NOVATEK-ELECTRO LTD
Research-and-Manufacture Company

DIGITAL TEMPERATURE RELAY

TR-101

USERS MANUAL

www.novatek-electro.com

This manual is provided in order to introduce the operating personnel to structure, operating principle, design, mode of operation and maintenance of TR-101 digital temperature relay (further referred to as “device”, "TR-101” or “ TR-101 unit”).

1 APPLICATION

TR-101 is designed for measuring and controlling a device temperature by means of four sensors connected according to a two- or four-wire diagram, with subsequent temperature display. The device can find various applications in industrial sector, in municipal utilities service, and agriculture.

The device allows for performing the following functions:

- taking temperature measurement on 4 channels with use of standard sensors;
- controlling temperature according to proportional-integral-differential (PID) principle;
- temperature on-off regulation;
- displaying currently measured temperature value on the integral LED digital display;
- transferring the measured values for the sensors monitored via Modbus RTU standard protocol;
- defining a break or a short circuit on the connected sensors lines;
- measured temperature digital filtering and correction;
- programming by the front panel keys and via PC;
- settings backup when de-energized;
- settings protection from unauthorized change;

TR-101 has a flexible power supply and can use any voltage form 24 to 260 V, regardless of polarity.

TR-100 can use the following types of temperature sensors:

Table 1

Sensor type	**Rated resis-tance at 0 °C, R0, Ohm**	**Unique sensor curve (USC) notation**			**Temperature range**
		national	**international**		
Platinum			**W100 =1,3850**	**W100 =1,3910**	
	50	50П	Pt50	Pt’50	-50…+200
	100	100П	Pt100	Pt’100	-50…+200
	500	500П	Pt500	Pt’500	-50…+200
	1000	1000П	Pt1000	Pt’1000	-50…+200
Copper			**W100 =1,4260**	**W100 =1,4280**	
	50	50M	Cu50	Cu’50	-50…+200
	100	100M	Cu100	Cu’100	-50…+200
Nickel			**W100 = 1,6170**		
	100	100H		Ni100	-50…+180
	120	120H		Ni120	-50…+180
	500	500H		Ni500	-50…+180
	1000	1000H		Ni1000	-50…+180
Other			**W100 = 2,0805**	**W100 = 2,0805**	
	990 by 25°C	807 by 0°C	PTC1000	EKS111	-50…+100

W100 – ratio rate of sensor resistance at 100°C to its resistance at 0°C (W100 = R100 / R0)

2 TECHNICAL BRIEF AND OPERATING CONDITIONS

2.1 The basic technical parameters are shown below in table 2.

Table 2

Supply voltage, V	24 – 260 AC/DC
Recommended fuse, A	1
Type of temperature measurement sensors	Pt50, Pt100, Pt500, Pt1000, Cu50, Cu100, Ni100, Ni120, Ni500, Ni1000, PTC1000
Quantity of sensors connectable, pcs	1 – 4

Sensors wiring schematic	2 / 3 wires
Sensor wire length, depending on the wiring schematic, m	2- wire, up to 5 3- wire, up to 100
Quantity of output relays, pcs	4
Data memory, years, no less than	10
Temperature measurement error, °C	± 2
Measured temperature range, °C	from -50 to +200
Output relay testing	available
RS-485 MODBUS RTU	available
PID regulation with keyword (relay)	available
Two-position regulator	available
Channel measurement time, sec, no more than	0,6
Protection degree: - enclosure - terminal block	IP30 IP20
Climatic resistance version	У3.1 (moderate)
Power consumption (under load), no more than, VA	4,0
Weight, not more, kg	0,370
Dimensions, mm	90 x 139 x 63
Output contacts commutation lifetime: - electrical life 10A, 250V AC, times, no less than - electrical life 10A, 24V DC, times, no less than	 100 thousand 100 thousand
Mounting onto standard 35 mm DIN-rail	
Mounting position any	

Output contacts specification

Cos φ	Max. current at ~ 250 V AC	Maximum power	Max. voltage ~	Max. current for U = 30V D.C.
1,0	10 A	4000 VA	440 V	3 A

2.2 The device is designed for operating in the following environment:
- ambient temperature: from - 35 to +55 °C;
- storage temperature: from - 45 to +70 °C;
- atmospheric pressure from 84 to 106,7 kPa;
- relative air humidity (at temperature 35 °C) 30…80%.

3 EQUIPMENT DESIGN AND OPERATION

3.1 TR-101 DEVICE EQUIPMENT

Trace of symbols at numeric display to letters of Roman alphabet is shown at picture № 3.

Figure 3 - Trace of symbols at numeric display to letters of Roman alphabet

3.1.1 Design

The device is manufactured in plastic casing (9 S-type modules) to be mounted onto standard DIN rail. The casing outline with overall and mounting dimensions is presented in Figure 3.1.

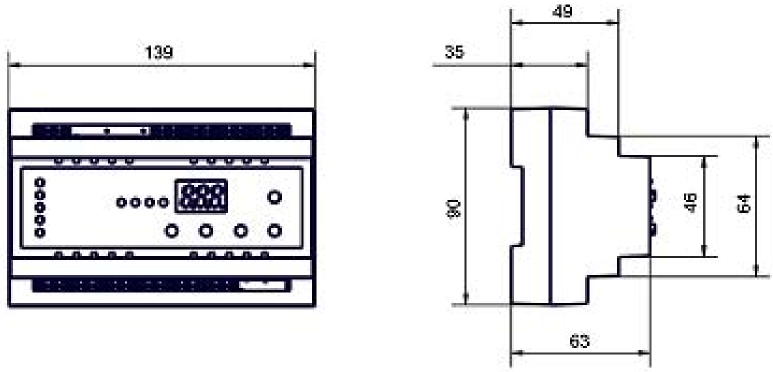
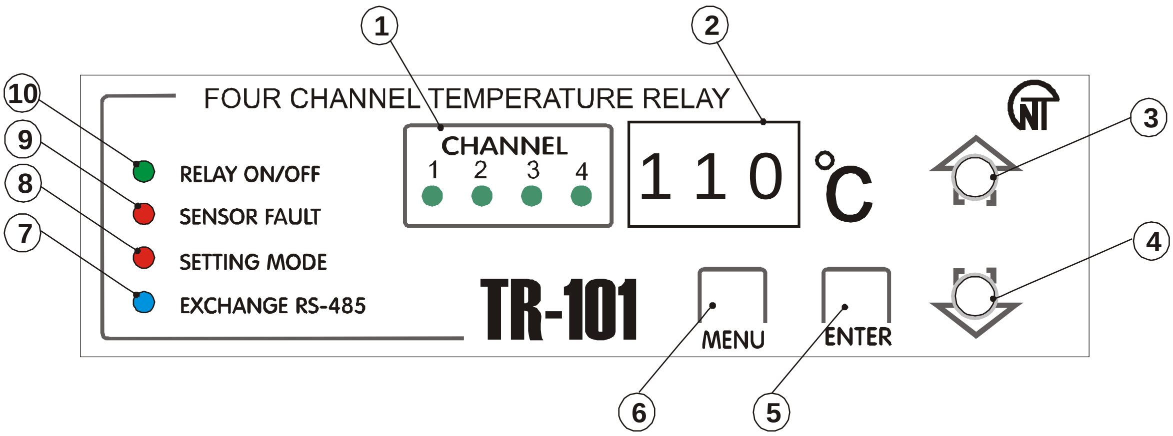


Figure 3.1 – TR-101 dimensions

3.1.2 Displaying and control

Figure 3.2. presents the TR-101 front panel exterior.



1 – currently displayed channel number indicator;
2 – seven-digit numerical display;
3 – up key;
4 – down key;
5 – enter key, used in the device programming mode;
6 – view mode and device programming mode enter key;
7 – RS-485 connection and communication activity indicator;
8 – parameter programming mode indicator;
9 – sensors failure indicator;
10 – relay close (open) indicator;

Figure 3.2 – TR –101 Front Panel

In the menu mode, (1,7) indicators display the corresponding parameter (on/off), (r5A, ch 1, ch2, ch3, ch4 Table 7.1).

