PIEZUS

ULTRASONIC FLOWMETERS

PIEZOSONIC

Operation Manual

38978553.407251.008 RE

OKPD-2

26.51.52.110

Electronic copy of this Manual can be downloaded from the website:

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This Operation Manual applies to **PIEZOSONIC Ultrasonic Flowmeters** (hereinafter referred to as Flowmeter, Instrument or Item) and contains operation description, technical specifications, and information intended for the maintenance personnel to learn about the Item design and its main operating instructions.

Flowmeters have been manufactured in compliance with the 38978553.407251.008 TU Technical Specifications.

The Instruments consist of two parts: measuring section (MS) based on ultrasonic piezoelectric transducers (PET) and electronic module (EM) that provides processing of the data received.

The flowmeters are available in various designs that differ in the measuring section design, number of channels, operating range and some other parameters. The design version information is given in the ordering code designation, see Appendix A.

Overall and installation dimensions of the flowmeter components are given in Appendix B.

In compliance with GOST R 52931, Item is as follows:

– by the type of energy used, it belongs to electrical devices;

– intended for information communication with other devices;

– by resistance to the effect of atmospheric pressure, it complies with Group P1 (altitude above sea level is maximum 1000 m);

– by resistance to vibration, it belongs to Group L1.

In terms of the method of protecting people from electric shock, the Items comply with class 0I as per GOST 12.2.007.0.

The following abbreviations are used:

MS – measuring section (pipe with PET transmitters installed).
US – ultrasound.
SW – software.
PC – personal computer (IBM-compatible mobile or desktop).
PFT – primary flow transducer (twomeasuring probes PET operating in one beam at MS).
PET – piezoelectric transducer (measuring probes) operating as receiver/emitter of US pulses.
OM (RE)– Operation Manual.
EM – electronic module that converts signals according to a program.
Dn – nominal diameter of the pipeline with installed PET transmitters.
Q – flow rate measured value
Q_{nom} – flow rate rated value ($Q_{nom}=0.5\cdot Q_{max}$).
Q_{max} – maximum value of flow rate measurement.
Q_{min} – minimum value of flow rate measurement.
V – the volume of liquid passed.

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1 Use and Field of Application

1.1 The flowmeter is designed for commercial metering of the average flow rate (Q) and volume (V) of liquid media containing air or suspended particles up to 1% of the volume with a Reynolds number of at least 5000 and kinematic viscosity from 0.2 to 25 mm^2/s in completely filled pipelines with nominal diameters (Dn) from 50 to 2000 mm. The maximum gauge pressure in the pipe is up to 2.5 MPa (up to 6.3 MPa on request).

1.2 The flowmeter meets the requirements of TR TS 004/2011 On the Safety of Low-voltage Equipment, TR TS 020/2011 Electromagnetic Compatibility of Technical Products, GOST R 52931, GOST R IEC 61326-1.

1.3 The flowmeter is a measuring instrument and is part of the state system of instruments and automation equipment in accordance with GOST R 52931.

2 Specifications

2.1 Main technical data

2.1.1 The Instrument measures volumetric flow from 0.47 m^3/h (Q_{min}) to 120,000 m^3/h (Q_{max}), depending on the diameter Dn of the pipeline, in accordance with table A.1 (Appendix A).

2.1.2 The flowmeter can have one or two independent measurement channels in different pipelines or implement a two-beam measurement design in one pipeline. It is also possible to use a sum channel (group) when combining two beams as a pair, each of which, depending on Dn of measuring section, provides flow rate measurement in the range presented in Table A.1 (Appendix A).

2.1.3 The Instrument measures the volume of liquid (V) for each flow channel in the range from 0 to 999999.999 m^3. The least significant digit when measuring flow rate is 0.001 m^3/h, for volume, it is 0.01 m^3.

2.1.4 The ranges and accuracy of volumetric flow rate and volume during flushing and simulation verification methods are within the limits specified in Tables 2.1—2.3 (where v is the flow velocity of the measured liquid, m/s).

2.1.5 The electronic module of the Flowmeter provides an accuracy in converting the volumetric flow rate value into a frequency output signal from 0.5 to 2000 Hz no more than ±0.05%. The accuracy reduced to the upper range limit of the measurement range in converting the volumetric flow rate into a current output signal 4-20 mA is no more than ±0.5%.

Table 2.1. Values of flow rates in depending on Dn of measurement section

Specification	Parameter Value							
Dn Diameter, mm	50	65	80	100	150	200	250	300
Minimum flow rate Q_{min}, m^3/hr	0.47	0.8	1.2	1.87	4.24	7.5	11.8	17.0
Rated flow rate Q_{nom}, m^3/hr	36.5	62	93	145	328	582	915	1320
Maximum flow rate Q_{max}, m^3/hr	73	124	186	290	656	1164	1830	2640

Note:
1. For Dn above 300 mm, the flow rate values shall be determined by formulas:
$Q_{max}= 0.03\cdot(Dn)^2$; $Q_{nom}= 0.5\cdot Q_{max}$; $Q_{min} = 6.4\cdot10^{-3}\cdot Q_{max}$.

Table 2.2. Limits of accuracy of volumetric flow rate and volume when performing the flushing verification.

Dn Diameter, mm (including)	Method of the PET installation on pipeline	Limits of accuracy in measuring the flow rate and volume, %
50 to 80	by diameter	±(1.2+0.2/v)
100 to 1600	by diameter	±(1.0+0.2/v)
50 to 80	by two chords	±(0.7+0.2/v)
100 to 1600	by two chords	±(0.5+0.2/v)

Table 2.3. Limits of accuracy of volumetric flow rate and volume when performing the simulation verification

Dn Diameter, mm (including)	Method of the PET installation on pipeline	Limits of accuracy in measuring the flow rate and volume, %
50 to 300	by diameter	±(2.5+0.2/v)
350 to 2000	by diameter	±(2.0+0.2/v)
50 to 80	by two chords	±(2.0+0.2/v)
100 to 350	by two chords	±(1.5+0.2/v)
400 to 2000	by two chords	±(1.0+0.2/v)

Note. Accuracies correspond to the values specified in tables 2.2–2.3, if the lengths of straight sections before PET are not less than those specified in table 2.4.

Table 2.4. Lengths of straight sections before PET

Option No.	Method of the PET installation on pipeline	Straight-line sections	
		before PET	after PET
1	by diameter	10 Dn	5 Dn
2	by two chords	10 Dn	5 Dn
3	by one chord	15 Dn	5 Dn
4	by the pipeline central line	not limited	not limited

WARNING!

1. The lengths of straight sections indicated in options 1–3 of Table 2.4, can be decreased by 25%, but this may result in an additional error in measuring volumetric flow and volume ±0.5%.

2. The local hydraulic resistance, which can be because of presence of diffusers, valves, adapters, crosses and branches, is not allowed on straight sections.

2.1.6 The measurement results are displayed on the electronic indicator of EM and can be transmitted to other external devices via the RS-485 digital interface, as well as by electrical signals: by pulse frequency and by current 4...20 mA. Output parameters are indicated in Table 2.5.

Table 2.5. Output signals of Flowmeter

Current analog output (by quantity of channels):	1 or 2
Output type	2-wire active
Signal range (linearly increases with flow rate increase)	4 to 20 mA
Load resistance	0 to 500 Ohm
Galvanic isolation (in a dual channel version, the outputs are connected with a common wire)	there is a group isolation between outer circuits (500 V)
Isolation resistance, min	40 MOhm
Frequency output (by quantity of channels)	1 or 2
Output type (transistor switch)	passive
Load parameters, max	35 V / 50 mA
Range of signal frequency (linearly increases with flow rate increase)	0.5 to 2000 Hz
Galvanic isolation	available (500 V)
Isolation resistance, min	40 MOhm
RS-485 digital interface (one)	always available
Communication protocol	Modbus RTU
Data transfer rate, bps.	4800, 9600, 19,200, 38,400
Galvanic isolation	available (500 V)
Isolation resistance, min	40 MOhm

Note. In the table, the isolation resistance value is indicated under normal conditions: ambient temperature (20 ± 5) ° C, relative humidity no more than 80%.

2.1.7 The primary power supply of the flowmeter should be from an industrial network with alternating current with a frequency of 49 to 51 Hz, voltage in the range from 187 to 242 V (nominal 220±11) V).

2.1.8 Power consumption is max. 15 V·A.

2.1.9 The main parameters of design are in Table 2.6.

2.1.10 The Flowmeter functional specifications are specified in Table 2.7.

Table 2.6. Design parameters

Name	Value (properties)
Version by the method of PET transmitters installation	PET on the shipped measuring section
	PET installed on the working pipeline
Electrical connections	cable length is up to 500 m between PET and EM
	cable length is up to 1200 m between RS-485 EM and ACS
	cable length is up to 1200 m with current output 4-20 mA
	cable length is up to 1200 m with frequency output 0.5-20 mA,
Overall dimensions of components*, max: – PET transmitter – EM	Ø29×78 mm 200×200×112 mm
Weight, max.*: – PET transmitter – EM	0.14 kg 1.9 kg
Protection degree of components by GOST 14254: – PET transmitter and MS – EM	IP65 (IP67 and IP68 on request) IP65
* Overall dimensions and weight of the shipped MS depend on Dn diameter	

Table 2.7 Functional specifications

Name	Value (properties)
Operation Mode	continuous
Uptime after switched on	max 15 s
Indication of measurement information and messages	2 lines of 20 characters
Reading interval on the indicator	1 s
Operating mode establishment time after power supply is on	max 15 min
Average time between failures (taking into account maintenance) is minimum	65,700 hrs
Average service life	10 years
Vibration resistance as per GOST R 52931	Group L1
Vibration resistance in transport packaging as per GOST R 52931	Group F3

2.1.11 Flowmeter has the following functions:

- self-testing of PET and main units when switched on;
- programming operating parameters for each channel, taking into account the peculiarities of the medium being measured and the installation dimensions of MS;
- measurement of the average volumetric flow rate of liquid through 1 or 2 channels (pipelines) for any direction of flow;
- determination of the growing volume of liquid separately for the forward and reverse flow directions and their algebraic sum, taking into account the flow direction for each measurement channel;
- determining the current value of speed and direction of liquid flow through each channel;
- has a built-in real-time clock for recording calendar data and operating time of the Item during operation;
- automatic monitoring and indication of of failures, as well as recording their type and duration in the logs;
- archiving of measurement results and parameter settings in non-volatile memory;
- protection of archive and installation data from unauthorized access.

- The EM calculates hourly and daily volume values and archives the specified information in electronic memory. The volume of archive memory provides accumulation of information during at least 1 year:

- about the measured average flow rate (m^3/hr) for a set interval of 5/15 min; 1/6/24 hr;

- about the volume of liquid passed through the pipeline (m^3) from the moment of switching on.

After turning off the power, the flowmeter stores programmable parameters and accumulated measurement information for 10 years.

2.2 Operating conditions

Measured medium:

– temperature of the monitored liquid from -40 to +150°C;
– content of solid particles by weight no more than 1%;
– liquid with a Reynolds number of at least 5000;
– kinematic viscosity from 0.2 to 25 mm^2/s;
– gauge pressure is up to 2.5 MPa (up to 6.3 MPa on request);
– range of operating flow velocities from 0.1 to 12.5 m 11 m/s.

Operating conditions:

– closed explosion-proof areas without aggressive vapors and gases;

– ambient air temperature from 0°C to +50°C;

– relative air humidity up to 98%, without moisture condensation;

– atmospheric pressure 84 to 106.7 kPa (630 to 800 mm Hg).

Normal conditions:

– monitored liquid temperature +(20 ±5) °C;

– ambient air temperature +(20 ± 5) °C;

– relative air humidity up to 80%, without moisture condensation;

– atmospheric pressure 84 to 106.4 kPa (630 to 800 mm Hg).

2.3 Resistance to interferences and electromagnetic emission

2.3.1 In terms of resistance to industrial radio interference, the flowmeter complies with the performance criterion A as per GOST R IEC 61326-1.

2.3.2 In terms of the level of radio frequency interference emission (electromagnetic emission), the flowmeter corresponds to standards established for class B equipment according to GOST R 51318.22.

2.3.3 The flowmeter is resistant to alternating magnetic fields with a frequency (50 ±1) Hz with voltage up to 400 A/m.

3 Design and Operation

3.1 Design features

3.1.1 The flowmeter design consists of a flowing part of the pipeline, on which ultrasonic piezoelectric transducers (PETs) are permanently installed and connected by a cable to electronic module (EM).

3.1.2 The measuring section (MS) can be made of a metal (steel) pipe, to the ends of which two flanges are welded in accordance with GOST 12815–80. In the middle of the pipe, two holders are welded at a certain angle, in which PETs are attached (through sealing gaskets) using special nuts shown in Figure B.3 (Appendix B).

3.1.3 In order to place probes, their position is specified when ordering. If the delivery order does not include a ready-made measuring section, the PETs are installed in a convenient location on the working pipeline - all the necessary mounting parts are included in the delivery kit.

3.1.4 The number of PETs used is related to the number of output channels used in the EM, and there can be one or two channels (for measurements in ultrasonic channel, PETs work in pairs). PETs are connected to EM with cables of type RK 50 2-11 (or similar, with a characteristic impedance of 50 Ohms).

3.1.5 The EM housing is made of plastic in moisture-proof design, with a transparent cover through which an indicator displaying measurement results is visible, and can be mounted on a DIN rail (35 mm) or on a wall.

