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USER MANUAL

AR653.B

Input RTD, TC, mA V, mV, Ω, BIN
Output 3(2) x P/SSR 1 x mA/V
Control ON/OFF, PID Program, Servo
Alarms STB function LATCH
Access protection Password
Protection rating IP65 IP40
RS485 MODBUS-RTU
USB port COM MODBUS-RTU
Ethernet MODBUS-TCP MQTT
Software ARSOFT-CFG

AR633.B

AR663.B

TWO-CHANNEL UNIVERSAL CONTROLLERS

Version 2.0.0
2022.01.11

Thank you for choosing our product.
This manual will enable proper handling, secure
and full use of the controller's capabilities.
Before assembling and starting the device please read
and understand this manual.
If you have additional questions, please contact our technical consultant.

TABLE OF CONTENTS

⚠ Special attention should be paid to texts marked with this sign

The manufacturer reserves the right to make changes to the design and software of the device without deteriorating its technical parameters.
All applications with possible comments should be sent to the Technical Service Department Dardex.

1. *SAFETY RULES*

Before using the device, please read this manual carefully, and:
a) in order to avoid electric shock or damage to the device mechanical and electrical assembly should be commissioned to qualified personnel
b) before turning on the power, make sure that all cables have been connected correctly
c) before modifying cable connections, disconnect the voltage connected to the device
d) ensure proper working conditions, compliant with the technical data of the device (*chapter 4*, supply voltage, humidity, temperature, etc.), do not expose the device to direct and strong influence of heat radiation

2. ASSEMBLY RECOMMENDATIONS

The device has been designed to provide an adequate level of resistance to most of the disturbances that can occur in industrial and home environments. In environments with an unknown/high level of interference, it is recommended to use the following measures to prevent any possible disruption of the device's operation:
a) do not supply power to the device from the same lines as large capacity devices without proper mains filters
b) for power, sensor and signal cables, use shielding and ferrite filters, where the filter and screen grounding (single point) should be as close as possible to the instrument
c) avoid laying measuring (signal) wires in the immediate vicinity and parallel to power and supply cables
d) it is recommended to twist signal wires in pairs or use a ready UTP wire
e) use the same cables for resistance sensors in a 3-wire connection
f) avoid the proximity of remotely controlled devices, electromagnetic meters, high power loads, loads with phase or group power control and other devices generating large impulse noise
g) ground or neutralize the metal rails on which the rail devices are mounted
Before starting working with the device, remove the protective foil of the LED display.

3. GENERAL CHARACTERISTIC OF CONTROLLERS. ACCESSORIES AND KIT CONTENTS

- control and supervision of temperature and other physical values (humidity, pressure, flow, level, velocity, etc.) converted into a standard electrical signal
- configurable architecture enabling using in many fields and applications (industrial, heating, food, energy, etc.)
- **2 universal measurement input** (RTD thermo-resistive, TC thermocouple, analogue 0/4÷20mA, 0÷10V, 0÷60mV, 0÷2.5kΩ) **with mathematical functions** (difference, sum, average, greater or lesser of the measurements) available independently for displaying and controlling control/alarm outputs
- **2 function keys** (**F** and **SET**) and **digital input** (**BIN**) for quick change of the controller operating mode, separately programmable: control start/stop, manual/automatic mode for outputs, step change of the SP setpoint (day/night, i.e. **SE1** / **SE2**, with separate control parameters), keypad lock, reset of errors and STB alarms (LATCH), unconditional preview of measured values from inputs 1 and 2
- **3 control/alarm outputs** of the on/off type (binary P/SSR) with independent functionalities and control algorithms (setpoints defined by the parameter or taken from the measurement input 1/2):
  - **ON-OFF with hysteresis** (threshold characteristics for heating and cooling, band alarms within and out of range and with an offset for three-point control)
  - **PID** (choice of **3 separate sets of parameters**, gain scheduling for SP setpoint taken from measurement input 1 or 2), advanced functions of automatic selection of PID **smart logic** parameters
  - programmable operation characteristics (**process controller with timer**, up to **6 segments**, including 3 segments of **ramping** type-slope for heating/cooling or cooling/defrosting, 3 SP setpoints with ON-OFF or PID control, selection of the auxiliary output and its condition, displaying the remaining time for the entire segment or after exceeding the SP, etc.)
  - thermostat/controller/safety switch **STB** (alarm condition open or closed, erased F/SET/BIN, can also be used as an **alarm memory** of **LATCH** type, e.g. after exceeding the minimum, maximum or band)
  - the ability to control a three-way mixing valve with an actuator (**step control**, **servo**) with two pin inputs (open - close), implemented on outputs 1 and 2
  - **manual mode** (open control loop) with the initial value of the control signal (MV) taken from the current automatic mode or programmed by the user in the range of 0÷100%, also for sensor failure

- direct or reversed **copy of the output 1 state** (applies to outputs 2 and 3, it can be used, for example, to implement a **DPDT** change-over relay or to take over the function of a damaged P1)
- **limitation** of the maximum level of the output signal (**power**), also includes the connected mA/V analog output

- **analogue output 0/4÷20mA or 0/2÷10V** for adjustment or retransmission of measurements and setpoints:
  - download of the control parameters from any connected output/alarm (1, 2, 3), both in automatic and manual mode
  - shock-free (soft) switching of the output signal, e.g. after changing the manual/automatic mode or control start/stop
  - correction (calibration) of the range of changes of the output signal (shift for the extreme values allowing to obtain non-standard ranges, e.g. 2÷16mA or 1÷9V)
- wide range of supply voltages (**18÷265 Vac /22÷350 Vdc**) and built-in power supply for object transducers **24Vdc**/50mA
- **clear LED** display with adjustable brightness and signaling of the operating status (messages, errors, etc.):
  - white color - measured value 1 (PV1, upper line), typical measurement **units** (°C, %, %RH, mA, A, mV, V, m and kPa, Pa, k for AR633.B/653.B or missing), symbols of outputs status and serial transmissions (1, 2, 3, **.**)
  - red, bottom line- selectable measured value 2 (PV2) or set SP or 8-segment **bargraph** for MV (control signal in the range of 0÷100%), PV (measurement), mA/V output signal or none (off)
- optional **RS485** serial interface, **MODBUS-RTU** protocol for reading measurements and parameters configuration
- optional **Ethernet** interface, **MODBUS-TCP** and **MQTT** protocols (for the Internet of Things **IoT/M2M**, cloud and mobile applications), the possibility to exchange measurement and configuration data via the **Internet**
- **USB** interface (micro USB connector, standard equipment, for parameter programming, measurement preview and firmware update)
- automatic/constant compensation of RTD and R line resistance and temperature of thermocouple cold junctions
- programmable input type, range of indications (for analogue inputs), options of control, alarms, display, communication, access, and other configuration parameters
- access to configuration parameters protected by a user's password or without protection
- ways to configure parameters:
  - from the membrane keyboard placed on the front panel of the device
  - via the USB port, RS485 or Ethernet and the ARSOFT-CFG program (for Windows 7/10) or the user's application (using the MODBUS-RTU and TCP communication protocols)
- **free ARSOFT-CFG** software enabling the preview of the measured value and quick configuration of single or ready sets of parameters previously saved on the computer for re-use, e.g. in other controllers of the same type (duplication of configuration)
- panel housing, protection **class IP65** from the front (after using an additional accessory gasket or other seal), IP54 without a gasket, AR663.B - housing for mounting on the TS35 rail (DIN EN 60715), IP40 (IP20 from the connectors side), AR633.B - industrial housing IP65 adapted to work in difficult environmental conditions, wall mounting
- modern technical solutions, intuitive and simple handling, **high accuracy** and long-term stability as well as resistance to interferences
- optional (in ordering mode): control outputs for SSR, analog output 0/2÷10V (instead of 0/4÷20mA) and RS485 interface and Ethernet (RJ45 connector)
- **available accessories** (you can also buy it through the online store apar.sklep.pl):
  - seal for IP65 tightness from the front (applies to panel housings)
  - USB cable (A - micro B) for connection to a computer, length 1.5 m
  - USB to RS485 converter (with galvanic separation)
- **kit contents**:
  - controller (with mounting brackets for panel enclosures) as well as the user manual and warranty card

CAUTION: 

- before starting work with the controller , read this manual and correctly perform mechanical, electrical installation and parameter configuration in accordance with Chapters *5, 6* and *8* (naming of the parameters was adopted according to the principle: index from *Table 8*: name in the 7-segment code, e.g. 0: ),

- **by default, the controller is configured to present the temperature from the Pt100 sensors, heating type control (ON-OFF algorithm with hysteresis) for P1/SSR1, P2/SSR2 and P3/SSR3 outputs (alarm 3), description in** *chapter 9*.

4. TECHNICAL DATA

Universal inputs(2 programmable - parameters *0/9*: inP 1/2, 17 types, 18 bit A/C processing), measuring ranges			
- Pt100 (RTD, 3- or 2-wire)	-200 ÷ 850 °C	- R (TC, PtRh13-Pt) thermocouple	-40 ÷ 1600 °C
- Ni100 (RTD, 3- or 2-wire)	-50 ÷ 170 °C	- T (TC, Cu-CuNi) thermocouple	-25 ÷ 350 °C
- Pt500 (RTD, 3- or 2-wire)	-200 ÷ 620 °C	- E (TC, NiCr-CuNi) thermocouple	-25 ÷ 820 °C
- Pt1000 (RTD, 3- or 2-wire)	-200 ÷ 520 °C	- N (TC, NiCrSi-NiSi) thermocouple	-35 ÷ 1300 °C
- J (TC, Fe-CuNi) thermocouple	-40 ÷ 800 °C	- current (mA, R_{we} = 50 Ω)	0/4 ÷ 20 mA
- K (TC, NiCr-NiAl) thermocouple	-40 ÷ 1200 °C	- voltage (V, R_{we} = 110 kΩ)	0 ÷ 10 V
- thermocouple S (TC, PtRh10-Pt)	-40 ÷ 1600 °C	- voltage (mV, R_{we} > 2 MΩ)	0 ÷ 60 mV
- B (TC, PtRh30PtRh6) thermocouple	300 ÷ 1800 °C	- resistive (R, 3-p or 2-p)	0 ÷ 2500 Ω
Response time for measurements (10÷90%)		0.5 ÷ 5 s (programmable), default ~1 s	
Leads resistance (RTD, Ω)		R_d < 25 Ω (for each line), auto or fixed compensation	
Resistance input current (RTD, Ω)		400 µA (Pt100, Ni100), 200 µA (Pt500, Pt1000, 2500 Ω)	
Processing errors (at an ambient temperature of 25°C):			
- basic	- for RTD, mA, V, mV, Ω	0.1% of the measuring range ± 1 digit	
	- for thermocouples	0.2% of the measuring range ± 1 digit	
- additional for thermocouples		<2 ° C (temperature of cold ends)	
- additional caused by ambient temperature changes		<0.004 % of input range /°C	
Resolution of measured temperature		0.1°C or 1°C, programmable (parameters *3/12*: dot 1/2)	
Indications range (resolution for analog inputs)		maximum -1999 ÷ 9999, programmable	
Decimal point position for analog inputs		programmable (dot 1/2) in the range of 0 3, i.e. 0 ÷ 0.000	
BIN digital input (contact or voltage <24V)		bi-state, active level: short-circuit or <0.8V	
P/SSR binary outputs (3 independent)	- relay **P** (P1, P2, P3), standard for outputs 1 and 2, option for output 3, (current for resistive loads)	AR653.B: **8**A/250Vac, 1xSPDT, 2xSPST-NO AR663.B: **5**A/250Vac, 2xSPDT, 1xSPST-NO AR633.B: **8**A/250Vac (1xSPDT), **5**A/250Vac (2xSPST-NO)	
	- **SSR** (SSR1, SSR2, SSR3), option	transistor type NPN OC, 11V, current < 35mA	
Analog output mA/V (1 current or voltage, not galvanically separated from the input)	- **current** 0/4 ÷ 20 mA, active (standard)	maximum resolution 1.4 µA (14 bit)	
		output load Ro < 1 kΩ	
	- **voltage** 0/2 ÷ 10 V (option, instead of 0/4 ÷ 20 mA output)	maximum resolution 0.7 mV (14 bit)	
		output load Io < 3.7 mA (Ro> 2.7kΩ)	
	- errors (% of the initial range)	basic<0.1%, additional<0.004%/°C, at 25°C	
Power supply (Usup, universal, compliant with the standards 24Vac/dc, 48Vac/dc, 110Vac, 230Vac, etc.)		18 ÷ 265 Vac, <3VA (alternating current voltage, 50/60Hz)	
		22 ÷ 350 Vdc, <4W (direct voltage)	
Power supply for object transducers		24Vdc / 50mA	
Communication interfaces	- **USB** (micro connector type B, communication with a computer), standard	drivers for Windows 7/8/10 (virtual COM serial port, MODBUS-RTU protocol, Slave)	