Device control:

- use ▼ ▲ keys to toggle channels;
- use MENU key to enter the parameter view mode;
- to enter the parameter edit mode - press MENU key and hold it within 7 seconds, the "setting" indicator (fig. 3.2, 8) shall light.
- to save modified value – use ENTER key;
- if no key has been pressed within 20 sec, TR-101 will display EHt sign(within 1 sec), and will switch to the initial state.

3.2 OPERATING PRINCIPLE AND INPUT SIGNAL PROCESSING

3.2.1 Operating principle

In course of its operation, TR-101 performs input sensors scanning, then, based on the data obtained, calculates the current temperature value and outputs it on the digital display and sends Control signals to the corresponding channel relay.

3.2.2 Input signal processing

The signal that is received from sensor is transformed into a temperature digital value.

In order to eliminate the initial input signal processing error, as well as errors that are produced by the connection wiring; the device measured value can be adjusted. TR-101 provides for two adjustment types, which allow performing a gain shift or sloping by a specified degree for each channel independently.

3.2.3 Measurements adjustment

3.2.3.1 To provide for the error compensation ΔR = (R0 - R0.TC) produced by the input wiring resistance RTC, each **measured temperature value** (**Тизм**) is added with a user specified value **δ**. Figure 3.3 shows an example of a characteristics shift for Pt100 sensor.

Programmable parameters: SH1, SH2, SH3, SH4.

3.2.3.2 To provide for sensor error compensation upon W100 value deviation from the rated value each Тизм parameter measured value is multiplied by the user set adjustment parameter **α**.

The ratio boundaries are set within 0,50 to 2,00 limits.

Figure 3.4 shows an example of the characteristic slant variation for Pt100 sensor.

Programmable parameters: PU1, PU2, PU3, PU4.

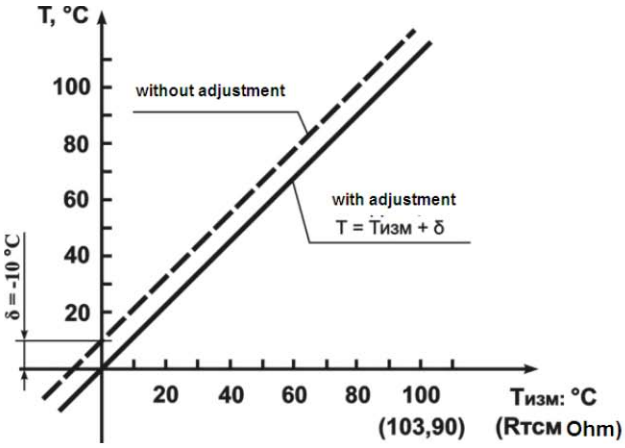


Figure 3.3

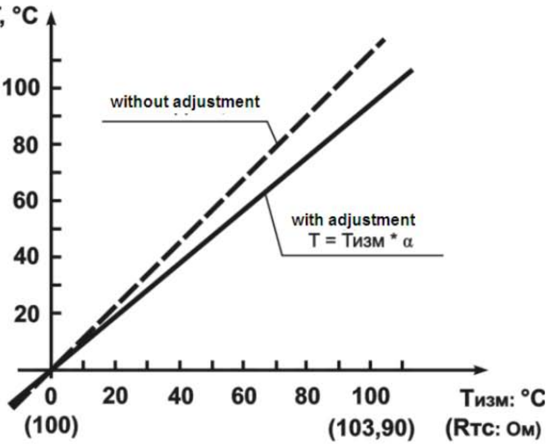


Figure 3.4

3.2.4 Digital filter

To provide for the input signal properties improvement the device employs digital filters that allow reducing the random interference effect on the temperature measurement.

Programmable parameters:

- digital filter band Fb1, Fb2, Fb3, Fb4;
- digital filter time constant Ft1, Ft2, Ft3, Ft4.

The filters are set for each input independently.

3.2.4.1 The digital filter band allows protecting the measurement route from single interference and is set in °C. If the measured value **Тизм** is different from the previous **Тизм**–1 by the value larger than Fb parameter value, the device assigns to it a value equal to (Тизм + Fb**)** (Figure 3.5). Thus the characteristic is smoothed out.

As seen in Figure 3.5, smaller band width of the filter leads to slowing down the device reaction to temperature change. That is why in case of low interference level or during operation with discontinuous temperatures it is recommended to increase the parameter value or switch off the filter band action by setting the Fb1 **(**Fb2, Fb3, Fb4**)** parameter value to 0.

When working under strong interference, in order to eliminate its impact onto the device operation, it is necessary to reduce the parameter value.

3.2.4.2 The digital filter eliminates the noise signal components by smoothing it exponentially. The main characteristic of the exponential filter is **τф** – the digital filter time constant, Ft1 **(**Ft2, Ft3, Ft4**)** interval, within which the temperature reaches the 63,2% from measured value **Тизм** (Figure 3.6).

Reducing τф will lead to a faster device reaction onto discontinuous temperature variations, but also will reduce its protection against interference. Increasing τф value increases the device response rate, while noise is significantly suppressed.

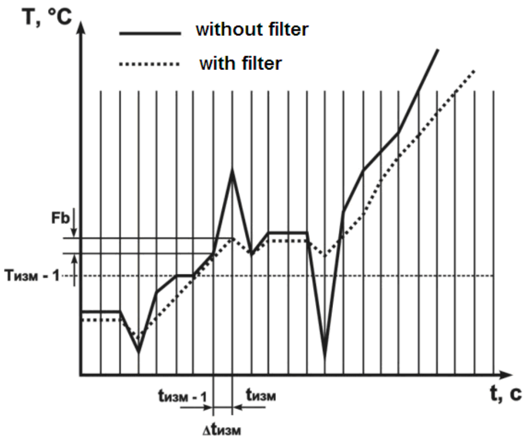


Figure 3.5

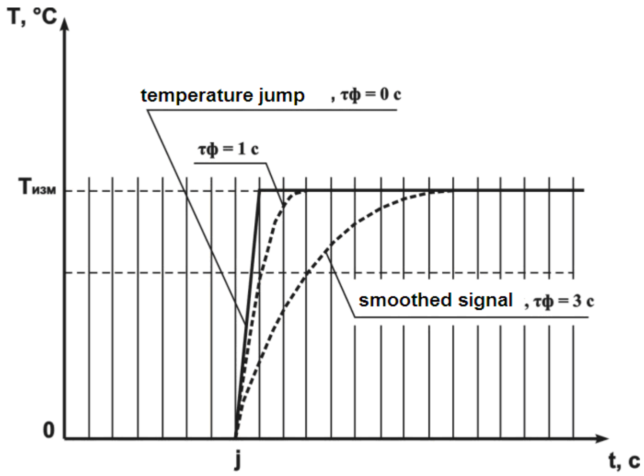


Figure 3.6

3.2.5 Two-position regulator (two-position control)

In the two-position control mode the device works according to one of the two logic types, Figure 3.7:

- Logic №1 (heater) is used to control a heater operation (tubular electric heaters, for instance), or to produce warning that the **current temperature value** (**Tтек**) is less than the **setting value** (**Tуст**). Upon that the output relay initially closes at values of **Tтек** < **Tуст** – **HS**, then opens at **Tтек** > **Tуст** + **HS** and closes again at **Tтек** < **Tуст** – **HS** thus effecting the two-position control by **Tуст** setting with the **HS** hysteresis.
- Logic №2 (cooler) is used to control a cooler operation (a fan, for instance), or a warning of exceeding **Tуст** setting value. Upon that the output relay initially is ON at values of **Tтек** > **Tуст** + **HS**, then is OFF at **Tтек** < **Tуст** and ON again at **Tтек** > **Tуст** + **HS**. If using as compressor cooler recommended define **HS** in such a manner to provide the normal (minimum) compressor off time to avoid the device damage.