3.2 Instrument operation

3.2.1 The functional chart shows the main elements involved in the flowmeter operation, Figure 3.1.

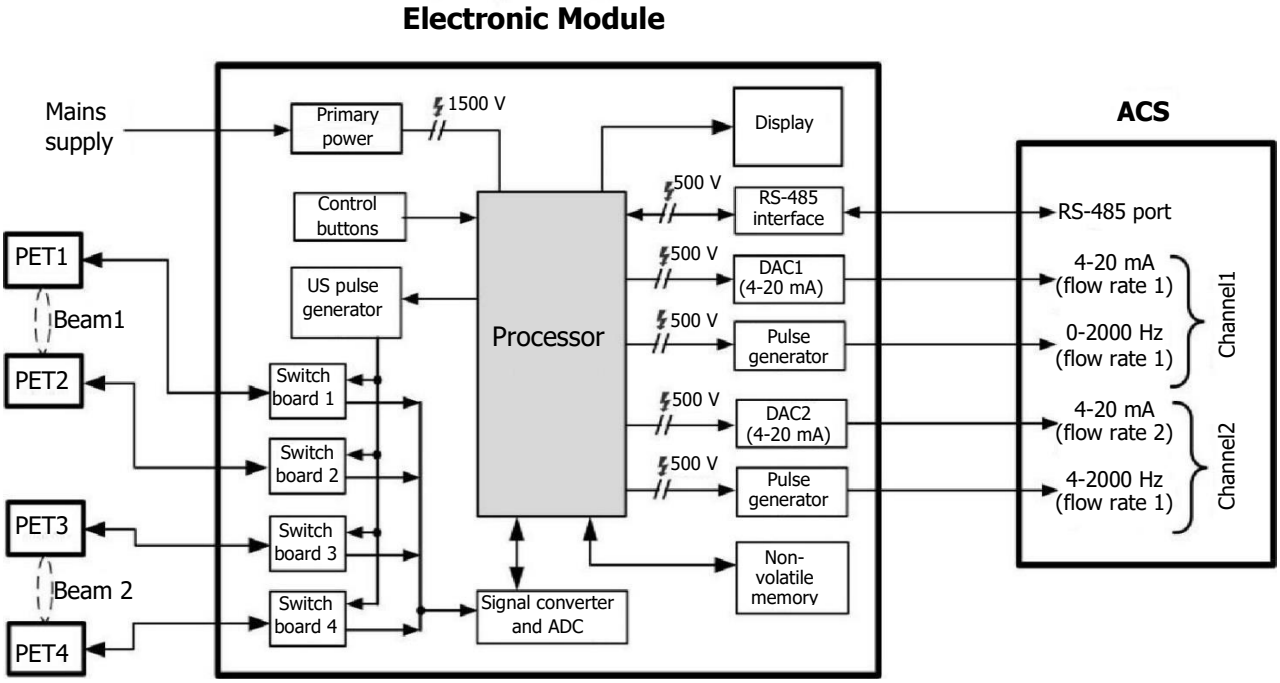


Figure 3.1. Functional chart of the flowmeter

3.2.2 When turned on, the following sequence runs:

1) self-diagnosis of the EM and PET technical condition;

2) microprocessor reads information about the parameters of all ultrasonic measuring channels (beams) from non-volatile memory for further use in calculations;

3) through switches, the EM sends electrical impulses alternately to one or the other PET - each PET can be used as an emitter or receiver of an ultrasonic impulse (as a result of this, ultrasound travels in the liquid downstream and upstream);

4) PET converts the electrical pulse signal coming from the electronic module into ultrasonic vibrations, which, after passing through the liquid, reach another PET, which converts them into electrical vibrations transmitted through cable to the signal converter of EM;

5) processor, using the data entered into its memory about the diameter of the pipeline, the distance between the PET and the measured time of passage of ultrasound in the controlled medium, calculates the flow rate and volume of the liquid;

6) calculation results are displayed on the digital indicator of EM and transmitted to external circuits in the form of a pulse-frequency signal (0.5...2000 Hz), as well as an analog current (4...20 mA), - the magnitude of the signals increases in direct proportion to the flow rate;

7) measured values are transmitted via a serial digital interface RS-485 (Modbus RTU protocol);

8) resulting measurement data and event log are archived in non-volatile memory, which can be accessed remotely or through the flowmeter menu.

3.2.3 The flowmeter has a digital interference filter at the inputs of ultrasonic measuring channels.

3.3 Measurement principle

3.3.1 Operation of the flowmeter is based on the method of direct measuring the transit time of ultrasound in a liquid from one PET to another (Figure 3.2).

The ultrasonic pulse transit time from PET1 to PET2 ($T_{1,2}$) and from PET2 to PET1 ($T_{2,1}$) depends on the speed of liquid movement in accordance with the formulas

$$T_{1,2} = \frac{L\_c}{C_0 + v \cdot \cos\alpha}; \quad (1)$$

$$T_{2,1} = \frac{L\_c}{C_0 - v \cdot \cos\alpha}, \quad (2)$$

where $T_{1,2}$, $T_{2,1}$ are time of the ultrasonic pulse transition downstream and upstream, s;

L_c is length of the acoustic ultrasonic channel between PETs, m;

C_0 is speed of ultrasound propagation in motionless liquid, m/s;

v is the speed of liquid flow in the pipe, m/s;

α is angle in accordance with Figure 3.2, in degrees.

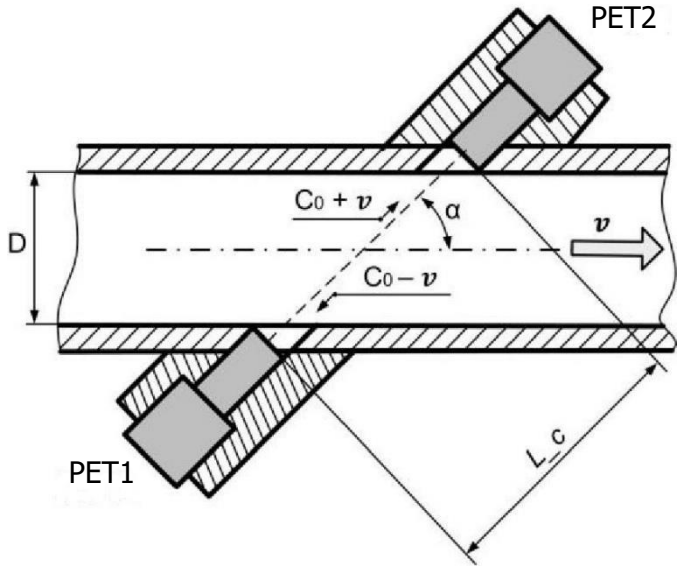


Figure 3.2. Measured metrological dimensions

The speed of ultrasonic signal in a liquid in a pipeline is the sum of the speeds: the speed of ultrasound in motionless liquid (C_0) and the speed of liquid flow in projection onto the direction, determined by the formulas

$$\frac{L_c}{T_{1,2}} = C_0 + v \cdot \cos\alpha, \quad (3)$$

$$\frac{L_c}{T_{2,1}} = C_0 - v \cdot \cos\alpha, \quad (4)$$

where C_0 is speed of ultrasound in motionless liquid, m/s;

v is the speed of liquid flow in the pipe, m/s;

α is the angle between the direction of ultrasound and the axis of the pipeline, in degrees;

$T_{1,2}$ is time of the ultrasonic signal going from PET1 to PET2;

$T_{2,1}$ is time of the ultrasonic signal going from PET2 to PET1.

From formulas (3) and (4) we get an expression for determining the speed of liquid flow averaged along the trajectory of the ultrasonic beam

$$v = \frac{L_c(1/T_{1,2} - 1/T_{2,1})}{2\cos\alpha}. \quad (5)$$

The liquid speed, determined by formula (5), differs from the average flow speed averaged over the cross-section of the pipeline.

In order to determine the flow rate, it is necessary to multiply the speed determined by formula (5) by the correction factor ***K***, which takes into account the properties of the liquid and possible features of the installation of the PET. The correction coefficient is determined according to the Verification Methodology (by the simulation method or by flushing at the calibration stage).

By multiplying the average flow speed by the pipeline cross-section, we obtain the value of the liquid flow rate ***Q*** flowing at the location where the PET transmitters are installed

$$Q = \frac{\pi D^2 \cdot K \cdot v}{4}. \quad (6)$$

The length of straight sections and the error in flow measurement can be significantly decreased by using two pairs of transmitters installed on one pipeline, with the direction of movement of each ultrasonic beam being along a chord. The chords in the two-chord version are located in the middle of the radii of the measuring sections. The measured flow speed (v) will be determined as

$$v = \frac{v_{k1} + v_{k2}}{4}, \quad (7)$$

where v_{k1} is the speed of flow along chord 1;

v_{k2} is the speed of flow along chord 2;

3.3.2 The measured flow rate can be determined from the electrical output signals of EM in accordance with the formulas of the nominal static characteristic:

a) for current signal 4...20 mA

$$Q_{CUR} = \frac{(I_{out} - I_{min}) \cdot Q_{URL}}{I_{max} - I_{min}}, \quad (8)$$

where Q_{CUR} is the measured volumetric flow rate of liquid, m^3/s (m^3/hr; l/min);

Q_{URL} is the set value of the upper limit of flow measurement by the current signal, m^3/s (m^3/hr; l/min);

I_{min} = 4 mA is the minimum value of the current output signal;

I_{max} = 20 mA is the maximum value of the current output signal;

I_{out} - is the value of current at the EM output, mA.

b) for frequency signal 0.5...2000 Hz

$$Q_F = Q_{LRL} + \frac{f_{out} \cdot (Q_{URL} - Q_{LRL})}{f_{max}}, \quad (9)$$

where Q_F is the measured volumetric flow rate of liquid, m^3/s (m^3/hr; l/min);

Q_{URL}, Q_{LRL} is the set value of the upper and lower range limits of flow rate measurement by the frequency signal, m^3/s (m^3/hr; l/min);

f_{max} is the maximum value of output signal frequency;

f_{out} is the measured value of the frequency of the signal at the output of EM, Hz.

4 Safety Measures

4.1 Installation (dismantling), connection, adjustment and maintenance of the flowmeter must be performed only by qualified specialists who have studied this operating manual and have been briefed in general safety rules that take into account the specifics of the given type of works.

4.2 In terms of the method of protecting people from electric shock, the flowmeter - depending on design version - complies with class 0I as per GOST 12.2.007.0.

4.3 The following are sources of danger during installation and operation:

– mains supply voltage 220 V AC with a frequency of 50 Hz: connection of the flowmeter electrical circuits must be made only when the power is turned off;

– gauge pressure in the pipeline: a PET must be connected and disconnected from the main lines supplying the measured medium after dropping the pressure down to atmospheric.

– high temperature of the measured medium.

4.4 Before carrying out works on the pipeline, with help of measuring instruments, make sure that there is no life-threatening direct or alternating current voltage.

4.5 During operation, maintenance and calibration, it is necessary to observe the requirements of GOST 12.3.019, Operational Code for Electrical Installations and Rules for Labor Protection During the Operation of Electric Consumers below 1000 V.

5 Operating Controls and Displays

5.1 Front panel buttons

In order to control the mode of displaying and programming the operating parameters of the flowmeter, there are five buttons, Appendix C. Arrow buttons <Left>, <Right>, <Up>, <Down> serve to navigate through the menu and change parameter values.

Transition from main operating mode to SERVICE mode for setting is carried out by pressing the <ENTER> button for at least 3 s. The Instrument automatically returns from setup mode to operating mode if buttons on the front panel are not pressed for 5 minutes.

A password and physical access restriction (sealing the front panel) can be used to protect against unauthorized entry into the programming mode. All flowmeter setup operations must be completed before the start of measurements.

5.2 Digital display

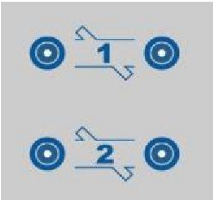
After turning the power on, the firmware is initialized and self-diagnosis of the components runs (the following message will appear briefly: PIEZOSONIC, Software Version 1.2) – the process takes about 5 s, after which the flowmeter is ready for operation.

The front panel display indicates in two lines the values being measured (Figure 5.1) - the <Up> and <Down> arrow buttons allow selection of visible parameters from the list of available ones.

Figure 5.1. Movable window of the list of parameters of a 2-channel flowmeter

5.3 LED indicators

On the front panel there are additional single indicators for diagnosing the operating state of the PET transmitters on the MS (Figure 5.2).



– beam 1 – the LED lights up green during the MS normal operation. A red LED indication or no lights indicate operational errors or malfunctions.
– beam 2 – indication similar to beam 1.

Figure 5.2. The MS status indication on the front panel of EM

6 Before Operation

6.1 Installation

The installation of flowmeter components is carried out in accordance with instructions 38978553.407251.008 IM.

In case that PET is being installed on a pipeline, it will be necessary to perform all measurements for MS described in the installation instructions (these dimensions are used for programming the operation and verification of flowmeter).

Note: The manufacturer and authorized service centers provide services for setting up and launching the flowmeter.

Electrical connections of components are made according to the selected application diagram (Appendix D).

It is possible to combine several flowmeters operating in an RS-485 network. In addition to flowmeters, other devices operating on a similar protocol can be connected to the information network, Figure D.5 (Appendix D). In order to ensure conflict-free operation of the devices, the following conditions shall be observed:

- each device in the RS-485 network shall be assigned a unique number from 0 to 246;
- all devices in the network and computer SW must operate at the same data exchange rate.

The operating parameters of the RS-485 interface are specified in Appendix E.

6.2 Test run

After installing the measuring section and filling the pipeline with liquid, the flowmeter is ready for operation. Upon power-up, a self-diagnostic process begins, checking the main components and software integrity. If any malfunctions occur, a relevant error message will be displayed.

After the initial boot-up is complete and the internal check is successfully completed (this process takes approximately 15 seconds), the flowmeter will automatically start measurements using the parameters last configured by the user (setting up during installation or initial factory configuration). The measurement results will be shown on the display.

In operating mode, the display shows the accumulated value of liquid volume passed through each connected MS and the current flow rate value through the measurement channels.

Note: The accumulated value of the passed volume begins to change 15 seconds after the device is turned on. This time is required for the flowmeter to reach a steady-state operating mode.

If there is no flow rate, the digital display will show a zero value of 000000.000, while:

- there are no pulses at the frequency output;
- a signal is set at the current output, 4 mA;
- a zero value of the actual flow rate is transmitted via the digital interface

6.3 Operation modes and configuration menu

The flowmeter has modes that differ in the level of access to the information indicated on the display and the capabilities to change settings:

- OPERATION is the user operating mode; set when the power is turned on and enables reading of measurement data by service personnel, as well as viewing of the archive parameters from the front panel of EM.

