Assisting the automation industry since 1986

User manual
TEMPERATURE TRANSMITTER
SPT-86L

- Firmware: v.1.00 or higher
- Input type: Pt100/500/1000; TC or 0-60/75/100/150 m
- temperature and voltage to 4-20 mA transmitter

Read the user's manual carefully before starting to use the unit or software.
Producer reserves the right to implement changes without prior notice.

CONTENTS

Explanation of symbols used in the manual:

- This symbol denotes especially important guidelines concerning the installation and operation of the device. Not complying with the guidelines denoted by this symbol may cause an accident, damage or equipment destruction.

IF THE DEVICE IS NOT USED ACCORDING TO THE MANUAL THE USER IS RESPONSIBLE FOR POSSIBLE DAMAGES.

- This symbol denotes especially important characteristics of the unit.
Read any information regarding this symbol carefully

1. BASIC REQUIREMENTS AND USER SAFETY

- **The manufacturer is not responsible for any damages caused by inappropriate installation, not maintaining the proper environmental conditions and using the unit contrary to its assignment.**
- Installation should be conducted by qualified personnel . During installation all available safety requirements should be considered. The fitter is responsible for executing the installation according to this manual, local safety and EMC regulations.

- The unit must be properly set-up, according to the application. Incorrect configuration can cause defective operation, which can lead to unit damage or an accident.
- **If in the case of a unit malfunction there is a risk of a serious threat to the safety of people or property additional, independent systems and solutions to prevent such a threat must be used.**
- Neighbouring and connected equipment must meet the appropriate standards and regulations concerning safety and be equipped with adequate overvoltage and interference filters.
- **Do not attempt to disassemble, repair or modify the unit yourself. The unit has no user serviceable parts. Defective units must be disconnected and submitted for repairs at an authorized service centre.**

The unit is designed for operation in an industrial environment and must not be used in a household environment or similar.

2. GENERAL CHARACTERISTICS

The **SPT-86L** module is an isolated temperature and voltage to current (in 4-20 mA standard) converter. The device is equipped with one voltage input (0-150 mV), one RTD input (Pt 100/500/1000) and one TC (thermocouple) input (K, S, J, T, N, R, B, E). The device automatically compensates the cold junction temperature. Both RTD and TC inputs have full linearisation of characteristics. Only one type of input can be used at a time. Ranges of individual inputs are given in the next chapter. The module is able to detect a break of any of the measurement wire. The measurement after being processed according to the scale given by the user is used to drive the passive current output.

The configuration of the device can be done on request or by the user. The communication with the device is through RS-485 interface with Modbus RTU protocol.

The supply input together with RS-485 interface, measurement input and current output are all galvanically isolated from each other.

3. TECHNICAL DATA

Power supply voltage	16...**24**...36V DC (separated)
External fuse (required)	T - type, max. 1 A
Current consumption	typically 0.65 W
Voltage input (150mV range)	0÷60 mV, 0÷75 mV, 0÷100 mV, 0÷150 mV
Voltage measurement accuracy	± 0.1% @ 25°C; ± one digit (for 0÷150 mV range)
Voltage input resistance	> 1,5 MΩ
Accepted prolonged input overload	+20%

RTD input (resistive)	Pt 100, Pt 500,Pt 1000
Measurement range	-100°C ÷ +600°C
Measurement accuracy	± 0.1% @ 25°C; ± one digit
Measurement wires resistance	max. 20 Ω (every wire)

Thermocouple input	K, S, J, T, N, R, B, E
Thermocouple input range	K: -200˚C ÷ +1370˚C S: -50˚C ÷ +1768˚C J: -210˚C ÷ +1200˚C T: -200˚C ÷ + 400˚C N: -200˚C ÷ +1300˚C R: -50˚C ÷ +1768˚C B: +250˚C ÷ +1820˚C E: -200˚C ÷ +1000˚C
Measurement accuracy	K, J, E: ± 0.1% @ 25°C; ± one digit N: ± 0.2% @ 25°C; ± one digit S, T, R, B: ± 0.5% @ 25°C; ± one digit
Accuracy of cold ends temperature compensation	± 1˚C

Temperature stability	50 ppm / °C
Galvanic isolation	Supply input together with RS-485 interface, measurement input and current output are all galvanically isolated from each other
Passive current output	range max. 2.8 ÷ 24 mA, supply voltage: Us = 9.5 ÷ 36 V load resistance 0...(Us - 9.5V) / 24mA [kΩ] resolution: 12 bits
Communication interface	RS-485, 8N1 and 8N2, Modbus RTU, not separated from power supply circuit
Baud rate	1200 bit/s ÷ 115200 bit/s
Number of modules in 1 network	maximum 128
Data memory	non-volatile memory, EEPROM type
Protection level	IP 20
Housing type Housing dimensions (L x W x D)	DIN rail mounted (35 mm rail) 101 x 22.5 x 80 mm
Operating temperature (depending on version)	0°C to +50°C or -20°C to +50°C
Storage temperature (depending on version)	-10°C to +70°C or -20°C to +70°C

Humidity	5 to 90% no condensation
Altitude	up to 2000 meters above sea level
Screws tightening max. torque	0.5 Nm
Max. connection leads diameter	2.5 mm^2
EMC	according to: PN-EN 61326-1

This is a class A unit. In housing or a similar area it can cause radio frequency interference. In such cases the user can be requested to use appropriate preventive measures.

4. DEVICE INSTALLATION

The unit has been designed and manufactured in a way assuring a high level of user safety and resistance to interference occurring in a typical industrial environment. In order to take full advantage of these characteristics installation of the unit must be conducted correctly and according to the local regulations.

- Read the basic safety requirements on page 2 prior to starting the installation.

- Ensure that the power supply network voltage corresponds to the nominal voltage stated on the unit's identification label.

- The load must correspond to the requirements listed in the technical data.

- All installation works must be conducted with a disconnected power supply.

4.1. UNPACKING

After removing the unit from the protective packaging, check for transportation damage. Any transportation damage must be immediately reported to the carrier. Also, write down the unit serial number on the housing and report the damage to the manufacturer.