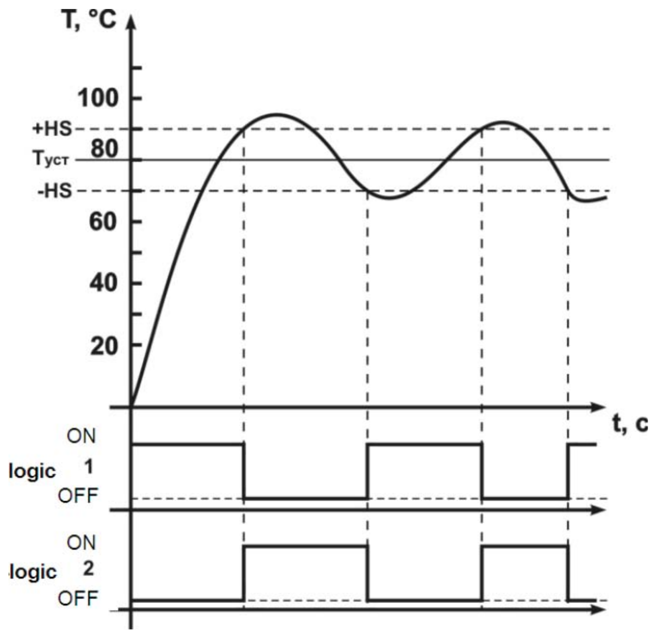


Figure 3.7 - Diagram of output relay function based on the logic type

Programmable parameters:

Tуст – temperature setting SP.1 (SP.2, SP.3, SP.4);
HS – hysteresis HS.1 (HS.2, HS.3, HS.4);
rt.1 (rt.2, rt.3, rt.4) – output relay function logic.

3.2.6 PID- controller (proportional-plus-integral-plus-derivative control)

3.2.6.1 **PID control general principles**

On the control relay the “controlling” signal Yi is generated; its action is directed at reducing the E*i* deviation.

$$Y_i = \frac{1}{X_p}\left(E_i + \frac{1}{\tau_{\text{и}}}\sum_{i=0}^{n} E_i * \Delta t_{\text{изм}} + \tau_{\text{д}} * \frac{\Delta E_i}{\Delta t_{\text{изм}}}\right) * 100\%$$

wherein:

Xp – proportionality band (P - programmable parameter);
Ei – is the difference between the set **Тусt** and current **Tтек** temperature value, or unbalance;
τд – response speed derivation (programmable parameter “PID-controller derivative constant ” - d);
ΔEi – difference between two adjacent measurements Ei and Ei-1;
Δtизм – difference between two adjacent measurements **Tтек** and **Tтек**-1;
τи – integration response time (programmable parameter “PID controller integral constant i ”);
$\sum_{i=1}^{n} E_i * \Delta t_{\text{изм}}$ - derivation cumulative sum.

To provide for the efficient PID controller operation it is important that proper values of **X**p, τд and τи ratios for the given controlled object be set.
Programmable parameters:
[**X**p] – P.1 (P.2, P.3, P.4);
[τд] – **d.1 (d.2, d.3, d.4);**
[τи] – **i.1 (i.2, i.3, i.4).**

ATTENTION! Sometimes PID regulation is overmuch or irremissible. In such cases fixing coefficient τи = 0 or τд = 0 is possible to get PD and PID regulator.

3.2.6.2 **Proportional regulator**

Proportional regulator is the main where the task of temperature is directly proportional to mistake. Using only proportional regulator lead to mistake. The low values of proportional regulator lead to lack of stability and vibration in system but too high lead to low operation.

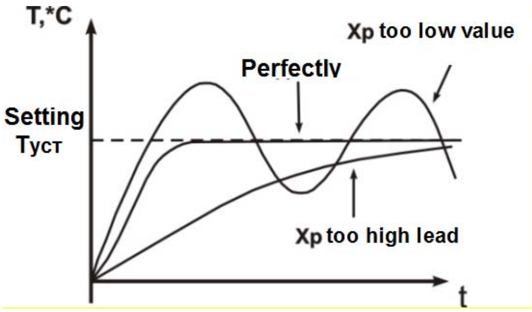


Figure 3.8 - Working hours of proportional regulator

3.2.6.3 **Integral regulator**

It’s used for compensation of errors. The temperature will be grow to the moment compensation of errors. (or diminish by negative error). The minor constituents of integral element influence to regulator job much. If the value fixed very high it mean’s the system doesn’t recognize it and will be work with overshoot.

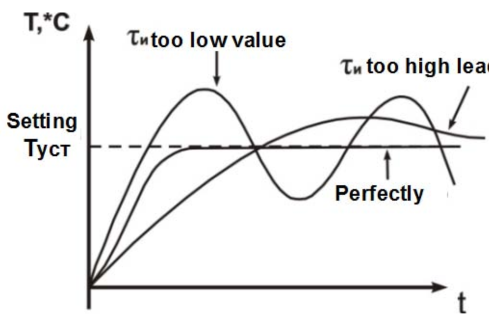


Figure 3.9 - Working hours of integral regulator

3.2.6.4 **Differntial regulator**

It’s used for icreasing system performance rating the mistake change.

The regulator speeding lead to incresing overshoot and as a result is lack of stability the system. Most cases derivative term is fixed neutral or low value to avoid this lack of stability.

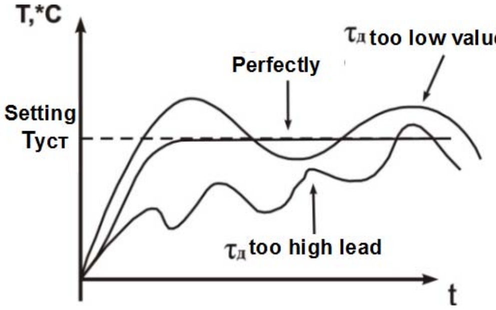


Figure 3.10 - Working hours of differential regulator

3.2.6.5 **Methods of PID controlling**

During the controlling, one of the control methods is selected: “Heater” or “Cooler”.
“Heater” – the output signal value decreases while the controlled temperature grows.
“Cooler” – the output signal value increases while the controlled temperature grows.
Programmable parameters: rt.1 (rt.2, rt.3, rt.4).

ATTENTION! Not recommended using PID control in cooler range of compressor in relation of lack control the minimal off time compressor can lead to damage device.

3.2.6.6 **Action in PID - regulator mode with output key element (pulse-length modulation)**

Command current from PID regulator (Yi) is transforming to multiple pulses (picture 3.11) according following formula:

$$D = T_{сл} * \frac{Y_i}{100\%}$$

where :
D – impulse duration (second) L.1, L.2, L.3, L.4;
Tсл – pulse repetition period (minute) t.1, t.2, t.3, t.4;
Yi – command current of PID regulator (%).

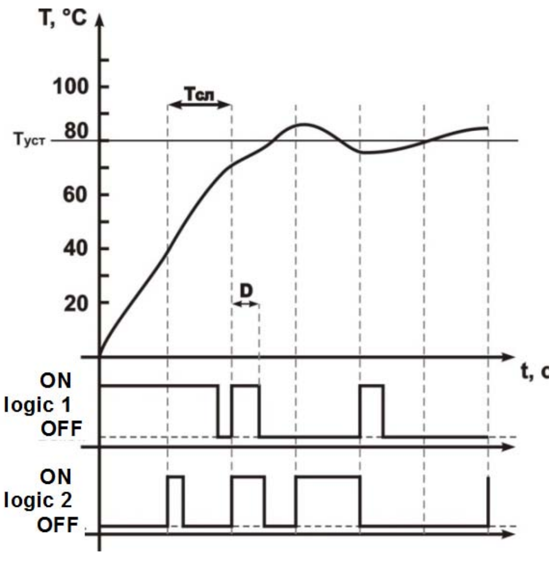


Figure 3.11 - Diagram act output relay in mode of PID regulation

ATTENTION! The little value of **Tсл** leads to often commutation and short life power contacts but The big value of **Tсл** leads to quality loss regulation.

3.2.7 RS-485 communication interface

Using of interface is described in Supplement A.

4 MAINTENANCE AND SAFETY

4.1 SAFETY

Open terminals of the device carry dangerous voltage of up to 250 V. Any connections to the device and its maintenance operations must be performed only on de-energized device and executive units.

