2O in 4°C	171dec / 0xAB
InH2O in 4°C	238dec / 0xEE	mmHg	5dec / 0x05
InHg	1dec / 0x01	MPa	237dec / 0xED
kg/cm²	2dec / 0x01	Pa	11dec / 0x0B
kPa	10dec / 0x0A	psi	6dec / 0x06
mbar	12dec / 0x0C	torr	13dec / 0x0D

8.3.4.16. Register 0x0017 or 0x012E or 0x9C58, standby

0x0017, 0x012E, 0x9C58	----------	----------	----------	2 bytes (1 register)

Standby register. Data to be read are always zero.

8.3.4.17. Register 0x0018 or 0x0130 or 0x9C59, upper sensor limit

0x0018, 0x0130, 0x9C59	**Upper sensor limit**	Upper limit of the basic range	IEEE754	4 bytes (2 registers)

An upper value of the transmitter's basic range expressed in the transmitter's pressure units. This value is sent in 4-byte floating point format conforming to IEEE754.

8.3.4.18. Register 0x001A or 0x0134 or 0x9C5B, lower sensor limit

0x001A, 0x0134, 0x9C5B	**Lower sensor limit**	Lower limit of the basic range	IEEE754	4 bytes (2 registers)

A lower value of the transmitter's basic range expressed in the transmitter's pressure units. This value is sent in 4-byte floating point format conforming to IEEE754.

8.3.4.19. Register 0x001C or 0x0138 or 0x9C5D, damping value

0x001C, 0x0138, 0x9C5D	**Damping value**	The seconds [s]	IEEE754	4 bytes (2 registers)

A damping block time constant in the transmitter expressed in seconds. This value is sent in 4-byte floating point format conforming to IEEE754.

8.3.4.20. Register 0x001E or 0x013C or 0x9C5F, response delay value

0x001E, 0x013C, 0x9C5F	**Response delay value**	Milliseconds [ms]	Unsigned 16-bit int	2 bytes (1 register)

Value of response delay subsequent to the Master request. It describes the time between the stop bit of checksum byte in request message and the start bit of address byte in response message. This time depends on the bit rate and always exceeds 3,5T. This time may be useful in designing the time of a measurement cycle in a Modbus network.

8.3.4.21. Register 0x001F or 0x013E or 0x9C60, Modbus address

0x001F, 0x013E, 0x9C60	**Modbus Address**	1 … 247	Unsigned 8-bit int	2 bytes (1 register)

Values of the transmitter's network address register. The address is sent using 2 bytes. The first, more significant byte is always zero. The second, less significant byte is used for the address. The address can be set in the range of 1 to 247. Each transmitter connected to the network must have a unique network address. If the same address is assigned to more than one transmitter, the Master will not be able to communicate with these transmitters.

8.3.4.22. Register 0x0020 or 0x0140 or 0x9C61, identity register

0x0020, 0x0140, 0x9C61	**Identity register**		Unsigned 8-bit int	6 bytes (3 registers)

Value identifying the manufacturer, the type of transmitter and its serial number. A unique number, different for each transmitter.
Meaning of bytes according to the transmission sequence:

- 1st byte – insignificant, always 0;
- 2nd byte – manufacturer's number acc. to HCF, APLISENS S.A. number: 188 dec (BC hex);
- 3rd byte – device type number, number for the transmitters described in this document: 125 dec (7D hex);
- 4th-6th byte – 24-bit binary identification number of the device. This number contains encoded date of production and serial number.

8.3.4.23. Register 0x0023 or 0x0146 or 0x9C64, status register

0x0023, 0x0146, 0x9C64	**Status register**		8-bit flags	2 bytes (1 register)

A 2-byte register monitoring the functioning of the transmitter's subsystems. Events and the transmitter's irregularities modify bits contained in the Modbus register below:

15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	0	0	0	SV,TV,FV out of limit	PV out of limit	0	0	0	0	0

These irregularities can be identified in detail in configuration/HART mode with the use of programmes such as e.g. Raport 2 from APLISENS S.A.

8.4. Configuration using “Modbus Configurator” software

Chapter ➔ 8.3. Application layer, description of implemented functions describes functions that can be used to read or modify various parameters of a transmitter operating in a Modbus network. The user can also use software for a PC running WIN7, WIN10, WIN11, called “Modbus Configurator” produced by APLISENS S.A. It allows you to connect directly to a single APC(R)-200ALM transmitter and after switching to configuration mode perform extended parameter modifications. The configuration mode replaces the Modbus RTU protocol used by transmitter with the HART 5.1. protocol. For this reason, the transmitter operating in this mode can also be configured with other tools using HART protocol, e.g. “Raport 2” software produced by APLISENS S.A. After configuring the APC(R)-2000ALM transmitter in configuration mode, before connecting it to the Modbus network, use the “Modbus Configurator” software or LCD local MENU to set it back to the Modbus protocol mode.

8.4.1. Serial port configuration, Modbus network scanning, single transmitter search

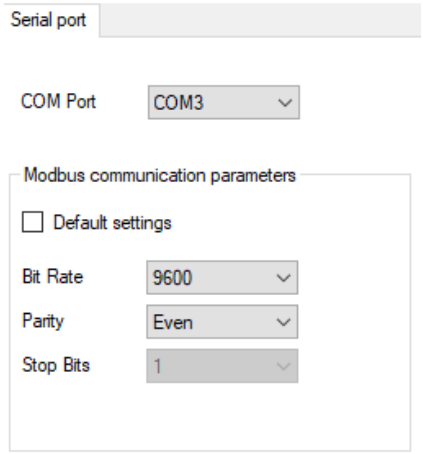
The transmitter APC(R)-2000ALM software version 18 and above allows you to perform basic actions or parameter changes via Modbus functions as described in section ➔ 8.3. Application layer, description of implemented functions. However, to carry out specific settings or calibration operations, the transmitter must be adjusted using the APLISENS S.A. software “Modbus Configurator” to the configuration mode by pressing the respective program key. Link to software: https://aplisens.pl/download/pliki_do_pobrania/Modbus%20Configurator%20Setup.exe.

For operation in the configuration mode, it is recommended to disconnect the transmitter to be configured from the Modbus network and connect it directly to a RS485 converter connected to a PC (with Windows) with the Modbus Configurator software installed.

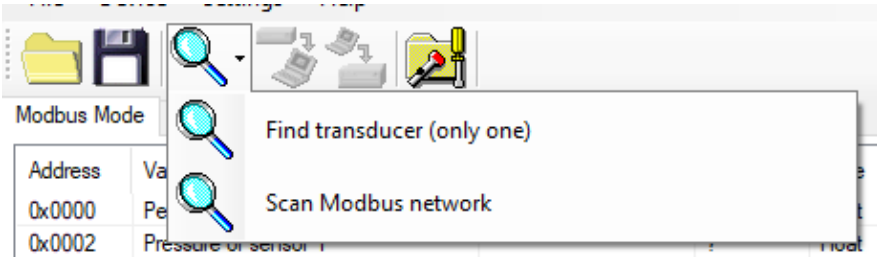
Proceeding when a change of parameters of one of the Modbus network transmitters is required:
To change settings or perform calibration operations on the transmitter in the configuration mode, disconnect it from the Modbus network and perform these operations on a single transmitter. If this is not possible, you can use the functions of parameter change shared in the transmitter by introducing their support into the controller. You can also temporarily stop the Master process controller that supports the Modbus network and plug in an additional PC-based Master with the Modbus Configurator software to proceed with the configuration.

After launching the Modbus Configurator, open the tab Serial port settings  and set the number of COM port which the RS485 converter is connected to, set Modbus bit rate, parity mode and stop bits for the transmitters in the network. When connecting electrical cables to the communication bus, the use of a COM bus is not required.

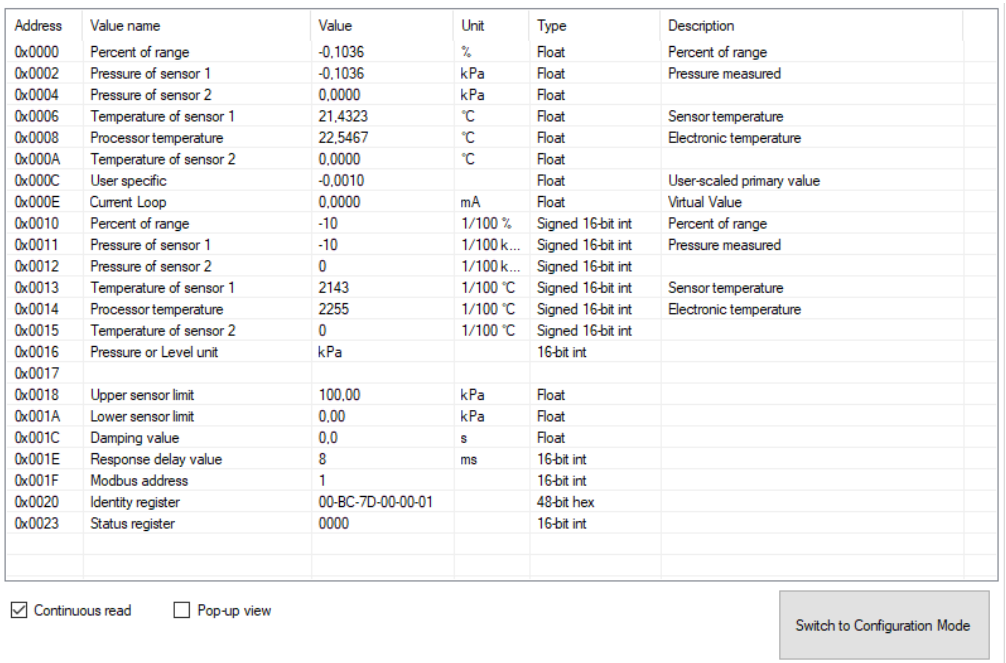
Serial port settings (example).