Attached with the unit please find:
- user's manual,
- warranty,

4.2. ASSEMBLY

- Disconnect the power supply prior to starting assembly.

- Check the connections are wired correctly prior to switching the unit on.

4.3. CONNECTION METHOD

Caution

- Installation should be conducted by qualified personnel . During installation all available safety requirements should be considered. The fitter is responsible for executing the installation according to this manual, local safety and EMC regulations.

- Wiring must meet appropriate standards and local regulations and laws.

- In order to secure against accidental short circuit the connection cables must be terminated with appropriate insulated cable tips.

- Tighten the clamping screws. The recommended tightening torque is 0.5 Nm. Loose screws can cause fire or defective operation. Over tightening can lead to damaging the connections inside the units and breaking the thread.

- In the case of the unit being fitted with separable clamps they should be inserted into appropriate connectors in the unit, even if they are not used for any connections.

- Unused clamps (marked as n.c.) must not be used for connecting any connecting cables (e.g. as bridges), because this can cause damage to the equipment or electric shock.

Due to possible significant interference in industrial installations appropriate measures assuring correct operation of the unit must be applied. To avoid the unit of improper indications keep recommendations listed below.

– Avoid common (parallel) leading of signal cables and transmission cables together with power supply cables and cables controlling induction loads (e.g. contactors). Such cables should cross at a right angle.

– Contactor coils and induction loads should be equipped with anti-interference protection systems, e.g. RC-type.

– Use of screened signal cables is recommended. Signal cable screens should be connected to the earthing only at one of the ends of the screened cable.

– In the case of magnetically induced interference the use of twisted couples of signal cables (so-called ”spirals”) is recommended. The spiral (best if shielded) must be used with RS-485 serial transmission connections.

– In the case of interference from the power supply side the use of appropriate anti-interference filters is recommended. Bear in mind that the connection between the filter and the unit should be as short as possible and the metal housing of the filter must be connected to the earthing with largest possible surface. The cables connected to the filter output must not run in parallel with cables with interference (e.g. circuits controlling relays or contactors).

Connections of power supply voltage and measurement signals are executed using the screw connections on the front and bottom of the unit’s housing.

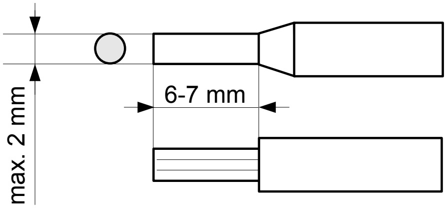


Fig. 4.1. Method of cable insulation replacing and cable terminals

- **When use of SMPS it is strongly recommended to connect PE wire.**
- **All connections must be made while power supply is disconnected !**

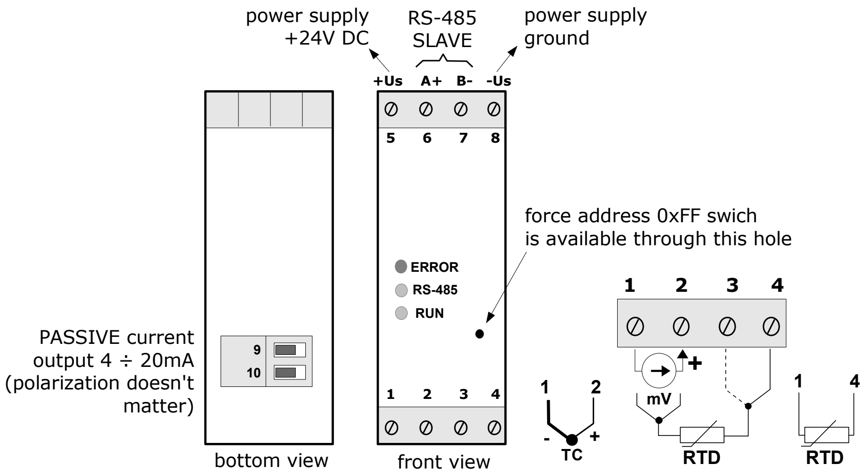


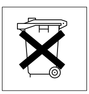
Fig. 4.2. Terminals description

4.4. MAINTENANCE

The unit does not have any internal replaceable or adjustable components available to the user. Pay attention to the ambient temperature in the room where the unit is operating. Excessively high temperatures cause faster ageing of the internal components and shorten the fault-free time of unit operation.

In cases where the unit gets dirty do not clean with solvents. For cleaning use warm water with small amount of detergent or in the case of more significant contamination ethyl or isopropyl alcohol.

Using any other agents can cause permanent damage to the housing.



Product marked with this symbol should not be placed in municipal waste. Please check local regulations for disposal and electronic products.

5. PRINCIPLE OF OPERATION

SPT-86L module allows the conversion of temperature and voltage on current in 4-20 mA standard. Present value of temperature or voltage is available as measurement register of device (reg. addr. 01h). If input signal exceeds the permissible range, shortcut or break of measurement circuit occur, appropriate error code will be set in ***status register*** (register 02h).

Measurement input's parameters are located in the group of registers ”**Input**” (see ***LIST OF REGISTERS*** on page 18) and allow:

- input type selection (parameter ”**InputType**”)
- connection type selection (parameter ”**InputConn**”, applies only to RTD measurement),
- change of the filtration degree of the values in measurement register (parameter ”**InputFilter**”),
- shift of the measurement scale (parameter ”**InputOffset**”, applies only to temperature measurement),
- processing characteristic setup (applies only to voltage measurement).

The proper operation of the module is signalized by flashing green LED diode placed on the front panel and labelled **RUN**. The yellow LED diode (labelled **RS-485**), by fast flashes, signalizes data transmission via serial interface. The red LED diode (labelled **ERROR**), if lit, signalizes measurement error. It may mean that measured signal exceeded the permissible range, the sensor was damaged or wires' short circuit or break occurred.

Parameters are kept in non-volatile EEPROM memory. All parameters can be set via serial interface (see ***LIST OF REGISTERS*** on page 18).

5.1. VOLTAGE MEASUREMENT

Measurement results can be internally recalculated due to one of available characteristics: linear, square, square root or user definable multipoint (max. 20 points length). The expansion of nominal range is defined by ”**InputHiRange**” parameter (see figure below).