Ingress of moisture to the output terminals and the device inside electronic elements is not allowed. The use of the device in aggressive environments containing acids, alkali, oils, etc. is prohibited.

The device connection, adjustment and maintenance must be performed only by authorized personnel that is familiar with this manual.

4.2 MAINTENANCE SCHEDULE

Recommended maintenance schedule – semiannually.

Maintenance scheduled operations consist of visual observation, during which wiring connection to terminals is checked, frame and casing integrity check for cracking and chipping.

During maintenance operations, the safety precautions listed in chapter 4.1 must be followed.

5 DEVICE CONNECTION

5.1 PERIPHERY CONNECTIONS

5.1.1 General instructions

Prepare cables for connecting the device to sensors, execution mechanisms and peripheral equipment, as well as to the power supply. To provide for the electric connections reliability it is recommended to use cables with copper stranded wires, the ends of which should be carefully cleaned and soldered prior to connecting. The wire core shall be cleared in such way, that its bare ends would not project beyond the terminals after connection to the device. The cable section must not exceed 2,5 mm^2.

5.1.2 Mounting instructions aimed at electromagnetic interference reduction

When laying the “device-sensor” lines, they should be separated into an individual tract (or several tracts). The tracts shall be placed separately from the power cables, as well as from cables that produce high frequency and pulse interference.

ATTENTION! The tracts shall be planned in such manner, that the signal lines length is kept minimal.

5.1.3 Mounting instructions aimed at reduction of the power circuit interference

The device shall be connected to 220V 50Hz, circuit feeder that is not connected with supplying power to heavy-duty industrial equipment. It is recommended installing in the peripheral supply line a feed switch providing disconnecting the device from the circuit, as well as 1A fuses.

5.2 DEVICE CONNECTION

The device shall be connected in accordance with the diagram on figure 5.1, observing the listed below sequence:

A) Connect the device to power supply and execution units;
B) connect the “device-sensor” communication lines to the device inputs.

ATTENTION! The device terminals for connecting power circuit and peripheral heavy-duty equipment are designed for max voltage of 250V. To avoid disruptive electric discharge or insulation arc-over it is prohibited to connect power sources with higher voltage that one mentioned to the device terminals.

5.3 CONNECTING SENSORS (RTDS)

TR-101 devices employ a three-wire diagram for connecting RTDs (resistance temperature detectors). Two wires are connected to one of the RTD outputs, and the third wire is connected to the other RTD output (see figure 5.1). Such diagram, provided that impedance of all three wires is equal, allows to compensate its impact onto the temperature measurement.

The resistance temperature detectors can be connected to the device under a two-wire diagram as well, but such arrangement does not provide for the connecting wiring impedance compensation which may lead to certain dependence of the device measurement from the wires temperature variation.

5.3.1 Connecting sensors (RTDs) according to a two-wire diagram

5.3.1.1 The RTDs (resistance temperature detectors) are connected to the device according to a two-wire diagram in case when a three-wire diagram cannot be used, for example, whenTR-101 is installed within units equipped with earlier laid two-wire connection lines.

5.3.1.2 Please, mind that the device readings will depend on the “device-sensor” communication line wires impedance change, that takes place under influence of the outside air temperature. To compensate for the wires parasitic resistance, perform the following:

- Before the operation start install a jumper between contacts 23 and 24 ((26 and 27), (29 and 30), (32 and 33)) of the terminal block, and connect the two-wire line immediately to contacts 22 and 23 ((25 and 26), (28 and 29), (31 and 32)).
- Then connect a resistor box with accuracy rating not less than 0,05 (MCP-63, for example) to the opposite ends of the "device-sensor" communication line, instead of the thermal element.
- On the resistor box, set the value equal to the RTD resistance at temperature of 0C (50, 100, 500, 1000 Ohms, depending on the sensor type).
- Energize the device and after 20-30 sec, by the digital display readings, define the value of the temperature deviation from 0 ºC .
- Set the SH1 (SH2, SH3, SH4) parameter value equal to the temperature deviation value, taken with the opposite sign.
- Check the accuracy of the value assigned; to do it, without changing the resistance value on the resistor box, switch the device to the temperature measurement mode, and verify that its reading is equal to 0±1 ºC.
- De-energize the device, disconnect the communication line from the resistor box and connect it to RTD.
- After all these actions, the device is ready for further operation.

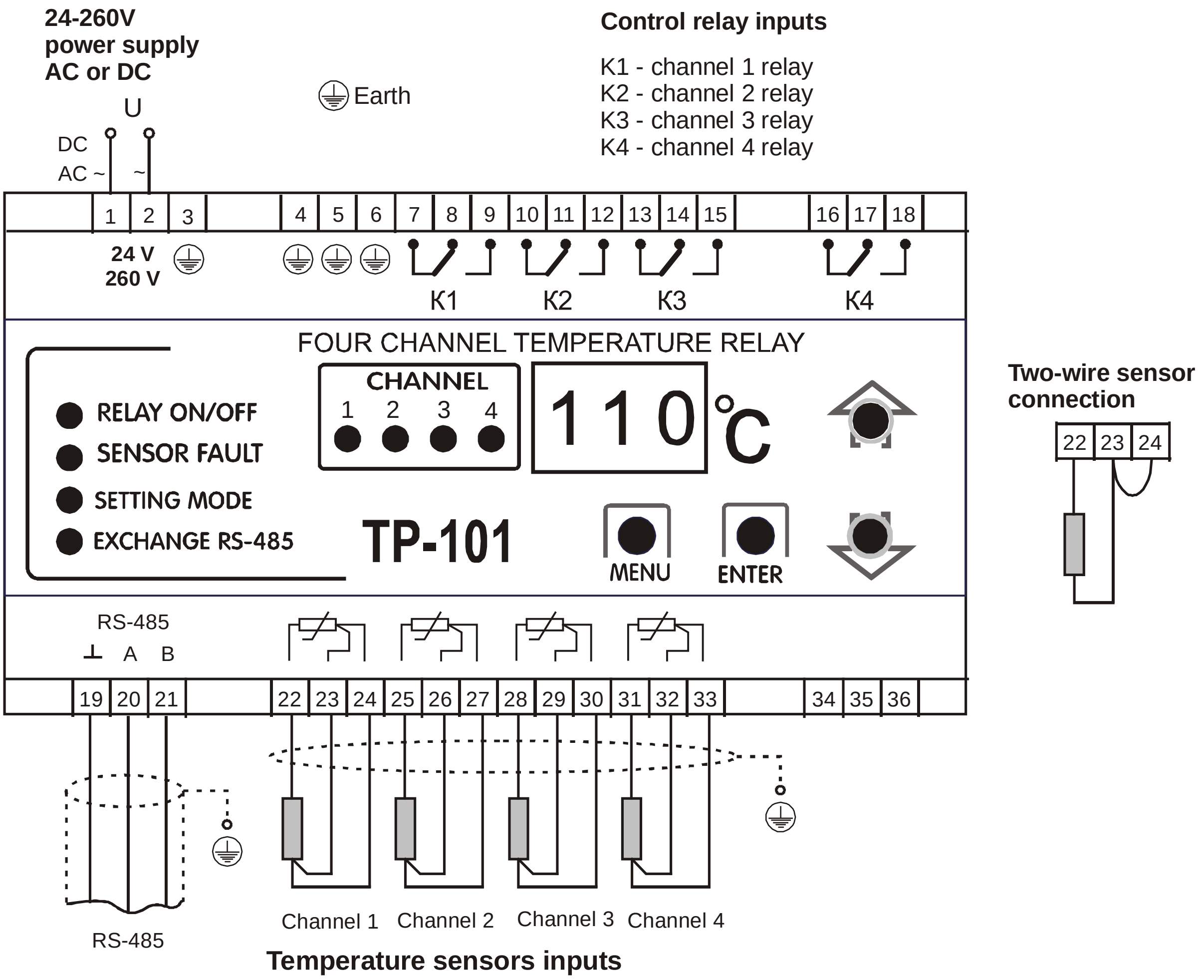


Figure 5.1 – TR–101 Connection Diagram

ATTENTION! To avoid interference impact to the measurement part of the device, the "device-sensor" communication lines must be:

- made of screened cable of twisted pair (triple);
- have section of not less than 0,5mm^2.
- be reliably connected to the device terminals;
- the cable connection route must be separate form the high voltage cables and inductive load feeding cables.