(independent, can be used simultaneously)	- **RS485** (separated), option	MODBUS-RTU protocol, Slave, speed 2.4÷115.2 kb/s, programmable character format (8N1, 8E1, 8o1, 8N2)
	- **Ethernet** (separated), option	RJ45 connector, 10base-T, TCP/IP protocols: **MODBUS-TCP** (Server), **MQTT** (client, v. 3.1.1), DHCP (client), ICMP (ping)
Display (LED, 7-segment, 2 lines, 4 digits each, brightness adjustment, symbols for signaling the status of outputs, typical measuring units)	- top, white	digit height: 13 mm (AR633.B/653.B), 9 mm (AR663.B)
	- bottom, red	digit height: 10.5 mm (AR633.B/653.B), 7 mm (AR663.B)
Rated operating conditions	0 ÷ 50°C, <90 %RH, for AR633.B <100%RH, no condensation inside the device, working environment: air and neutral gases	
Protection degree	IP65 for AR633.B and for AR653.B from the front with a seal (IP54 without a seal), IP40 for AR663.B, IP20 from the connector side (not applicable to AR633.B)	
Weight	~200g (AR653.B), ~190g (AR663.B), ~320g (AR633.B)	
Electromagnetic Compatibility (**EMC**)	resistance: according to PN-EN 61000-6-2 standard, emissivity: PN-EN 61000-6-4	
Safety requirements according to PN-EN 61010-1 norm	installation category: II	pollution degree: 2
	voltage to ground: 300 V for the supply circuit and relay outputs, 50 V for the remaining input and output circuits and communication interfaces	
	insulation resistance > 20 MΩ	altitude above the sea level <2000 m

5. HOUSING DIMENSIONS AND ASSEMBLY DATA

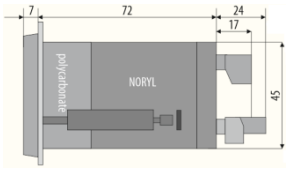
a) AR653.B

Mounting	panel, handles on the side of the housing
Material	self-extinguishing NORYL 94V-0, polycarbonate
Housing dimensions	96 x 48 x 79 mm (W x H x D, without connectors)
Panel window	92 x 46 mm (W x H)
Cable cross-sections (for separable connectors)	2.5 mm^2 (power supply and P/SSR outputs), 1.5 mm^2 (other)

AR653.B

View from the side of the mounting handle.

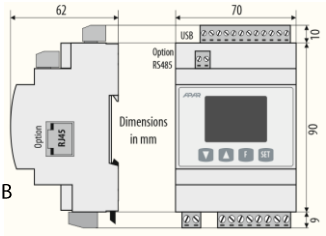
Dimensions in mm



b) AR663.B

Housing type	for rail, XTS 4MH53A Modulbox
Material	PC/ABS self-extinguishing
Housing dimensions	70 x 90 x 62 mm (W x H x D, without connectors)
Mounting	on the TS35 rail (DIN EN 60715)
Cable cross-sections (for separable connectors)	2.5 mm^2 (power supply and P/SSR outputs), 1.5mm^2 (other)

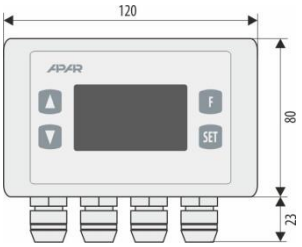
AR663.B



c) AR633.B

Housing type	industrial IP65, Gainta G2104
Material	polycarbonate
Housing dimensions	120 x 80 x 55 mm (W x H x D, without glands)
Mounting	4 holes Φ4.3 mm, spacing 108x50 mm, accessible after removing the front cover
Cable cross-sections (for separable connectors)	2.5 mm^2 (power supply and P/SSR outputs), 1.5mm^2 (other)

AR633.B

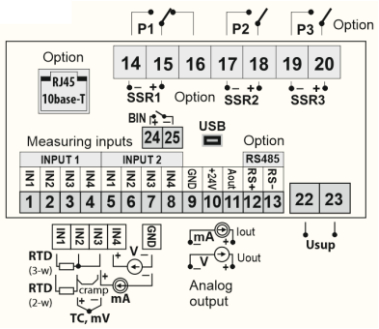


6. DESCRIPTION OF CLAMPING RAILS AND ELECTRICAL CONNECTIONS

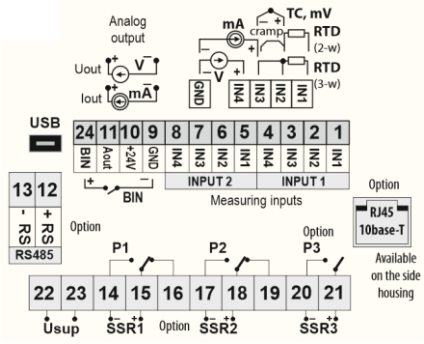
Table 7. Numbering and description of clamping rails

Clamps / Connectors	Description
IN1-IN2-IN3	Pt100, Ni100, Pt500, Pt1000 input, resistive, (2- and 3-wire)
IN2-IN3	thermocouple input TC (J, K, S, B, R, T, E, N) and voltage input 0÷60mV
IN3-GND (9)	current input 0/4÷20mA
IN4-GND (9)	voltage input 0÷10V
10	+24V output (in relation to 9-GND) of the built-in power supply of object transducers
24-25 (9)	BIN binary input (contact or voltage <24 V)
11-9 (GND)	analog output: current (0/4 ÷ 20mA) or voltage (0/2 ÷ 10V)
12-13 (optional)	RS485 serial interface (MODBUS-RTU protocol), *chapter11*
22-23	power supply input (universal)
14-15-16	P1 or SSR1 relay output (14-15)
17-18 or 17-18-19	P2 or SSR2 relay output (terminals 17-18-19 apply only to **AR663.B**)
19-20 or 20-21	P3 or SSR3relay output (terminals 20-21 apply to AR663 **only.B**)
USB (micro type B)	USB serial interface for cooperation with a computer, *chapter 11*
RJ45 (option)	Ethernet serial interface (MODBUS-TCP, MQTT protocols, etc.), *chapter 11*

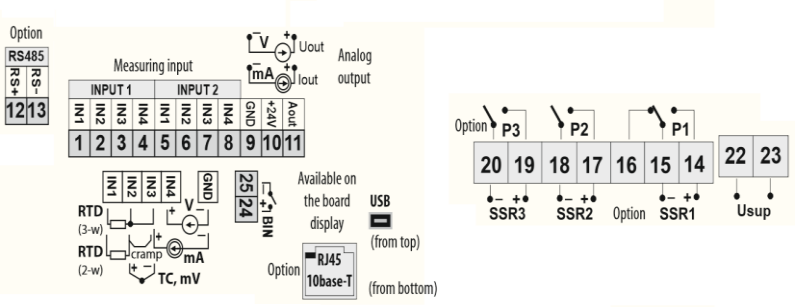
a.1) Connectors for AR653.B



a.2) Connectors for AR663.B (description of clamps Table 7)



a.3) Connectors for AR633.B (connectors are accessible after removing the front cover and display board, except for USB)

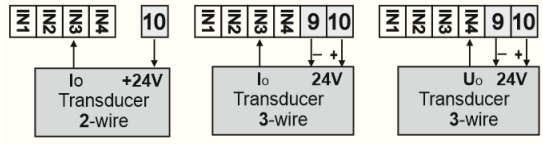


CAUTION

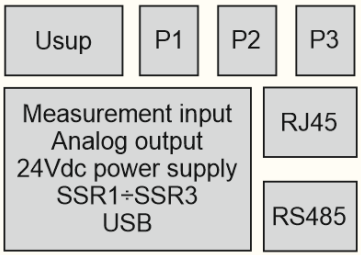
In order to assemble the wiring for **AR633.B** follow the instructions below:
- unscrew 4 screws in the front plate and remove it from the device
- the device can be screwed to the base with 4 screws in the mounting holes
- unscrew 1 screw on the display board and carefully slide the board out of the mounting sockets
- connectors for signal cables, power supply and relay outputs are available
- lead the electric wires into the housing through cable glands (and tighten the optional RJ45 pin)
- after assembly, assemble the device in the reverse order to that described above
- IP65 tightness requires precise tightening of the gland nuts and the housing cover
- to avoid possible mechanical and electrostatic damage, care should be taken in the operations related to the display board.

a) Connection of 2- and 3-wire transducers

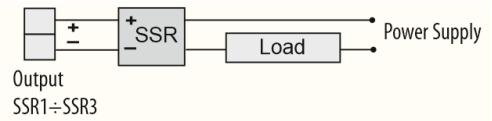
(Io - current, Uo - output voltage)



b) Galvanic separation of circuits



c) Connection of SSR type relay (to control output of the controller)



CAUTION:

For inductive loads, consider the use of blowout that will reduce the burnout of the relay pins