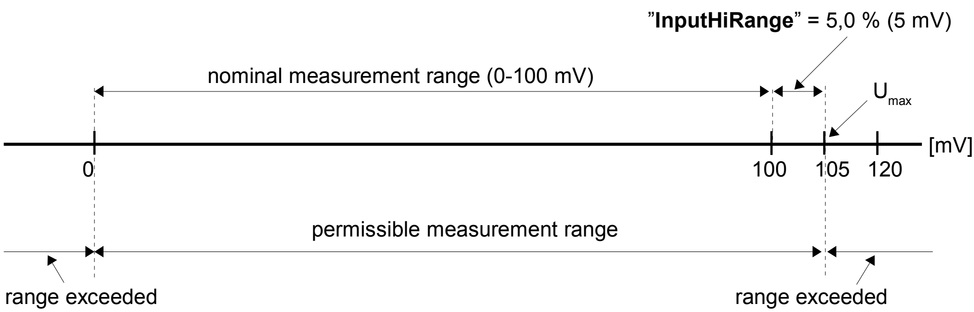


*Fig. 5.1 Example of definition of permissible range of input signal - ”**InputHiRange**” parameter (0-100 mV mode)*

If input signal exceeds the permissible range, appropriate code in status register (register 02h) will be set.

Parameter ”**InputHiRange**” determines the upper border of the permissible range accordingly to the expression (for all voltage modes). For example, if input is set to 0-100 mV mode, then the upper border is calculated due to expression:

$$U_{max} = 100\text{ mV} + 100\text{ mV} \times \text{"InputHiRange" }\%.$$

Value of ”**InputHiRange**” can be set from 0 to 19.9% (the procedure of calculating the input voltage range is presented in the example no 1 on the page 15).

When linear, square or square root characteristic is chosen then the value returned to the measurement register (register 01h) is defined by ”**InputLow**” and ”**InputHigh**” parameters. These parameters describe the values returned for minimum and maximum input value. For example, if input type is set to 0-100 mV, ”**InputLow**” parameter defines the returned value when input voltage equals 0 mV, and ”**InputHigh**” parameter defines the returned value for 100 mV. Available range for these parameters: -999 ÷ 9999.

When user defined multipoint characteristic is chosen then the value returned in measurement register (register 01h) is calculated according to coordinates defined by user (X, Y points, maximally 20 points). Coordinate ”**X**” defines the percentage ratio of input value to selected measurement range. The „X” range: -99,9 ÷ 199,9. Coordinate ”**Y**” defines the value (returned in measurement register) for particular ”**X**” coordinate. The ”**Y**” value can be changed in range: -999 ÷ 9999.

5.2. CURRENT OUTPUT CONTROL

Way of processing the measurement to the current value is determined by the parameters contained in the "**Output**" group of parameters (see ***LIST OF REGISTERS*** on page 18).

The current output can be controlled on the basis of the measurement result or on the basis of the value written to the register 05h via the serial interface (remote control mode via RS-485).

In control mode using the measurement result parameter ”**OutLow**” defines the measurement value for which current equal 4 mA will be generated, while the parameter ”**OutHigh**” defines the measurement value for which current equal 20 mA will be generated. Output current for any result can be calculated from the formula:

$$I_{out} = \frac{W - \text{"OutLow"}}{\text{"OutHigh"} - \text{"OutLow"}} \times 16\,mA + 4\,mA$$

where ”**W**” is a measurement value in the register (01h or 06h - depending on the parameter ”**HoldOut**”).

- In control mode based on the measurement result the current output can be controlled by the present value (register 01h) or by the stored peak value (register 06h, in the case of using the peak detection function - see parameter ”**HoldOut**”).
- Value of parameter ”**OutLow**” can be greater than the value of parameter ”**OutHigh**”. In this case, the characteristic of the current output is reversed (ie, when the measured value is increasing the output current is decreasing).

Parameters ”**OutLoRange**” and ”**OutHiRange**” define the permissible output current range beyond the nominal range 4-20 mA. If the calculated current $\mathbf{I_{out}}$ would exceed the permissible range, the output would generate current equal to the upper or lower border of the range. Parameter ”**OutLoRange**” defines the lower border of the range due to formula:

$$\mathbf{I_{min}} = 4 \text{ mA} - 4 \text{ mA} \times \text{"}\mathbf{OutLoRange}\text{"} \%$$

Parameter ”**OutLoRagne**” can be set from 0 to 29.9%. Parameter ”**OutHiRange**” defines the lower border of the range due to formula:

$$\mathbf{I_{max}} = 20 \text{ mA} + 20 \text{ mA} \times \text{"}\mathbf{OutHiRange}\text{"} \%$$

Parameter ”**OutHiRange**” can be set from 0 to 19.9%.

The minimum current which can flow in the current output's circuit is about 2.5 mA. It occurs when the current output is disabled (parameter ”**OutMode**”). This is the current needed to power the current output circuit.

Parameter ”**OutAlarm**” defines how the current output reacts in the critical situation (exceeding the permissible range, shorting or opening measuring inputs). In such a situation the output current will be unchanged or will be set to the desired value (depending on the parameter ”**OutAlarm**”).

- Critical situation is signalized by the red LED (labeled **ERROR**).
- After resolution of the critical situation output current returns to the value determined on the basis of the measurement result.
- Before turning off the device it is recommended to first disable the current output's power supply, and then the device itself. If the current output is supplied while the device itself is turned off, the output current will be about 27.5 mA.

5.3. FORCING OF ADDRESS FFH

New devices has set to Modbus addresses FEh. To enhance system installation process special operation mode has been developed. It allows to force address FFh in single module using internal momentary switch mounted on module mainboard (fig. 4.1). Switch is accessible through a small hole in .the front panel.

To change address of the device to FFh, wait for a moment after power up until green LED (RUN) starts flashes. Next press and hold push-button about 4 seconds until green LED will lights permanently, then release push-button.

The device changes its MODBUS address to FFh and waits for a new address (readdressing). Green LED (RUN) stay permanently on until readdressing via RS-485, or power off. While module is in this state it is possible to control its inputs, and communication is possible using temporal address FFh.