6 TR-101 OPERATION

6.1 GENERAL INFORMATION

6.1.1 When the device is powered on, all displays light up for 2 seconds. After that on the digital display the changed temperature for Channel 1 is shown. The device sequentially displays the temperature of the active channels with 4 sec. interval.

6.1.2 In case of certain faults presence, the device displays the error code (Table 6.1).

Table 6.1

FAILURE	DESCRIPTION
Parameter error	Instead of the faulty parameter TR-101 loads the default value, and the display shows ErP and TR-101 continues to function normally.
EEPROM failure	All relays are open and the display outputs EEP message.
Any sensor short circuit	The corresponding channel relay opens and “sensor failure” and “relay” lights begin to flicker. The display outputs Fcc message.
Any sensor disconnection	The corresponding channel relay opens and “sensor failure” and “relay” lights begin to flicker. The display outputs Foc message.

6.2 OUTPUT RELAY TESTING

The device gives an opportunity to test both all relays at once, or each relay independently; to test, perform the following:

- When in parameter edit mode, set the tSt parameter value according to table 7.1 and press ENTER key; upon that, the display will show oFF message (which means that all relays that are being tested are currently in the normally open (de-energized) state), all LED lights will go off.

- single pressing of ENTER key changes the status of the relays under testing:

oFF -the relays are in normally open (de-energized) state;
on -the relays are in normally closed (energized) state;

To switch back to the menu press the MENU key. If no key is pressed during 20 sec the TR-101 device goes into the initial state.

7 PROGRAMMING

7.1. GENERAL INFORMATION

ATTENTION! During in program mode of stay device doesn’t make regulation but power output loading relay switch to mode OFF.

7.1.1 Programmable parameters are set by the user during programming session and are stored in device’s nonvolatile memory.

The complete list of programmable parameter registers is given in table 7.1.

Table 7.1

Addres	Parameter	Mnemonic	Min/Max	Factory setting	Action
dec	**General**				
21	Sensor fault	Act	0/1	0	Condition of loading relay in case of a sensor fault: 0 – loading relay is OFF; 1 – loading relay is ON
	System parameters				
22	Indication mode	dSP	0/1	0	Device indication operation mode: 0 – the TR-101 sequentially, at 4 sec interval,

Addres	Parameter	Mnemonic	Min/Max	Factory setting	Action
					displays the active sensors temperature. 1 – operator views the temperature manually;
23	Password	PAS**	000/999	000	000 – password is off, any other value activates password prompt
24	Reset	rSt*	0/1	0	Resetting all settings to factory values 0 – do not reset; 1 – reset all parameters to factory values
25	Relay Testing	tSt*	0/4	0	Test TR-101 output relays: 0 – test all relays; 1 – test relay 1; 2 – test relay 2; 3 – test relay 3; 4 – test relay 4.
26	Version	uEr*		52	Device version
	RS-485				
27	Switching	r.S.A	0/2	0	RS-485 ON/OFF: 0 – OFF; 1 – ON; 2 – Remote Control for Power Relays
28	Identifier	r.S.n	1/247	1	Device number (network address)
29	Bit rate	r.S.S	0/2	2	Data transfer bit rate: 0 – 2400 (bps); 1 – 4800 (bps) 2 – 9600 (bps);
30	Timing	r.S.L	0/999	0	Delay time of response (x100µs) Single unit of value is 100 µs
	Channel 1				
31	Switching channel	cH. 1	0/3	1	Channel use: 0- off; 1 – channel functions with two-position action control; 2 – channel functions with PID control 3- auto tuning of PID(Xp, **τ**и, **τд**)
32	Setting	SP. 1	-50/200 ºC	100	Temperature setting (**Т**уст)
33	Hysteresis	HS. 1	0/50 ºC	1	Temperature hysteresis (HS)
34	Relay	rt. 1	0/1	0	Relay control method 0 – logic 1 (heater); 1 – logic 2 (cooler);
35	Proportional PID	P. 1	1/999 ºC	40	PID Proportionality band (Xp)
36	Integr. PID	i. 1	0/999 min	130	PID integrated constant (**τ**и)
37	Diff. PID	d. 1	0/999 min	4	PID differential constant (**τд**)
38	Period	t. 1	60/999 s	60	Pulse-repetition interval of pulse-length modulation (**Т**сл)
39	Interval	L. 1	1/999 s	1	Minimal length of pulse-length modulation
40	Characteristic shift	SH. 1	-50/50 ºC	0	Sensor characteristic shift 0 – prohibited (any other value triggers this mode)
41	Characteristic slope	UU. 1	0,50/2,00	1,00	Sensor characteristic slope (in mode “modbus” - value centuple)
42	Filter band	Fb. 1	0/50 ºC	0	Digital filter band 0 – prohibited (any other value triggers this mode)
43	Filter time	Ft. 1	0/60 s	2	Digital filter time constant 0 – prohibited (any other value triggers this mode)
44	Sensor type	ct. 1	0/16	1	The utilized sensor type: 0 – Pt50; 8 – Ni500; 16 – PTC1000;

Addres	Parameter	Mnemonic	Min/Max	Factory setting	Action
					1 – Pt100; 9 – Ni1000; 2 – Pt500; 10 – Pt'50; 3 – Pt1000; 11 – Pt'100; 4 – Cu50; 12 – Pt'500; 5 – Cu100; 13 – Pt'1000; 6 – Ni100; 14 – Cu'50; 7 – Ni120; 15 – Cu'100;
	Channel 2				
45	Switching channel	cH2	0/3	1	Channel use: 0- off; 1 – channel functions with two-position action control; 2 – channel functions with PID control 3 – auto tuning of PID(Xp, **τ**и, **τд**)
46	Setting	SP.2	-50/200 ºC	100	Temperature setting, (**Т**уст)
47	Hysteresis	HS.2	0/50 ºC	1	Temperature hysteresis (HS)
48	Relay	rt.2	0/1	0	Relay control method 0 – logic 1 (heater); 1 – logic 2 (cooler)
49	Proportional PID	P.2	1/999 ºC	40	PID Proportionality band (**X**p)
50	Integr. PID	i.2	0/999 min	130	PID integrated constant (**τ**и)
51	Diff. PID	d.2	0/999 min	4	PID differential constant (**τд**)
52	Period	t.2	60/999 s	60	Pulse-repetition interval of pulse-length modulation (**Т**сп)
53	Interval	L.2	1/999 s	1	Minimal length of pulse-length modulation
54	Characteristic shift	SH.2	-50/50 ºC	0	Sensor characteristic shift 0 – prohibited (any other value triggers this mode)
55	Characteristic slope	kU.2	0,50/2,00	1,00	Sensor characteristic slope (in mode "modbus" - value centuple)
56	Filter band	Fb.2	0/50 ºC	0	Digital filter band 0 – prohibited (any other value triggers this mode)
57	Filter time	Ft.2	0/60 s	2	Digital filter time constant 0 – prohibited (any other value triggers this mode)
58	Sensor type	ct.2	0/16	1	The utilized sensor type: 0 – Pt50; 8 – Ni500; 16 – PTC1000; 1 – Pt100; 9 – Ni1000; 2 – Pt500; 10 – Pt'50; 3 – Pt1000; 11 – Pt'100; 4 – Cu50; 12 – Pt'500; 5 – Cu100; 13 – Pt'1000; 6 – Ni100; 14 – Cu'50; 7 – Ni120; 15 – Cu'100;
	Channel 3				
59	Switching channel	cH3	0/3	1	Channel use: 0- off; 1 – channel functions with two-position action control; 2 – channel functions with PID control 3 – auto tuning of PID(Xp, **τ**и, **τд**)
60	Setting	SP.3	-50/200 ºC	100	Temperature setting, (**Т**уст)
61	Hysteresis	HS.3	0/50 ºC	1	Temperature hysteresis (HS)
62	Relay	rt.3	0/1	0	Relay control method 0 – logic 1 (heater); 1 – logic 2 (cooler);