7. DESCRIPTION OF KEYS AND LED DISPLAY FUNCTIONS

a) keys functions in the measurement display mode

Key	**Description** [and the method of marking in the content of the manual]
▼ + ▲	**[DOWN]** and **[UP]** (simultaneously): **1.** entering the parameter configuration menu (after holding time longer than 1.5 seconds), proceed as described in *chapter 8*, point 1, **2.** resetting errors (confirmed by the message tLER), *chapter 10*
▼ or ▲	quick change of the displayed output setpoint (SEt1 SEt2 or HSEt, selection of values for the lower row sets the parameter 89: diod, *chapter 8*), step **x1** (or **x10**, description of *point c*)
SET	**[SET]**: **1.** entering the quick access menu (after a short press, *chapter 9.1*), **2.** activation of the additional function selected with parameter 81: FunS (pressing> 1.5s, *chap. 7.1* and *8)*
F	**[F]**: activation of the function selected by the parameter 79: FunF (pressing longer than 1.5 seconds, description in *chapters 7.1* and *8)*
[UP]+**[DOWN]**+ **[SET]** (simultaneously) or **[F]**, **[SET]** and BIN **input** when no function (79: FunF/S/b =nonE)	**Device status**: upper line of the display - firmware version, lower – Ethernet interface status (nE- none, dE - available but disabled by the 93 parameter: EtAo or not connected to the LAN network, LE - connected to the LAN network, tE or bE - open port of the MODBUS-TCP protocol, RE or bE - established connection to the MQTT broker) and **RS485** (nY- none, dY - available), **analogue output** type (**mA** unit – current **V**, -voltage)

b) keys functions in the parameter configuration menu and in the quick access menu (*chapters 8* and *9.1)*

Key	**Description** [and the method of marking in the content of the manual]
SET	**[SET]**: **1.** selection of the displayed item in the configuration menu (entering a lower level), **2.** editing the current parameter (value blinking on the lower display), **3.** approval and saving of the edited parameter value
▼ or ▲	**[UP]** or **[DOWN]**: **1.** going to the next or previous parameter, **2.** change of the value of the edited parameter with a step of changes **x1** (or **x10**, description *in point c*)
▼ + ▲ or F	**[UP]** and **[DOWN]** (simultaneously) or **[F]**: **1.** returning to the previous menu (one level higher), **2.** cancelling changes of the edited value (flashing stops), **3.** returning to the measurement display mode (holding time > 0.5s, except for **[F]**)

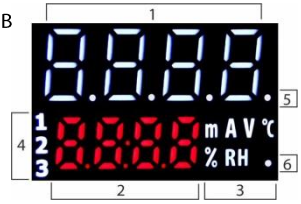
c) additional functions of keys during the change (edition) of setpoints and other configuration parameters

Keys	Description
[SET]+**[UP]** or **[SET]**+**[DOWN]**	changing the value of the edited parameter (with a step of changes **x10**, keyes pressed simultaneously)
[SET]+ **[UP]**+**[DOWN]**	restoring **the factory value of** the edited parameter (according to *Table 8*, *chapter 8*)

In addition, the speed of changing the edited value depends on the time the keys are held (the longer the faster).

d) functions of the LED display elements

AR663.B



AR633.B
AR653.B

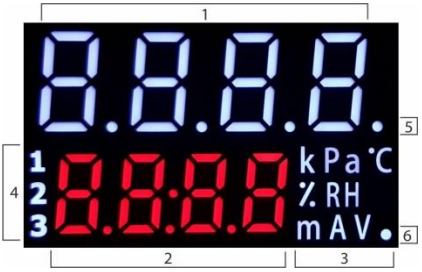


Fig.7. View of all segments of the display

Element	Description [and the method of marking in the content of the manual]
1, 2	upper and lower line for presenting (in 7-segment code) PV measured values and SP setpoints or bargraph values (8-segment, *chapter 8*, parameter 89:dSbo) and other messages and errors (*chapter 10*)
3	units for displayed values (for measurements set with parameter 87:Unit, description in *chapter 8*)
4	**[1] [2] [3]** - signal of switching on outputs P1/SSR1, P2/SSR2, P3/SSR3
5	**[T]: 1.** analysis of the object for PID tuning signaling (auto-tuning) in the Auto mode (smart logic, *chapter 9.4*), **2.** time measurement signaling in the software algorithm (process controller with timer, *chapter 9.6*)
6	**[Tx/Rx]** - icon of the presence of USB, RS485 or Ethernet transmission and saving parameters in the controller's memory

7.1. FUNCTION KEYS AND BINARY INPUT

The independent function keys **[F]** and **[SET]** and the binary BIN **input** are used to quickly start the programmed functions (with parameters 79:FunF, 81:FunS and 80:FunB, described in *chapter 8*). The **BIN** digital input cooperates with a bistable signal, i.e. the supplied signal (voltage or switch) must be permanent (on/off type, active level: short-circuit or < 0.8V). Moreover, **BIN** has priority higher than the **[F]** and **[SET]** keys. Activating or stopping the function is signaled by appropriate messages on the lower display (described in *Table 8* and *chapter 10*). The action for **[F]** and **[SET]** is performed only in the mode with measurement display (after holding time> 1.5 sec), for **BIN** - always (in every operating state).

8. SETTING CONFIGURATION PARAMETERS

All controller configuration parameters are contained in non-volatile (permanent) internal memory.
When switching on the appliance for the first time, the display may show an error signal related to the lack of sensor or attached one other than factory programmed one. In such case, connect the appropriate sensor or analog signal, or perform the programming of the configuration.
There are two ways to configure the parameters (manual and remote, do not use simultaneously):

1. Manually, from the membrane keyboard placed on the front panel of the device:
- from the display mode of input measurements in the configuration menu (simultaneously press the **[UP]** and **[DOWN]** keys for longer than 1.5 sec.) If parameter 84:PPro = on (password protection is enabled) the message CodE will appear on display, followed by 0000 with the first digit flashing, with the **[UP]** or **[DOWN] key** enter the access password (default parameter 85:PASS = 1111), to move to the next positions and confirm the code use the **[SET]**key, to cancel the changes use the **[UP]+[DOWN]** or **[F]**keys,
- after entering the main configuration menu (with the message Conf) the upper line shows the mnemonic name of the submenu (parameter groups: inL 1 <-> inL2 <-> out 1 <-> etc.), the bottom line is

dimmed or displays nonE (no module, depending on the hardware version of the controller),
- use the **[UP]** or **[DOWN]** keys to select the appropriate submenu, and then press **[SET]** to confirm the selection (the name of the parameter is now visible on the upper line and the value on the lower line of the display),
- the **[UP]** key takes you to the next parameter, **[DOWN]** to the previous one (eg: inP 1 <-> t_cr 1 <-> cut 1 <-> etc., only parameters compatible with the hardware version are available, a summary list in *Table 8*),
- to change the value of the current parameter, briefly press the **[SET]** key (flashing in edit mode),
- use the combination of **[UP]**, **[DOWN]** and **[SET]** **keys** to change the value of the edited parameter (with a step of changes x1 or x10 or load the default value of a parameter, description of the function in *chapter 7*, points b and c),
- confirm the changed value of the parameter with the **[SET]** key or cancel it with the **[F]** or **[UP]**+**[DOWN]** keys,
- pressing **[UP]**+**[DOWN]** or **[F]** again causes the return to the main configuration menu (one level up),
- exit from configuration: long press of **[UP]**+**[DOWN]** keys or automatically after approx. 2 minutes of inactivity

2. Remotely through the USB port, RS485 or Ethernet and the ARSOFT-CFG **computer** program (*chapter 11*):
- connect the controller to the computer port, run and configure the ARSOFT-CFG application,
- after establishing the connection, the program displays the current measurement, the icon **[Tx/Rx]** signals transmission (*chapter 7, point d*)
- setting and viewing device parameters are available in the parameter configuration window
- new parameter values must be confirmed with the ***Approve changes*** key
- the current configuration can be saved to a file or set with values read from the file

NOTICE:
- before disconnecting the device from the computer, use ***the Disconnect the device*** (ARSOFT-CFG) key
- in the absence of a response:
  - check the settings in ***Edit of configuration*** (*Connection type*, *COM Port*, *MODBUS address of the device*, etc.)
  - for USB, check whether the drivers for the serial port in the computer have been correctly installed (*see section 11*)
  - disconnect for a few seconds and reconnect the regulator or the RS485 converter to the USB port of the computer
- restart the ARSOFT-CFG and/or the computer

If there is a discrepancy between the indications and the actual value of the input signal, it is possible to tune the zero and sensitivity to a given sensor: parameters 7/16: cAL 1/2 (zero) and 8/17: cAG 1/2 (sensitivity).

In order to restore the factory settings, press the **[UP]** and **[DOWN]** keys during start until the password entry menu appears (CodE), and then enter the code 0112. Alternatively, you can use the file with the default configuration in the ARSOFT-CFG program.

Table 8. List of configuration parameters

Parameter (index: name)	**Value and range of variability of the parameter** (value: name) **and description**		**Default**
I. CONFIGURATION OF MEASUREMENT INPUTS, submenu inC 1, inC2, in 2 groups inC 1/2 there are identical sets of parameters differing in indices and numbering in names			
0/9: inP 1/inP2 type of measurement input	0: Pt Pt100 sensor (RTD, -200÷850°C)	1: ni Ni100 sensor (RTD, -50÷170°C)	Pt
	2: Pt5 Pt500 sensor (RTD, -200÷620°C)	3: Pt10 Pt1000 sensor (RTD, -200÷520°C)	
	4: tc-J thermocouple type J (-40 ÷ 800 ° C)	5: tc-K K type thermocouple (-40÷1200°C)	
	6: tc-S thermocouple type S (-40 ÷ 1600 ° C)	7: tc-b type B thermocouple (300÷1800°C)	
	8: tc-r thermocouple type R (-40÷1600°C)	9: tc-t thermocouple type T (-25÷350°C)	
	10: tc-E E type thermocouple (-25÷820°C)	11: tc-n N type thermocouple (-35÷1300°C)	
	12/13: I/ 0-20 4÷20 mA / 0÷20 mA current signals		