Next, search for Modbus transmitters by address – click on “Scan Modbus network”.



When searching the network, a list of Modbus transmitters from Aplisens S.A., connected to the network, will be displayed. If you know the network address of the transmitter to be set up, click on the appropriate transmitter in the scanned list. A list of registers will appear with read-out parameters from Modbus registers.

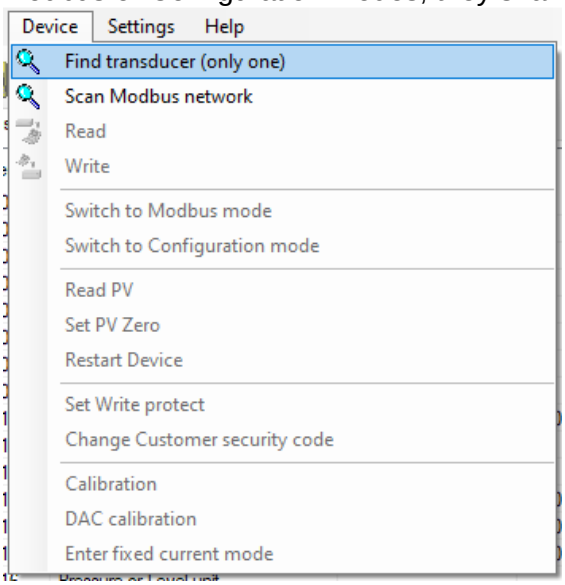


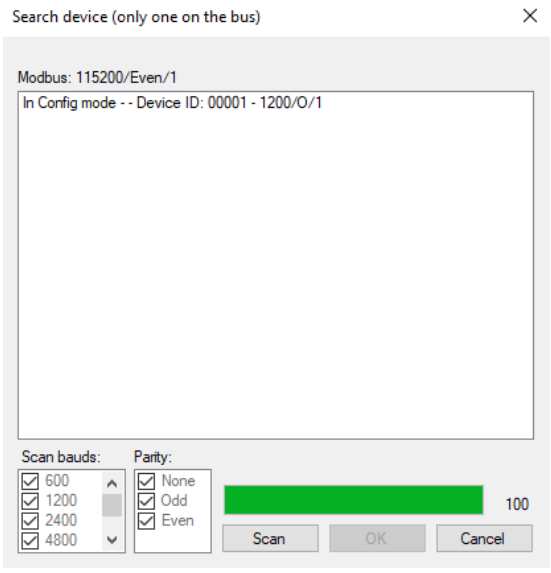
Address	Value name	Value	Unit	Type	Description
0x0000	Percent of range	-0,1036	%	Float	Percent of range
0x0002	Pressure of sensor 1	-0,1036	kPa	Float	Pressure measured
0x0004	Pressure of sensor 2	0,0000	kPa	Float	
0x0006	Temperature of sensor 1	21,4323	°C	Float	Sensor temperature
0x0008	Processor temperature	22,5467	°C	Float	Electronic temperature
0x000A	Temperature of sensor 2	0,0000	°C	Float	
0x000C	User specific	-0,0010		Float	User-scaled primary value
0x000E	Current Loop	0,0000	mA	Float	Virtual Value
0x0010	Percent of range	-10	1/100 %	Signed 16-bit int	Percent of range
0x0011	Pressure of sensor 1	-10	1/100 k...	Signed 16-bit int	Pressure measured
0x0012	Pressure of sensor 2	0	1/100 k...	Signed 16-bit int	
0x0013	Temperature of sensor 1	2143	1/100 °C	Signed 16-bit int	Sensor temperature
0x0014	Processor temperature	2255	1/100 °C	Signed 16-bit int	Electronic temperature
0x0015	Temperature of sensor 2	0	1/100 °C	Signed 16-bit int	
0x0016	Pressure or Level unit	kPa		16-bit int	
0x0017					
0x0018	Upper sensor limit	100,00	kPa	Float	
0x001A	Lower sensor limit	0,00	kPa	Float	
0x001C	Damping value	0,0	s	Float	
0x001E	Response delay value	8	ms	16-bit int	
0x001F	Modbus address	1		16-bit int	
0x0020	Identity register	00-BC-7D-00-00-01		48-bit hex	
0x0023	Status register	0000		16-bit int	

Switch the transmitter from Modbus mode to configuration mode working with HART communication protocol.

The procedure to be followed, if it is required to reconfigure parameter or identify an individual transmitter not connected via the Modbus network with other transmitters:

If the user wishes to identify an individual transmitter and they are not sure whether it is operating in the Modbus or Configuration modes, they shall use the "Find transducer (only one)" option.





Transmitter search parameters related to potential transmission settings must be configured in the opened window. When in doubt, as to the range of settings, the best solution is to tick all the options. Clicking the "Scan" button prompts the programme to start searching for a transmitter, in a sequence, starting from the Configuration mode, and then it will go through an indicated range of bit rate and parity in the Modbus mode.

Searching for a transmitter in the Modbus mode is carried out with a broadcast address. Therefore, only one transmitter may be connected, when scanning through a communication bus. When there are a larger number of transmitters operating in the Modbus mode connected to the bus and set to the same transmission parameters – sending a broadcast address will make transmitters respond to a request message at the same time, causing data corruption and an unreadable answer.

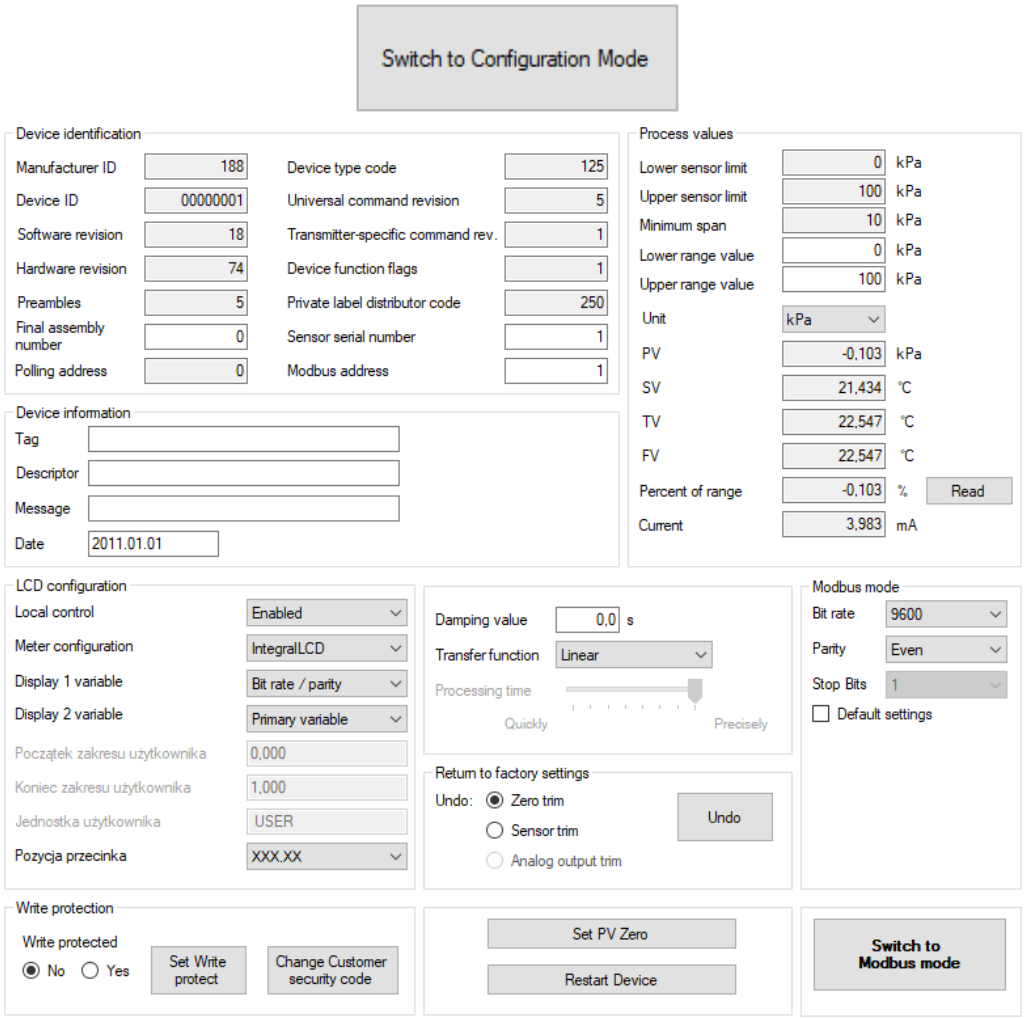
Click on the detected transmitter. A list of registers will appear with parameters read out from Modbus registers.