Addres	Parameter	Mnemonic	Min/Max	Factory setting	Action
63	Proportional PID	P.3	1/999 ºC	40	PID Proportionality band (Xp)
64	Integr. PID	i.3	0/999 min	130	PID integrated constant (τи)
65	Diff. PID	d.3	0/999 min	4	PID differential constant (**τд**)
66	Period	t.3	60/999 s	60	Pulse-repetition interval of pulse-length modulation (**Т**сл)
67	Interval	L.3	1/999 s	1	Minimal length of pulse-length modulation
68	Characteristic shift	SH.3	-50/50 ºC	0	Sensor characteristic shift 0 – prohibited (any other value triggers this mode)
69	Characteristic slope	KU.3	0,50/2,00	1,00	Sensor characteristic slope (in mode “modbus” - value centuple)
70	Filter band	Fb.3	0/50 ºC	0	Digital filter band 0 – prohibited (any other value triggers this mode)
71	Filter time	Ft.3	0/60 s	2	Digital filter time constant 0 – prohibited (any other value triggers this mode)
72	Sensor type	ct.3	0/16	1	The utilized sensor type: 0 – Pt50; 8 – Ni500; 16 – PTC1000; 1 – Pt100; 9 – Ni1000; 2 – Pt500; 10 – Pt’50; 3 – Pt1000; 11 – Pt’100; 4 – Cu50; 12 – Pt’500; 5 – Cu100; 13 – Pt’1000; 6 – Ni100; 14 – Cu’50; 7 – Ni120; 15 – Cu’100;
	Channel 4				
73	Switching channel	cH4	0/3	1	Channel use: 0- off; 1 – channel functions with two-position action control; 2 – channel functions with PID control. 3 – auto tuning of PID(Xp, **τи**, **τд**)
74	Setting	SP.4	-50/200 ºC	100	Temperature setting, (**Т**уст)
75	Hysteresis	HS.4	0/50 ºC	1	Temperature hysteresis (HS)
76	Relay	rt.4	0/1	0	Relay control method 0 – logic 1 (heater); 1 – logic 2 (cooler)
77	Proportional PID	P.4	1/999 ºC	40	PID Proportionality band (**X**p)
78	Integr. PID	i.4	0/999 min	130	PID integrated constant (**τ**и)
79	Diff. PID	d.4	0/999 мин	4	PID differential constant (τд)
80	Period	t.4	60/999 сек	60	Pulse-repetition interval of pulse-length modulation (**Т**сл)
81	Interval Длительность	L.4	1/999 сек	1	Minimal length of pulse-length modulation
82	Characteristic shift	SH.4	-50/50 ºC	0	Sensor characteristic shift 0 – prohibited. (any other value triggers this mode)
83	Characteristic slope	KU.4	0,50/2,00	1,00	Sensor characteristic slope (in mode “modbus” - value centuple)
84	Filter band	Fb.4	0/50 ºC	0	Digital filter band 0 – prohibited. (any other value triggers this mode)
85	Filter time	Ft.4	0/60 сек	2	Digital filter time constant 0 – prohibited. (any other value triggers this mode)

Addres	Parameter	Mnemonic	Min/Max	Factory setting	Action
86	Sensor type	ct.4	0/16	1	The utilized sensor type: 0 – Pt50; 8 – Ni500; 16 – PTC1000; 1 – Pt100; 9 – Ni1000; 2 – Pt500; 10 – Pt'50; 3 – Pt1000; 11 – Pt'100; 4 – Cu50; 12 – Pt'500; 5 – Cu100; 13 – Pt'1000; 6 – Ni100; 14 – Cu'50; 7 – Ni120; 15 – Cu'100;

* *Parameter available only for reading.*
*** Remote access to computer is forbidden.*
Commercial units of PID coefficients is settled as a result of following object characteristic:
*- the heating is performed from 0*C to 100*C;*
*- rate of heating is 1*C per minute*
- yield of rated temperature takes place by 70% of power heating in such a way excess of power is 30%.

7.1.2 Viewing parameters

To view parameters, press [MENU] key once, the display will show parameter 1 from Table 7.1. Scroll parameters with [▼] [▲], parameter view – press key [MENU], passage back to menu – press key. [MENU]

7.1.3 Editing parameters

To edit parameters, press and hold [MENU] key for 7 seconds, at that:

- If a password had been set up, enter it. Use [▼] [▲] keys to change current position, use [MENU] key to move to next position, use [ENTER] key to confirm the password. Cancel password prompt - if no key has been pressed during 20 sec the TR-101 device returns to the initial state.
- If the entered password is correct, the "**Setting mode**" LED will light, Figure 3.2 (8), and the display will present the first parameter from Table 7.1.
- If the password entered is incorrect, the TR-101 will return to its initial state.
- If PAS has been set to "0" , password prompt will not be activated. "**Setting mode**" LED will light (Figure 3.2 (8)) , and the display will present the first parameter from Table 7.1.

Use [▼] [▲] keys to toggle parameters, use [ENTER] key to store parameter and return to menu, to return to menu without storing parameter, press [MENU] key. If no key is pressed during 20 sec the device goes into the initial state.

7.1.4 Reset to factory settings

- In the parameter edit mode (п.7.1.3) set rSt parameter to 1 and press [ENTER] key, after that, the device will perform resetting to default factory set parameters. Password will not be reset in this case.
- Energize the device while pressing down [▼] [▲] keys and hold them pressed for over 2 seconds, at that the display will show nAU message; release the keys. De-energize the device. All factory settings including the password have been restored (password is off).

7.2 Programming sequence

7.2.1 Setting up measurement entry parameters

7.2.1.1 Enter the ct.1 (ct.2, ct.3, ct.4) parameter value in accordance with the sensor type (table 1, table 7.1).

7.2.1.2 **Measurement characteristic adjustment**

The measurement adjustment procedure performed by the device is described in paragraph 3.2.3. The device performs measurement adjustment after the necessary values for parameters Sh – sensor measurement characteristic shift and PU – sensor measurement characteristic slope, have been set.

Sh parameter can be modified within boundaries from -50 to +50 ºC.

PU parameter can be modified within boundaries from 0.50 to 2.00.

ATTENTION!

1. The necessity of measurement accuracy adjustment becomes clear after the sensors and device have been verified.
2. When thermal element is connected under a two-wire diagram, the Sh parameter must be entered. The Sh parameter value definition is perform according to methodology described in 5.3.1.

7.2.2 Setting up digital filter parameters

The digital filter operation is described in paragraph 3.2.4.

The measurement digital filter setting up is performed by specifying two parameters values:

Fb – digital filter band and Ft – digital filter time constant.

The Ft value can be set within limits from 0 to 60 sec; when Ft=0 filtration by way of exponential smoothing is unavailable.

The Fb value is set within range from 0 to 200 ºC; when Fb=0 the “single interference termination” is off.

7.2.3 Setting up relay control method parameters

For a specific regulation system the control method has to be selected by means of setting corresponding values to rt.1 (rt.2, rt.3, rt.4) parameter:

0 – logic 1 (heater);

1 – logic 2 (cooler);

7.2.4 Setting control modes.

The device can function in one of the two modes: the two-position control and PID-control.

The proper mode is set by specifying a proper value for ch.1 (ch.2, ch.3, ch.4) parameter:

0 - OFF;

1 – two-position control;

2 – PID control;

3 – Automatic adjustment of PID regulator

The two-position control and PID control operation is described in paragraphs 3.2.5 and 3.2.6.

The two-position controller hysteresis HS (ºC) is set under HS.1 (HS.2, HS.3, HS.4) parameter, see 3.2.5; the parameter may be modified within range from 0 to +50 ºC.

7.2.5 PID regulator ajustment

7.2.5.1 **General concept**

PID regulator operation is described at p.3.2.6.