At this moment MASTER controller should find new device and readdress it (to address other than FFh and FEh). After remote readdressing green LED indicator starts to flashes again.

Simultaneously with change of device address, its baud rate is changed to 9600 bit / s. Required transmission speed (1200 bit/s. to 115200 bit/s.) can be set by write to register 22h. After change of transmission speed the device sends the answer with new baud rate. While installation of the new network it is recommended to readdress all devices using baud rate 9600 bit/s, and next change speed of all devices simultaneously, using BROADCAST query (with address 00h).

5.4. DETECTION OF THE PEAK VALUES

The **SPT-86L** module is equipped with peaks detection function. It can detect peaks of the input signal and hold their values. Presets connected with this function are placed in group of registers named "**Hold**" (see ***LIST OF REGISTERS***). The detection of the peak can be done if the measured signal raises and drops of value at least equal to parameter "**HoldPeak**". Detected peaks are hold during the time defined by parameter "**HoldTime**". If a new peak will be detected while one is hold, this new peak will be held and value holding time counter will restarted (fig. 5.2). If no peaks are detected while time "**HoldTime**" elapses**,** device returns the current value of input signal in the peak value register (06h register).

The current output can be controlled depending on the current value of input signal (01h register) or the peak value (06h register, see ***LIST OF REGISTERS***).

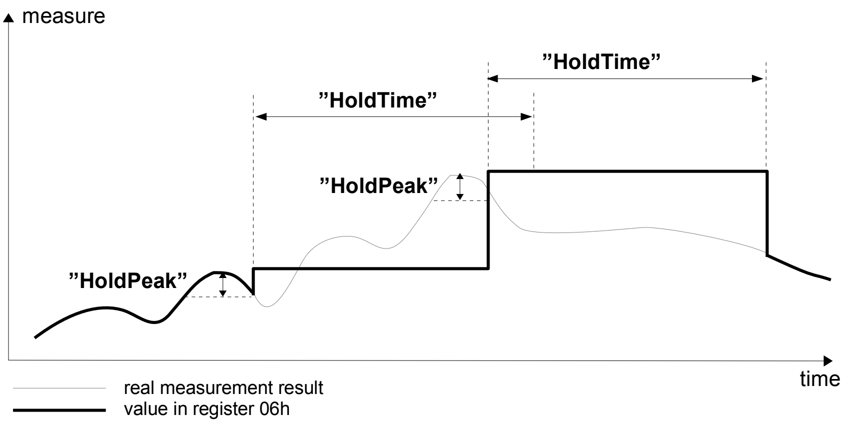


Fig. 5.2. Process of peaks detection

6. MEASURED VALUES CALCULATION

All calculations in the following examples are made for the input in 0-100 mV mode. For temperature inputs (TC and RTD) only linear characteristic is available.

The first step to compute the result of measure is the calculation of the normalized result (it means result of 0-1 range). To do it, the begin of the input range (0 mV for 0-100 mV range) must be subtracted from measured value. Next, received result must be divided by the width of the input range (it means 100 mV for 0-100 mV range). So normalized result can be expressed by expressions:

$$U_n = \frac{U_{inp.}}{100} \qquad for\,range \quad 0 \div 100\,mV$$

where $U_{inp.}$ means input voltage (in mV), and U_n - normalized result.

If measured value exceeds the nominal input range (0-100 mV), and do not exceed the permissible input range, then received normalized U_n result will exceed 0-1 range, e.g. input range 0-100 mA and input voltage = -10 mV the normalized result is equal -0.1, and for input voltage = 110 mV, the normalized result is equal 1.1. In such cases presented expressions are still correct.

6.1. ADDITIONAL CALCULATIONS (USED CONVERSION CHARACTERISTIC)

The manner of the additional computation of the returned result depends on selected conversion characteristic. All presented charts are connected with the input range 0-100 mV.

6.1.1. Linear characteristic

The normalized result is converted by fixed coefficients determined by ”**InputLow**” and ”**InputHigh**” parameters (when the normalized results is equal 0, then value ”**InputHigh**” is returned, and when the normalized results is equal 1, then value ”**InputHigh**” is returned). Expression presented below shows the manner of result calculation:

$$W = U_n \times ("InputHigh" - "InputLow") + "InputLow"\,,$$

where W means the value returned in measurement register.

The value of the ”**InputLow**” parameter can be higher than the value of ”**InputHigh**” parameter. In such a case, for an increasing value of input voltage the returned value decreases.

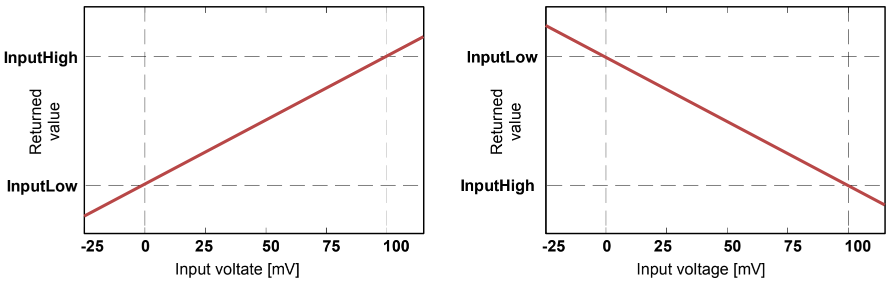


Fig. 6.1 Normal (”InputLow” < ”InputHigh”) and inverted (”InputLow” > ”InputHigh”) characteristic.

6.1.2. Square characteristic

The normalized result is squared and further conversion is done as for linear characteristic. Conversion is made accordingly with the expression:

$$W = U_n^2 \times ("InputHigh" - "InputLow") + "InputLow",$$

where W means the value returned in measurement register.