Address	Value name	Value	Unit	Type	Description
0x0000	Percent of range	-0,1036	%	Float	Percent of range
0x0002	Pressure of sensor 1	-0,1036	kPa	Float	Pressure measured
0x0004	Pressure of sensor 2	0,0000	kPa	Float	
0x0006	Temperature of sensor 1	21,4323	°C	Float	Sensor temperature
0x0008	Processor temperature	22,5467	°C	Float	Electronic temperature
0x000A	Temperature of sensor 2	0,0000	°C	Float	
0x000C	User specific	-0,0010		Float	User-scaled primary value
0x000E	Current Loop	0,0000	mA	Float	Virtual Value
0x0010	Percent of range	-10	1/100 %	Signed 16-bit int	Percent of range
0x0011	Pressure of sensor 1	-10	1/100 k...	Signed 16-bit int	Pressure measured
0x0012	Pressure of sensor 2	0	1/100 k...	Signed 16-bit int	
0x0013	Temperature of sensor 1	2143	1/100 °C	Signed 16-bit int	Sensor temperature
0x0014	Processor temperature	2255	1/100 °C	Signed 16-bit int	Electronic temperature
0x0015	Temperature of sensor 2	0	1/100 °C	Signed 16-bit int	
0x0016	Pressure or Level unit	kPa		16-bit int	
0x0017					
0x0018	Upper sensor limit	100,00	kPa	Float	
0x001A	Lower sensor limit	0,00	kPa	Float	
0x001C	Damping value	0,0	s	Float	
0x001E	Response delay value	8	ms	16-bit int	
0x001F	Modbus address	1		16-bit int	
0x0020	Identity register	00-BC-7D-00-00-01		48-bit hex	
0x0023	Status register	0000		16-bit int	

☑ Continuous read ☐ Pop-up view

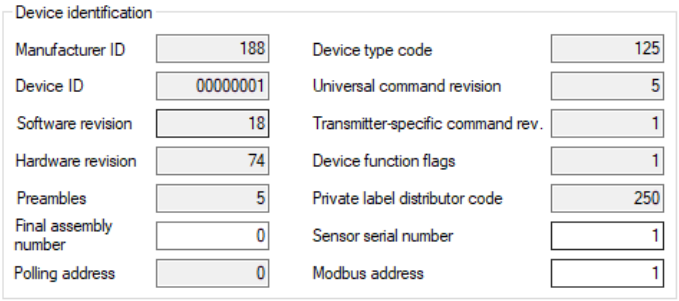
Switch to Configuration Mode

Then, switch the transmitter from the Modbus mode to the Configuration mode.



Configuration mode view

8.4.2. Transmitter identification data



Identification data frames (example). Read-only values are shaded.

Read-only information fields:

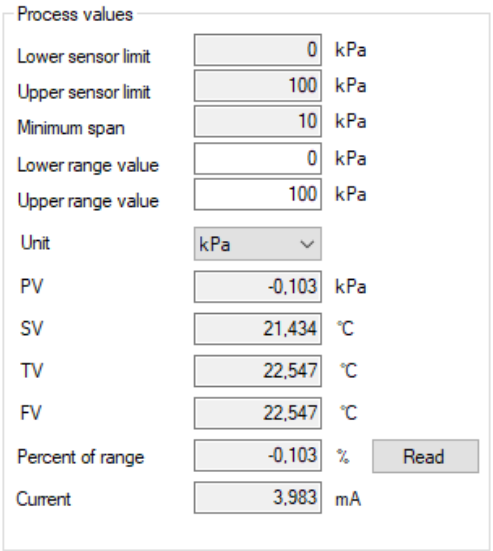
- **Manufacturer ID** – manufacturer's code according to HCF (HART) specifications.
- **Device ID** – transmitter's serial number.
- **Software revision** – CPU software version.
- **Hardware revision** – transmitter's PCB version.
- **Preambles** – number of preambles used for communication in configuration mode.
- **Pooling address** – address used for communication in configuration mode.
- **Device type code** – code indicating the transmitter type.
- **Universal command revision** – number in configuration mode.
- **Transmitter-specific command revision** – number in configuration mode.
- **Device function flags** – related to record handling type.
- **Private label distributor code**.

Editable information fields:

- **Final assembly number** of the device, recorded in binary format using 3 bytes, an integer in the range of 0 … 16777215 used for identification (modifiable by user).
- **Sensor serial number**, recorded in binary format using 3 bytes, an integer in the range of 0 … 16777215 used for identification (modifiable by user).
- **Modbus address**, an integer in the range of 1 … 247 (modifiable by user).

The field "**Modbus address**" used for defining the transmitter's network address is highly significant.

8.4.3. Reading the transmitter's limit values and process variable



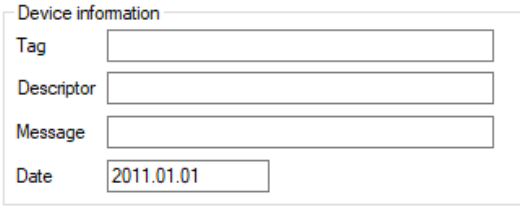
Process variable and limit values (example)

- **Lower sensor limit** – a read-only value. If exceeded, accuracy of measurements using the transmitter cannot be guaranteed. However, the transmitter will continue to process measuring signals up to 50% of the basic range below this point.
- **Upper sensor limit** - a read-only value. If exceeded, accuracy of measurements using the transmitter cannot be guaranteed. However, the transmitter will continue to process measuring signals up to 50% of the basic range above this point.

- **Minimum span** - a read-only value that defines the minimum width of the set range, modifiable by user by changing the start and/or the end points of the range. This parameter is also important when calibrating pressure or level. If intervals between calibration points are insufficient, the transmitter cannot be calibrated.
- **Lower range value** - value related to the [1)]current loop mode: 4 … 20 mA. Specific pressure or level is assigned to the current of 4 mA.
- **Upper range value** - value related to the [1)]current loop mode: 4 … 20 mA. Specific pressure or level is assigned to the current of 20 mA.
- Standard **Unit** is the physical unit used for standardizing measurements performed with the transmitter (definable by user).
- **PV** is the value of the pressure or level process variable, standardized basic unit as defined. Additionally, the [1)]current process variable of the 4 … 20 mA loop is displayed.
- **SV** is the value of the temperature process variable of the pressure measuring structure located in the measuring head, expressed in degrees Celsius.
- **TV**, **FV** is the value of the main CPU temperature process variable, expressed in degrees Celsius.

To refresh the process variable, click on the button "**Read**".

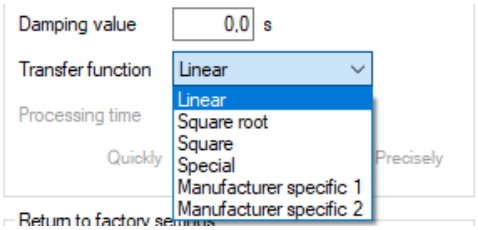
8.4.4. Reading alphanumeric identification data



Alphanumeric identification data frame (example).

User can read or modify the transmitter's alphanumeric identification data.
Tag is an 8-character alphanumeric field where you can enter e.g. an identification number of the transmitter in the system. This field can contain digits and capital letters without diacritics.
Descriptor is a 16-character alphanumeric field where you can enter a short description of e.g. an installation site. This field can contain digits and capital letters without diacritics.
Message is a 32-character alphanumeric field where you can enter a longer description. This field can contain digits and capital letters without diacritics.

8.4.5. Damping and transfer function

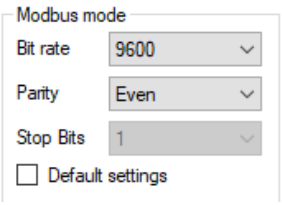


User can read or modify the measurement damping value and transfer function type.
Damping value is expressed in seconds and describes the duration of a transient state after which the process variable will achieve 63.2% of the total value change. The process variable value will be nearly fully changed with an accuracy of below 1% after ca 5 time constants.
The transfer function determines the method of transforming a process variable, related to pressure / differential pressure measurement, into a control value of a process output (user value, 4 …20 mA [1)]current loop or a percentage value of the set range). The following functions are available from a drop-down list:

- Linear,
- Square root,
- Square,
- Special,
- Manufacturer specific 1,
- Manufacturer specific 2.