For adjustment of PID regulator needed attend following actions:

1. Value of regulator setting set SP.1 (SP.2, SP.3, SP.4).
2. Set parameters of pulse-length modulation (PLM) regulation:
   t – pulse repetition period **T**сл;
   L – minimal pulse lengh
3. Set parameters of PID regulation:
   P – Proportionality band of regulator **X**р;
   i – Reaction time of integration τи;
   d – Reaction time of peaker τд

Option setting t.1 (t.2, t.3, t.4) set in seconds from 60 to 999

Option setting L.1 (L.2, L.3, L.4) set in seconds from 1 to 999.

Option setting P.1 (P.2, P.3, P.4) set in ºC from 1 to 999.

Option setting i.1 (i.2, i.3, i.4) set in minutes from 0 to 999.

For i = 0 device works as PD regulator

Option setting d.1 (d.2, d.3, d.4) set in minutes from 0 to 999

For d = 0 device works as PI regulator.

For i = 0 and d = 0 device works as P regulator.

Considering that at each individual scheme there is non periodic external actions different characters all coefficients in above shown formulas can change for getting optimal behavior in positive conditions.

Selected parameters for superfine temperature maintenance in steady-state may happen totally unacceptable for suppression transient phenomena for external action or on-exit onto mode.

As well as alternatively.

For another thing in the course of operation controlled plant characteristic regulation can change very much. Like for operational changes and in time.

Usually calculated value require repeated correcting and selection. And changing single parameter involves necessity correcting other.

7.2.5.2 **Automatic adjustment of PID regulator**

This mode designed to autodetection initial approximate values of PID coefficients **τи**, **τд** и **X**р when operated at concrete scheme.

Automatic tuning is recommended to lead by start and system debugging.

7.2.5.2.1 Enter to program mode (see p.7.1.3).

7.2.5.2.2 Define SP ($\mathbf{T_{уст}}$) like setting value which in future will be supported by device.

If necessary fix **PLM** pulses repetition period and **minimal PLM pulse lengh, parameters** t.1 and L.1.

Factory setting are t.1 = 60 seconds, L.1 =1 second.

7.2.5.2.3 Define parameter cH.1 = 3 (cH.2, cH.3, cH.4).

After press key ENTER, at display device will appear blink caption "PiD" with number display device for 10 seconds (the time can change depending on fixed time filter Ft.1 ,Ft.2, Ft.3, Ft.4).

On the morrow of time regulator will give continuous output limit and at display device will appear current temperature dotted in low order position "xxx**.**".

Whereby output relay of loading will be power on till will not be reach the volume of temperature like SP ($\mathbf{T_{уст}}$).

After switching off loading relay (period I, point B at figure 7.1) sometime the temperature mechanically will be increase further.

As soon as the control temperature will come down low SP ($\mathbf{T_{уст}}$), process automatic tuning will be finish (point G figure 7.1) and to display device display continuous lettering "PiD".

TR-101 calculate coefficient of PID regulator: band proportionality $X_р$, characteristic time of integration $\tau_и$, characteristic time of peaker $\tau_д$.

After finishing automatic tuning needed press key MENU and switch device to program mode in which is possible to look and correct received coefficients value.

<u>The coefficients were received as a result of "Automatic tuning PID" are not optimal and work for preliminary analysis</u>

ATTENTION! For cancellation started mode of automatic tuning needed hold the MENU key for seven seconds.

7.2.5.3 PID regulator manual setting

Low mentioned method allows define approximate generic parameters of regulator.

7.2.5.3.1 Enter to program mode.

7.2.5.3.2 If necessary fix ***PLM*** pulses repetition period and minimal PLM pulse lengh, parameters t.1 and L.1.

Factory setting are t.1= 60 seconds, L.1=1 second.

7.2.5.3.3 Fix the value equal null for i ($\tau_и$), d ($\tau_д$) и P ($X_р$). Fix SP ($\mathbf{T_{уст}}$) value equal temperature setting value which will be supported by device in future.

After passage to mode regulation (at the end of 20 seconds the device automatically pass into mode regulation) output relay of loading will be power on till fail to reach regulation temperature (setting limit) $\mathbf{T_{уст}}$ (period I, point B into figure 7.1)

7.2.5.3.4 Take measure t_1 – time from the moment of temperature increase to 10% (point A at figure 7.1) and to the moment of temperature increase to 63% from the range $\mathbf{T_{уст}} - \mathbf{T_{нач}}$ (point B at figure 7.1).

7.2.5.3.6 Take measure of maximum value overshoot between points B and G (Емакс. figure 7.1).

7.2.5.3.7 Fix the value $X_p = 2 * E_{макс}$ (period II at figure 7.1).

Make sure that for datum value $X_p$does not absent achievement of setting value $\mathbf{T_{уст}}$. Otherwise necessary increase the value X_p.

If the value of $X_p = 2 * E_{макс}$ and the difference between steady-state temperature and setting value is too much that X_p need to diminish.

7.2.5.3.8 Fix the value $\tau_и = 2{,}4 * t_1$. Make sure that given value $\tau_и$ not appear temperature vibration around setting value (period III). For decreasing vibration is necessary increase value $\tau_{и}$, for increasing delivery speed necessary diminish value $\tau_{и}$.

7.2.5.3.9 Fix the value $\tau_{д}$ equal $[0{,}1;\ 0{,}2;\ 0{,}3;\ 0{,}4] * \tau_0$.

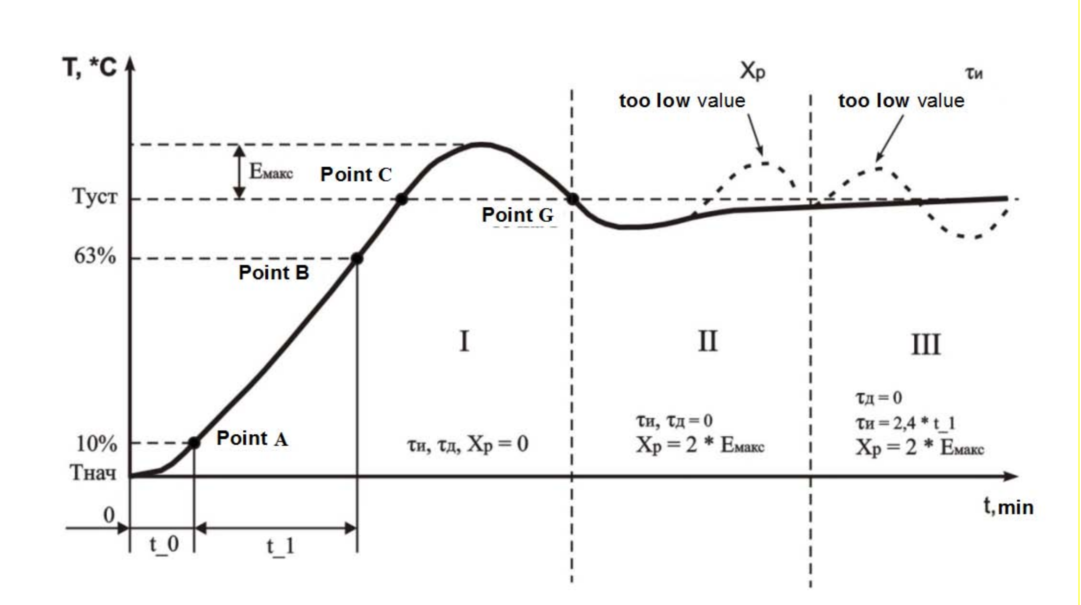


Figure 7.1 - PID regulator manual tuning

8 PERIOD OF SERVICE AND STORAGE, AND MANUFACTURER'S WARRANTY

The TR-101 has 10-year life period. Upon expiration of the service period, please, contact the manufacturer.

The manufacturer warrants defect-free performance of TR-101 within 3 years after the sales date, provided that the following conditions have been met:

- proper installation;
- proper operation and storage;
- manufacturer's QC department inspection seal is intact;
- integrity of the device case, no traces of opening, cracks, chipping, etc.

9 TRANSPORTATION

Transportation of TR-101 in package may be performed by any type of transport according to the transportation rules and regulations valid for such mode transportation.

During transportation, shipping and storing in a warehouse TR-101 must be protected form blows, shocks and moisture.