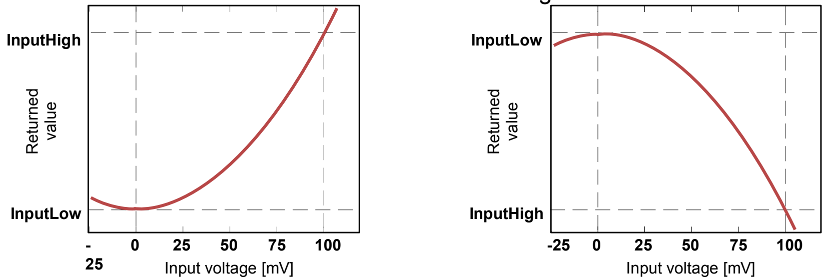


Fig. 6.2 Normal ("InputLow" < "InputHigh") and inverted ("InputLow" > "InputHigh") characteristic.

6.1.3. Square root characteristic

The normalized result is rooted and further conversion is done as for linear characteristic. Conversion is made accordingly with the expression:

$$W = \sqrt{U_n} \times ("InputHigh" - "InputLow") + "InputLow",$$

where W means the value returned in measurement register.

Showed above expression is not valid when normalized result is negative. In this case (U_n<0) the returned result is equal "**InputLow**" (see graphs below).

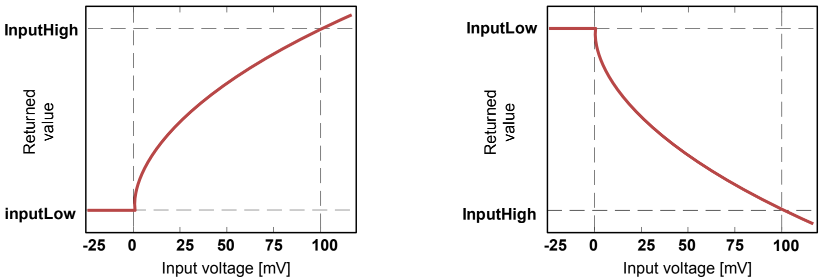


Fig. 6.3 Normal ("InputLow" < "InputHigh") and inverted ("InputLow" > "InputHigh") characteristic.

6.1.4. User defined characteristic

User defined characteristic is defined as set of X-Y points. Number of the points is variable and may be set from 2 to 20 points which make linear segments (see figure below and "**UserChar**" group of registers). Due to the normalized result U_n, the device computes specific segment, e.g. for characteristic from figure below, and U_n = 0,65 the segment between points X = "**50.0.**" and X = "**70.0.**" will be chosen.

Let's mark those points as PL (point low) i PH (point high) - in this example PL= "**50.0.**" and PH = "**70.0.**", and the normalized result U_n for the point PL as U_p (in this example $U_p = U_n(PL)$ = 0.5). The returned result is calculated accordingly to the expression:

$$W=(U_n-U_p)\times\frac{[Y(PH)-Y(PL)]}{[X(PH)-X(PL)]}\times 100+Y(PL)$$

where Y(PH), X(PH), Y(PL), X(PL) mean values of X and Y coordinates of PH i PL points.

If the normalized result exceeds the user defined characteristic values, then specific utmost segment, defined by two next points, is used for calculations. If characteristic from figure below is used, and if U_n>1 then segment defined by points X(PL) = "**90.0.**", X(PH) = "**100.0.**" will be used.

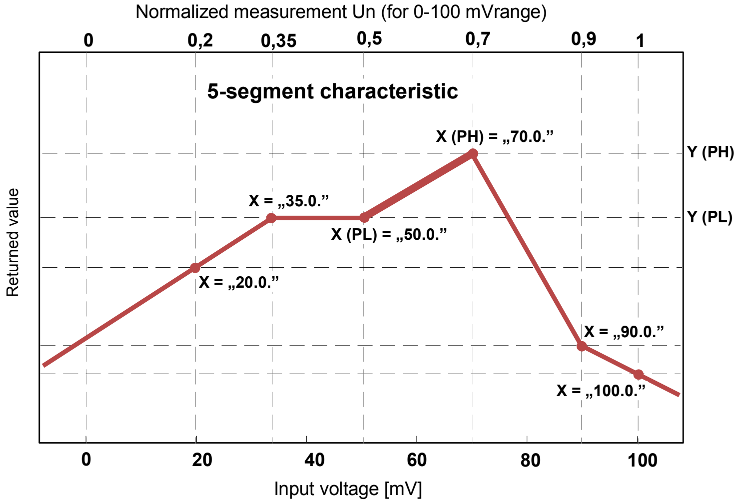


Fig. 6.4 Example of user defined characteristic

6.2. EXAMPLES OF CALCULATIONS

Example 1: *Selection of the permissible input range ("0-100" mode)*

If in "0-100" mode the user sets "**InputHiRange**" = 10.0%, then permissible input voltage range will be equal: 0÷110 mV. Upper border of the range is the result of calculations: 100 mV + 100 mV × 10%.

Example 2: *The normalized U_n result calculation*

Let assume the input mode "0-100" is chosen. The normalized U_n result is calculated accordingly to the expression on page 11. Assume that $U_{inp.}$ = 37.5 mV, this value should be divided by the width of input range (100 mV). Finally the normalized result: U_n = 37.5/100 = 0.375.

In case when input voltage exceeds nominal measurement range, calculations are similar. For example if input voltage is equal -9.38 mV then U_n = -9.38/100 = -0.0938, and if input voltage is equal 103.13 mV then U_n = 103.13/100 = 1.0313.

Example 3: *The linear characteristic*

Let assume the input mode "0-100" is chosen. Parameter "**InputLow**" and "**InputHigh**" equal to -300 and 1200 respectively. The calculations will be done for three different input voltages from example 2.

a) $U_{inp.}$ = 37.5 mV and U_n = 0.375

Accordingly to expression on page 12 for linear characteristic:

0.375 × [1200 -(- 300)] ≅ 562 and next, the "**InputLow**" value is added to the result, so the returned value equals:

W ≅ 562 + (-300) = 262

b) $U_{inp.}$ = -9.38 mV and U_n = -0.0938.

W ≅ -441.

c) $U_{inp.}$ = 103.13 mV and U_n = 1.0313.

W ≅ 1247.