- SERVICE mode is used during getting started for operation, as well as before starting the flowmeter at the site of operation:

- setting the instrument time and calendar data;
- entering service information into memory (address and speed in the RS-485 network, as well as other parameters that do not affect measurements);
- zeroing out information in the archives of non-volatile memory.

During initial and periodic inspections, full access to viewing and changing the required parameters is password-protected:

- set flowrate measurement units (m^3/h; m^3/s; l/min);
- set volume measurement units (m^3; l);
- set measurement results processing parameters;
- adjust process parameters;
- configure parameters for the archive recording period.

The flowmeter operating mode is selected using buttons on the front panel. The parameters indicated on the display are given in the tables in Appendix G, and the menu structure and its description are in Appendix I of this manual.

Parameter settings menu

In order to switch from the main operating mode to the SERVICE menu, hold down the <ENTER> button for at least 3 seconds, until the first line of SERVICE is on the display.

The SERVICE menu main sections are as follows: **About instrument, SFT settings, PET1 settings, PET2 settings, Change passwords.** The purpose of all menu items is described in detail in Appendix I.

The arrow buttons <Up/Down> switch menu sections, and transition to a section is performed by pressing the <ENTER> button.

It is possible to change parameters only after entering password corresponding to the user access rights (ENG or ADM), which is specified in menu section About instrument|User.

6.4 Factory settings of parameters

Programmable settings are stored in the EM non-volatile memory and comply with the order. At the same time, a number of flowmeter parameters have factory default settings, which can be changed from the front panel of EM using buttons, as well as using external SW. The main ones of them are indicated in the passport:

– SW version identification number;

– serial number and month/year of manufacture;

– nominal diameter, Dn, on the pipeline measuring section;

– installation dimensions of PET at the measuring section;

– calibration coefficients depending on the measured medium type.

Notes:

1) When the flowmeter is supplied without MS, the correction factors (K_{corr}) are set equal to 1.000, and their adjusted value must be set by the customer during commissioning in accordance with the installation instructions.

2) If the flowmeter can be tested at the site by using the flushing method verification with the specified accuracy grade, the correction factor (K_{corr}) can be used for correction based on the flushing results.

Additional factory settings are as follows:

– measurement values hold time 20 s;

– for the RS-485 communication interface: speed is 9600 baud (bps); Modbus RTU protocol (8 data bits + 1 stop bit) without parity check; network address 1;

– in the SERVICE menu, the following are factory passwords for user groups:

USR – general access for viewing, no password required;

ENG – (engineer) password 2000000 (standard factory password);

ADM – (administrator) password 3000000 (default factory password).

After completing the setup, we recommend setting a new unique password to access the parameter changing menu: Change passwords|Password ENG and Change passwords|Password ADM.

6.5 Settings change and check

6.5.1 Checkup of the flowmeter **settings conformity** with the actual specifications indicated in the passport can be performed by using a special program on a PC. In order to do this, connect EM to computer via an RS-485/USB interface converter, as shown in Appendix D, and use the SiMaster program, see Appendix J.

The flowmeter settings (including the pipe internal diameter and operating range) should be compared with the passport data.

6.5.2 Setting the instrument date and time can be done by using buttons on the flowmeter EM front panel or from the SiMaster program.

Date and time settings using in the flowmeter SERVICE menu:

– select **SFT Settings|Clock Adjustment**;

– use the <Left> button to move the cursor sequentially to the "day", "month", "year", "hours", "minutes" position;

– in each position, use the <Up> or <Down> buttons to change the value of the selected parameter.

The set value is saved by pressing the <ENTER> button.

Settings through the SiMaster SW is by following steps:

1) start the SiMaster program on PC: extract the program archive file and open the SiMaster folder, wherein, start the executable SiMaster.exe file;

2) select the COM Settings. Specify the communication parameters: the number of the COM port being used, the communication speed

(38400/19200/9600/4800 bps), and the polling timeout (valid values are from 100 to 2000 ms). When making changes to the parameters, first click the Save button, and then the Next button;

3) select the Device Search command; specify the range of addresses polled in the network. By default, all addresses from 1 to 247 are polled sequentially (address 255 is reserved for working with one flowmeter).

When making changes to the parameters, first click the Save button, and then the Next button; an automatic search will start for instruments connected to the RS-485 network and the list of those available will appear in the List of Devices section;

4) in the Device List, select the device and check the operating parameters on the tabs of the software;

5) open the Status tab, select the Set Date to correct the values;

6) In order to end the communication session press button  .

7 Operation of Flowmeter

7.1 General information

7.1.1 The flowmeter passport should indicate the date of commissioning, the report number and date of approval by the management of the customer. It is also recommended to make notes in the passport regarding operation: the composition of the measured medium, installation location, data on verification and maintenance, malfunctions that occurred and causes.

WARNING!
It is prohibited to operate the flowmeter in inappropriate climatic conditions, as well as at a temperature of the measured medium below or above the permissible limits.

7.1.2 The flowmeter does a self-diagnosis after turning on. Then signal values corresponding to the measured parameter are set at the outputs.

7.1.3 The flowmeter operates continuously in automatic mode.

7.2 Troubleshooting

7.2.1 During operation of the flowmeter, malfunctions may occur that require a response from service personnel. Table 7.1 provides information about possible malfunctions and troubleshooting.

7.2.2 In case of malfunctions not listed in Table 7.1, contact the manufacturer for additional information.

7.2.3 Claims will not be accepted in cases of the Item manufacturer seals damaged and there are defects caused by violation of rules of operation, transportation and storage.

7.2.4 The flowmeter can be repaired by the manufacturer or an organization authorized to do so. Before sending for repair, the operating company must make a report indicating the date and circumstances of the failure.

7.2.5 If the flowmeter is sent for repair it must be cleaned of residual working medium and other contaminants on the internal and external surfaces.

Note: If it is impossible to restore the flowmeter, the manufacturer can replace the entire product or its components with similar ones.

7.2.6 The manufacturer reserves the right to refuse repair if there are obvious signs of unqualified interference in the product.

Table 7.1. Troubleshooting

Problem	Cause	Troubleshooting
1. When the electronic module (EM) is connected to the power, the LEDs and display do not light up	No supply voltage	Check for power supply voltage at the EM terminals and, if absent, provide power supply
2. The instrument does not go to the measurement mode, the red LED lights up	Operating mode of the instrument is selected	Check electronic module settings
	Contact connections to PET are damaged	Check reliability of contact connections with PET
	No water in pipeline	Make sure there is water in the pipeline
3. Red LED lights up periodically	There is an air plug	Open vent and remove the air plug
	There are solid inclusions in the liquid or air bubbles in the liquid in volumes exceeding those specified in the OM	Eliminate violations of operating conditions
4. Flow rate readings increase over time for no apparent reasons	Deposits on the internal surface of the MS caused a decrease in the pipe internal diameter	Clean the inside surface of the MS or measure the actual inside diameter and reprogram the instrument. Make verification.
5. Unable to establish communication with flowmeter via RS-485 interface	Network address or communication speed settings are wrong	Check address in the network and communication speed settings
	Communication equipment connection is not matched	Check the equipment for communication with PC (interface converter)
6. Output current is greater than 20 mA or less than 4 mA	Flowmeter current outlet is damaged	Needs repairs by Manufacturer
7. Measurements are unstable, the measurement error exceeds permissible	Deposits on the PET emitting surface that inhibit passage of the US signal	Clean the PET emitting surface and its installation area from dirt
	Flowmeter components are faulty	Prepare a set of documentation for the installation site, send it to the manufacturer along with photo/video evidence. After receiving the Manufacturer's response about readiness to accept the instrument - send it for repair

8 Maintenance and Verification

8.1 Maintenance shall be carried out at least once every six months and consist of removing dust and dirt, as well as preventive inspections, during which the following is checked for:

- integrity of housings, absence of dents and visible mechanical damage;
- reliability of fastening of screw connections and the Item itself in the working position;
- no signs of loss of tightness in the pressure supply lines;
- no damage to the insulation in the connecting electrical cables;
- condition of grounding (the grounding bolts must be rust-free and tightened; clean and tighten if necessary);
- make sure that the electrical contacts of the termination box are in good condition (tighten the screw connections of the termination box if necessary);
- make sure that the sealing of the supply cables is reliable.

DO NOT operate the flowmeter with visible mechanical damage.

8.2 During operation, the flowmeter is subject to periodic verification in accordance with the passport data. Verification of the flowmeter shall be carried in terms of flow rate and volume measurement functions in accordance with the verification methodology approved in the prescribed manner. In this case, the initial verification:

1) of instruments with MS and nominal diameter Dn≤1600 mm shall be carried out at the manufacturer by flushing or simulation method according to the Verification Methodology;

2) of instruments with MS and nominal diameter Dn≤1600 mm shall be carried out by simulation method according to the Verification Methodology;

3) of instruments without MS shall carried out according to the Verification Methodology, according to which verification of the EM of the instrument shall be carried out at the manufacturer, and determination and input of geometric parameters and calibration factors shall be carried out at the site of operation in the presence of a verification officer.

8.3 The established verification interval is 4 years.

9 Supply Kit

9.1 The flowmeter, depending on the size of the pipeline nominal diameter Dn, has a different design:

– for Dn from 50 to 600 mm it can be supplied with MS, on which PETs are already installed, and without MS, but supplemented with PETs and their holders for subsequent welding on the pipeline (according to installation instructions 38978553.407251.008 IM);

– for Dn over 600 mm only PETs are supplied with holders for subsequent welding on the pipeline (according to installation instructions 38978553.407251.008 IM).

9.2 For a flowmeter supplied without a measuring section (PETs are cut into the pipe), the supply kit is indicated in Table 9.1.

Table 9.1. Measuring instrument supply kit

Article	Quantity
Electronic module of the PIEZOSONIC flowmeter	1 pc.
Piezoelectric transducers (PET)	2 / 4 pcs*
Connecting cables RK 50-2 for PET	according to order
Installation Kit for PET: – PET holder with nut (per number of transmitters) – O-ring (per number of transmitters)	 2 / 4 pcs 2 / 4 pcs
Technical Passport. PET-3-4 (per a set of 2 pcs)	1 / 2 pcs
Technical Passport. 38978553.407251.008 PS	1 copy
Operation Manual. 38978553.407251.008 RE	1 copy**
Installation and configuration instructions. 38978553.407251.008 IM	1 copy per batch **

* Quantity specified when ordering.
** Electronically available on the manufacturer website.

9.3 For the flowmeter supplied with the MS, the supply kit is shown in Table 9.2.

Table 9.2. Measuring instrument supply kit

Article	Quantity
Electronic module of the PIEZOSONIC flowmeter	1 pc.
Measuring section with installed PETs (for Dn up to 600 mm)	from 1 to 2 pcs*
Connecting cables RK 50-2 for PET	according to order
Technical Passport. PET-3-4 (per a set of 2 pcs)	1 / 2 pcs
Technical Passport. 38978553.407251.008 PS	1 copy
Operation Manual. 38978553.407251.008 RE	1 copy**
Installation and configuration instructions. 38978553.407251.008 IM	1 copy per batch **

* The quantity and parameters of the supplied control unit are specified when ordering.
** Electronically available on the manufacturer website.

10 Marking, Sealing and Packaging

10.1 Marking

10.1.1 The Item can be identified by its manufacturing markings. The marking is made in a sticker on the side of the electronic module and contains (Figure 10.1) as follows:

– logo of the manufacturer;

– measuring instrument type approval mark;

– mark of product circulation on the market of the Customs Union states;

– item name and Ordering Code (Appendix A);

– factory serial number (S/N), month and year of manufacture;

– degree of protection against water and dust of EM as per GOST 14254 (IP code);

– working temperature of operation for EM (T=0…+50°C);

– degree of protection against water and dust of UFT as per GOST 14254 (IP code);

– inscription Made in the Russian Federation;

– URL of the manufacturer's website.

10.1.2 The measuring section must bear designations in accordance with the manufacturer's technical documentation for this Item.

10.1.3 PET holders are marked with numbers (1, 2, 3, 4) in pairs (operating in one transmitter beam), starting from the one installed first downstream.

Figure 10.1. Example of identification sticker for EM

10.1.4 Transport marking of packages with packaged devices must comply with GOST 14192 and a set of design documentation.

Handling signs *This side up, do not turn over!* and *Fragile. Handle with care* must be applied to the box with instruments. Marking must be applied to paper and plywood labels typographically, by stamping, stenciling or, depending on transportation conditions, directly on the box using stenciling. The name of the consignee and destination are allowed to be written clearly and legibly by hand.

10.2 Sealing

10.2.1 In order to confirm the completed initial or periodic verifications, as well as to prevent unauthorized interference in the settings, sealing is performed in the places where the housing cover is secured.

10.2.2 Sealing is carried out by installing a QCD or verification officer mastic seal onto the housing screws of the design of EM.

10.3 Packaging

10.3.1 The flowmeter is packaged in a special container of the manufacturer, made in accordance with the requirements of GOST 9.014.

10.3.2 It is allowed to pack the installation elements of the flowmeter in a separate box.

11 Transportation and Storage

11.1 In the Manufacturer standard container, the flowmeter can be transported in closed transport of any type and over any distance. Transportation can be carried out at an ambient temperature from -35 to +55 °C, subject to protection measures against impacts and vibrations.

11.2 Flowmeters in transport container withstand the effects of vibration for Group F3 as per GOST R 52931.

11.3 Flowmeters must be stored in the shipping container. Ventilated areas should be selected where condensation on the surface is excluded. The air in the room should not contain dust, acid and alkali vapors, or gases that cause corrosion. Storage temperature from -10 to +50 °C.

12 Manufacturer Warranty

12.1 The manufacturer's warranty period is for 12 months from the date of installation of the Item recorded in the passport, but not more than 24 months from the date of sale.