The control value of a process output transformed with a transfer function is available in Modbus registers such as:
➔ 8.3.4.7. Register 0x000C or 0x0118 or 0x9C4D, user specific,
➔ 8.3.4.8. Register 0x000E or 0x011C or 0x9C4F, [1)]current loop,
➔ 8.3.4.9. Register 0x0010 or 0x0120 or 0x9C51, percentage of set range control.

8.4.6. RS485 Modbus communication parameters



User can read or edit and save: Modbus RTU bit rate, parity control and assign values as default settings. The available bit rates to set are: 1200, 2400, 4800, 9600, 19200, 28800, 38400, 57600, 115200 bps. The number of data bits – parity – STOP bits available to set is: even (8E1), odd (8O1), no parity with one (8N1) or two (8N2) STOP bits.

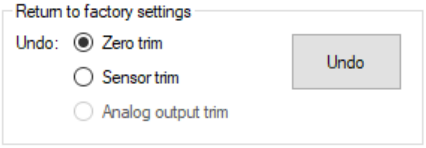
8.4.7. Restore default settings

In the configuration mode user can restore default settings for the following parameters:

- Zero-point calibration.
- Zero-point and pressure sensor calibration.
- [1)]Analogue output calibration.

The return to factory settings can also be performed using the local MENU of the LCD display by selecting “FACTORy RECALL” option. In this case , the default Modbus transmission parameters will be restored and the last address pool number (247) will be set.
Local MENU operation is described in section ➔ 9.1. Local LCD display.
Return to factory settings can be used when the user has uncontrollably changed any of the above settings and is unable to perform calibration on his own or is unsure about the Modbus communication settings.

After performing the return to factory settings operation, you will return to the calibration settings made at the production plant. If the user calibrated the transmitter on his own during operation, its calibrations will be lost after performing the above operations.



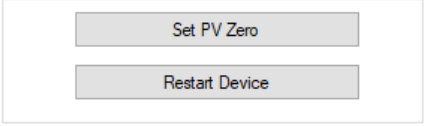
8.4.8. Write lock

You can set a lock that prevents from modification of the transmitter parameters and change the security code to remove the lock. The lock code has a format of 8 hexadecimal characters, i.e. in the range 0 … 9, A-F, **the default value is 00000000**.
It is not possible to change the transmitter settings when the lock is activated.

8.4.9. Additional operation

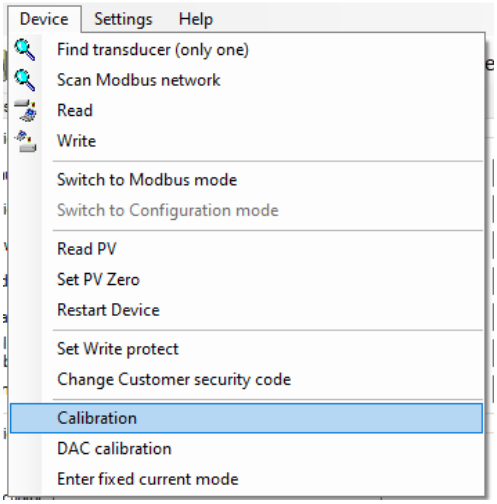
User can perform additional operations on the transmitter:

- **Set PV Zero** enables resetting pressure in a non-pressurized transmitter. The resetting option is used for eliminating any deviations of the zero point caused by installation (impact of position or possible mechanical stress on the measuring head resulting from installation). The operation cannot be performed if deviation of the zero point exceeds the permissible limit or if the transmitter measures absolute pressure.
- **Restart Device** enables sending a command to hot restart the transmitter without the need to disconnect the power supply.



8.4.10. Calibrations

User can perform 2-point pressure calibration and in an optional version of the transmitter with [1]current controller 4 … 20 mA also DAC (analogue output) calibration and, in addition to that, enter fixed current mode.



8.4.10.1. Pressure or differential pressure calibration.

To open the pressure, differential pressure or level calibration tab, select “Device → Calibration” on the top bar of the programme screen.
Calibration of the lower and upper pressure limits should be performed for the transmitter’s basic measuring range. For metrological reasons, if the used range is only a small section of the basic range, the transmitter should be calibrated based on the lower and upper limits of the used range. The calibration procedure involves supplying reference pressure to the transmitter for the lower calibration point. The reference pressure or differential pressure should be entered into the set value field. As soon as the read value is stable, press “Calibrate”. If calibration is successful, an appropriate message will appear. Repeat the above steps for the upper pressure limit.
If the difference between the reference pressure and the actual pressure read by the transmitter exceeds the permissible limit, calibration will not be performed and an appropriate message will be displayed. A similar situation arises if the selected calibration point lies outside the transmitter’s lower or upper limit.

8.4.10.2. Calibrating the [1]analogue output

Select the "Device → DAC calibration" option in the top bar to access the analogue output calibration tab. With the calibration wizard, you can perform a two-point calibration of the low (4 mA) or high (20 mA) [1]current.

8.4.10.3. Setting the fixed [1]current mode

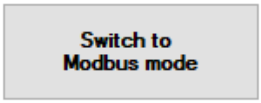
To enter fixed current mode tab, select "Device → Enter fixed current mode", in the top bar. In this mode, on transmitters equipped with a current controller, you can set the controller current between 3.600 and 23.000 mA for testing purposes.

8.4.10.4. Configuration write

Once the parameters have been configured, save the changes to the transmitter. To do this, select the "Device → Write" on the top bar of the program or press the save configuration icon.

8.5. Modbus communication mode

After configuring the transmitter as necessary to restore Modbus communication mode, you must save new settings. Click on the button Switch to Modbus mode to save new settings and switch the transmitter into Modbus communication mode.



8.6. Characteristics of process measurement input

8.6.1. Measurement process variables

The basic input variable of the measuring process is pressure or differential pressure (PV). They can be used to measure derivative values such as level (liquid column, volume, weight) or flow. Additionally, further process variables related to temperature are measured. These are:

- temperature of the pressure measuring module in the measuring head (SV);
- temperature of the structure of an ADC analog-digital converter used to perform pressure measurements (TV) (depends on version);
- temperature of the main microcontroller CPU (FV).

Temperature measurement process variables are used to adjust the temperature impact on the transmitter measuring elements to ensure high measurement accuracy. Process variables can be read out e.g. using Modbus Configurator or Report 2.

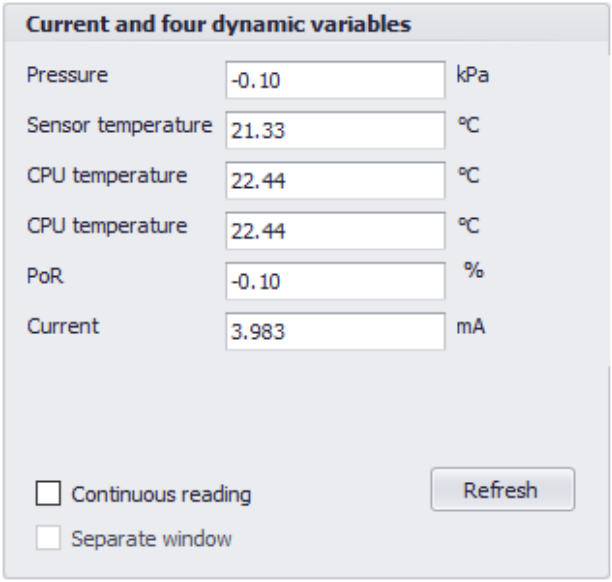


Figure 8. Example of process variables read-out window in Raport 2

8.6.2. Measurement input diagnostics

The input measurement circuits are subject to continuous diagnostics, providing the CPU with data on the correctness of the measurement process. The monitoring covers, inter alia, the sensor measuring bridge, ADC converter, EEPROM of sensor parameters, sensor power supply systems, connections between sensor components, digital data transfer via sensor galvanic insulation barrier. The detected failures are analyzed by the software and (in case of malfunction) the appropriate status “Exception Error” is returned in the Modbus response frame.

8.7. Pressure measurement resolution, refresh time of successive measurement

The resolution of the digital measurement value depends to some extent on the measuring range of the transmitter and is slightly different for each base range. A 24-bit ADC analog-digital converter is used for pressure / differential pressure measurement. Part of the range of processing voltage, which is a difference between the full range and the usable range, reduces the theoretical effective measurement resolution for the basic pressure range to about 17 bits. Therefore, the theoretical resolution of the digital measurement is approximately 0,0007% of the base range.