	14/15: 0-10 / 0÷10 V / 0÷60 mV voltage signals		
	16: rES resistance signal 0÷2500 Ω		
1/10: L in 1/2 line resistance	000 ÷ 5000 Ω	total line resistance for 2-wire RTD and 2500Ω sensors *(1)*	000 Ω
2/11: cJt 1/2 temperature of cold ends of thermocouples	0: Auto 0.1 ÷ 60.0 C	automatic or constant temperature compensation of the reference junction of thermocouples, Auto = 0.0 C	Auto
3/12: dot 1/2 dot position/resolution	0 / 1	no dot / 0.0 *(2)* or resolution 1/0.1°C for temperature	1 (0.1°C)
	2 / 3	000 / 0000 *(2)*	
4/13: inL 1/2 lower limit for SP or lower range of indications	-999 ÷ 1800	lower setting limit for setpoints SP (22: SEt 1 ÷ SEt3)	-999 °C
	-999 ÷ 9999 *(2)*	beginning of the scale for the 0/4mA, 0V, 0Ω input and the PV **bargraph**	
5/14: inH 1/2 upper limit for SP or upper range of indications	-999 ÷ 1800	upper limit of setpoints for SP setpoints (22: SEt 1 ÷ SEt3)	850.0 °C
	-999 ÷ 9999 *(2)*	end of scale for 20mA, 10V, 60mV, 2.5kΩ inputs and **PV** bargraph	
6/15: / filtration *(3)*	1 ÷ 20	digital filtering degree (response time)	3 (~1s)
7/16: cAL 1/2 zero calibration	zero offset for measurements: -1000 ÷ 1000 C or -1000 ÷ 1000 units *(2)*		0.0 °C
8/17: cAG 1/2 gain	850 ÷ 1150 %	slope calibration (sensitivity) for measurements	1000 %
II. CONFIGURATION OF OUTPUTS 1÷3 (P/SSR), submenu out 1 ÷ out3, in 3 groups out 1/2/3 there are the same sets of parameters with different indices and numbering in the names (and possibly the range of variability), description *chapter 9*			
18/27/36: coS 1/2/3 **PV** control signal for output (input assignment)	0: inP 1 = input 1 measurement, 1: inP2 = input 2 measurement, 2: Subt = measurement difference 1-2, 3: Add 1 = sum of measurements 1+2, 4: AvrG = average value of measurements 1 and 2, 5: LArG = greater of measurements 1 and 2, 6: SmAL = smaller of measurements 1 and 2		inP 1/2/1
19: Ctr1 control algorithm 28: Ctr2 for output 2 (out2) 37: Ctr3 for output 3 (out3) **Caution** (for 9/10 values): if **[F]**/**[SET]** or **BIN** with the start/stop function of the outputs operation was used to reset the STB (LATCH) alarm, a start is always needed to restart the STB and regulation	0: oFF output permanently switched off	1: onoF ON / OFF with hysteresis	onoF
	2/3/4: Pid 1/2/3	PID with parameter set 1/2/3 (*chapter 9.3*)	
	5: Pidd gain scheduling	PID - parameter set 1 when SP from input ≤ 22: SEt 1/2/3 or set 2 for SP>SEt 1/2/3, works for 21: SES 1/2/3 = inP 1/2	
	6/7: PrGr/A	software - main/auxiliary output (*chapter 9.6*)	
	8: MAnd (manual) M	manual (with the set point set by the parameter 82: MSEt and the pulse period of the P/SSR output, 25/34/43: PEr 1/2/3)	
	9/10: StbF/M	safety thermostat STB (alarm with memory, LATCH), emergency open/closed state (deleted **[F]**, **[SET]**, **BIN**, *chap. 7.1*)	
	11/12: d/diA	direct/inversed copy of the state of output 1 (only for parameters 28/37: Ctr2/3, outputs 2/3, e.g. for the implementation of a switching output of DPDT type)	
	13: SAtc	servo valve control on the outputs 1-open and 2-close (only for parameter 28: Ctr2, *chapter 9.7*), step adjustment	

20: Fun1 type of regulation/alarm

29: Fun2 for output 2 (out2)
38: Fun3 for output 3 (out3)

1. concerns the control algorithms: ON-OFF with hysteresis, PID, software (main output), STB (LATCH) and step adjustment (servo)

2. for PID, software (main output) and servo algorithms, only heating/inversed and cooling/direct characteristics apply

3. characteristics 4÷7 (i.e. in relation to **SP1**) are available only for parameters Fun2/3 (outputs 2/3)

SP1/2/3 -setpoints for outputs 1/2/3 selected with parameters 21/30/39: SES1/2/3, i.e. 22/31/40:/ SEt1/2/3 or input measurement)

0: indH heating / inversed

(activated below SP)

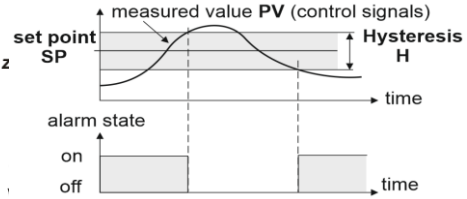


Fig.8.1. Characteristics of *the heating* type (for ON-OFF)

indH

1: dirE cooling/ direct

(activated over SP)

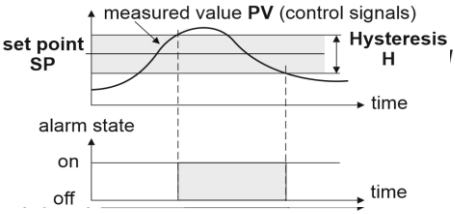


Fig.8.2. Characteristics of *the cooling* type (for ON-OFF)

2: inbA in band alarm

(activated in band)

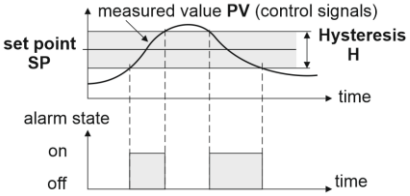


Fig.8.3. Characteristics of *the in band* alarm (ON-OFF)

3: oubA out of band alarm

(disabled in band)

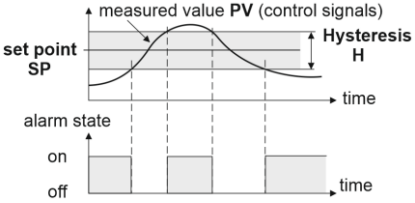


Fig.8.4. *Out of band* alarm characteristics (ON-OFF)

4: rbaN alarm in band ± **SP2/3** around **SP1**- setpoint output 1

(activated in band)

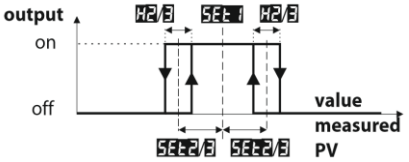


Fig.8.5. Characteristic *in band in* relation to **SP1**

5: rboF alarm out of ± band **SP2/3** around **SP1**- output 1 setpoint

(disabled in band)

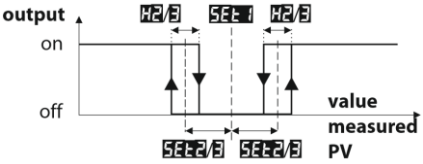
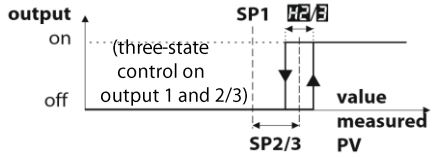
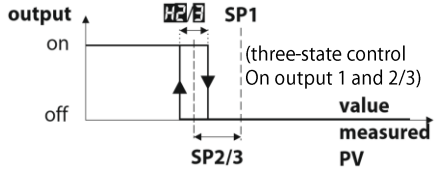


Fig.8.6. Characteristic *out of band* in relation to **SP1**

	6: dEoF disabled below SP= **SP1**+**SP2/3** (activated above SP)	 **Fig.8.7.** Deviation from **SP1** (for **SP2/3** > 0)		
	7: dEon enclosed below SP= **SP1**+ **SP2/3** (activated below SP)	 **Fig.8.8.** Deviation from **SP1** (**SP2/3** < 0)		
21/30/39 SES 1/2/3 setpoint selection **SP** (**1/2/3**)	0: inP1 = input 1 measurement, 1: inP2 = input 2 measurement, 2: SEtP = fixed setpoint SP defined by parameter 22/31/40: SEt 1/2/3			
22/31/40: SEt 1/2/3 setpoint **SP** for controlling/alarm	changes in the range set by parameters 4/13: rL 1/2 and 5/14: rH 1/2 (depending on the assigned control signal, 18/27/36: CoS 1/2/3)			1000 °C
23/32/41: H 1/2/3 hysteresis **H** or PID tuning zone	hysteresis or PID tuning dead band in mode Auto (smart logic, *chapter 9.4*), 0.0 ÷ 9999 C or 0 ÷ 9999 units *(2)*			1.0 °C
24/33/42: oPF 1/2/3 power limitation (available power)	0 ÷ 100 %, maximum level of control signal/power (also for connected analogue output **mA/V** with parameter 46: FunA), step every 1% *(4)*			100 %
25/34/43: PEr 1/2/3 pulse period of the **Tc** output	1÷360 s, applies to limitation of power and manual mode, PID and servo algorithm, for P/SSR outputs (pulsing with 0÷ 100% fill factor)			4 sec.
26/35/44: Fto 1/2/3 output emergency state	for lack of/damage of the sensor/signal/input or outside the measuring range: 0: noCh = unchanged, 1: oFF = disabled, 2: = enabled, 3: mAnd = manual mode with the set level of the output signal (parameter 82: MSEt)			oFF
III. CONFIGURATION OF THE ANALOG OUTPUT mA/V, submenu outA, detailed description in *chapter 9.2*				
45: analog output AtyP type/standard	depending on the order code (hardware version): for current output 0: 0-20 or 1: 4-20 mA, for voltage output 0: 0-10 or 1: 2-10 V			0-20 mA (0-10 V)
46: FunA analog output function	0: oFF = permanently disabled (0mA or 0V), 1: rE.1 = retransmission of input 1 measurement , 2: rE.2 = retransmission of input 2measurement, 3: rESu = retransmission of the measurement difference 1-2, 4: rEAd = retransmission of the sum of measurements 1+2, 5: rEAd = retransmission of the average of measurements 1+2, 6: rEAd = retransmission of the greater of measurements 1 and 2, 7: rEAd = retransmission of the smaller of measurements 1 and 2, 8/9/10: rSE 1/2/3 = SP setpoint retransmission (i.e. 22/31/40: SEt 1/2/3), 11/12/13: Con 1/2/3 = control output associated with 1/2/3 output parameters			oFF
47: ArLo beginning of scale for retransmission of measurements and SP	-999 ÷ 1800	lower indication for output signal values 0/4mA or 0/2V	parameters active only for retransmission of measurements or setpoints	0.0 °C
48: ArH. end of scale for measurement retransmission and SP	-999 ÷ 9999 *(2)*	upper indication for 20mA or 10V output signal values		1000 °C
49: bottom cbot adjustment	000÷395 mA/V	calibration of the variability range of the output signal, with a step of	for 0/4mA or 0/2V	000 mA/V