Example 4: *The square characteristic*

Let assume the input mode "0-100" is chosen. Parameter "**InputLow**" and "**InputHigh**" equal to -300 and 1200 respectively. The calculations will be done for three different input voltages from example 2.

a) $U_{inp.}$ = 37.5 mV and U_n = 0.375

Accordingly to expression on page 13 for square characteristic:

$(0.375)^2$ × [1200 -(- 300)] ≅ 211 and next, the "**InputLow**" value is added to the result, so the returned value equals:

W ≅ 211 + (-300) = -89.

b) $U_{inp.}$ = -9.38 mV and U_n = -0.0938.
W ≅ -287.

c) $U_{inp.}$ = 103.13 mV and U_n = 1.0313.
W ≅ 1295.

***Example 5:* The square root characteristic**

Let assume the input mode ”0-100” is chosen. Parameter ”**InputLow**” and ”**InputHigh**” equal to -300 and 1200 respectively. The calculations will be done for three different input voltages from example 2.

a) $U_{inp.}$ = 37.5 mV and U_n = 0.375
Accordingly to expression on page 13 for square root characteristic:
$\sqrt{0,375}$ × [1200 -(- 300)] ≅ 919 and next, the ”**InputLow**” value is added to the result, so the returned value equals:
W ≅ 919 + (-300) = -619.

b) $U_{inp.}$ = -9.38 mV and U_n = -0.0938.
Normalized result is negative, so the returned value is equal to ”**InputLow**” parameter:
W = -300.

c) $U_{inp.}$ = 103.13 mV and U_n = 1.0313.
W ≅ 1223.

***Example 6:* The user defined characteristic**

Let assume the input mode ”0-100” is chosen, and the user selected the 10 segment characteristic. To do this, it is necessary to enter X and Y coordinates of 11 points (see registers 70h÷97h).
The calculations will be done for three different input voltages from example 2, so in calculations some of the segments will be used only.

Let the following points will be given:
X1 = ”**00.0.**”, Y1 = ”**-50.0**”,
X 2= ”**10.0.**”, Y2 = ”**-30.0**”,
....
X6 = ”**30.0.**”, Y6 = ”**30.0**”,
X7 = ”**40.0.**”, Y7 = ”**80.0**”,
....
X10 = ”**90.0.**”, Y10 = ”**900.0**”,
X11 = ”**100.0.**”, Y11 = ”**820.0**”,

Additionally all other points must to be defined and stored in the device memory.

a) $U_{inp.}$ = 37.5 mV and U_n = 0.375
The segment defined by X6 = ”**30.0.**” and X7 = ”**40.0.**” for this U_n will be selected. Accordingly to expressions given for user defined characteristic (see page 14) X6(PL) = 30, Y6(PL) = 30, X7(PH) = 40, Y7(PH) = 80 and U_p = 0,3 , the returned value:

$$W = (U_n - U_p) \times \frac{[Y(PH) - Y(PL)]}{[X(PH) - X(PL)]} \times 100 + Y(PL) =$$

$$= (0.375 - 0.3) \times \frac{[80 - 30]}{[40 - 30]} \times 100 + 30 \simeq 67$$

b) $U_{inp.}$ = -9.38 mV and U_n = -0.0938.
Because of the normalized U_n value is lower than 0, the segment defined by X1 and X2 will be selected. X1(PL) = 0, Y1(PL) = -50, X2(PH) = 10,
Y2(PH) = -30 and U_p = 0. For these values the returned value W ≅ -69.

c) $U_{inp.}$ = 103.13 mV and U_n = 1.0313.
Because of the normalized U_n value is higher than 1, the segment defined by X10 and X11 will be selected, and X10(PL) = 90, Y10(PL) = 900,
X11(PH) = 100, Y11(PH) = 820 and U_p = 0.9 for these values the returned value W ≅ 795.

7. CURRENT OUTPUT VALUE CALCULATION

Output current value may be calculated by the equation (described on page 9):

$$I_{out} = \frac{W - "OutLow"}{"OutHigh" - "OutLow"} \times 16\,mA + 4\,mA$$

where W means the measurement result.

***Example 1:* Current output value calculation**
Let the current output parameters be:
”**OutMode**” = control according to measurement result,
”**OutLow**” = 100, ”**OutHigh**” = 200, ”**OutLoRange**” = 5.0, ”**OutHiRange**” = 5.0.

Parameters ”**OutLoRange**” and ”**OutHiRange**” define working range of current output to 3,8 ÷ 21 mA. Output current will be calculated for three measurement values:

a) W = 175
According to formula from page 9:
I_{out} = (175-100) / (200-100) × 16 mA + 4 mA = 0.75 ·16 + 4 = 16 mA
Calculated I_{out} do not exceeds the output working range (3.8 ÷ 21 mA).

b) W = 205
According to formula from page 9:
I_{out} = (205-100) / (200-100) × 16 mA + 4 mA = 1.05 ·16 + 4 = 20.08 mA.
Calculated I_{out} do not exceeds the output working range 3.8 ÷ 21 mA.

c) W = 300
According to formula from page 9:
I_{out} = (300-100) / (200-100) × 16 mA + 4 mA = 2 ·16 + 4 = 36 mA.
Calculated I_{out} exceeds the output working range (3.8 ÷ 21 mA), so current output will generate current equal to the upper border of range defined by parameter ”**OutLoRange**” and ”**OutHiRange**” (that is 21 mA).

8. THE MODBUS PROTOCOL HANDLING

Transmission parameters: 1 start bit, 8 data bits, 1 or 2 stop bit (2 bits are send, 1 and 2 bits are accepted when receive), no parity control
Baud rate: selectable from: 1200 to 115200 bits/second
Transmission protocol: MODBUS RTU compatible

The device parameters and measurement value are available via RS-485 interface, as HOLDING-type registers (numeric values are given in U2 code) of Modbus RTU protocol. The registers (or groups of the registers) can be read by 03h function, and wrote by 06h (single registers) or 10h (group of the registers) accordingly to Modbus RTU specification. Maximum group size for 03h and 10h functions can not exceeds 16 registers (for single frame).

The device interprets the broadcast messages, but then do not sends the answers.