Table 3. Pressure measurement resolution

Type of measurement	Parameter value	Comments
ADC measurement resolution	0,0007%	Applies to the total resolution of the analog-digital module for the basic range.
Time between successive ADC measurements	22 ms (45 Hz)	-

9. OPERATION

9.1. Local LCD display

Transmitter APC(R)-2000ALM options can be changed in local MENU using buttons located on the LCD display casing. To do this, unscrew the front cover of the transmitter. The schematic appearance of the display's character fields is shown in the figure below.

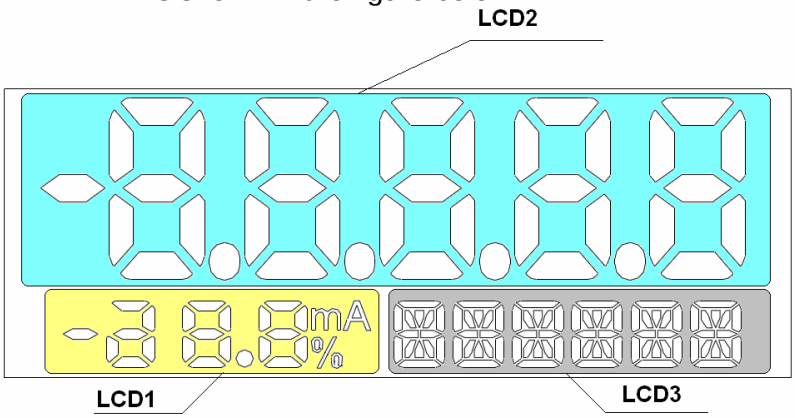


Figure 9. LCD Display

9.1.1. Description of information fields

There are three basic fields on the display:

LCD1 field depending on the configuration, it is used to display:

- RS485 link parameters such as bit rate in kilobits per second, number of data bits, parity, number of STOP bits. Additionally, if the transmitter is in "configuration" mode, the "cnF" message is displayed. If the transmitter is in "Modbus" mode, the "run" message and the rotating letters of this message are displayed.
- Values of the current output control range in percent [%] with resolution of 1%.

LCD2 field depending on the configuration, it is used to display:

- values of pressure / pressure difference / hydrostatic level in physical units;
- values of pressure / pressure difference in user units and scaling;
- values of temperature of the pressure sensor structure;
- values of CPU temperature;
- values of range set when changing the range by entering a number;
- information about error or damage number;
- information about exceeding the value display range;

LCD3 field depending on the configuration, it is used to display:

- physical unit of the pressure / pressure difference / hydrostatic level value displayed on LCD2;
- user unit when displaying pressure / pressure difference / hydrostatic level / flow values in LCD2 in units and user scaling;
- setting selection option when using the MENU function for local setting change;
- error numbers related to the execution of MENU commands to change local settings.

9.1.2. Display configuration

The user can change the transmitter/display settings using the buttons below the LCD display. The buttons can be accessed by unscrewing the display cover. The buttons are marked with symbols: [↓], [↑] and [●]. The buttons [↓], [↑] are used to move up and down the MENU structure, and the button [●] confirms and executes the selected option.

Pressing and holding any button for about 2 s will cause enter to the local setting mode, and the first of the MENU tree message with the label "EXIT" appears on the display in the field LCD3. Holding the button required to trigger the action is approx. 0.5 s. Pressing the button continuously scrolls the MENU items approx. every 0.5 s.

Pressing and holding the buttons [↓], [↑] simultaneously for approx. 2 s will exit from any place in the MENU tree to the process variable display mode.

No activity in the MENU area for longer than 2 min automatically exits the local setting mode and goes to display process variable. After confirming the selected parameter, the display will confirm the acceptance of the command with a "DONE" message. The "🡐 BACK" button allows to move up a level higher in the MENU structure. After changing the setpoint, the transmitter leaves the local configuration change MENU.
The way of navigating in the MENU structure of the local display is shown in ➔ Table 4. Structure of local setpoints MENU.

9.1.3. Abbreviations used

The local LCD display has a limited number of character fields. For this reason, most messages are given in abbreviated form. Below is a list of abbreviations used for each display field:

LCD1 field:
[mA] - value (milliamperes) of process current in line 4 … 20 mA, proportional to the measured pressure.
[%] - value (percentage) of the setpoint U(t) of set range and [1)]current controller in current loop 4 … 20 mA. This value is quotient of the difference of the process pressure P and the pressure at the beginning of the set range to the width of the set range (URV-LRV) according to the formula below:

$$\%U(t) = \frac{P(t)-LRV}{(URV-LRV)} \cdot 100[\%]$$

or it is the quotient of the difference in the process current Ip(t) and the 4 mA current to the width of the current range according to the formula below:

$$\%U(t) = \frac{Ip(t)-4}{16}\frac{[mA]}{[mA]} \cdot 100[\%]$$

[cnF] – symbol displayed in configuration/HART mode.

[run] – symbol displayed in Modbus communication mode.

1.2, 2.4, 4.8, 9.6, 19.2, 28.8, 38.4, 57.6, 115 – Modbus transmission speed symbols in kilobits per second. They correspond to speed 1200, 2400, 4800, 9600, 28800, 38400, 57600, 115200 bps.

[8-None-1], [8-None-2], [8-Odd-1], [8-Even-1] – symbols defining the RS485/Modbus communication configuration.

LCD2 field:
The LCD2 field is used mainly to display floating point decimal values in a unit displayed on LCD3. In some cases, other messages may be displayed:

- **ERROR** in case of some operating errors or failure diagnosed in the transmitter, error/failure number **Exxxx** will appear on LCD2, the **ERROR** message will be displayed on LCD3. The transmitter will set the [1)]current output to alarm status depending on the configuration I_AL < 3,650 mA or I_AL > 21,500 mA.
- **undEr** message will appear when 50% of the base range below the lower limit range of the set LRL (LSL) is exceeded. After reaching the LPL and when below this value up to LSAL, the transmitter freezes the refreshing of digital value of the measurement. In this situation, message “undEr” will be displayed. The diagnostic alarm mode will be enabled depending on the settings I_AL < 3,650 mA or I_AL > 21,500 mA. The transmitter will set the [1)]current output to alarm status depending on the configuration I_AL < 3,650 mA or I_AL > 21,500 mA. Additionally, common status PV_OUT_OF_LIMITS and status PV_LOW_LIMITED in the Sensor Block will be set, which can be read in the Modbus status register or in configuration mode via HART communication.
- **ovEr** message will appear when 50% of the base range above the upper limit range of the set URL (USL) is exceeded. After reaching the UPL and when above this value up to USAL, the transmitter freezes the refreshing of digital value of the measurement. In this situation, the message ”ovEr” will be displayed. Additionally, common status PV_OUT_OF_LIMITS and status PV_HIGH_LIMITED in the Sensor Block will be set, which can be read in the Modbus status register or in configuration mode via HART communication. The transmitter will set the [1)]current output to alarm status depending on the configuration I_AL < 3,650 mA or I_AL > 21,500 mA.
- ● ● ● ● when the set position of comma (point) on LCD2 does not allow for the correct display of the process variable, four dots ● ● ● ● will appear on LCD. In this situation, change the decimal point position in the local setpoint change MENU using the Modbus function or in the configuration mode via HART communication until a satisfactory reading is obtained.

LCD3 field:
Abbreviations of physical units of pressures and level:

INH2O	inches of water column with temperature of 20°C (68°F)	**PA**	pascals
INHG	inches of mercury column with temperature of 0°C	**KPA**	kilopascals
FTH2O	feet of water column with temperature of 20°C (68°F)	**TORR**	torrs
MMH2O	millimeters of water column with temperature of 20°C (68°F)	**ATM**	atmosphere
MMHG	millimeters of mercury column with temperature of 0°C	**MH2O4**	meters of water column with temperature of 4°C
PSI	pounds per square inch	**MPA**	megapascals
BAR	bars	**INH2O4**	inches of water column with temperature of 4°C
MBAR	millibars	**MMH2O4**	millimeters of water column with temperature of 4°C
GSQCM	grams per square centimeter	**NOUNIT**	the shortcut displayed when a unit not implemented in the transmitter is configured via HART communication
KGSQCM	kilograms per square centimeter		

Abbreviations of temperature measurement point name:

SENS °C Temperature of pressure / differential pressure sensor measurement structure in degrees Celsius.

CPU °C Temperature of the CPU structure in degrees Celsius.