50: tAoP upper correction	-9.99÷9.99 mA/V	changes 0.05 mA/V	for 20mA or 10V	
IV. PID ALGORITHM CONFIGURATION (1÷3), submenu Pid1÷Pid3, in the 3 groups Pid1/2/3 there are the same parameter sets with different indices and numbering in the names, description in *chapters 9.3÷9.5*				
51/55/59: tun1/2/3 type of tuning (autotuning) PID	0: oFF =disabled, 1: Auto =smart logic, 2: StEP = step response method (fast), 3: oSCi = oscillation method (longer), *chapter 9.4*			oFF
52/56/60: Pb1/2/3 proportionality band **Pb**	0.1 ÷ 1800 or 1 ÷ 9999 units *(2)*			10 °C
53/57/61: ti1/2/3 integration constant **Ti**	0÷3600 s, PID algorithm integral action time, 0 turns off the integral element			0 sec.
54/58/62: td1/2/3 derivative time **Td**	0÷999 s, PID derivative action time, 0 turns off the derivative element			0 sec.
V. CONFIGURATION OF THE PROCESS CONTROLLER (programmable operating characteristic, ramping), submenu ProG, description - *chapter 9.6*				
63/68/73: tyP1/2/3 stage type 1/2/3	0: Grt1	stage consisting of 2 sections: reaching the selected setpoint SP 1/2/3 with the slope specified by the parameter 64: GrA1/2/3 (ramping) and counting the time (65: tiM1/2/3) after reaching it		Grt1
	1: tiME	countdown after reaching the set point SP 1/2/3 (H/2)		
	2: tot1	countdown of time for the entire stage (regardless of the setpoint)		
	3: End	continuous - no time limit		
	4: StoP	end - the last stage of the program, available only for stage 2/3		
64/69/74: GrA1/2/3 slope of the stage segment 1/2/3	pace of changes (gradient) for the 1st segment of the type stage Grt1, ramping, -300 ÷ 300 C/min or -300 ÷ 300 units/min *(2)*			10 °C/min
65/70/75: tiM1/2/3 time for stage 1/2/3	0÷1440 min, duration of the segment for the stage with countdown			60 min
66/71/76: PSE1/2/3 control algorithm for stage 1/2/3	1: onoF = ON-OFF with hysteresis, 2/3/4: Pid1/2/3 = PID with parameter set1/2/3 (*ch. 9.3*, not recommended for the stage Grt1 - gradient may disturb PID operation)			onoF
67/72/77: AUt1/2/3 auxiliary output status during stage 1/2/3, 78: AUtE after the end of stage 3	1: oFF = disabled, 2: on = enabled, 3: HAnd = manual mode with set output signal level (parameter 82: MSEt), auxiliary output selection (1/2/3) is defined by parameter 19/28/37: Ety1/2/3 = PrOA			oFF
VI. KEYS, ACCESS OPTIONS AND OTHER CONFIGURATION PARAMETERS, submenu otHE				
79: FunF function of **[F]** key 80: Funb function of the binary input **BIN** 81: FunS additional function of the **[SET]** key **1.** detailed description in *chapter 7.1*) **2.** values 3÷8 (quick manual mode) interrupts and resets the tuning and	0: nonE	inactive - device status (description, *chapter 7, point a*)		nonE
	1: SEt3	step change of the setpoint with a set of parameters for outputs 1 and 3 (day=22: SEt1/night=40: SEt3), both outputs work the same way (copy)		
	2: bLoc	keyboard lock, messages bLoF (stop)/bLon (start, default)		
	3: Hd1A 5: Hd2A 7: Hd3A	unconditional manual M mode for output 1/2/3 with the level of the output signal (MV) set by the parameter 82: MSEt, messages Hnd1/2/3 (start)/ HoF1/2/3 (stop)	start (unchanged) with an initial value for 82: MSEt taken from the current automatic control mode	
	4: Hd1U 6: Hd2U 8: Hd3U		start (step) with the preset value of parameter 82: MSEt	
	9: inPu	unconditional preview of measured values of inputs 1 and 2		

the PID and software algorithm for the given output (1/2/3)	10: CLEA (also 11/12)	deleting errors and alarm memory (LATCH) of the **STB** safety controller with the message CLEA or none (when there are no errors and alarms)		
	11: SPSt	start/stop of outputs 1/2/3 with function 9: CLEA, messages StAr / StoP / CLEA	when power is on, default stop	
	12: St.SP		default start (only for **[F]** and **[SET]**)	
82: MSEt control signal setpoint (MV) for outputs in manual mode	0 ÷ 100 % M	applies to all outputs (1, 2, 3 and analog one), 100 % means the maximum available output power (set by parameters 24/33/42: oPF1/2/3), step every 1% *(4)*		50.0 %
83: bSEt lock of quick setpoint changes SEt1/2/3, (*chapter 9.1*)	0: oFF = no lock, 1/2/3: SEt1/2/3 = lock of one of the settings (SEt1/2/3), 4: SEt2 = simultaneous for SEt1 i SEt2, 5: SEt3 = for SEt1 i SEt3, 6: SE23 = for SEt2 and SEt3, 7: ALL = for all settings (SEt1, SEt2 and SEt3)			oFF
84: PPro protection of configuration with an access password	0: oFF = entering the manual and remote configuration menu is not protected with a password, 1: on = manual and remote configuration (only for ARSOFT-CFG) is protected with password			on
85: PASS access password	0.000 ÷ 9.999	password for entering the configuration menu and for the MQTT (*chapter 11.1*)		1.111
VII. DISPLAY OPTIONS, submenu d.SP				
86: br.id light brightness	10 ÷ 100 %	display brightness, step by 10%		100 %
87: Un.t display unit of measurement	0: none = none, 1: m = m, 2: mA = mA, 3: A = A, 4: mV = mV, 5: V = V, 6: °C = °C, 7: Pr.H = %RH, 8: Perc = %, 9: °C.H = °C%RH, except AR663.B: 10: k = k, 11: PA = Pa, 12: kPA = kPa			°C
88: d.uP value displayed for the upper row	0: inP1 = input 1 measurement, 1: inP2 = input 2 measurement, 2: Subt = measurement difference 1-2, 3: Add.t = sum of measurements 1+2, 4: AvrG = average value of measurements 1 and 2, 5: LArG = greater of measurements 1 and 2, 6: SMAL = smaller of measurements 1 and 2			inP1
89: d.bo displayed value for the bottom line	0: inP1 = input measurement 1, 1: inP2 = input measurement 2, 2: Subt = measurement difference 1-2, 3: Add.t = sum of measurements 1+2, 4: = average value of measurements 1 and 2, 5: = greater of measurements 1 and 2, 6: SMAL = lesser of measurements 1 and 2, 7/8/9: con1/2/3 = set value for output 1/2/3, 10/11/12: bAr1/2/3 = bargraph MV1/2/3 (MV output control signal 1/2/3 in the range of 0÷100%), 13: bArA = bargraph for output mA/V, 14: bAr1 = bargraph for input measurement 1, 15: bAr2 = bargraph for input measurement 2, 16: bASu = bargraph for measurement difference 1-2, 3: bAAd = bargraph for sum of measurements 1+2, 17: bAAv = bargraph for average value of measurements 1 and 2, 18: bALA = bargraph for greater of measurements 1 and 2, 19: bASA = bargraph for smaller of measurements 1 and 2, for the range of bargraph 4/13 rL1/2 ÷ 5/14 rH1/2			inP2
VIII. COMMUNICATION OPTIONS FOR RS485 AND ETHERNET, submenu CoMn, description in *chapters 11 ÷ 11.5*				
90: r4br speed for RS485	bitrate kbit/s, 0: 2.4, 1: 4.8, 2: 9.6, 3: 19.2, 4: 38.4, 5: 57.6, 6: 115.2			19.2 kbit / s
91: r4cF character format RS485	selection of parity and stop bits, 0: 8n1 (none), 1: 8E1 (even), 2: 8o1 (odd), 3: 8n2			8n1
92: Addr MODBUS-RTU address	1 ÷ 247	device address for RS485 and suffix (suffix) for the name, *(5)*		1
93: EtAb Ethernet interface	0: oFF	Ethernet always off (recommended when not in use)		oFF

operation mode (MAC hardware address available from ARSOFT-CFG and MODBUS-RTU/TCP)	1: Auto	DHCP client enabled, network parameters (from 94: E IP3 to 105: EGA0, i.e. IP address of the device, mask and gateway) are set automatically	
	2: StAt	DHCP client disabled, network parameters are set manually	
94÷97: E IP3/2/1/0 IP address	0÷255	device's IPv4 address in the local network (Ethernet), 4 consecutive octets	192.168.0.200
98÷101: ESu3/2/1/0 IP mask	0÷255	mask of the IPv4 address in the local network (Ethernet), 4 consecutive octets	255.255.255.0
102÷105: EGA3/2/1/0 IP gateway	0÷255	router's IPv4 address in the local network (Ethernet), 4 consecutive octets	192.168.0.1
106: EtcP MODBUS-TCP port	1÷39999	TCP port number for the MODBUS-TCP protocol (also for ARSOFT-CFG)	502
107: A9Ao operating mode and type of published MQTT messages (Ethernet) (detailed description of MQTT communication, chapter 11.1)	0: oFF	MQTT protocol disabled (recommended when not used)	oFF
	1: mP1	MQTT protocol enabled, only measurement 1 (PV1) in the publication, e.g. "*4.5*"	
	2: mP2	MQTT protocol enabled, only measurement 2 (PV2) in the publication, e.g. „*9.9*"	
	3: Subt	MQTT protocol enabled, in the content of the publication only the measurement difference 1-2	
	4: Add	MQTT protocol enabled, in the content of the publication only the sum of measurements 1+2	
	5: AvrG	MQTT enabled, in the content of the publication only the average value of measurements 1 and 2	
	6: LArG	MQTT protocol enabled, in the content of the publication, the greater value of measurements 1 and 2	
	7: SmAL	MQTT protocol enabled, in the content of the publication the smaller value of measurements 1 and 2	
	8: mn2	MQTT enabled, device name included, measurements 1 and 2, unit, (5)	
	9: FULL	publication of full operating status (PV1/2, MV, mA/V output status, BIN, etc.)	
108÷111: A9b3 0 MQTT address	0÷255	IPv4 address of the MQTT broker (Ethernet), 4 consecutive octets	192.168.0.10
112: A9tP broker port	1÷39999	MQTT broker TCP port number	1883
113: A9tP MQTT publication period	1÷3600 s	interval of sending messages to the MQTT broker (Ethernet)	10 sec.
114: A9tL MQTT subject level	1÷9999	numeric suffix for MQTT publication subject name (APAR/A9tL)	APAR/1

Notes: **(1)** - for 3-wire sensors the parameter LinE must be equal to 000 Ω (automatic compensation),

(2) - applies to analog inputs (mA, V, mV, Ω),

(3) - for Filt = 1 the response time is 0.5 second, for Filt = 20 at least 5 seconds. Higher degree of filtration stands for the more "smoothed" measured value and the longer response time recommended for measurements of turbulent nature (e.g. water temperature in the boiler),

(4) - for binary outputs (P/SSR) large rounding can occur, 1% is possible only for the pulse period (parameters 25/34/43: PEr1/2/3) greater than 20s, for 4s it is 5%, for 2s 10%, for 1s up to 20%. The control signal **MV=100%** means the maximum available output power (limited by 24/33/42: oPF1/2/3),

(5) - the device name is created according to the template: AR6x3_Addr (e.g. "AR6x3_1" for 92: Addr = 1). It is used in the content of the published MQTT message (chapter 11.1) and by the DHCP client (when 93: EtAo = Auto).

9. OUTPUT OPERATION CONFIGURATION

Programmable architecture of the controller allows its use in many fields and applications. Before starting the operation of the device, set parameters for individual needs (such as control algorithms 19/28/37: **ctY1/2/3**, types of control /alarms 20/29/38: **Fun1/2/3**, setpoints 22/31/40: **SEt1/2/3** and others described in *Table 8, chapter 8*). If there is a need to start the control for a specific time (timer function), you should additionally use the possibilities offered by the program control (*chapter 9.6*).
A detailed description of configuration of the operation of outputs is included in *chapters 9.1÷9.7*.
The default (factory) configuration is as follows: outputs 1, 2 and 3 in heating control mode (ON-OFF algorithm with hysteresis), analog output is disabled (*Table 8*, column *company* settings).