12.2 In the event of failure of the Item during the warranty period, provided that the consumer complies with the rules of transportation, storage, installation and operation, the manufacturer undertakes to repair it free of charge or replace it. For repairs, contact the address specified in the Item passport.

13 Service Life and Lifetime

13.1 Operating mode is continuous.

13.2 Average non-failure operating life, min. 65,700 hrs

13.3 Average service life is 10 years (this reliability indicator is set for normal operating conditions: non-aggressive environment, temperature +(20 ±5) °C, no vibration or shaking).

13.4 The flowmeter state of operability average restoration time is no more than 1.5 hours.

14 Information on Disposal

14.1 The Item is environmentally safe: does not contain toxic substances and chemical materials, does not pose a danger to human health and the environment.

14.2 After the specified service life runs out, the company operating the Item shall determine the disposal procedure.

APPENDIX A. Structure of Ordering Code

PIEZOSONIC	-XX	-XXXX	-XX	-XXXX	-XX	-XX	-XX	-XXXXX	-X	-XXXX
1	2	3	4	5	6	7	8	9	10	11

1) flowmeter name;

2) version:
11 – single-channel single-beam, PET 1 pair, electronic module in a plastic housing IP65;
12 – single-channel two-beam, PET 2 pairs, electronic module in a plastic housing IP65;
22 – two-channel, one beam per channel, PET 2 pairs, electronic module in a plastic housing IP65;

3-5) Parameters of the measuring section

Version without measuring section

- permissible pressure:

PN10 – 1.0 MPa;
PN16 – 1.6 MPa;
PN25 – 2.5 MPa;
PN40 – 4.0 MPa;
PN63 – 6.3 MPa;

- electronic module:

LV – MS not supplied, electronic module version LV, installation kit(s);
HV – MS not supplied, electronic module version HV, installation kit(s);

- measuring section:

XXX – MS not supplied;

Design version with measuring section

- permissible pressure:

PN10 – 1.0 MPa;
PN16 – 1.6 MPa;
PN25 – 2.5 MPa;
PN40 – 4.0 MPa;
PN63 – 6.3 MPa;

- Dn diameter of MS – with MS (Dn from 50 to 2000 mm); diameter of the measuring section (for a two-channel version, the diameter of MS is indicated in the format XXXX/XXXX):

0050 – Dn 50;
0065 – Dn 65;
0080 – Dn 80;
0100 – Dn 100;
0150 – Dn 150;
0200 – Dn 200;
0250 – Dn 250;
0300 – Dn 300;
…

6)Material of flow part (in case of two MS materials are indicated in the format XX/XX):
MS – carbon steel;
SS – stainless steel;
09– 09G2S;
XX – other;

7) Material of flanges (in case of two MS materials are indicated in the format XX/XX):
MS – carbon steel;
SS – stainless steel;
09– 09G2S;
XX – other;

8) electrical connection of the PET transmitters;
65 – PET – electrical connector DIN 43650C (IP65);
67 – PET – electrical connector M12x1 (IP67);
68 – PET – cable inlet (IP68);

9) cable length (all lengths from each PET are summed up, the same length is used for each PET pair, for two different PET pairs the length is indicated in the format XXXXX/XXXXX):
00000 – no cable;
XXXXR – RK-50 from 20 to 2000 m (maximum length 4×500=2000 m), e.g. 20 m - 0020R.

10) Verification type:
L – Verification by method of flushing;
N - No Verification. Verification of the version without MS is carried out at the flowmeter installation location;
P - Verification by method of simulation.

11) Additional options:
0 – no;
TG: TAG number (stainless steel plate);

C2 - Welded mounting adapters for PET-3-4 made of carbon steel, 2 pcs

S2 - Welded mounting adapters for PET-3-4 made of stainless steel, 2 pcs;

C4: Welded mounting adapters for PET-3-4 made of carbon steel, 4 pcs;

S4: Welded mounting adapters for PET-3-4 made of stainless steel, 4 pcs;

Notes:

1. When ordering Instrument with two independent channels for operation in different pipelines, "/" is used to indicate separation of the parameter values: Dn, method of PET installation. Pipelines on which the flowmeter transmitters operate may differ in diameter, according to the following conditions: $0.5 \cdot Dn1 \leq Dn2 \leq 1.5 \cdot Dn1$.
2. The flow measurement scale is selected in accordance with the measurement range of flow rates ($Q_{max}...Q_{min}$) for the corresponding nominal diameters Dn specified in Table A.1.

Note: the table shows the flow rate values for the version with straight measuring sections.

Appendix A continued

Table A.1

Nominal diameter Dn, mm	Lower Range Limit of flow rate Q_{min}, m^3/hr	Upper Range Limit of flow rate Q_{max}, m^3/hr
50	0.47	73
65	0.8	124
80	1.2	186
100	1.87	290
150	4.24	656
200	7.5	1164
250	11.8	1830
300	17.0	2640
400	30.72	4800
500	48.00	7500
600	69.12	10,800
700	94.08	14,700
800	122.88	19,200
900	155.52	24,300
1000	192.00	30,000
1200	276.48	43,200
1400	376.32	58,800
1600	491.52	76,800
2000	768.00	120,000

Example of the ordering code:
PIEZOSONIC-11-PN16-DN-0100-MS-MS-65-0020R-L-0, that corresponds to:

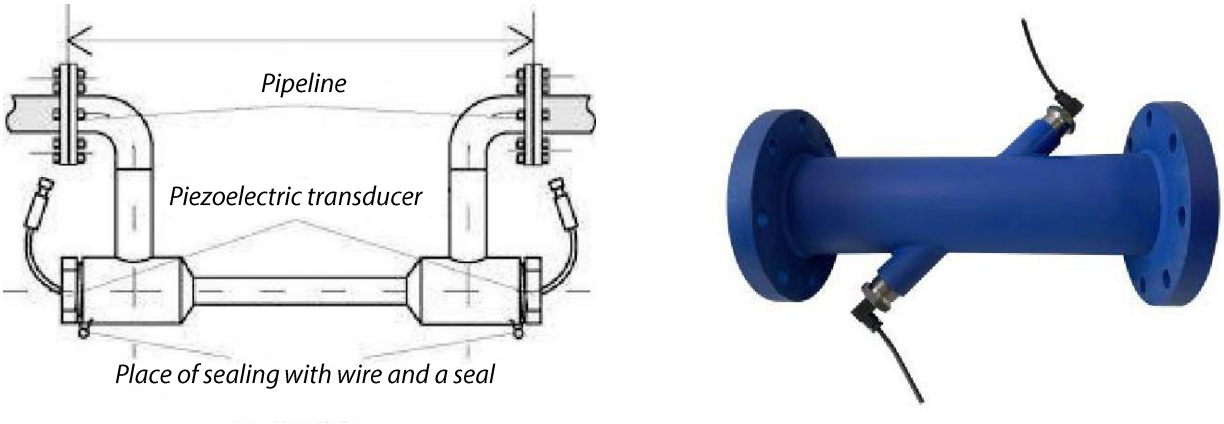
Modification	11: single-channel single-beam, PET 1 pair, electronic module in a plastic housing IP65;
Diameter of measuring section	PN16-DN100: With measuring section, DN 100, PN 1.6 MPa;
Material of flow part	MS: carbon steel;
Material of flanges	MS: carbon steel;
Electrical connection of the PET transmitters;	65: PET – electrical connector DIN 43650C (IP65)
Cable length	0020R: PK-50 20 m;
Verification type:	L: Verification by method of flushing;
Additional options:	0: N/A;

Note: When ordering the PET transmitters, specify the type of electrical connections in the code:

– PET-3-4 – connector DIN 43650C (IP65);
– PET-3-4-M – connector M12x1 (IP67);
– PET-3-4-S-100 – cable gland (IP68), e.g., 100 m (the last number).

APPENDIX B. The Overall and Mounting Dimensions

Figure B.1. Appearance of flowmeter components: example of a measuring section with installed PET transmitters (without connecting cables) and EM



a) b)

Figure B.2. Design versions of measuring section:
a) with U-pipeline;
b) with a straight pipeline according to a single-beam scheme with a diametrically positioned acoustic channel

Appendix B continued

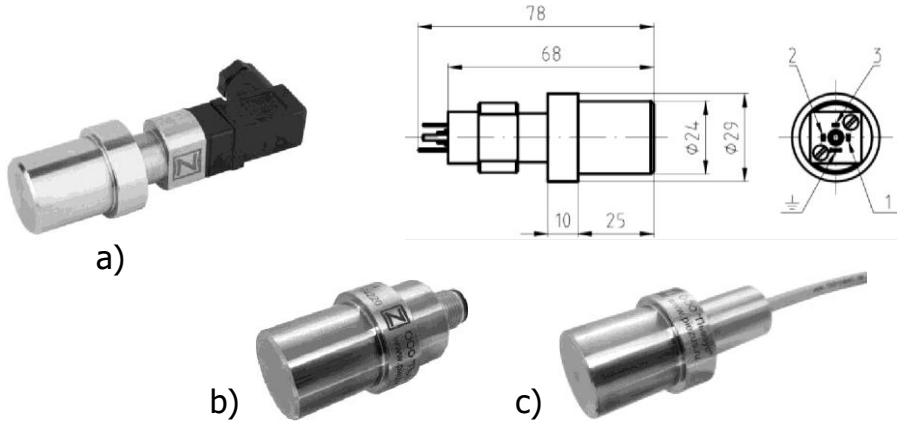


Figure B.3. View of PET-3-4 for the following versions:

a) IP65 with DIN 43650C connector (contacts: ⏚ – common; 1 – signal)
b) IP67 with connector M12x1; c) IP68 with cable gland

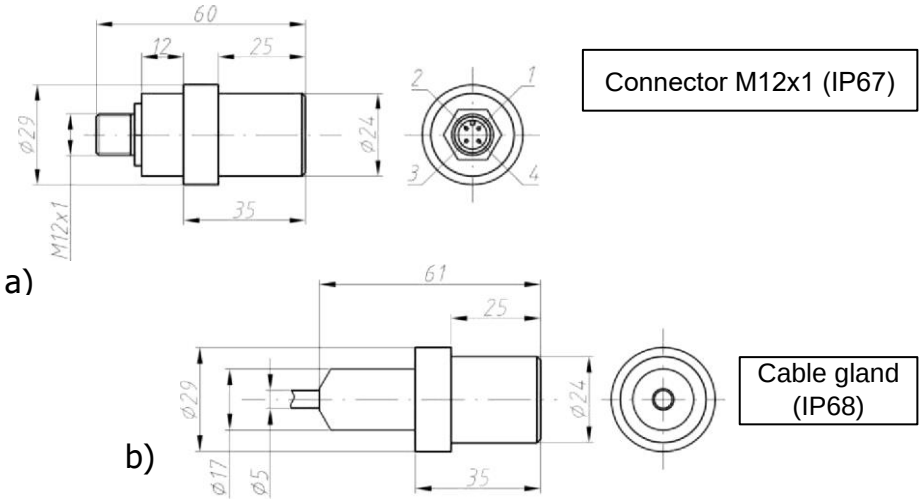


Figure B.4. Overall dimensions of PET-3-4 transmitters:
a) design version IP67 with connector M12x1; b) design version IP68 with cable gland

Appendix B continued

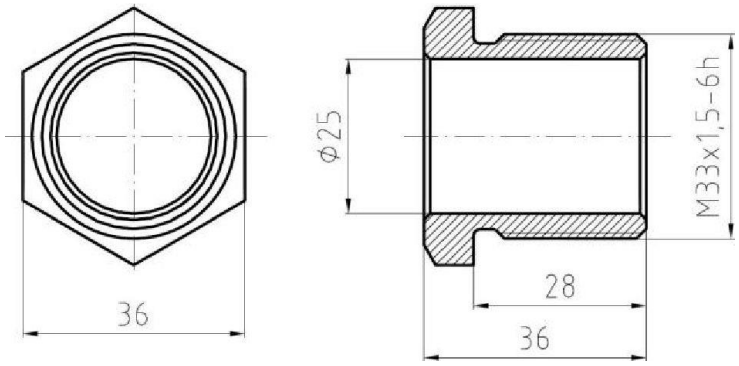
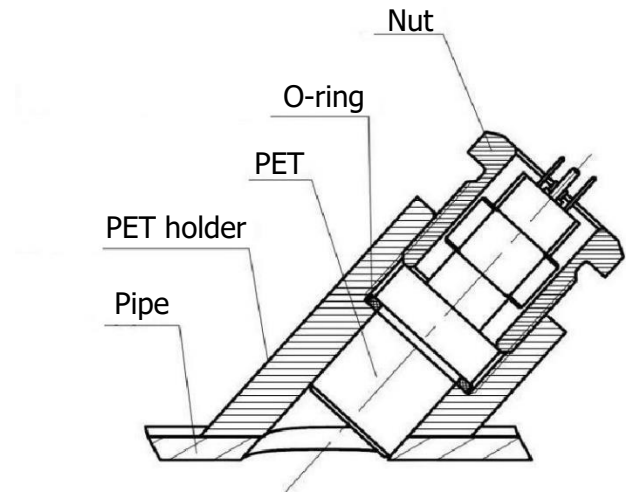