APPENDIX A

1 RS-485 COMMUNICATION INTERFACE

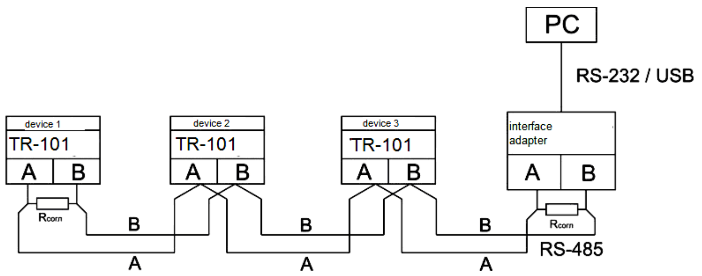
1.1 General information

The communication interface is employed to connect the TR-101 device to RS-485 network. The device utilization within RS-485 network allows for the following functions.

- collecting data of measured temperatures within SCADA system;
- setting device parameters with use of configuration software;
- remote control of the channels output relays.

RS-485 as an interface standard has found extensive industrial application; it provides for establishing networks with node count of up to 247 and data transfer at distance of up to 1200 m. With use of duplicators, the number of nodes and the transmission distance can be increased.

All network devices are connected in a serial bus (Figure A1). To maintain the reliable operation of transmitters/receivers and to eliminate interference impact, the communication line ends must be equipped with a terminating resistor of impedance Rcorл = 120 Ohm that is connected immediately to the device terminals (see Figure A1).



The device is connected to a PC via RS-485 / RS-232 or RS-485 / USB interface adapter.

The data exchange may take place at one of the following bitrates: 2400, 4800, 9600 bps.

1.2 Remote control for power relays.

By installation the value rSA = 2 (table 7.1) device will be switched to the value of remote management power relay. Control registers are shown at table A2.

If the channel working with two level action and labeled to control register value 0 or 1 is possible switch on or switch off prorated power relay.

If the channel working with PID regulation and labeled to control register value 0 or 100 is possible to manage capacity plug into correspondent relay (pos. 3.2.6.6).

If the mode 'Remote management of power relay' is switched on Tr-101 continuous working in usual mode.

Exception is the fact that management of power relay is passed to operator.

1.3 Data exchange adjustment through interface RS-485.

Data exchange adjustment is realized by parameters:

rSA – set switching on (switching off) RS-485 and the mode of remote management

rSn – device base address (1…247);

rSS -Rate of exchange the facts online (2400, 4800, 9600 bit/s);

rSL – Time delay the packet answer 0-99,9 ms.

Device TR-101 has following fixed exchange parameters not shown at the indicator:

Quality Stop-bit –2; Length of a data word – 8; Parity check – not.

Attention! New option exchange value come into effect only after device restarting or restarting at RS-485.

1.4 Data exchange through interface RS-485.

1.4.1 Working through interface RS-485 it should be done relevant connection (p. 1.1 of Appendix A) and set the value of net parameters (p. 1.3 of Appendix A) .

1.4.2 For organization data exchange online through interface RS-485 necessary have net Master. The main function of this device is to activate data exchange between sender and recipient. TP-101 may work at Slave mode by ModBus RTU protocol.

1.4.3 ModBus is the open network protocol that was developed by company Modicon. Protocol description takes a look at website www.modbus-ida.org.

Register addresses of program parameters are shown at table 7.1.

Check list of supported function (Modbus) is shown at table A1.

Additional registers and their function are shown at table A2.

Table A1

FUNCTION (hex)	DESCRIPTION	NOTE

0x03		Receiving value of one or several registers	max. 125
0x06		Recording one value to the register	
0x08	0x00	Return query data	Diagnostics
	0x01	Communication options restart	
	0x04	Setting up “listen only” mode	

Table A2

ADDRESS (dec)	NAME	DESCRIPTION		NOTE
0	Device ID	MSB	TP-101 – 0x0002	ID
1		LSB	weaving process - v50	Version
2	Status register TP-101	bit 0	0 – no emergency; 1 – Emergency (emergency code in register).	bit 5 – bit 15 reserved
		bit 1	0 –relay of 1 channel is switched off 1 – relay of 1 channel is switched on	
		bit 2	0- relay of 2 channel is switched off 1- relay of 2 channel is switched on	
		bit 3	0 – relay of 3 channel is switched off 1 – relay of 3 channel is switched on	
		bit 4	0 – relay of 4 channel is switched off 1 – relay of 4 channel is switched on	
3	Emergency register	bit 0	0 – Not emergency; 1- EEPROM rejection EEP	bit 10 – bit 15 reserved
		bit 1	0 – Not emergency; 1- parameter mistake ErP.	
		bit 2	0 – Not emergency; 1- sensor short curcuit 1 Fcc	
		bit 3	0 – Not emergency; 1 – sensor short curcuit 2 Fcc	
		bit 4	0 – Not emergency; 1 – sensor short curcuit 3 Fcc	
		bit 5	0 – Not emergency; 1 – sensor short curcuit 4 Fcc	
		bit 6	0 – Not emergency; 1- sensor disconnection 1 Foc	
		bit 7	0 – Not emergency; 1 – sensor disconnection 2 Foc	
		bit 8	0 – Not emergency; 1 – sensor disconnection 3 Foc	
		Bit 9	0 – Not emergency; 1 – sensor disconnection 4 Foc	
4	Sensor temperature 1			
5	Sensor temperature 2			
6	Sensor temperature 3			
7	Sensor temperature 4			
		when cH = 1	when cH = 2 (PID)	
8	Register of relay control 1	0- relay isswitched off 1-relay is switched on	0- capacity 0% 100 – capacity 100%;	channel 1
9	Register of relay control 2	0 – relay is switched off 1 –relay is switched on	0 – capacity 0%; 100 – capacity 100%;	channel 2
10	Register of relay control 3	0 – relay is switched off 1 – relay is switched on	0 – capacity 0%; 100 – capacity 100%;	channel 3
11	Register of relay control 4	0 – relay is switched off 1 –relay is switched on	0 – capacity 0%; 100 – capacity 100%;	channel 4
12-20		Registers from 12 to 20 are registered.		equal to zero always

APPENDIX B

1. Adjustment of instrument

1.1 General instructions

Adjusment of instrument must be done by qualifying specialists of metrological service if the measurement errors of input parameters are more settled value.
Before this operation necessary to check parameter set value SH1 **(**SH2**,**SH3**,**SH4) - “characteristic shift” and fix it equal zero.

1.2 *A*djustment of instrument TR-101

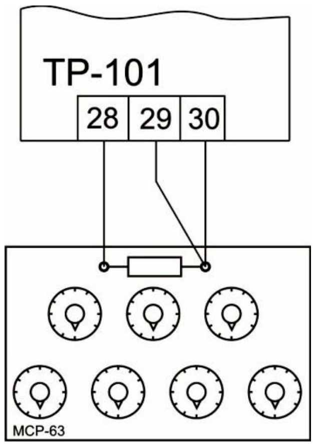


Figure B.1

1.2.1 Resistance of wires should be equal in a line each other and everyone should not exceed size 15 Ohm.
Plug into device input resistance box (instead of sensor) with accuracy class at least 0,05 For example (MSR-63) on three wire line (Figure B.1).

Fix at resistance box:
R= 50,00 using sensors type Pt50, Cu50;
R= 100,00 using sensors type Pt100, Cu100, Ni100;
R= 120,00 using sensor type Ni120;
R= 500,00 using sensors type Pt500, Ni 500;
R= 1000,00 using sensors type Pt1000, Ni1000;
R= 807,00 using sensor type PTC1000 (EKS111);

1.2.2 Power to TR-101. After 20-30 seconds make adjustment of device.
Be sure that the temperature value: 50, 100, 120, 500, 807, 1000 is equal 0 ºC. The pink limit of absolute accuracy is ±1 ºC.

1.2.3 Fix parameter value SH1 **(**SH2**,**SH3**,**SH4) equivalent temperature deviation but taken with opposite sighting. Test accuracy of settled value wherefore not changing the resistance wait till the device pass into temperature mode and be sure at what it’s indications are 0±1 ºC.