9.1. CHANGE OF SETPOINTS FOR OUTPUTS. QUICK ACCESS MENU.

All SP setpoints (i.e. parameters 22/31/40:/ **SEt1/2/3** and optionally 82: **HSEt** - when the output is in manual mode) are available in the quick access menu and in the parameter configuration mode (the methods of changes are described in *chapter 8*). The quick access menu is entered from the measurement display mode (PV) after pressing the **[SET]** key, without the need to enter a password. Optionally, to disable fast SP changes (with the message **bLoc**), you can use parameter 83: **bSEt** (*Table 8*). Exit from the menu takes place after long pressing the **[DOWN]** + **[UP]** keys or automatically after 7 seconds of inactivity. Alternatively, when the bottom row is set to present a defined SP setpoint for a given output (selection by parameter 89: **diSo**, *chapter 8*), the simplest way to change this value is to use the combination of **[DOWN]**, **[UP]** and **[SET]** keys described in *chapter 7* (with a step of x1 or x10).

9.2. ANALOG OUTPUT (mA/V)

The standard of the output signal is set by parameter 45: **AtYP** (*chapter 8, Table 8, point III*). The analog output can be programmed (with parameter 46: **FunA**) to work in one of the following modes: retransmission of the PV measurement or setpoint SP and as a control output associated with the parameters of the selected output 1, 2 or 3.
In the measurement or setpoint retransmission mode, the output signal is proportional to the measured signal or SP within the range set with parameters 47: **ArLo** and 48: **ArH1** (e.g. 0mA for the measured value 0°C when **ArLo** = 0°C, 20mA for 100°C when **ArH1** = 100°C and respectively 10mA for the half of the range, i.e. 50°C). In other words, the output operating in the retransmission mode enables the conversion of the input signal to the output signal (in the range **ArLo** ÷ **ArH1**). In the control output mode, the control parameters and functions performed are identical to those for the related 1/2/3 output, with the range of variability of the analog signal being continuous (0÷100%) only for the PID algorithm (*chapter 9.3*) and manual operation. For ON-OFF regulation with hysteresis, the output adopts limit values (lower or upper value, e.g. 0mA = 0% = OFF or 20mA = 100% = ON) without intermediate values, which can be used e.g. to activate the SSR relay.
The values of the output signal (mA/V) can be presented in the form of a bargraph on the bottom line of the display (parameter 89: **diSo** = **bArA**) or read from the level of MODBUS-RTU/TCP and MQTT protocols, *chapter 11*.
In addition, it is possible to correct (calibrate) the range of changes in the output signal (parameters 49: **cbot** and 50: **ctoP**).

9.3. PID CONTROL

The PID algorithm makes it possible to obtain smaller control errors (e.g. temperature) than the ON-OFF method with hysteresis. However, this algorithm requires selection of parameters characteristic for a specific regulation object (eg a furnace). In order to simplify the handling, the controller is equipped with advanced functions of PID parameters selection, described in *chapter 9.4*. In addition, it is always possible to manually adjust the settings (*chapter 9.5*).

The PID control for a given control output is active when one of the three sets of PID parameters is selected (with the parameter tUn 1/2/3, *description in chapter 8, Table 8, point II*, or with the parameter PSE 1/2/3, *point V*), i.e. Pid 1/2/3.

The position of the proportionality band **Pb** (Pb 1/2/3, *Table 8, point IV*) in relation to the setpoint **SP**(**1**/**2**/**3**) is shown in Figures 9.3 a) and b).

Parameters tn 1/2/3 and td 1/2/3 are responsible for the influence of the integrating and differentiating element of the PID control. Parameter PEr 1/2/3 sets the pulse period **Tc** for the P/SSR output (it is also the time of updating its status), while oPF 1/2/3 the available power used in the selection of PID parameters.

If the PID algorithm is implemented by the 0/4 ÷ 20mA or 0/2 ÷ 10V analog output, the **Tc** period is irrelevant. The mA/V output signal is then updated every 1 s and it can adopt intermediate values from the entire range of output variability (0÷100%).

The principle of operation of the P-type control (proportional control) for the P/SSR output is shown in figures d), e) for the analog output, figure c).

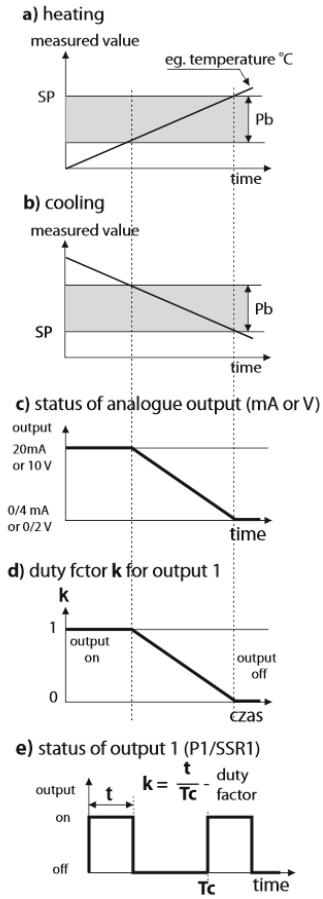


Fig. 9.3. Principle of PID regulation operation:
a) position of the **Pb** proportional band in relation to the setpoint **SP** for the heating type control (Fun 1/2/3 = HEAt)
b) position of the proportional band **Pb** in relation to the setpoint **SP** for the cooling type control (Fun 1/2/3 = CooL)
c) the status of the analog output 0/4÷20 mA or 0/2÷10V
d) fill factor **k** for a bi-state P/SSR output
e) the status of the output for the measured value **PV** within the **Pb** range

9.4. AUTOMATIC SELECTION OF PID PARAMETERS

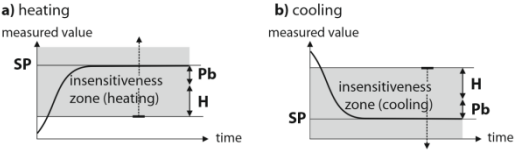
In order to use the PID parameter selection function for a given control output (1/2/3), first select the PID parameters set (using the method described in *chapter 9.3*) to which the calculated data will be saved, and then set the type of auto-tuning (with the parameter tUn 1/2/3 description in *chapter 8, Table 8, point IV*). The auto-tuning is activated at the start of the control (automatically after switching the supply on or manually using the **[F]**, **[SET]** function keys or the **BIN** binary input programmed as the start/stop of outputs operation, *chapter 7.1*). Autotuning is performed independently for each of the outputs with the maximum available power (defined by the parameter oPF 1/2/3 *Table 8, point II*) and is signaled by cyclic messages 1/2/3 (for the method StEP) or tUn 1/2/3 (for oSCi) or flashing of the upper right dot during the object analysis for AUto (*chapter 7, point d*).

The value of the parameter 51/55/59: tUn 1/2/3 determines the choice of the PID parameter selection method:

a) tUn 1/2/3 = AUto **(continuous mode, smart logic)** - the controller continuously checks whether there are conditions for starting the tuning and tests the object in order to select the appropriate method. The algorithm continuously forces operating in the PID mode. The necessary condition to initiate the PID parameter selection

procedure is the location of the **PV** current measured value outside the dead band defined as the sum of the parameters value of the Pb proportional band and the associated hysteresis **H** in relation to the SP setpoint, as in figures 9.4.

Fig.9.4.
Location of the deadband for the type of heating type control (Fun 1/2/3 = indH) and cooling type control (Fun 1/2/3 = d irE)



In order to avoid unnecessary activation of tuning, which may delay the course of the process, it is recommended to set the hysteresis **H** to the highest possible value, not less than 10 ÷ 30% of the process value variation range (e.g. measured temperature). Testing of the object with the short deactivation of the output and the flashing of the upper right dot also takes place in the dead band in case of detecting sudden changes of the measured value **PV** or the setpoint **SP**. The choice of the parameter selection method depends on the nature of the initial conditions. For a stabilized controlled quantity, the **step response method (fast)** will be selected, otherwise the oscillation **(longer) method** will be activated.

Automatic selection (**continuous mode**) enables the optimal selection of PID parameters for the current conditions on the site, without user intervention. It is recommended for variable value control (disturbance of set conditions during operation by modification of e.g. the setpoint **SP** or the furnace batch).

b) Fun 1/2/3 = StEP **(step response method, fast)**- selection of parameters in the step stage (response to step-forcing function). While determining the characteristics of the object, the algorithm does not cause an additional delay in reaching the setpoint **SP**. This method is dedicated to facilities with stabilized initial controlled value (e.g. temperature in a cold furnace). In order not to disturb the initial conditions, before starting the auto-tuning, turn off the power supply of the actuator (e.g. heater) with an external switch or use the control start/stop function (keys **[F]**, **[SET]** or **BIN** input). The power supply should be switched on immediately after starting the tuning, in the delay phase of switching on the output. Turning on the power at a later stage will result in an incorrect analysis of the object and, as a result, incorrect selection of PID parameters.

c) Fun 1/2/3 = oSCt **(oscillation method, longer)**- selection of parameters using the oscillation method. The algorithm involves the measurement of the oscillation amplitude and period at a slightly lower level (for heating or a slightly higher level for cooling) than the setpoint **SP** in order to eliminate the danger that the target value will be exceeded during the object test stage. While determining the characteristics of the object, the algorithm causes additional delays in reaching the setpoint. This method is dedicated to objects with unstable initial controlled value (e.g. temperature in a hot furnace).

The algorithms from subpoints **b** and **c** consist of the following stages:
- delay in activating the output (approx.15 seconds - time for switching on the power of the actuator, i.e. heating/ cooling power, fan, etc.) and determining the characteristics of the object,
- calculation and permanent saving of parameters (**Pb**, **Ti**, **Td** to the selected PID and **Tc** set, i.e. PEr 1/2/3, *chapter 8*),
- switching on the control for a given output with new PID settings

The program can discontinue the autotuning **b** or **c** (with the tEP 1/2/3 message) in the following situations:
- the initial value of **PV** is higher than the setpoint **SP** for heating or lower than the setpoint for cooling,
- the **SP** setpoint has been changed or the measured value of the **PV** process changes too quickly or too slowly,
- the maximum tuning time (4 hours) has been exceeded

It is recommended to restart the **autotuning b** or **c** after a significant change in the **SP** threshold or the parameters of the control object (e.g. heating/cooling power, batch mass, initial temperature, etc.).
Autotuning **does not work** in program control (**process controller**) and valve control (**servo**) mode.

9.5. CORRECTION OF PID PARAMETERS

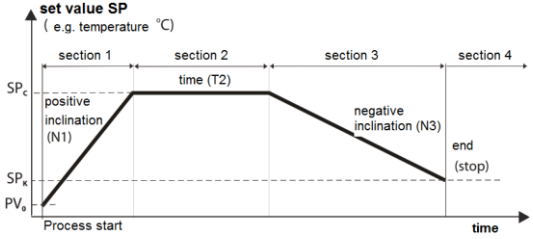
The autotuning function correctly selects the PID regulation parameters for most processes, but sometimes it may be necessary to correct them. Due to the strong interdependence of these parameters (described in *chapters 9.3 and 8*, *Table 8*), only one of them should be changed and the impact on the process should be observed:
a) oscillation around the threshold - increase the proportional band **Pb**, increase the integration time **Ti** , decrease differentiation time **Td** , (or reduce the pulse period of the output by half, parameter **Tc**)
b) slow response - reduce the **Pb** proportional band, **Td** differentiation time and **Ti** integration time
c) overshoot - increase the **Pb** proportional band, **Td** differentiation time and **Ti** integration time
d) instability - increase the integration time **Ti**.