Figure B.5. Nut for fixing PET in the holder



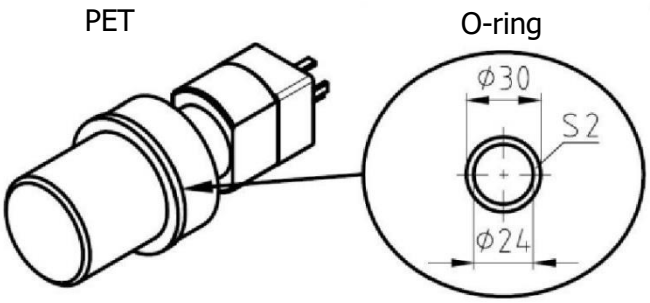
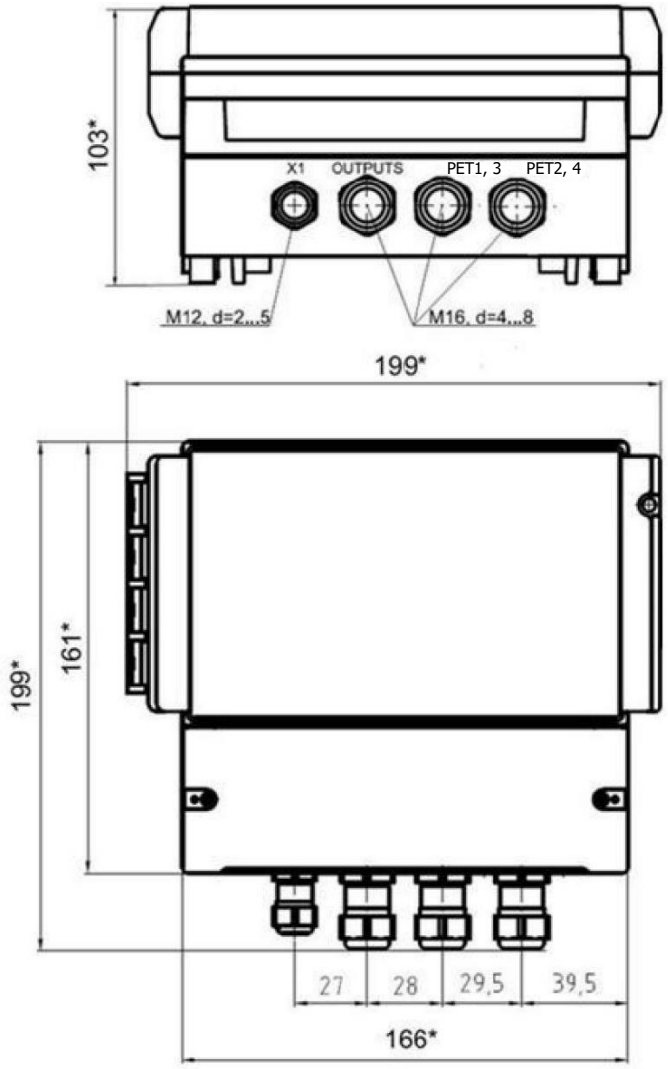


Figure B.6. Fixing PET in the holder on the pipe using O-ring

Appendix B continued



* Reference dimensions

Figure B.7. Overall dimensions of the electronic module (longer cable inlets, if necessary, can be installed)

Note: Manufacturer reserves the right to make changes to the design and circuitry of the Item that do not degrade its performance.

Appendix B continued

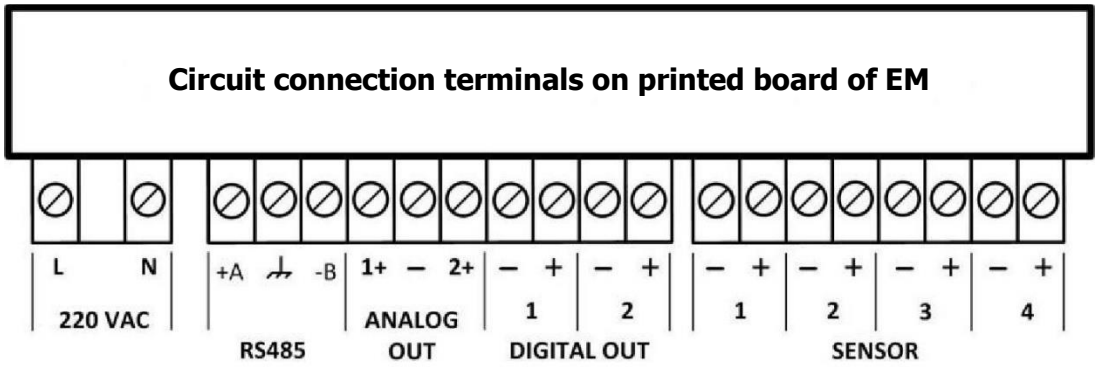
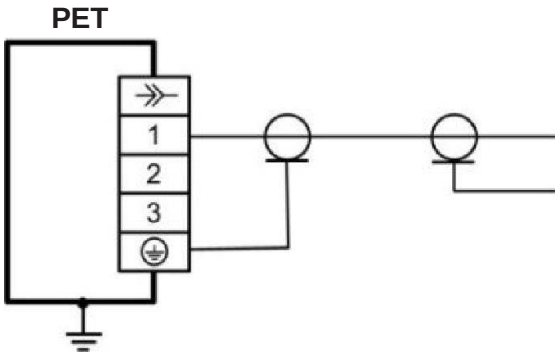


Figure B.8. Circuit arrangement on the terminal block of electronic module for electrical installation

PET connection layout



PET circuits connection options

Transmitter circuits	Pins		Cable gland of the wire
	DIN 43650C	M12x1	
signal	1	1	white
housing	⏚	4	brown

Figure B.9. Connection of the PET transmitter circuits

APPENDIX C. Front Panel of Display and Control

The flowmeter has the following control and display elements:

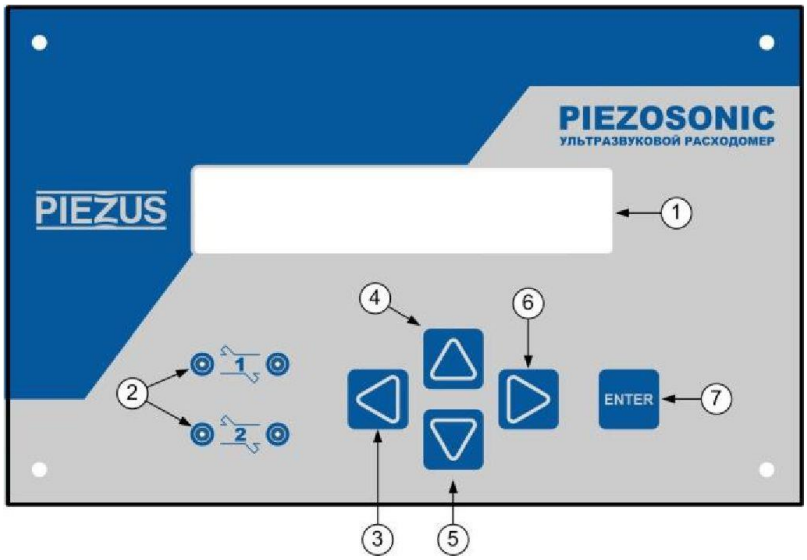


Figure C.1 Purpose of the front panel elements:
1 – 2-line display; 2 – indication of the operating status of the PET transmitters;
3 – button for moving cursor left; 4 and 5 – two buttons for moving cursor up or down;
6 – button for moving cursor right; 7 – <ENTER> – button
for confirming command selection during programming and menu navigation.

Press the <ENTER> button for at least 3 s to transit from main operating mode to the setting mode (SERVICE). The Instrument automatically returns from setting mode to operating mode if buttons on the front panel are not pressed for 5 minutes.

Returning to the previous menu level (rejecting to change a parameter) is done by pressing the <Up> button for at least 3 seconds.

A password (see Programming Menu, Appendix I) and physical access restriction (sealing the cover of EM) can be used to protect against unauthorized entry into the programming mode.

Use the arrow buttons to change the value of a programmable parameter:

<Right> selects the parameter value digit (the selection is confirmed by the corresponding symbol flashing);
<Up> makes cyclic variation of the number of the selected digit.
The <ENTER> button selects menu items or confirms the entry of a changed value.

APPENDIX D. Electrical Connections

In the diagrams, numbers 1, 2, 3, 4 indicate the numbers of the PET transmitters installed on the pipe; the arrow indicates the direction of liquid flow.

Single-Channel, Single-Beam Flowmeter

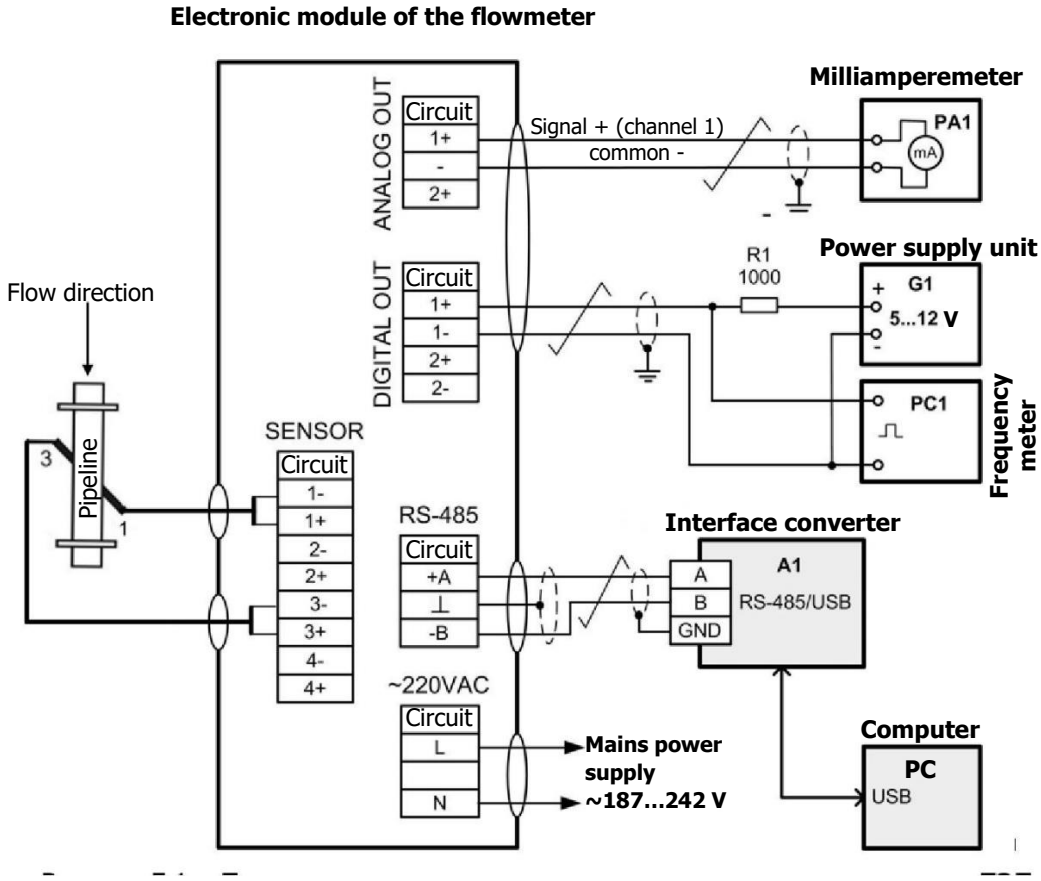


Figure D.1. Connecting a single-channel flowmeter when installing PET along a chord on a pipe: G1 is stabilized power supply unit converting 220 V AC to 12 V DC (output current up to 100 mA); PA1 is 4–20 mA milliammeter (or ACS controller input); PC1 is 0–2000 Hz range frequency meter (or ACS controller input); A1 is interface converter of any type of RS-485/USB; PC is Personal computer

The voltage value of the external power source G1 and the impedance of resistor R1 are selected taking into account the following limitations: $U \leq 35$ V; $R1 \geq U/0.05 = 700$ Ohm. The power of resistor R1 is determined by the formula: $P = U^2/R1$ [W].

Appendix D. continued

Single-Channel, Two-Beam Flowmeter

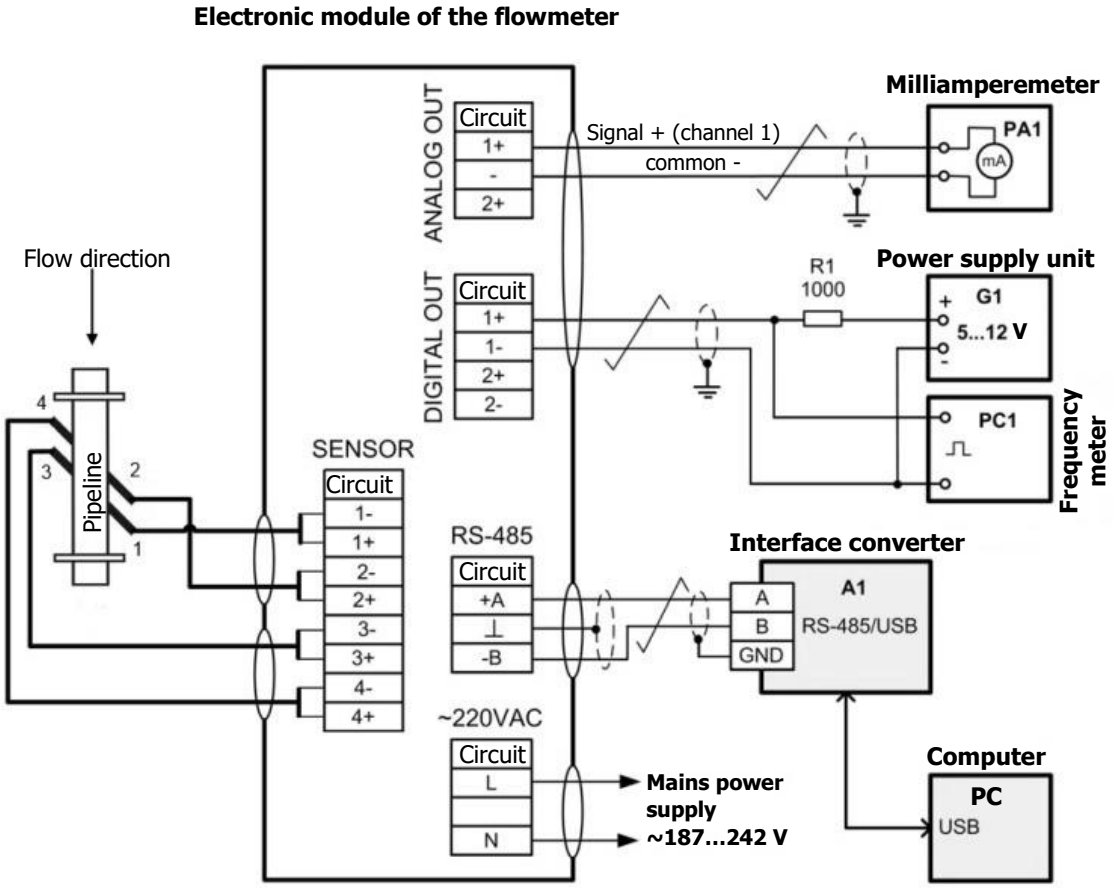


Figure D.2. Connecting a single-channel flowmeter when installing PET along 2 chords on a pipe: G1 is stabilized power supply unit converting 220 V AC to 12 V DC (output current up to 100 mA); PA1 is 4–20 mA milliammeter (or ACS controller input); PC1 is 0–2000 Hz range frequency meter (or ACS controller input); A1 is interface converter of any type of RS-485/USB; PC is Personal computer

Note: It is recommended to use an RS-485/USB interface converter with galvanic circuit isolation.