Abbreviations of local configuration errors:

ER_L07	Message displayed on LCD3. It is displayed if a user tries to change the setpoint in the transmitter protected against entry (change of setpoints).
ER_L09	Message displayed on LCD3. It is displayed if: – The user tries to change the set range by set pressure which is not within the allowable upper URL pressure. – The user tries to pressure reset when the pressure exceeds the allowable upper limit.
ER_L10	Message displayed on LCD3. It is displayed if: – The user tries to change the set range by set pressure which is not within the allowable lower LRL pressure. – The user tries to pressure reset when the pressure exceeds the allowable lower limit.
ER_L14	Message displayed on LCD3. It is displayed if: – The adopted URV value through the set pressure or entry of a value cannot be accepted because it causes a reduction of the set pressure range set below the allowable limit.
ER_L16	Message displayed on LCD3. It is displayed if: – The user tried to perform an operation that is disabled or unavailable. It may be caused by: • attempting to access the local setpoint change MENU when the access to the local MENU is disabled; • attempting to pressure reset in the absolute pressure measurement transmitter.
WG_L14	The message will appear if the assumed LRV value through the set pressure or entry of a value causes a decrease of the current set range. Entry of LRV automatically results in the transmitter's attempt to set URV in such a way that the current width of the set range is maintained. If this is not possible due to exceeded URL, the transmitter automatically adopts the URV=URL value and a new LRV value. Since the set range width and URV deviate from previous values, a message is displayed.

ASCII characters displayed on LCD3 in user's unit:

Using HART communication, the user can configure its own 6-character unit displayed on LCD3. It is possible to display ASCII characters from the range 32 … 96 dec or 20 … 60 hex, i.e.:

!"#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`

Abbreviations displayed during configuration via the local MENU and their descriptions are provided in table below:

Table 4. Structure of local setpoints MENU

EXIT		The first message displayed after turning on local MENU. If you confirm this option with [●], you will leave the local MENU and the process variable will be displayed again.
PVZERO		Zeroing the pressure / pressure difference *does not apply to ABS transmitters.
	BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.
	EXEC	If you confirm this option, the transmitter will confirm receipt of the pressure zeroing command with the "DONE" message or report the appropriate error number.
SETLRV		Setting of the beginning of set range LRV.
	BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.
	BYPRESsure	Setting LRV via set pressure. After confirming the transmitter that it received the command using “DONE” message or report appropriate error number.
	BYVALUe	Setting the LRV by entering a number. After confirmation, the current LRV value will be displayed before proceeding to editing. ↓ ↓ **+/-** Select and confirm the character of the parameter you entered. ↓ **00000** Enter a 5-digit number, digit by digit, with or without a decimal point, using [↓] or [↑]. After confirming the last 5th digit of the parameter the transmitter will confirm that it received the command using “DONE” message or will display a relevant error number. The parameter is entered in “UNIT”.
SETURV		Setting of the end of set range URV.
	BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.
	BYPRESsure	Setting URV via set pressure. After confirming the transmitter that it received the command using “DONE” message or report appropriate error number.
	BYVALUe	Setting the URV by entering a number. After confirmation, the current LRV value will be displayed before proceeding to editing. ↓ ↓ **+/-** Select and confirm the character of the parameter you entered. ↓ **00000** Enter a 5-digit number, digit by digit, with or without a decimal point, using [↓] or [↑]. After confirming the last 5th digit of the parameter the transmitter will confirm that it received the command using “DONE” message or will display a relevant error number. The parameter is entered in “UNIT”.
UNIT		Setting the unit of the process variable.
	BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.
	INH2O **INHG** **FTH2O** **MMH2O** **MMHG** **PSI** **BAR** **MBAR** **GSQCM** **KGSQCM** **PA** **KPA** **TORR** **ATM** **MH2O4** **MPA** **INH2O4** **MMH2O4** **MA** **SENS”C** **CPU”C** **NOUNIT**	Confirm one of the values by pressing [●] continuously. After confirming the parameter, the transmitter will confirm the command using "DONE" message.

DAMPINg	Setting the time constant for damping the process variable.	
BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.	
0 [s] **2 [s]** **5 [s]** **10 [s]** **30 [s]** **60 [s]**	Confirm one of the values by pressing [●] continuously. After confirming the parameter, the transmitter will confirm the command using "DONE" message.	
TRANSFer	Setting of transfer type for current output characteristics.	
BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.	
LINEAR	Linear.	Confirm one of the values by pressing [●] continuously. After confirming the parameter, the transmitter will confirm the command using "DONE" message.
SQROOT	Basic square root.	
FUNC_1	Manufacturer 1st type square root.	
FUNC_2	Manufacturer 2nd type square root.	
USER'S	Special user-defined.	
SQUARE	Square.	
%SQRT	Setting of square root characteristic cut-off point.	
BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.	
0,2 % **0,4 %** **0,6 %** **0,9 %** **1 %** **2 %**	Confirm one of the values by pressing [●] continuously. After confirming the parameter, the transmitter will confirm the command using "DONE" message.	
LCD1VaRiable	Type of process variable displayed on LCD1.	
BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.	
BITRATe	The following will be displayed: bit rate in kilobits, the number of data bits, parity and the number of stop bits.	Confirm one of the values by pressing [●] continuously. After confirming the parameter, the transmitter will confirm the command using "DONE" message.
PERCENt	The percentage value of output control will be displayed.	
LCD2VaRiable	Type of process variable displayed on LCD2.	
BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.	
PRESSUre	The process variable relating to pressure or level will be displayed.	Confirm one of the values by pressing [●] continuously. After confirming the parameter, the transmitter will confirm the command using "DONE" message.
USER'S	The value scaled in user units will be displayed.	
SENSor_T	The current temperature of head pressure sensor in °C will be displayed.	
CPU_T	The current CPU temperature of the transmitter's electronics in °C will be displayed.	
LCD2DP	Position of decimal point of the variable displayed on LCD2.	
BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.	
●XXXXX **X●XXXX** **XX●XXX** **XXX●XX** **XXXX●X** **XXXXX●**	Confirm one of the values by pressing [●] continuously. After confirming the parameter, the transmitter will confirm the command using "DONE" message.	
MODBUS	Configuration of Modbus transmission parameters.	
BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.	
1200 **2400** **4800** **9600** **19200** **28800** **38400** **57600** **115200** **8N1** **8N2** **8O1**	Confirm one of the values by pressing [●] continuously. After confirming the parameter, the transmitter will confirm the command using "DONE" message and remain in the current MENU. You can set the bit rate in bits, parity and the number of stop bits in any order and activate the entered settings by confirming with the "RUN" option or reset the transmitter with the "RESET" command or by temporarily turning off the power.	

	8E1 **RUN**	
FACTORy		Return to the factory settings. Removal of zero-point and pressure calibration. Communication will be set to 9600/8E1 and the network address will be set to 247.
	BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.
	RECALL	Confirmation by pressing the [●] continuously. After confirming the parameter, it will perform hot restart.
RESET		Software forcing of transmitter reset.
	BACK	Return to local MENU. If you confirm this option, you will return to the main tree of the local MENU.
	RESET	Confirmation by pressing the [●] continuously. After confirming the parameter, it will perform hot restart.

9.2. Characteristic of processing ranges, measurement limits, alarms

9.2.1. Set range

The basic process variable of APC(R)-2000ALM transmitters is the pressure / differential pressure / level process variable expressed in physical units. Additionally, in order to enable measurements of e.g. flow, tank filling level, etc., it is possible to define the set range in the transmitter.
The set range is a parameter linked to the process variable called the "percentage of set range control" and the "user value" which is its rescaling according to the user settings. The LRV and URV points can be assigned different pressure values from the transmitter's basic range, subject to the minimum range span condition of the MSV setting. It is also possible to set a reverse characteristic, where the LRV point is assigned a higher pressure than the URV, subject to the minimum range span condition of the MSV setting.
Within a specific set range, a mathematical transformation can be applied to obtain values useful, e.g. in flow measurements (square root characteristic of the 2nd degree).
The figure below shows the transmitter set range and limits related to allowable set range, digital processing range and saturation limits of A/D pressure measurement converter.