9.6. PROGRAMMED WORK CHARACTERISTICS. SAMPLE CONFIGURATION.

The controller allows you to create a control program (process controller) consisting of a maximum of 6 segments (3 stages configured with the parameters described in *chapter 8, Table 8, point V*). Each stage (1/2/3) operates in accordance with the control parameters of the assigned setpoint SP (1/2/3), description in *Table 8, point II*.
The program can be assigned to any of the control outputs (1/2/3) by the parameter 19/28/37: **tY 1/2/3** set to the value **PrGr**. Additionally, it is possible to define an auxiliary output (**Pr gA**), which can be useful for signaling the operating status for individual program stages as well as for switching on additional devices (fans, additional heating sections, etc.) with the manual operation option (when parameter 67/72/77/78: **AS1/1/2/3/E** = **HAnd**).
The program starts at the moment of starting the control (automatically after switching on the power or manually using the **[F]**, **[SET]** function keys or the **BIN** binary input programmed as the start/stop of outputs, *chapter 7.1*) and is always performed from the beginning (1st stage/segment). Subsequent process stages (1/2/3) are signaled by messages appearing every few seconds **Pr- 1/2/3** alternately with the current setpoint SP (or other programmed parameter 89: **diSo**) and optionally the remaining time of the stage (in the format hh:mm with the unit **m** or 00:ss, when the time<1min, without the unit). During the countdown, the upper right dot flashes (*chapter 7, point d*). The program ends with message **PEnd** and switching off the control output.

Diagram of an exemplary program configuration consisting of 4 segments for the heating type control (**Fun 1/2/3** = **HEAt**) is presented in the diagram on the right. At the start of the process (control), the initial setpoint for segment 1 is the current measured value (PV_0, e.g. 25°C), target setpoint SP_C = SP1, which is achieved with the rate (slope) N1 = **GrA1** (e.g. 25°C/min). After reaching the SP_C value and adjusting at this level for the set time of the 2nd section T2 = there is a transition to the 3rd section, for which a cooling function at the speed of N3 = **GrA2** was designed (e.g. -10°C/min) to SP_K = SP2 level During cooling, an auxiliary output can be used to switch on e.g. the fan. The program is stopped (with switching off the control output) after reaching the SP_K and going to the 4th segment.

Fig.9.6. Diagram of a sample program.



The basic configuration parameters for individual stages are summarized in the table below:

Stage parameters	Stage 1		Stage 2	Stage 3
	segment 1	segment 2	segment 3	segment 4
Type of stage	63: **tYP1** = **GrE1** (2 segments)		68: **tYP2** = **GrE1**	73: **tYP3** = **StoP**
Stage **SP** set point	**SPC** = SP1 (e.g. **SEt1** = 700°C)		**SPK** = SP2 (e.g. **SEt2** = 60°C)	not relevant
Slope (°C/min)	**N1** = **GrA1** (e.g. 25°C/min)		**N3** = **GrA2** (e.g. -10°C/min)	not relevant
Stage/segment time	**T2** = **t.M1** (e.g. 90min)		**t.M2** = 0 (segment 2 is missing)	not relevant

9.7. MIXING VALVE CONTROL. SAMPLE CONFIGURATION.

The device allows you to control a servo valve with two open-close contact inputs, without a feedback signal. Standard characteristics (heating/cooling) and operating modes (ON-OFF, PID) are binding for valves controlled by the analog signal mA/V and do not require any additional comments. The servo-type algorithm is implemented on outputs 1 (open) and 2 (close) as a three-point step control. It requires setting parameter 19: `ctY2` to value `vALc` (which also prevents simultaneous activation of both outputs) and other configuration parameters (described in the example below and in *chapter 8*). The total time of opening/closing the valve is defined by parameters 25/34: `PEr1`/`2`.

The valve control is started at the start of control (automatically after switching on the power or manually with the **[F]**, **[SET]** function keys or the **BIN** binary input programmed as output operation start/stop, *chapter 7.1*) and begins with the valve positioning (complete closing) procedure (with the message `vALc`). This procedure also takes place after each change of the pulse period for output 2 (parameter 34: `PEr2`).

Example configuration (ON-OFF for heating with set temperature of 50°C and valve opening/closing time of 100s):

- output parameters 1 (*Table 8, point II*, group `out1`): `ctY1` = `onoF` (recommended), `Fun1` = `indH`, `H1` = 0°C, `SEt1` = 50°C,

`oPF1` = 1%, `PEr1` = 100s,

- output parameters 2 (group `out2`): `ctY2` = `vALc`, `Fun2` = `dEoF` (deviation from `SEt1`, *Table 8, Fig.8.7*), `H2` = 0°C, `SEt2` = 0.5°C (deviation value), `oPF2` = 100%, `PEr2` = 100s, `FtO2` = `on` (emergency state enabled)

Tips for adjusting the settings (change only one of the factors and observe the effect on the process):

a) increasing the rate of changes - increase the parameter `oPF1` (recommended 1÷5%) and decrease `PEr1`,

b) reducing overshoots and oscillations - reduce `oPF1` (recommended 1÷5%), increase `PEr1`, set a small dead zone (`SEt2`, e.g. 0.5 C), recommended `H1`/`2` = 0°C

Alternatively, for the output 1, the PID control (*chapter 9.3*) can also be used with a larger value of `oPF1` (suggested 10÷20%), which will result in reaching the setpoint faster, but at the same time, with incorrectly selected PID parameters, the control may be less accurate (due to overshoots and oscillations). In the range of Pb, the length of the opening pulse (step) will be variable (depending on the measured value PV, according to the principle of PID operation). If the PID algorithm is used, the P variant control is recommended (proportional, e.g. Pb=5°C, Ti=Td=0s) or PD (proportional-differential, e.g. Pb=5°C, Ti=0, Td=30s).

10. SIGNALING MESSAGES AND ERRORS

a) measurement errors:

Code	Possible causes of the error
`----` `----` `----`	- exceeding the measurement range of the sensor/signal above (`----`) or below (`----`) - incorrectly connected or different sensor/signal than set in the configuration (*rozdział 8*, *parametr 0:* `inP1`) - missing sensor/measuring signal or input damage (`----` with a critical message `E inP`)

b) messages and temporary errors (one time or periodic):

Code	Description of the message
`CodE`	the mode of entering the access password to configuration parameters, *chapter 8*
`Err`	a wrong password to access the parameter configuration menu has been entered, *chapter 8*
`ConF`	entering the parameter configuration menu, *chapter 8*

bLoc	- blockade of quick changes of setpoints (with parameter 83: bSEt, *chapter 9.1*), - blockade of other parameters (e.g. PASS, when PPro = oFF or IP addresses in DHCP client mode), - keypad lock with **[F]**, **[SET]** keys and **BIN** input (*chapter 7.1*), - **[F]**/**[SET]** key blocked by the active **BIN** input having the same function, - quick manual mode for **[F]**/**[SET]**/**BIN** blocked by active (permanent) manual mode of the output
tun1/2/3, tuo1/2/3	implementation of the PID tuning function (step response or oscillation method), *chapter 9.4*
EtP1/2/3	- error of interrupting PID tuning (*chapt.9.4*) or the program control due to a change in or incorrect configuration (e.g. when the characteristics is different than heating/cooling for PID or servo) - erasing the error with the **[UP]**+**[DOWN]** or **[F]**, **[SET]** keys and the **BIN** input (*chapt.7.1*)
CLEA / nonE (when missing)	erasing errors (one by one) or all with the function assigned to **[F]**/**[SET]**/**BIN**
StAr / StoP	start/stop of control with the function assigned to **[F]**/**[SET]**/**BIN**, *chapter 7.1*
SEt1 / SEt3	change of the setpoint (day/night) for outputs 1 and 3 with the **[F]**/**[SET]**/**BIN** function, *chapt.7.1*
bLon / bLoF	keyboard lock on/off with the function assigned to **[F]**/**[SET]**/**BIN**, *chap.7.1*
mnd1/2/3 / moF1/2/3	unconditional manual mode on/off, **[F]**/**[SET]**/**BIN** function, *chapter 7.1*
Pr-1/2/3, PEnd	process controller function (ramping) on output 1/2/3, *chapter 9.6*
Stb1/2/3	STB (LATCH) alarm for outputs 1/2/3 (cleared by **[F]**/**[SET]**/**BIN** with the function CLEA or start/stop)
vALc	the servo valve positioning (closing) procedure is performed (*chapter 9.7*)
LoAd dEFA	recording of company parameter values (description of the procedure in *chapter 8*)
ErrE	potential data memory error (erased **[UP]**+**[DOWN]** at the power switch-on, with loading company values), if the problem persists, send the device back for repair

11. SERIAL COMMUNICATION. AVAILABLE SOFTWARE AND USB DRIVERS

Communication with the controller is possible through each of the available serial interfaces (independently, i.e. RS485, Ethernet and USB) and can be useful (or necessary) in the following situations:
- remote monitoring and recording of current measurements as well as control of the operating status and control algorithms for outputs,
- quick configuration of parameters, including copying settings to other controllers of the same type

In order to establish long-distance communication, a connection should be made in the **RS485** standard (MODBUS-RTU protocol, *chapters 11.3 and* 11.4) or **Ethernet** using the MODBUS-TCP (*chapter 11.2*) and MQTT protocols (*chapter 11.1*).
When the controller (or RS485 converter) is connected to the computer for the first time via the USB port, the system will start the process of automatic installation of the COM serial port driver (from the ***Windows Update*** website). Alternatively, you can manually indicate the location of the driver on the computer's disk from the ***Device Manager***, following the instructions of the installation wizard (for the regulator, select the"AR2xx /..."drivers downloaded from the www.apar.pl website or from the ARSOFT-CFG program installation folder, by default „C:\Program Files (x86)\ARSOFT\Drivers\AR2xx…").
The following applications are available (for Windows 7/8/10 operating systems, downloadable from *www.apar.pl/oprogramowanie.html* or optionally from a CD or e-mail from the Sales Department):

Name	Description of the program
ARSOFT-CFG (free of charge)	- displaying current measurement data from the connected Apar device - configuration of the measurement input type, indication range, adjustment options, alarms, display, communication, access, etc. (*chapter 8*) - creation the disc a file with the extension "cfg" containing the current configuration of parameters for reuse (copying of configuration)
APSystem-PC (paid)	- display and recording of current measurements from many devices (via MODBUS-RTU/TCP/ASCII) - visual and audible alarms, e-mail alerts, event reporting, etc.

Detailed descriptions of the above mentioned applications can be found in the installation folders.

CAUTION: 

Before establishing a connection via **RS485**, make sure that the device parameters (90: rYbr , 92: Addr and 91: rYcF) are compatible with the settings of the computer program. Moreover, set the number of the COM serial port used in the program options (for the RS485 converter it was assigned by the system during the installation of drivers).