8.1. LIST OF REGISTERS

Register	***Write***	***Range***	***Register description***
"Measure" group of registers			
01h	No	-999 ÷ 9999	Measurement value (no decimal point)
02h	No	0h, A0h, 60h, C0h, 10h, 20h	Status of the current measurement: **0h** - data valid; **A0h** - top border of the measurement range is exceeded; **60h** - bottom border of the measurement range is exceeded; **C0h** - sensor failure; **10h** - error of user characteristic; **20h** - waiting for the first measure after reconfiguration
03h	Yes	0 ÷ 3	Parameter "**InputPoint**" - decimal point position (copy of register 13h): **0** - " **0**"; **1** - " **0.0**"; **2** - " **0.00**"; **3** - "**0.000**"
05h	Yes	0h ÷ 1800h	State of current output, expressed in 1/256 mA units – it means that high byte express integer part, and low byte fractional part of desired output current.
06h	No	-999 ÷ 9999	Peak (drop) value (no decimal point)
08h	No	0 ÷ 50	Temperature inside device housing expressed by 1°C
"Input" group of registers			
10h	Yes	0 ÷ 14	Parameter "**InputType**" - input's type: **0** - 0-60 mV range; **1** - 0-75 mV range; **2** - 0-100 mV range; **3** - 0-150 mV range; **4** - Pt 100; **5** - Pt 500; **6** - Pt 1000; **7** - thermocouple K; **8** - thermocouple S; **9** - thermocouple J; **10** - thermocouple T; **11** - thermocouple N; **12** - thermocouple R; **13** - thermocouple B; **14** - thermocouple E
11h	Yes	0 ÷ 3	Parameter "**InputChar**" - characteristic's type: **0** - linear; **1** - square; **2** - square root; **3** - user defined

Register	Write	Range	Register description
12h	Yes	0 ÷ 5	Parameter ”**InputFilter**” - measurement filtering rate: **0** - no filtration **1** - time constant ca. 0.2 sec. **2** - time constant ca. 0.4 sec. **3** - time constant ca. 0.8 sec. **4** - time constant ca. 1.5 sec. **5** - time constant ca. 3 sec.
13h	Yes	0 ÷ 3	Parameter ”**InputPoint**” - decimal point position: **0** - ” **0**”; **1** - ” **0.0**”; **2** - ” **0.00**”; **3** - ”**0.000**”
14h	Yes	-999 ÷ 9999	Parameter ”**InputLow**” (no decimal point included).
15h	Yes	-999 ÷ 9999	Parameter ”**InputHigh**” (no decimal point included).
17h	Yes	0 ÷ 199	Parameter ”**InputHiRange**”, expressed in 0.1%.
18h	Yes	-99 ÷ 99	Parameter ”**TempOffset**” - shift of measurement scale. Expressed in 0.1°C for RTD input, in 1.0°C for TC input.
19h	Yes	0 ÷ 2	Parameter ”**InputConn**” - RTD input connection method: **0** - 4-wire; **1** - 3-wire; **2** - 2-wire
”Modbus” group of registers			
20h[1]	Yes	0 ÷ 255	Parameter ”**ModbusAddr**” - device address.
21h	No	205Bh	Device identification code (ID)
22h[2]	Yes	0 ÷ 7	Parameter ”**ModbusBaud**” - baud rate: **0** - 1200 bit/sec.; **1** - 2400 bit/sec.; **2** - 4800 bit/sec.; **3** - 9600 bit/sec.; **4** - 19200 bit/sec.; **5** - 38400 bit/sec.; **6** - 57600 bit/sec.; **7** - 115200 bit/sec.
23h[3]	Yes	0 ÷ 1	Parameter ”**ModbusAccess**” - permission to write registers via RS-485 interface: **0** - write denied; **1** - write allowed
25h	Yes	0 ÷ 5	Parameter ”**ModbusDelay**” - additional response delay: **0** - no additional delay; **1** - delay equal to 10 characters; **2** - delay equal to 20 characters; **3** - delay equal to 50 characters; **4** - delay equal to 100 characters; **5** - delay equal to 200 characters;
27h	Yes	0 ÷ 99	Parameter ”**ModbusTimeout**” - maximum delay between received frames: **0** - no delay checking; **1** ÷ **99** - maximum delay expressed in seconds
”Hold” group of registers			
50h	Yes	0 ÷ 1	Parameter ”**HoldMode**” - type of detected changes: **0** - peaks; **1** - drops
51h	Yes	0 ÷ 9999	Parameter ”**HoldPeak**” - minimum detectable change; no decimal point included

Register	***Write***	***Range***	***Register description***
52h	Yes	0 ÷ 199	Parameter ”**HoldTime**” - maximum peaks' (or drops') hold time expressed in seconds
58h	Yes	0 ÷ 1	Parameter ”**HoldOut**”: **0** - output controlled by current value (from register 01h); **1** - output controlled by holded value (from register 06h);
”UserChar” group of registers			
70h[4]	Yes	-999 ÷ 1999	The value of ”**X**” coordinate of point **no. 1** of the user defined characteristic, expressed in 0.1%
71h[4]	Yes	-999 ÷ 9999	The value of „**Y**” coordinate of point **no. 1** of the user defined characteristic, no decimal point included
72h[4] ÷ 95h[4]			Further pairs of „**X**” - „**Y**” coordinates of points **no. 2** ÷ **19** of the user defined characteristic
96h[4]	Yes	-999 ÷ 1999	The value of „**X**” coordinate of point **no. 20** of the user defined characteristic, expressed in 0.1%
97h[4]	Yes	-999 ÷ 9999	The value of „**Y**” coordinate of point **no. 20** of the user defined characteristic, no decimal point included
”Output” group of registers			
A0h	Yes	0 ÷ 2	Parameter ”**OutputMode**” - current output mode: **0** - current output disabled (ca. 2.5 mA flows); **1** - current output controlled by the measured value; **2** - current output controlled via RS-485 interface (see 05h reg.)
A1h	Yes	-999 ÷ 9999	Parameter ”**OutputLow**”, no decimal point included
A2h	Yes	-999 ÷ 9999	Parameter ”**OutputHigh**”, no decimal point included
A3h	Yes	0 ÷ 299	Parameter ”**OutputLoRange**”, expressed in 0.1%
A4h	Yes	0 ÷ 199	Parameter ”**OutputHiRange**”, expressed in 0.1%
A5h	Yes	0 ÷ 2	Parameter ”**OutputAlarm**” - current output value on critical exception: **0** - no change; **1** - 22.1 mA; **2** - 3.4 mA

1 - after writing to register no 20h the device responds with an ”old” address in the message.