Appendix D continued

Two-Channel, Two-Beam Flowmeter

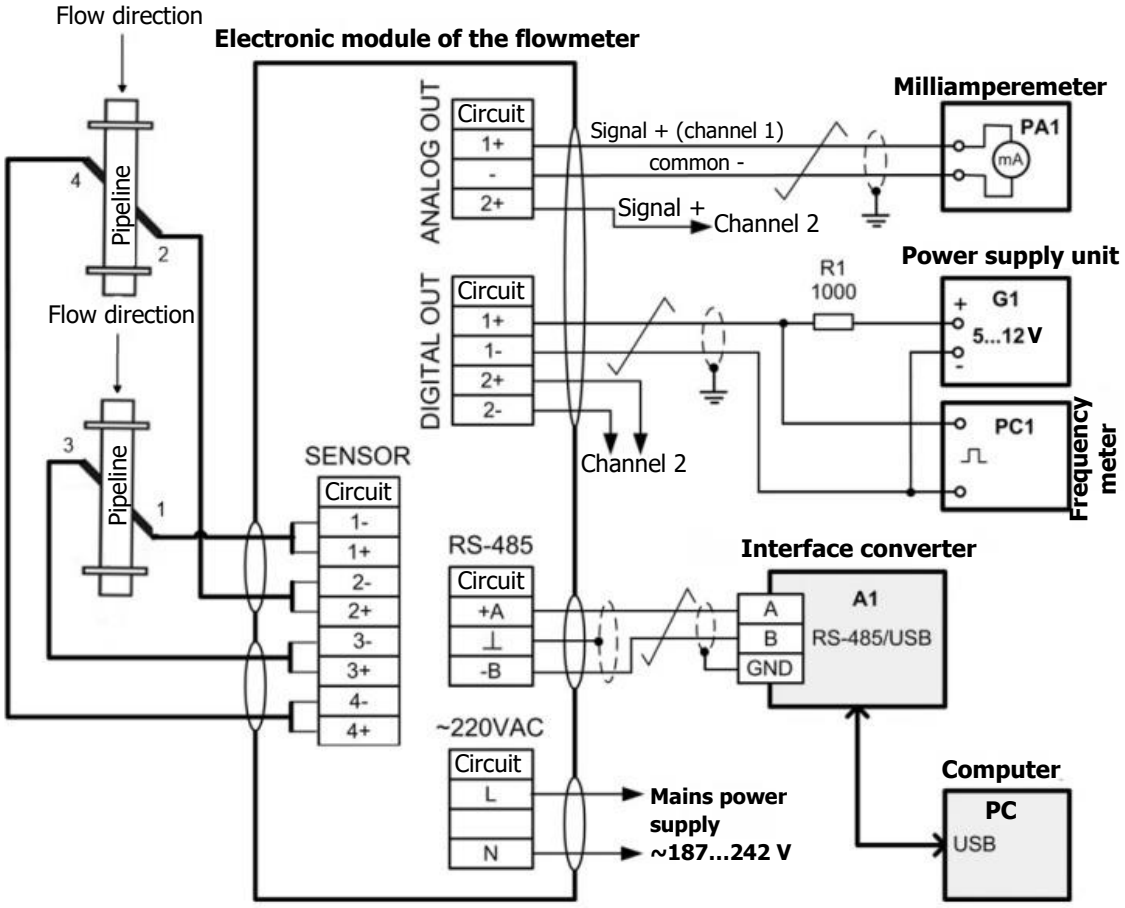


Figure D.3. Connection of a two-channel flowmeter when installing PET on different pipes along the chords (the outputs of the second measuring channel are connected in the same way as the first): G1 is stabilized power supply unit converting 220 V AC mains voltage to 12 V DC (output current up to 100 mA); PA1 is 4–20 mA current milliamperemeter (or ACS controller input); PC1 is 0–2000 Hz range frequency meter (or ACS controller input); A1 is RS-485/USB interface converter; PC is personal computer

Appendix D. continued

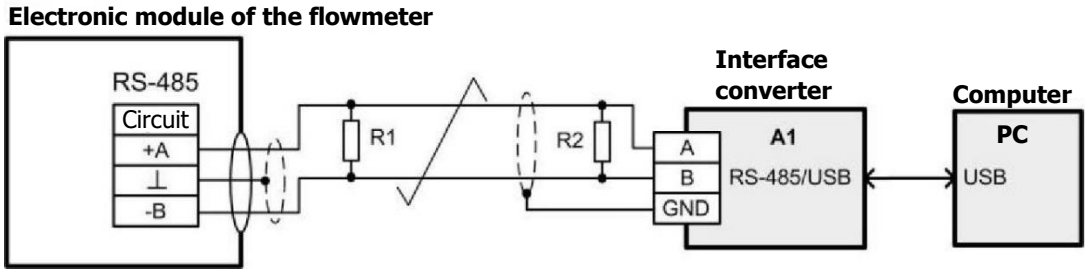


Figure D.4. Connection diagram of the RS-485 interface to a computer (or ACS system) when working on a long line: R1, R2 – C2-33m-0.25-120 Ohm ±5%

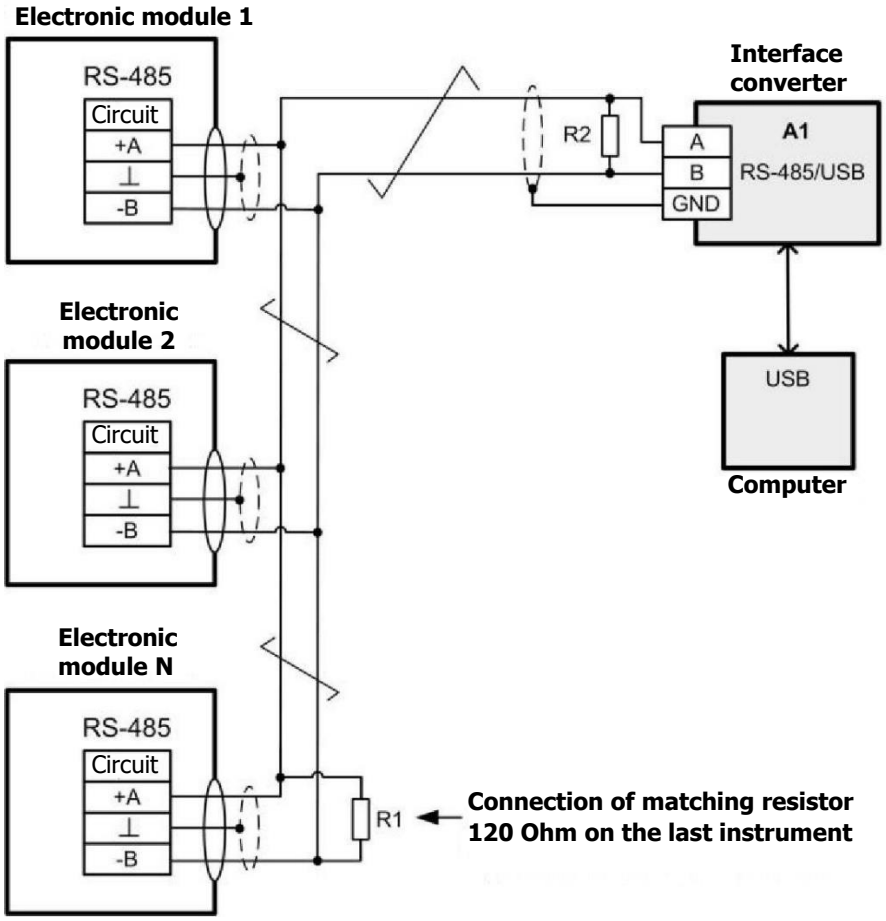


Figure D.5. Connection of multiple units in a local network via the RS-485 interface to a computer (or ACS system) when working on a long line: matching resistors R1, R2 – C2-33m-0.25-120 Ohm ±5%

APPENDIX E. RS-485 Interface Operation Parameters

In order to integrate the flowmeter into automated monitoring and control system, the user may need to develop proprietary software to read the data. Description of the exchange protocol (Modbus RTU):

1) Exchange rate is 9600 baud (when manufactured): 8 data bits, 1 start bit, 1 stop bit.
2) Two values can be requested from the flowmeter:

– accumulated value of volume by function 3 (value format **signed long, 32 data bits**);
– current flow rate by function 3 (value format **float**).

3) SL is network number of the Instrument on the RS-485 line.

Format of request frame:

SL address	Function	Initial address (lower byte)	Initial address (top byte)	Not used	Not used	CRC lower byte	CRC top byte
byte 0–255	3	1-6 (collective number of channel)	0	–	–	byte	byte

Format of request frame:

SL address	Function	Number of data bytes	lower byte [0] long	byte [1] long	byte [2] long	top byte [3] long	lower byte [0] float	Byte [1] float	byte [2] float	top byte [3] float	CRC lower byte	CRC top byte
0–255	3	8	byte	byte	byte	byte	byte	byte	byte	byte	byte	byte
			\ volume data 4 bytes /				\ flow rate data 4 bytes /					

CRC calculated by subprogram crc():

```
unsigned int crc(unsigned char buf[],unsigned char start,unsigned char cnt)
{
    unsigned char i, j;
    unsigned int temp, flag;
    temp = 0xFFFF; /*       */
    for (i = start; i < cnt; i++)
    {
        temp = temp ^ buf[i];
        for (j = 1; j <= 8; j++)
        {
            flag = temp & 0x0001;
            temp = temp >> 1; /*    */
            if (flag) temp = temp ^ 0xA001;
        }
    }
  return(temp);
}
```

APPENDIX G. Parameters Indicated on Display

Table G.1. List of parameters displayed in OPERATION mode

Par. No.	Display indication		Physical meaning of operating parameter
	Parameter symbol	Format and measurement units	
1	Time	XX.XX.20 XX:XX	Calendar: date.month.year. Current instrument time: hours:minutes
2	Q1	+XXXXX.XX m^3/hr	Current flow rate by channel 1 in cubic meters per hour (+in forward direction)
3	Q2	+XXXXX.XX m^3/hr	Current flow rate by channel 2 in cubic meters per hour (+in forward direction)
4	V1	+XXXXXXXXX.XX m^3	Accumulated volume by channel 1 (+in forward direction)
5	V2	+XXXXXXXXX.XX m^3	Accumulated volume by channel 2 (+in forward direction)
6	Turn-on time	000XX:XX	Instrument turn-on time: hours:minutes
7	Time in service	000XX:XX	Cumulative time in service: hours:minutes
8	Errors	00 00 00 00	Code of the last error entered in event archive. Their list is in Table G.4

Table G.2. Main parameters of SRVICE mode (SFT settings)

Group		Display indication		Physical meaning of operating parameter
		Parameter symbol	Measurement units	
SFT settings / Measuring	Parameters	C_{min}	m/s	Threshold value: minimum US speed in liquid; if lower, the measurements are incorrect
		C_{max}	m/s	Threshold value: maximum US speed in liquid; if higher, the measurements are incorrect
		Holding	s	Holding time of outputs in case signals are lost
		U_{pul}	V	Amplitude of impulse voltage fed to PET

Appendix G continued

Table G.2 continued

SFT settings / Measuring	Parameters	K_{gain}	–	Gain factor of US signal in EM
		Signal 1	–	Signal power of beam 1 in conditional units from 0 to 255
		Signal 2	–	Signal power of beam 2 in conditional units from 0 to 255
	Flow rate	Lower end cutoff of channel 1	m^3/hr	Cutoff of flow value from bottom for PFT1, if lower consider it zero
		Upper end cutoff of channel 1	m^3/hr	Cutoff of flow value from top for PFT1, if higher record this value
		Lower end cutoff of channel 2	m^3/hr	Cutoff of flow value from bottom for PFT2, if lower consider it zero
		Upper end cutoff of channel 2	m^3/hr	Cutoff of flow value from top for PFT2, if higher record this value
		Setup of zero 1	–	Setup of zero for channel 1 on motionless liquid
		Setup of zero 2	–	Setup of zero for channel 2 on motionless liquid
	Utility (beam 1)	t11	ns	Time of passage up for beam 1
		t12	ns	Time of passage down for beam 1
		t1avg	ns	Average time of passage for beam 1
		dt1	ns	Time difference of passage up and down for beam 1
		C1	m/s	Speed of ultrasound for beam 1
		T1	°C	Temperature of working medium for beam 1
		Q_t1	m^3/hr	Flow rate without correction (approximate) by data of beam 1
		Signal 1	–	Signal power of beam 1 in conditional units from 0 to 255
	Utility (beam 2)	t21	ns	Time of passage up for beam 2
		t22	ns	Time of passage down for beam 2
		t2avg	ns	Average time of passage for beam 2
		dt2	ns	Time difference of passage up and down for beam 2
		C2	m/s	Speed of ultrasound for beam 2
		T1	°C	Temperature of working medium for beam 2
		Q_ t2	m^3/hr	Flow rate without correction (approximate) by data of beam 2
		Signal 2	–	Signal power of beam 2 in conditional units from 0 to 255