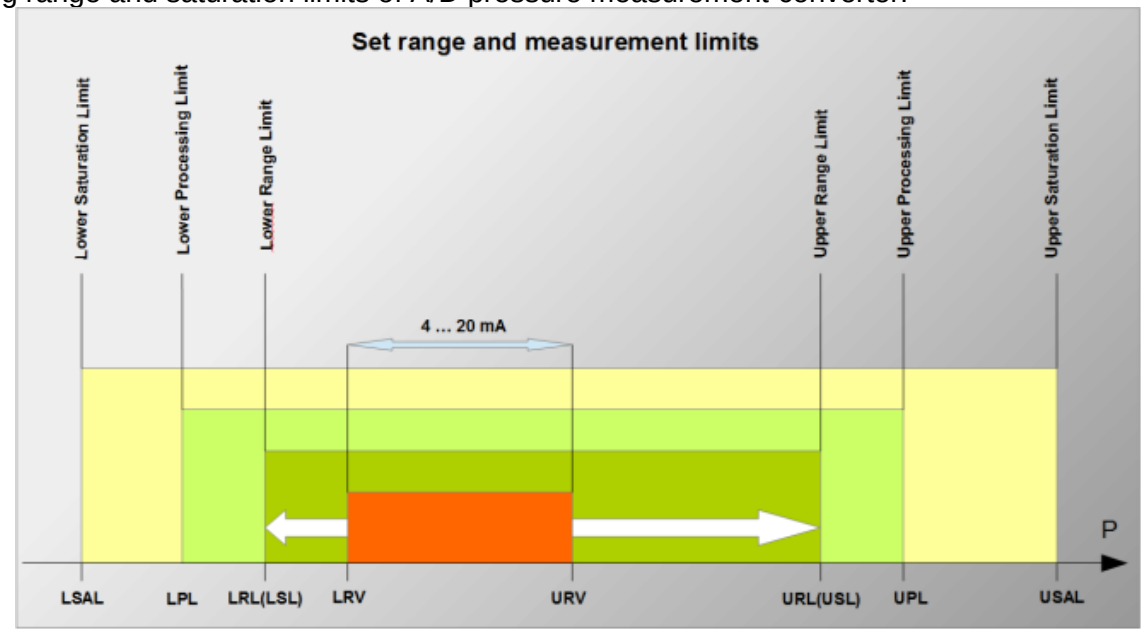


Figure 10. Set range and measurement limits

Table 5. Set range and measurement limits

Item no.	Abbr.	Meaning
1	**LRV**	"Lower Range Value" – the value of the set range expressed in physical units corresponding to the value of 0% of the this range, which cannot exceed the set range limits. The minimum width of the set range **|(URV-LRV)|** is limited to 10% of the base range **(URL-LRL)**.
2	**URV**	"Upper Range Value" – the value of the set range expressed in physical units corresponding to the value of 100% of the this range, which cannot exceed the set range limits. The minimum width of the set range **|(URV-LRV)|** is limited to 10% of the base range **(URL-LRL)**.
3	**LRL LSL**	"Lower Range Limit" or "Lower Sensor Limit" - lower limit of set range expressed in physical units. Value **(URL-LRL)** or **(USL-LSL)** is referred to as the base transmitter range.
4	**URL USL**	"Upper Range Limit" or "Upper Sensor Limit" – upper limit of set range expressed in physical units. Value **(URL-LRL)** or **(USL-LSL)** is referred to as the base transmitter range.
5	**LPL**	"Lower Processing Limit" – lower limit of digital processing of measured value. The transmitter digitally processes a measurement up to 50% of the base range width below the lower limit of set range **LRL (LSL)**. After reaching the **LPL** and when below this value up to **LSAL**, the transmitter freezes the refreshing of digital value of the measurement.
6	**UPL**	"Upper Processing Limit" – upper limit of digital processing of measured value. The transmitter digitally processes a measurement up to 50% of the base range width above the lower limit of set range **URL (USL)**. After reaching the **UPL** and when above this value up to **USAL**, the transmitter freezes the refreshing of digital value of the measurement.
7	**LSAL**	"Lower Saturation Limit" - lower limit of the ADC converter processing range. The lower limit of the ADC converter saturation is on the pressure / differential pressure scale below the **LPL** point and is associated with the minimum pressure, at which the analogue-digital pressure measurement converter reaches the lower limit of the processing capacity. Exact determination of this pressure is not possible, indicatively it is lower by 50% of the width of the (URL-LRL) basic range below the lower limit of digital processing of the UPL measured value. After reaching **LSAL** and when below this value diagnostic alarm mode will be activated depending on the settings.
8	**USAL**	"Upper Saturation Limit" - upper limit of the A/D converter processing range. The upper limit saturation point of A/D converter is on the pressure / differential pressure scale above the **UPL** point and is associated with the maximum pressure at which the analogue-digital pressure measurement converter reaches the upper limit of the processing capacity. Exact determination of this pressure is not possible, indicatively it is higher by 50% of the width of the (URL-LRL) basic range above the upper limit of digital processing of the UPL measured value. After reaching **LSAL** and when above this value diagnostic alarm mode will be activated depending on the settings.
9	**MSV**	"Minimum Span Value" – the value of the minimum span of the |URV - LRV| range setting possible to set in the transmitter. This value is written into the transmitter at the manufacturing stage and cannot be changed by the user.

9.2.2. Diagnostic alarms

The transmitter alarm state sends back the response of the Modbus Master exception code frame and is activated in the following cases:

- ADC converter fault;
- local quartz oscillator fault;
- dynamic RAM fault;
- coefficient memory or the FLASH program memory fault.

Alarms are enabled by default for all the above-mentioned cases. It is possible to mask individual types of alarms using software.

9.2.3. Dynamic parameters of digital pressure measurement

In the full measurement cycle the transmitter performs the measurements of basic input pressure values and temperatures and measurements of additional diagnostics-related variables. The time of a full measurement cycle related to the refreshing of the process output with a successive digital value is approximately 22 ms (approximately 45 measurement cycles per second).

9.2.4. Linear characteristics transfer functions

In some applications it is recommended to convert the linear process variable of the percentage of process output control with a specific function. In addition to linear characteristic available are the following mathematical percentage of control signal transform:

- basic square root "relay below the dead point" with adjustable dead band of the characteristic (➔ 9.2.5. Basic square root characteristic);
- manufacturer 1st type square root with fixed points of change characteristic, below dead point, to linear at points 0,6% and 0,8% (➔ 9.2.6. Square root characteristic "manufacturer specific 1");
- manufacturer 2nd type square root with adjustable dead point and linear characteristic below this point (➔ 9.2.7. Square root characteristic "manufacturer specific 2");
- square;
- special multi-point linearization based on user-modified table.

In addition to the linear characteristic used in measurements of level, force, pressure and differential pressure, the root characteristic is often used for flow measurement. This characteristic is described in section below.

9.2.5. Basic square root characteristic

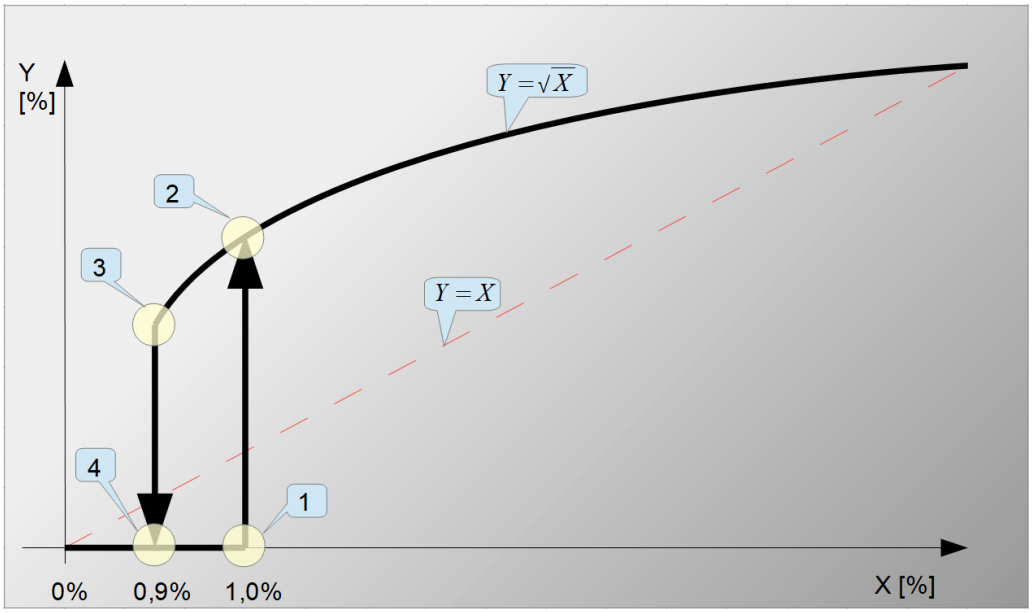


Figure 11. Basic square root characteristic with adjustable dead band

Below the dead point there is "relay" characteristic. The figure shows example values for a set dead band of 1%.

① - ② When the pressure/flow increases at point [1]-[2], the hysteresis of 0,1% is turned on and the function $Y = 0$ changes to the square root function $Y = \sqrt{X}$. The pressure measured above point [3] will be converted using the square root function.

③ - ④ When the pressure/flow drops at point [3]-[4], the square root function $Y = \sqrt{X}$ changes to the function $Y = 0$. The pressure below point [1] will be converted using the $Y = 0$ function.

The dead point of the square root characteristic is configurable in the full range of 0,2-100% in the configuration mode or in a limited range of predefined values using the local MENU. In object-oriented practice, values around 1% of the output control are most often set.