2 - after writing to register no 22h the device responds with the new baud rate.

3 - the value of the ”**ModbusAccess**” parameter is also connected to write to this register, so it is possible to block a writes, but impossible to unblock writes via RS-485 interface, The unblocking of the writes is possible from menu level only.

4 - the pairs of „**X** -**Y**” coordinates may be defined for any free point. The pair is ”free” (it means that particular point is not defined) if „**X**” coordinate of this point is equal 8000h. After writing both X and Y coordinate the point is defined and used in calculation of result. The coordinates of any point can be changed at any time.

8.2. TRANSMISSION ERRORS DESCRIPTION

If an error occurs while write or read of single register, then the device sends an error code according to Modbus RTU specifications (example message no 1).

Error codes:
01h - illegal function (only functions 03h, 06h and 10h are available),
02h - illegal register address
03h - illegal data value

08h - no write permission (see ”**ModbusAccess**”)
A0h - exceed of upper border of input range
60h - exceed of lower border of input range
C0h - sensor failure,
10h - incorrectly defined user multipoint characteristic,
20h - waiting for the first measurement after changing the configuration.

A0h, 60h, C0h, 10h, and 20h codes can appear only during reg. 01h is reading by 03h function (read of a single register).

8.3. EXAMPLES OF QUERY/ANSWER FRAMES

Examples apply for device with address 1. All values are represent hexadecimal.

Field description:
ADDR Device address on modbus network
FUNC Function code
REG H,L Starting address (address of first register to read/write, Hi and Lo byte)
COUNT H,L No. of registers to read/write (Hi and Lo byte)
BYTE C Data byte count in answer frame
DATA H,L Data byte (Hi and Lo byte)
CRC L,H CRC error check (Hi and Lo byte)

1. Read of the measured value, SPT-86L device address = 01h:

ADDR	FUNC	REG H,L		COUNT H,L		CRC L,H	
01	03	00	01	00	01	D5	CA

a) The answer (we assume that the measure result is not out of range):

ADDR	FUNC	BYTE C	DATA H,L		CRC L,H	
01	03	02	00	FF	F8	04

DATA H, L - measured value = 255, no decimal point.
Decimal point position can be read from reg. 03h.

b) The answer (if an error occur):

ADDR	FUNC	ERROR	CRC L,H	
01	83	60	41	18

ERROR - error code = 60h, bottom border of the measurement range is exceeded

2. Read of device ID code

ADDR	FUNC	REG H,L		COUNT H,L		CRC L,H	
01	03	00	21	00	01	D4	00

The answer:

ADDR	FUNC	BYTE C	DATA H,L		CRC L,H	
01	03	02	20	5B	E0	7F

DATA - identification code (205Bh)

3. Change of the device address from 1 to 2 (write to reg. 20h)

ADDR	FUNC	REG H,L		DATA H,L		CRC L,H	
01	06	00	20	00	02	09	C1

DATA H - 0
DATA L - new device address (2)

The answer (the same as the message):

ADDR	FUNC	REG H,L		DATA H,L		CRC L,H	
01	06	00	20	00	02	09	C1

4. Read of the registers 1, 2 and 3 in one message (example of reading a number of registries in one frame):

ADDR	FUNC	REG H,L		COUNT H,L		CRC L,H	
01	03	00	01	00	03	54	0B

COUNT L - the count of being read registers (max.16)

The answer:

ADDR	FUNC	BYTE C	DATA H1,L1		DATA H2,L2		DATA H3,L3		CRC L,H	
01	03	06	00	0A	00	00	00	01	78	B4

DATA H1, L1 - reg. 01h (10 - measured value ”1.0”),
DATA H2, L2 - reg. 02h (0 - no errors),,
DATA H3, L3 - reg. 03h (1 - decimal point position ” 0.0”).

There is no full implementation of the Modbus Protocol in the device. The functions presented above are available only.

9. DEFAULT AND USER'S SETTINGS LIST

Parameter	Description	Default value	User's value
Measurement input configuration (”Input” group of registers)			
InputType	Input type	Pt 100	
InputConn	RTD's connection method	4-wire	
InputFilter	Filtering ratio	0	
TempOffset	Shifting of measurement scale	0.0	
InputChar	Conversion characteristic mode	linear	
InputPoint	Decimal point position	0.0	
InputLow	Minimum returned value (for nominal range)	000.0	
InputHigh	Maximum returned value (for nominal range)	100.0	
InputHiRange	Extension of the top of the nominal input range	5.0 (%)	
Active current output configuration (”Output” group of registers)			
OutMode	Current output mode	measured value	
OutLow	Measured value for which 4 mA is generated	0.0	
OutHigh	Measured value for which 40 mA is generated	100.0	
OutLoRange	Extension of the bottom of the nominal output range	5.0 (%)	
OutHiRange	Extension of the top of the nominal output range	5.0 (%)	
OutAlarm	Current output value on critical exception	22.1 mA	
Peak detection function configuration (”Hold” group of registers)			
HoldMode	Kind of detected changes	peak	
HoldPeak	Minimum detected change	0.0	
HoldTime	Maximum time of holding the peak	0.0	
HoldOut	Source of current output control	current value	
RS-485 interface configuration (”Modbus” group of registers)			
ModbusAddress	Device address	FEh	
ModbusBaud	Baud rate	9600	
ModbusAccess	Permission to changes of configuration registers	yes	
ModbusTimeout	Maximum delay between received messages	0	
ModbusDelay	Additional delay of answer transmission	0	

SIMEX Sp. z o.o.
ul. Wielopole 11
80-556 Gdańsk
Poland

tel.: (+48 58) 762-07-77
fax: (+48 58) 762-07-70

http://www.simex.pl
e-mail: info@simex.pl