Appendix G continued

Table G.3. Main parameters of SERVICE mode (PFT1 and PFT2 settings)

Group	Display indication		Physical meaning of operating parameter
	Parameter symbol	Measurement units	
PFT1 settings	Dn	m	Inner diameter of pipe of flowmeter MS for channel 1
	Q_{min}	m^3/hr	Minimum value of measured flow rate
	Q_{max}	m^3/hr	Maximum value of measured flow rate
	Cable length	m	In one beam, for each pair of PET transmitters, the same cable length to the EM is used: L1=L2 (max 500 m)
	Base 1	m	Distance between the ends of the PET transmitters of beam 1 (L_c_1)
	Base 2	m	Distance between the ends of the PET transmitters of beam 2 (L_c_2)
	Projection 1	m	For beam chord 1 of transmitters projection onto the flow (L_f_1)
	Projection 2	m	For beam chord 2 of transmitters projection onto the flow (L_f_2)
	Angle 1	degrees, minutes	For a chord, the angle of inclination of the beam 1 axis of PET transmitters ($\alpha 1$)
	Angle 2	degrees, minutes	For a chord, the angle of inclination of the beam 2 axis of PET transmitters ($\alpha 2$)
	Offset X1	m	For a chord of beam 1 axis of PET transmitters, offset from center
	Offset X2	m	For a chord of beam 2 axis of PET transmitters, offset from center
	K1corr	–	Linear correction factor for beam 1
	K2corr	–	Linear correction factor for beam 2
	dt0 1	ns	Setup of zero on motionless liquid for beam 1
	dt0 2	ns	Setup of zero on motionless liquid for beam 2
	Direction 1	–	Forward/Reverse– for beam 1 selection of metering direction +/-
	Direction 2	–	Forward/Reverse– for beam 2 selection of metering direction +/-

Appendix G continued

Table G.3 continued

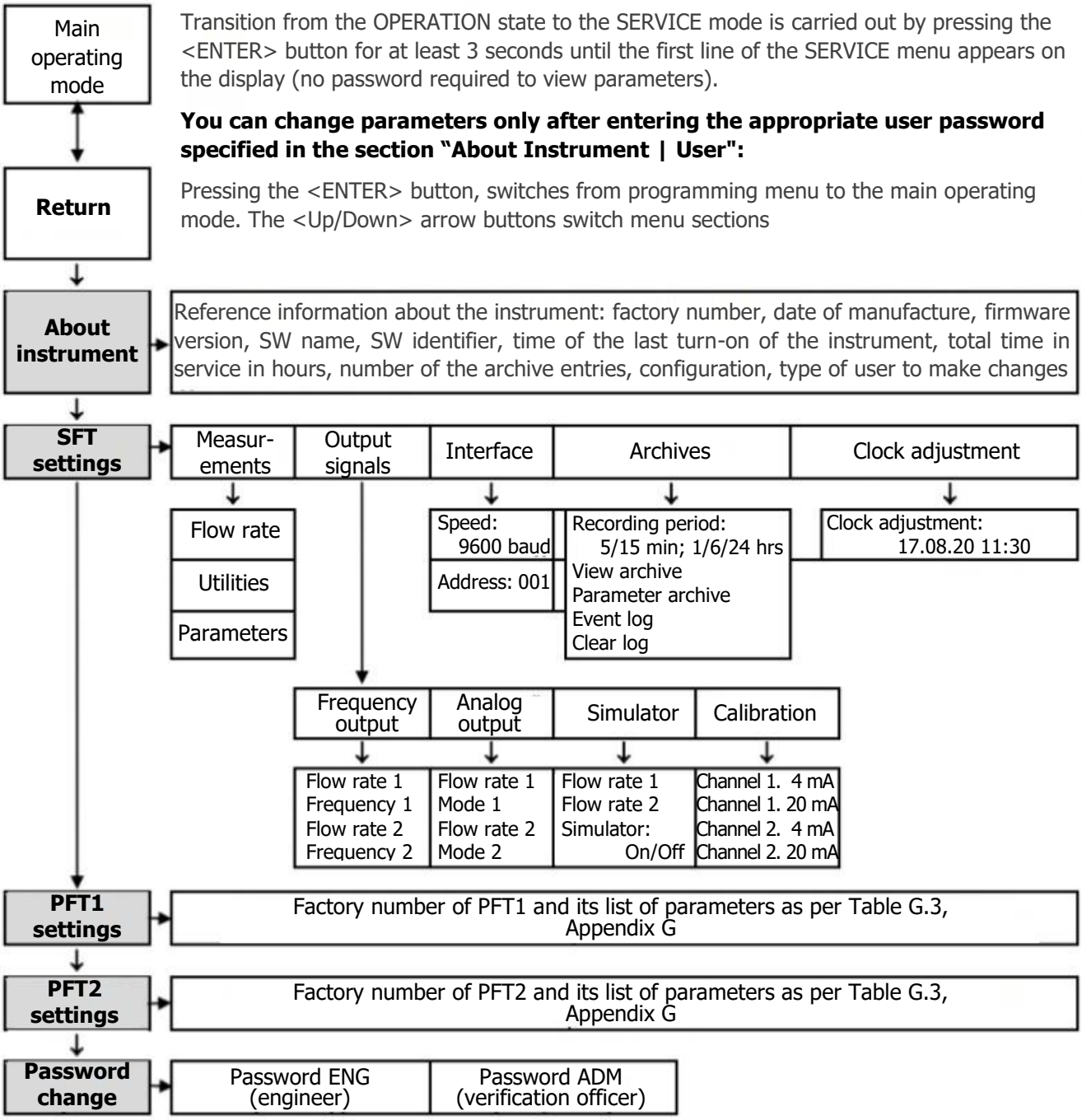
PFT2 settings	Dn	m	Inner diameter of pipe of flowmeter MS for channel 2
	Q_{min}	m^3/hr	Minimum value of measured flow rate
	Q_{max}	m^3/hr	Maximum value of measured flow rate
	Cable length	m	In one beam, for each pair of PET transmitters, the same cable length to the EM is used: L3=L4 (max 500 m)
	…	…	List of all parameters is similar to PFT1

Table G.4. Possible error codes of flowmeter

Code	Name	Status	Description
A0	ERR_EEPR_CONF	E	Configuration reading error in ROM. ROM has no data with correct check sum
A1	ERR_NVRAM_STAT	E	Error reading status from non-volatile RAM. RAM has no data with correct check sum
F0	ERR_ADC_INIT	E	ADC initialization error. Utility error
F1	ERR_ADC_TIME	E	Time-out during calibration. Utility error
F2	ERR_ADC_CONF	E	ADC configuring error. Utility error
C1	ERR_OUT_OVL	W	The value of current is outside the set range. The upper flow rate limit needs to be changed
C3	ERR_FOUT_OVL	W	The value of frequency is outside the set range. The upper flow rate limit needs to be changed
EE	ERR_MIF_OVL	W	The measured flow rate exceeds the maximum for a given Dn
B0	ERR_RTC_FAIL	I	Error starting real time clock. When power on or reset, time information reset is diagnosed
B1	ERR_POW_UP	I	Flowmeter power supply turning off/on. The error code along with a time stamp is saved in the error archive
C0	ERR_PAR_AOUT	I	The analog output parameter values are set incorrectly. Configuration parameters are set incorrectly
C2	ERR_PAR_FOUT	I	The frequency output parameter values are set incorrectly. Configuration parameters are set incorrectly

Error status: E – major error; W – warning; I – information.

APPENDIX I SERVICE Menu Structure



The flowmeter menu lines consist of the following elements:

- **sections** are the menu items containing other subsections of lower level. Moving to the second and subsequent levels is done with the cursor positioned on the desired line by pressing the <ENTER> button.

- **fields** display some information; in SERVICE mode, these positions are accessible for changing a numeric or symbolic value (if the value is blinking at the cursor position it indicates the access to change). The value entry is ended by pressing <ENTER> button.

Table I.1. Menu levels for accessing the Instrument parameters

First level	Second level	Explanations	
About Instrument	Factory No. 1234567 Date of manufacturing XX.20 SW Version 1.20 SW Name PIEZOSONIC Digital ID 0xD38B On time 0000:00 Time in serv. 0000:00 Records 0000 Configuration 2-2 User ENG	– factory serial number of Instrument – month and year of manufacture of Instrument – firmware version – name of the program used – SW identification code – time of the last turn-on of Instrument – total time in service in hours and minutes – number of archived records – configuration: two-channel (2 single-beam channels) – access level for making changes	
SFT settings	**Measurement**	**Flow rate**	Lower end cutoff 1 Upper end cutoff 1 Setup of zero 1 Setup of zero 2
		Utility	– parameters from Table G.2
		Parameters	C_{min}, m/s C_{max}, m/s Holding, s U_{pul}, V K_{gain} Signal 1 Signal 2
	Output signals: **Interface** **Archives** **Clock adjustment**	Subsections for switching to the third level of the menu for setting operating parameters corresponding to the list of the secondary flow rate transducer - EM	
PFT1 Settings	List of parameters in accordance with Table G.3, Appendix G	Setup of operating parameters of primary transducer 1	

Table I.1 continued

Settings PFT2	parameters as for PFT1 Settings	Setup of operating parameters of primary transducer 2
Change passwords	**User ADM**	Subsections of switching to menu of setup of passwords for corresponding group of users
	Verification officer ENG	

SERVICE main menu (first level)

►	.	.	.	R	E	T	U	R	N									- point of return to the starting menu OPERATION
►	A	b	o	u	t		i	n	s	t	r	u	m	e	n	t		- reference information on the instrument
►	V	P	R		s	e	t	t	i	n	g	s						- of the secondary flow rate transducer (EM)
►	P	F	T	1		s	e	t	t	i	n	g	s					- of the primary flow rate transducer 1
►	P	F	T	2		s	e	t	t	i	n	g	s					- of the primary flow rate transducer 2
►	P	a	s	s	w	o	r	d		c	h	a	n	g	e			- setting the individual access codes

The **ABOUT INSTRUMENT menu** (second level) provides monitoring and setup of reference information:

►	.	.	.	R	E	T	U	R	N									- point of return to the starting menu OPERATION
	F	a	c	t	o	r	y		N	o	.	1	2	3	4	5	6	7 - factory serial No. of instrument
	D	a	t	e		o	f		m	a	n	.		0	7	.	2	0 - month and year of instrument manufacture
	S	W		V	e	r	s	i	o	n					1	.	2	0 - firmware version
	S	W		N	a	m	e		P	I	E	Z	O	S	O	N	I	C - name of the program used
	D	i	g	i	t	a	l		I	D			0	x	D	3	8	B - firmware identification code
	O	n		t	i	m	e					0	0	0	0	:	0	0 - time of the last turn-on of instrument
	T		i	n		s	e	r	v	.		0	0	0	0	:	0	0 - total time in service, hours:minutes
	R	e	c	o	r	d	s								0	0	0	0 - number of archive entries
	C	o	n	f	i	g	u	r	a	t	i	o	n			2	-	2 - configuration: 2 channels have 2 beams
	U	s	e	r												E	N	G - access level for making changes

User access level for changing settings:

USR – (general) – viewing only, no ability to change parameters;
ENG – (engineer) – limited access to settings that do not affect measurements;
ADM – (calibration) – parameters can be changed, including those affecting measurements.

The **SFT SETTINGS menu** (second level) provides setting up of the operating parameters of the secondary flow transmitter in the EM:

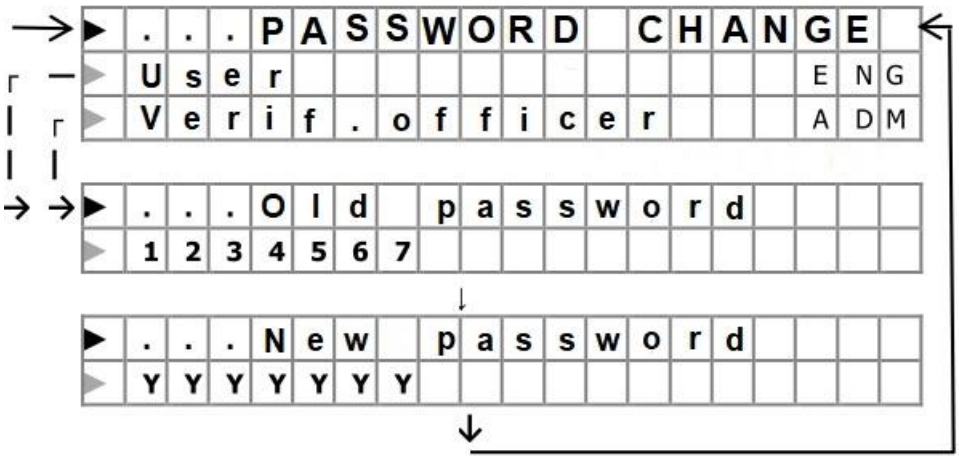
►	.	.	.	V	P	R		S	E	T	T	I	N	G	S				- point of return to the starting menu OPERATION
	M	e	a	s	u	r	e	m	e	n	t								Names of sections to go to the third level menu by each parameter from the given list
	O	u	t	p	u	t		s	i	g	n	a	l	s					
	I	n	t	e	r	f	a	c	e										
	A	r	c	h	i	v	e												
	C	l	o	c	k		a	d	j	u	s	t	m	e	n	t			- current time and date of the instrument calendar

The **PFT1 SETTINGS menu** (second level) provides setting up of the parameters of the primary flow transducer:

▶	.	.	.	P	F	T	1		S	E	T	T	I	N	G	S			List of all parameters available and their purpose are specified in Table G.3 (Appendix G)
	F	a	c	t	o	r	y		N	o	.	1	2	3	4	5	6	7	
	D	n	,	m										0	.	2	8	1	
	Q	m	i	n	,	m	3	/	h	r					1	0	.	0	
	Q	m	a	x	,	m	3	/	h	r			2	5	0	0	.	0	
	C	a	b	l	e		l	e	n	g	t	h	,	m			5	0	
	N	u	m	b	e	r		o	f		b	e	a	m	s			2	
	B	a	s	e		1	,	m					0	,	3	3	1	5	
	B	a	s	e		2	,	m					0	,	3	3	1	5	
	P	r	o	j	e	c	t	i	o	n	1		0	,	2	0	1	5	
	P	r	o	j	e	c	t	i	o	n	2		0	,	2	0	1	5	
	A	n	g	l	e		1	,	°					4	5	,	2	0	
	A	n	g	l	e		2	,	°					4	5	,	0	0	
	O	f	f	s	e	t		X	1	,	m		+	0	,	0	2	1	
	O	f	f	s	e	t		X	2	,	m		-	0	,	0	2	0	
	K	1	c	o	r	r									1	,	0	0	
	K	2	c	o	r	r									1	,	0	0	

The **PFT2 SETTINGS menu** (second level) menu similar to PFT1, if included in the ordered device configuration.