9.2.6. Square root characteristic “manufacturer specific 1”

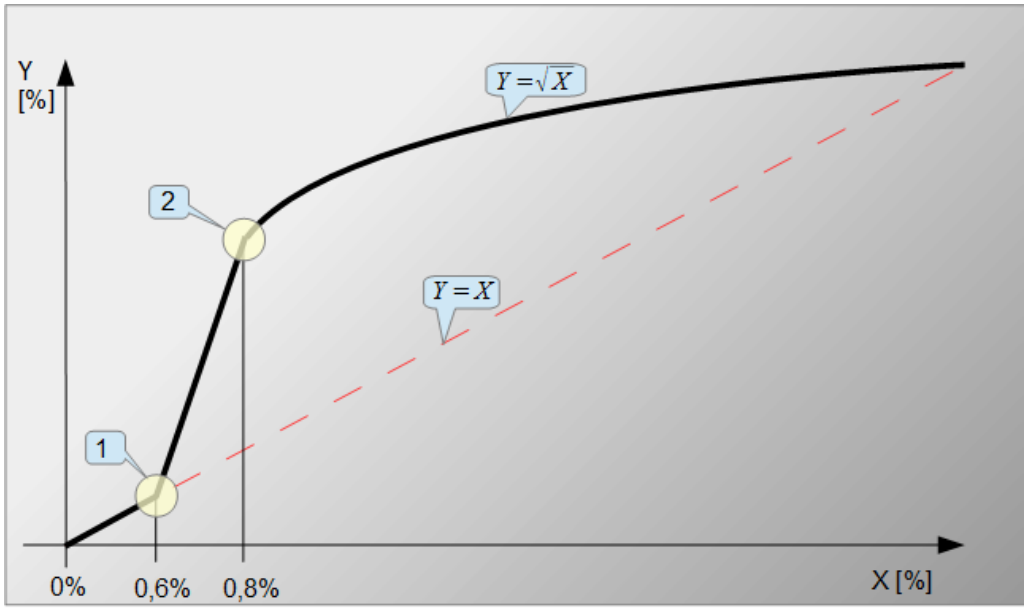


Figure 12. Square root characteristic “manufacturer specific 1” with fixed points of change characteristic in points 0,6% and 0,8%

① - Point [1] of 0,6% control of the X output, where the linear function $Y = X$ is changed to a linear function with a greater slope $Y = \mathrm{X}_n$.
② - At point [2] of 0,8% control of the X output, the linear function $Y = \mathrm{X}_n$ changes into the square root function $Y = \sqrt{X}$.
Unlike the basic square root characteristic, this characteristic allows the observation of small flows below the dead point, e.g. when closing or unscrewing the valve. The measuring stroke effect at the point of combining functions is also much smaller. The values are constant and cannot be modified.

9.2.7. Square root characteristic “manufacturer specific 2”

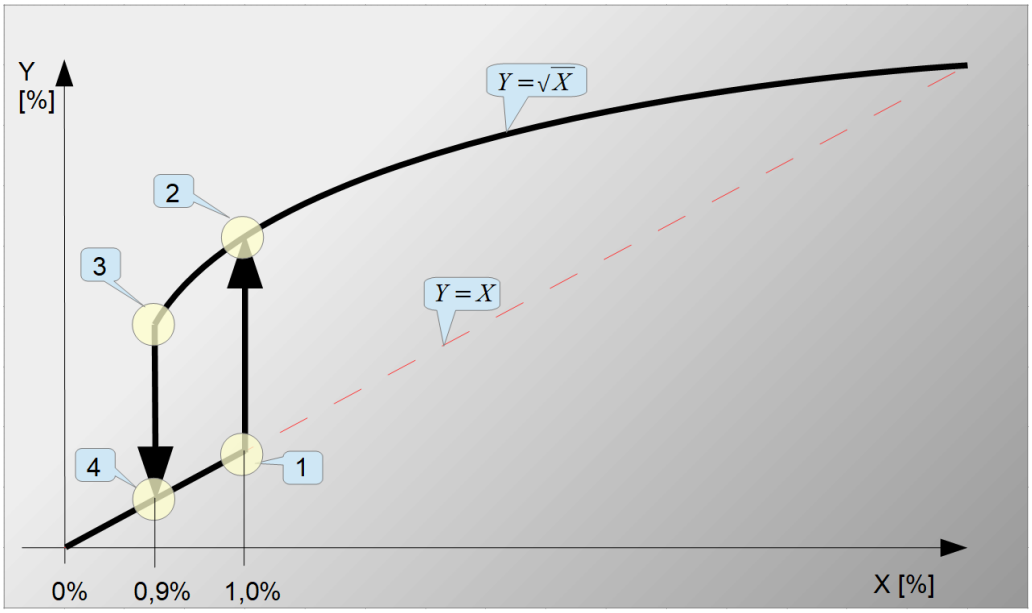


Figure 13. Square root characteristic “manufacturer specific 2” with adjustable dead point and hysteresis 0,1%

The figure shows example values for a set dead band of 1%.
① - ② When the pressure/flow increases at point [1]-[2], the hysteresis of 0,1% is turned on and the linear function $Y = X$ changes to square root function $Y = \sqrt{X}$. The pressure measured above point [1]-[2] will be converted using the square root function.
③ - ④ When the pressure/flow drops at point [3]-[4], the square root function $Y = \sqrt{X}$ changes into a linear function $Y = X$. The pressure below point [3]-[4] will be converted with linear function.

The dead point of the square root characteristic is configurable in the full range of 0,2-100% in the configuration mode or in a limited range of predefined values using the local MENU.
In object-oriented practice, values around 1% of the output control are most often set. Unlike the basic square root characteristic, this characteristic allows the observation of small flows, e.g. when closing or unscrewing the valve, while reducing the “ringing” effect of the output signal at the point of combining the linear and square root functions.

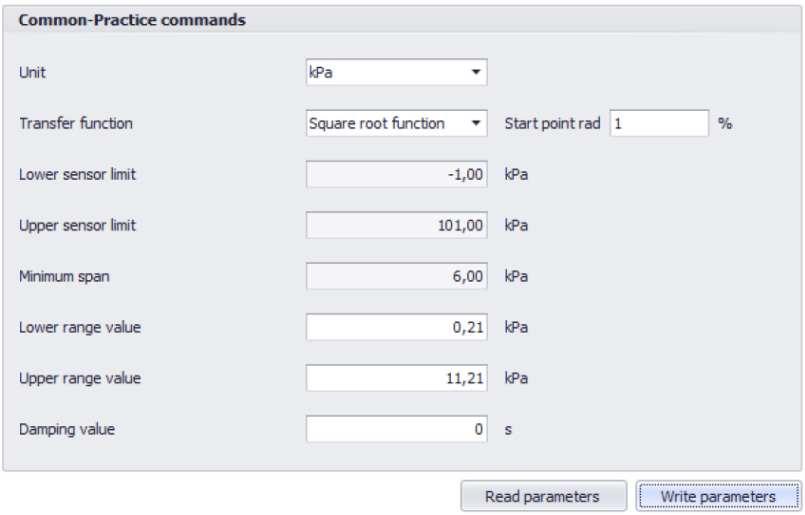


Figure 14. Configuration of transmitter parameters in the Raport 2 program

10. MAINTANCE

10.1. Periodic inspections

Periodic inspections shall be carried out in accordance with applicable standards. During the inspection, the condition of the pressure (absence of loosened elements and leaks) and electrical (check of connections reliability and condition of gaskets and glands) connectors, condition of separating diaphragms (tarnish, corrosion) and stability of fixing of the housing and mounting bracket (if used) shall be checked. Check the processing characteristics by performing the operations specific for the calibration and configuration procedure.

10.2. Non-periodic inspections

If the transmitter at the installation site has been exposed to mechanical damage, pressure overload, hydraulic pulses, overvoltage, deposits, medium crystallization, undercutting of the diaphragm, or incorrect operation of the transmitter is detected, the device should be inspected. Check the condition of the diaphragm, clean it, check the electrical functionality of the transmitter and the processing characteristics.

If there is no signal in transmission line or its value is improper, check the supply line, connection status on terminal blocks, connectors, etc. Check if the supply voltage and load resistance are correct.

10.3. Cleaning/washing

To remove impurities from the external surfaces of the transmitter wipe it with a cloth dampened in water.

10.4. Diaphragm cleaning

The only possible method of cleaning the transmitter diaphragms is to dissolve the sludge produced.

Do not remove deposits and impurities from the transmitter diaphragms, which are formed during operation, mechanically using tools, since the diaphragms and the transmitter can be damaged.

10.5. Spare parts

Parts of the transmitter that may be worn or damaged and thus replaced: cover gasket.

10.6. Repair

Faulty or non-operational transmitter shall be provided to the manufacturer.

10.7. Returns

In the following cases, the transmitter should be returned directly to the manufacturer:

- need for repair;
- need for factory calibration;
- replacement of improperly selected/shipped transmitter.

11. SCRAPPING, DISPOSAL

Worn or damaged devices shall be scrapped in accordance with WEEE Directive (2012/19/EU) on waste electrical and electronic equipment or returned to the manufacturer.

12. HISTORY OF REVISION

Revision No.	Document revision	Description of changes
-	01.A.001/2024.01	Initial document version. Prepared by: DBFD, DR.

12.1. PCB and software versions

01-11-2023 – Introduction of first firmware version of the transmitter marked with number 19.