The **CHANGE PASSWORDS menu** (second and third levels) provides possibility to set individual access codes for different user groups (passwords consist of seven numeric characters from 0 to 9):



When entering this field, the pointer blinks on the first character of the password. Using the horizontal and vertical arrows located on the front panel, the user selects values and confirms recording by pressing the <ENTER> button.

Once the password is s, it will be requested with each attempt to enter the SERVICE menu. If a password is entered incorrectly, the system returns to the main operating mode.

WARNING! If password is set, its loss will result in loss of access to the menu of the instrument.

Additional menu sections with a list of parameters:

The **SFT SETTINGS|Measurement menu** (third level):

►	.	.	.	M	E	A	S	U	R	E	M	E	N	T			- point of return to the SFT SETTINGS menu
	F	l	o	w		r	a	t	e								- name of sub-sections for going to the fourth level menu by each parameter from the given list
	U	t	i	l	i	t	i	e	s								
	P	a	r	a	m	e	t	e	r	s							

Subsections perform the following functions:

►**Flow rate** is for parameters of setting the flow rate measurements of immediate flow.

Measurement -> Flow rate		
Lower end cutoff of channel 1	m^3/hr	Cutoff of flow value from bottom for PFT1, if lower consider it zero
Upper end cutoff of channel 1	m^3/hr	Cutoff of flow value from top for PFT1, if higher record this value
Lower end cutoff of channel 2	m^3/hr	Cutoff of flow value from bottom for PFT2, if lower consider it zero
Upper end cutoff of channel 2	m^3/hr	Cutoff of flow value from top for PFT2, if higher record this value
Setup of zero 1	–	For channel 1 setting of zero on motionless liquid
Setup of zero 2	–	For channel 2 setting of zero on motionless liquid

Cutoff is the field of flow rate threshold value below which it is considered that there is no flow in the pipeline. In this case, the display indicates a sequence of dashes, there are no flow rate signals at the outputs and the volume meters do not work. The specified cutoff is applied to both positive and negative flow directions.

► **Utility** - operating parameters of measuring beams.

Measurement -> Utility		
t11	ns	Time of passage up for beam 1
t12	ns	Time of passage down for beam 1
t1avg	ns	Average time of passage for beam 1

Table continued

dt1	ns	Time difference of passage up and down for beam 1
C1	m/s	Speed of ultrasound (US) for beam 1
T1	°C	Temperature of working medium for beam 1
Q_t1	m^3/hr	Flow rate without correction (approximate) by data of beam 1
Signal 1	–	Beam 1 signal power from 0 to 255
t21	ns	Time of passage up for beam 2
t22	ns	Time of passage down for beam 2
t2avg	ns	Average time of passage for beam 2
dt2	ns	Time difference of passage up and down for beam 2
C2	m/s	Speed of ultrasound (US) for beam 2
T2	°C	Temperature of working medium for beam 2
Q_t2	m^3/hr	Flow rate without correction (approximate) by data of beam 2
Signal 2	–	Beam 2 signal power from 0 to 255

► **Parameters** - additional general settings of operation.

Measurement -> Parameters		
C_{min}	m/s	Minimum US speed in liquid; if lower - the measurements are incorrect
C_{max}	m/s	Maximum US speed in liquid; if lower - the measurements are incorrect
Holding	s	Holding time of outputs in case signals are lost
U_{pul}	V	Voltage amplitude for pulse fed to PET
K_{gain}	–	Gain factor of US signal in EM
Signal 1	–	Beam 1 signal power from 0 to 255
Signal 2	–	Beam 2 signal power from 0 to 255

The **SFT SETTINGS|Output signals menu** (third level) provides possibility to configure the output information signals of EM:

►	.	O	U	T	P	U	T		S	I	G	N	A	L	S			- point of return to the SFT SETTINGS menu
	F	r	e	q	u	e	n	c	y									- name of sub-sections for going to the fourth level menu by each parameter from the given list
	A	n	a	l	o	g												
	S	i	m	u	l	a	t	o	r									
	C	a	l	i	b	r	a	t	i	o	n							

Subsections perform the following functions:

► **Frequency** - two frequency output setups are programmed in the form of pulse signals proportional to the measured flow rates. The maximum pulse repetition frequency can be 2000 Hz (the default frequency is set for 1000 Hz).

Output Signals -> Frequency		
Flow rate 1	m^3/hr	The measured flow rate value is indicated in Channel 1 – $\|Q_F\|$
Frequency 1	Hz	Output pulse frequencies for the $\|Q_F\|$ value is assigned in Channel 1
Flow rate 2	m^3/hr	The measured flow rate value is indicated in Channel 2 – $\|Q_F\|$
Frequency 2	Hz	Output pulse frequencies for the $\|Q_F\|$ value is assigned in Channel 2

In the Frequency 1 (Frequency 2) line, output pulse repetition frequency values are entered, which must correspond to the flow rate $|Q_F|$ specified in the Flow Rate 1 (Flow Rate 2) field. In each channel, the output frequency is proportional to the absolute value of the measured flow rate – Figure I.1 (if necessary, the $|Q_F|$ value can be greater or less than $|Q_{max}|$).

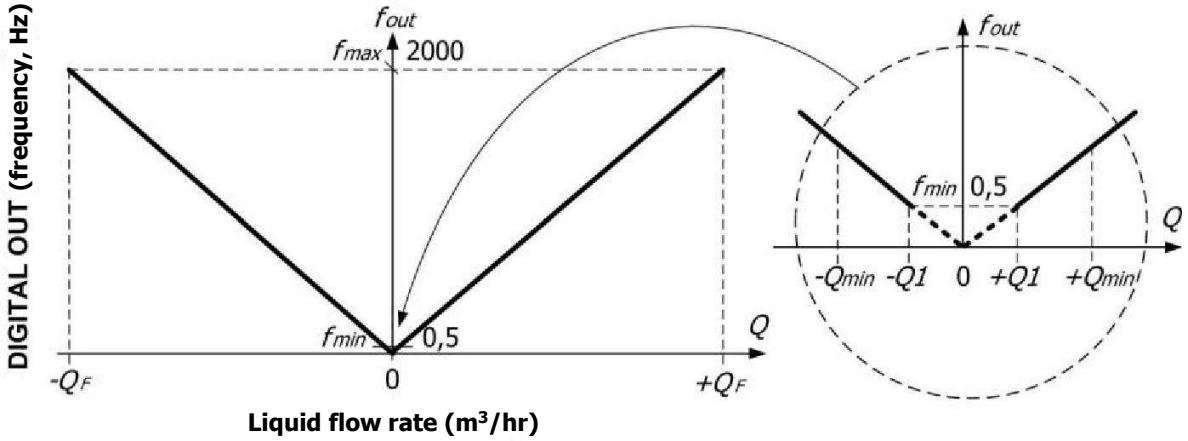


Figure I.1. Output frequency signal characteristic view

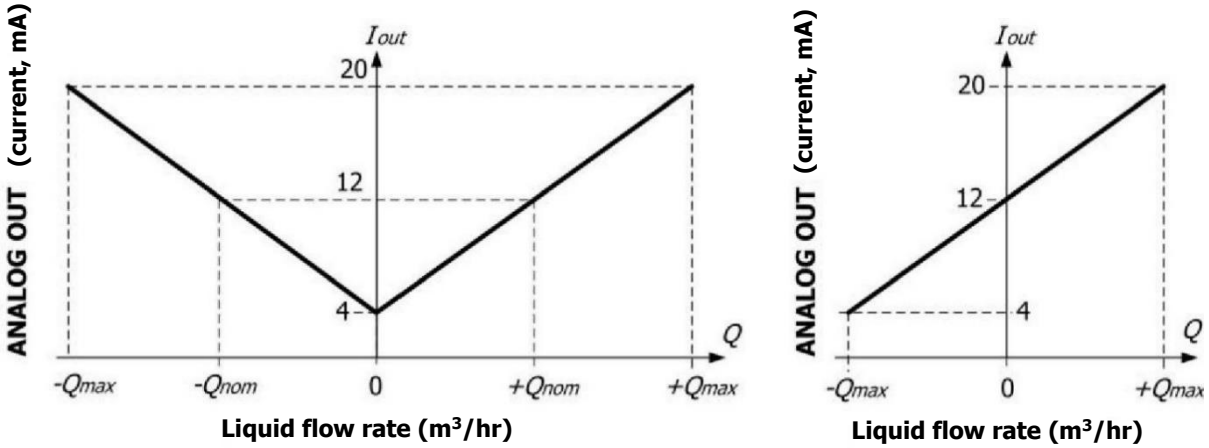
► **Analog** – specifies parameters for normalizing the 4...20 mA output current to output flow rate measurement results in two channels.

Output Signals -> Analog		
Flow rate 1	m^3/hr	Maximum flow rate measurement value in Channel 1
Mode 1	–	Channel 1 output signal characteristic view (Figure I.2): **ABS** (default) – current is proportional to the absolute flow rate (4 mA at zero flow rate); **AVG** – average value (12 mA corresponds to zero flow rate)

Table continued

Flow rate 2	m^3/hr	Flow rate measurement maximum value in Channel 2
Mode 2	-	Channel 2 output signal characteristic view (Figure I.2): **ABS** (default) – current is proportional to the absolute flow rate (4 mA at zero flow rate); **AVG** – average value (12 mA corresponds to zero flow rate)

The flow rate value cannot exceed the maximum possible flow rate for the used Dn diameter.



a) ABS b) AVG

Figure I.2. Current output signal characteristic view depending on the option set in the sub-items of Output signals|Analog|Mode 1/2

► **Simulator** – this section sets parameters of the simulator work, which serves to configure the flow rate measurement channel in APCS and allows simulation of signals at the flowmeter outputs proportional to the flow rate specified in the Flow Rate field. In this case, the actual flow rate in the pipeline does not matter – the enabled simulator affects all the outputs: frequency/pulse and current.

Output _ Signals -> Simulator		
Flow rate 1	m^3/hr	Field for entering the simulated flowrate value in Channel 1 (Q_{out})
Flow rate 2	m^3/hr	Field for entering the simulated flowrate value in Channel 2 (Q_{out})
Simulator	–	Control of the simulator operation mode: DISABLED/ENABLED

► **Calibration** sets parameters for calibrating output currents in channels.

Output Signals -> Calibration		
Channel 1	4 mA	Correction of output signal 1 in point 4 mA
Channel 1	20 mA	Correction of output signal 1 in point 20 mA
Channel 2	4 mA	Correction of output signal 2 in point 4 mA
Channel 2	20 mA	Correction of output signal 2 in point 20 mA

Correction Method: When the ultrasonic flowmeter outputs the extreme range signals in each channel, the values are measured using a reference milliamperemeter, the readings of which are entered into the corresponding menu field. Correction for each output channel of the Instrument must be performed at two points (4 and 20 mA).

The **SFT SETTINGS|Interface menu** (third level) of setting up the operating parameters of the RS-485 port:

Speed	baud	List of selection of one of the exchange rate values via the RS-485 interface: 4800, 9600, 19,200 and 38,400 (bps)
Address:	–	The field specifies the flowmeter's address on the data exchange bus – valid values range from 1 to 246.

The **SFT SETTINGS|Archives menu** (third level) of setting up the storage parameters for cumulative flow rate values in both directions (downstream and upstream), date, time, and error codes. The archive is circular; new records replace the oldest ones.

The Archives menu has the following subsections:

► **Recording Period** **1 hr** - the field specifies the time period after which records will be written to the archive: 5 min; 15 min; 1 hour; 6 hours; 24 hours (information is stored in non-volatile memory).

► **View Archive** - the subsection allows to view existing measurement records in the archive. Scroll through the records is by using the horizontal arrows <Right> and <Left>. Each record consists of several fields: record number, date/time of recording, instrument status, accumulated error codes, accumulated volume by the time of recording, and the minimum and maximum flow rate since the previous record (for the interval set in the "Record Period" field).

In order to exit viewing mode, press the <ENTER> button

The archive can be read remotely on a PC using the SiMaster program.

►**Parameter archive** - the subsection allows to view existing records of changes to the instrument's operating parameters. Contains the date the parameter was changed, the parameter number, and the old and new values in hexadecimal format.

The archive can be read remotely on a PC using the SiMaster program.

►**Event log** - the subsection allows to view existing records of errors. The entry stores the error code and date.

► **Clear Log** - the subsection allows to delete all existing entries in the measurement archive and event log.

The **SFT SETTINGS|Clock Adjustment menu** (third level) is a subsection for setting the current date and time. Using horizontal arrows, the user moves the pointer to the digit that needs to be changed. Using vertical arrows, the desired digit is set.

The correctly set date and time is confirmed by pressing the <ENTER> button.

APPENDIX J. Software for Flowmeter

P-Control program, which enables remote monitoring, diagnostics, and configuration of instruments that belong to the group of electronic flowmeters, can be used with the Flowmeter. The standard ModBus RTU protocol is used for communication with the Instruments. Multiple instruments can be connected to the RS-485 information network, but the P-Control software can only work with one at a time. See the P-Control operating manual.

For notes

Version 01-2025

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