Depending on the protocol used, the connection via the **Internet** requires the known public IP address of the broker for the MQTT protocol and the network IP address in the case of MODBUS-TCP (to facilitate access to the network with a variable public IP address, you can start the DDNS service, e.g. in a router). **The selection of network parameters in the controller and the configuration of the router** (including e.g. port redirection for MODBUS-TCP, port forwarding) **should be entrusted to a qualified person (network administrator)**. In addition, pay attention that the firewall does not block the ports and applications used (e.g. ARSOFT-CFG). The unique **MAC** (EUI-48) hardware address of the controller Ethernet interface is available in ARSOFT-CFG (Parameters-> Communication options) and in the MODBUS-RTU/TCP protocol *register map*.

The easiest way to test the correctness of the regulator's operation in the LAN network is to set the Ethernet interface in the automatic mode (parameter 93: Et.Ad = Auto), and then (with the IP address assigned by the DHCP server read from the device) establish connection with the ARSOFT -CFG program or execute the *ping* command from the computer's command line (and optionally *arp -a* for Windows or *arp-scan* for Linux, where we will also get the **MAC address**).

11.1. MQTT PROTOCOL

Popular in IoT/M2M (Internet of Things) applications, the MQTT protocol is a lightweight data transmission protocol based on the publication/subscription pattern (to/from the server). Using the protocol requires a correctly configured Ethernet network interface and MQTT parameters (*chapter 8, Table 8, point VIII*), as well as access to a broker (server) with a fixed numeric IP address (the controller does not support the DNS protocol - text domain names). The MQTT broker can be started independently (eg. Mosquitto) or use the ones available on the Internet (paid or free, e.g. EMQX). Knowing the name of the broker's website, you can check its IP address, e.g. with the *ping* command (from the computer's command line). To read (subscribe) the messages published by the controller from the broker, you can use your own solutions or one of the many applications available on the Internet (such as the free and easy-to-use "*MQTT Dash*" for Android). Establishing a connection with the broker may take some time (usually <1.5 minutes, restarting the device may speed up this process). The current status of the controller's connection with the MQTT broker is available from the keyboard level (*chapter 7point a*, device status) and from the MODBUS-TCP/RTU protocols (register at address 31: *Ethernet connection status*, *chapter 11.5*).

Parameter 107: AMd (description in *Table 8*) is responsible for selecting the content of messages sent cyclically to the MQTT broker. Sample content for the most advanced option (when 107: AMd = FULL, maximum size 115B):
"AR6x3_1;PV1=36.6;PV2=21.5;°C;MV1=100 %;MV2=100 %;MV3=0 %;cstat =0x0000;outA = 7.320 mA;BIN=0"
(AR6x3_Addr = device name;PV1-2=measurement values 1 and 2;unit;MV1=output 1 control signal value;MV2 for output 2;MV3 for output 3;cstat=control algorithm operation status, described in *chapter 11.5*;outA=analog output signal value mA/V;BIN= binary input state, 0=shorted, i.e. active).
In addition, for optional connection authorization, the following fields are set in the MQTT package: *client ID* (created according to the "aparMAC" template, where MAC is the hardware address of the EUI-48 controller, e.g.

"aparFCC23D21C54A") and *user name* (as „*apar*PASS";the last 2 digits of the 85: PASS, e.g. "*apar11*") and *password* (parameter 85: PASS).
Protocol parameters useful for advanced needs: version 3.1.1, QOS = 0, retain = 1, keep alive = 0 (off).
In the event of frequent disconnection with the broker, check the reliability of the network/internet connection (switch), test the possible impact of the message publication period (extend, recommended > 5s, parameter 113: PAPE), as well as MODBUS-TCP communication (temporarily stop if in use).

11.2. MODBUS–TCP SERIAL TRANSMISSION PROTOCOL

The MODBUS-TCP protocol is available for the Ethernet (RJ45) interface and uses the TCP/IP transport layer.
Parameters used by this service, such as the TCP port number, are described in *chapter 8, Table 8, point VIII*.
The timeout for the MODBUS-TCP transmission, after which the open but unused port is closed, is 60s.
Available functions : READ - 3 or 4, WRITE – 6

Table 11.2.1. MODBUS-TCP protocol request frame format for the READ and WRITE functions (frame length - 12B)

MODBUS protocol header (7 bytes)			Function code (READ or WRITE)	register address from *Table 11.5 (chapter 11.5)*	number of registers to read (1 ÷ 13) or value of a register to write
Transaction and protocol identifiers	Length field (value = 6)	Unit ID			
4 bytes	2 bytes	1 byte	1 byte	2 bytes (HB-LB)	2 bytes (HB-LB)

Example 11.2.1. Reading a register with address 0: 0x00 - 0x00 - 0x00 - 0x00 - 0x00 - 0x06 - 0xFF - 0x04 - 0x0000 - 0x0001

Table 11.2.2. Response frame format for the READ function (minimum frame length - 11 bytes):

MODBUS protocol header (7 bytes)			Function code (READ)	number of bytes in the data field (2 ÷ 26)	data field - register value (2B)
Transaction and protocol identifiers	Length field (max 29)	Unit ID			
4 bytes	2 bytes	1 byte	1 byte	1 byte	2÷26 bytes (HB-LB)

Example 11.2.2. The response frame for the register value equal to 0:
0x00 - 0x00 - 0x00 - 0x00 - 0x00 - 0x05 - 0xFF - 0x04 - 0x01 - 0x0000

Table 11.2.3. Response frame format for the WRITE function (frame length - 12 bytes)

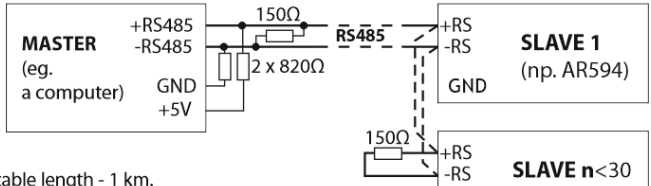
copy of the query frame for the WRITE function (Table 11.2.1)

The error codes are the same as for the MODBUS-RTU protocol (*Table 11.4.5*)

Example 11.2.3. Error frame for a non-existing register address to be read:
0x00 - 0x00 - 0x00 - 0x00 - 0x00 - 0x05 - 0xFF - 0x84 - 0x02 - 0x0001

11.3. RS485 COMMUNICATION INTERFACE (acc. To EIA RS-485)

The installation specification for RS485 interface is as follows:



Maximum RS485 cable length - 1 km.
The maximum number of devices in the 485 - 30 in order to increase number of devices, use RS485 / RS485 amplifiers.
Termination resistors when MASTER is at the beginning of the line (fig. above):
- at the beginning of the line - 2 x 820Ω to ground and +5V MASTERA ans150Ω between the lines,
-at the end of the line - 150Ω between lines.

Termination resistors when MASTER is in the middle of the line:
- at the converter - 2 x 820Ω, to ground and +5V the converter,
- at both ends of the line -150Ω between lines.

Equipment from different manufacturers that form the RS485 network (e.g. RS485/USB converters) may have integrated polarizing and terminating resistors; in such a case there is no need to use external elements.
When configuring the network, it is necessary to pay particular attention to the cabling installation recommendations given in *chapter 2*.

11.4. MODBUS-RTU SERIAL TRANSMISSION PROTOCOL (SLAVE)

Baudrate and character format for RS485 and MODBUS-RTU address set by parameters 74: rYbr, 75: rYcF, 76: Addr (*chapter 8, table 8, point VIII*). Available functions: READ = 3 or 4, WRITE = 6.

Table 11.4.1. Query frame format for the READ function (frame length - 8 bytes):

address of the device	function 4 or 3	register address to be read: from *Table 11.5 (chap. 11.5)*	number of registers to be read: 1 ÷ 13	CRC checksum
1 byte	1 byte	2 bytes (HB-LB)	2 bytes (HB-LB)	2 bytes (LB-HB)

Example 11.4.1. Reading of a register with address 0: 0x01 - 0x04 - 0x0000 - 0x0001 - 0x31CA

Table 11.4.2. Query frame format for the WRITE function (frame length - 8 bytes):

address of the device	function 6	register address to be written: from *Table 11.5 (chap. 11.5)*	register value to be written	CRC checksum
1 byte	1 byte	2 bytes (HB-LB)	2 bytes (HB-LB)	2 bytes (LB-HB)

Example 11.4.2. Writing a register with address 10 (0xA) with the value 0: 0x01 - 0x06 - 0x000A - 0x0000 - 0xA9C8

Table 11.4.3. Response frame format for the READ function (minimum frame length - 7 bytes):

address of the device	function 4 or 3	number of bytes in the data field (max. 13*2=26 bytes)	data field - register value	CRC checksum
1 byte	1 byte	1 byte	2 ÷ 26 bytes (HB-LB)	2 bytes (LB-HB)

Example 11.4.3. Response frame for register value equal to 0: 0x01 - 0x04 - 0x02 - 0x0000 - 0xB930

Table 11.4.4. Reply frame format for the WRITE function (frame length - 8 bytes):

copy of the query frame for the WRITE function (*Table 11.4.2*)

Table 11.4.5. Special reply (errors: function field = 0x84 or 0x83 in the case of the READ function and 0x86 in the case of the WRITE function):

Error code (HB-LB in data field)	**Error description**
0x0001	non-existing register address
0x0002	incorrect register value to be written
0x0003	incorrect function number

Example 11.4.5. Error frame for a non-existing register address to be read:

0x01 - 0x84 - 0x02 - 0x0001 –0x5130

11.5. MAP OF DEVICE REGISTERS FOR MODBUS-RTU/TCP

Table 11.5. Map of registers for the MODBUS-RTU and MODBUS-TCP protocol (1 register = 2 bytes)

Register address HEX (DEC)	**Value (HEX or DEC)**	**Description of register and access type** (R- read only register, R/W - read and write register)	
0x00 (0)	0	not used or reserved	**R**
0x01 (1)	6520 ÷ 6529	device type identifier	**R**
0x02 (2)	400 ÷ 999	controller firmware version	**R**
0x03 ÷ 0x05	0	not used or reserved	**R**
0x06 (6)	0 ÷ 65535	Status of algorithms and control functions and status of outputs/alarms: - status of outputs/alarms 1, 2, 3 (bits 0, 1, 2, bit=1= output enabled), - STB (LATCH) alarms for outputs 1, 2, 3 (bits 3, 4, 5, bit=1=active), - quick manual mode for outputs 1, 2, 3 (bits 6, 7, 8, bit=1=active), - PID tuning status for any of the outputs (bit 12, bit=1=active), - error SEE 1/2/3 PID, etc. (bit 13, bit=1=active), description in *chapter 10*, point b, - change of the setpoint SEE 1/SEE 3 (bit 14, bit=1=SEE 3), *chap.10 b*, - status of the start/stop function for **[F]/[SET]/BIN** (bit 15, bit=1=start), *chap.7.1*	**R**
0x07 (7)	0 ÷ 20000	current state of the analog output (0 ÷ 20000 µA or 0 ÷ 10000 mV)	**R**
0x08 (8)	-100 ÷ 700	temperature of cold ends for thermocouples (resolution 0.1°C)	**R**
0x09 ÷ 0x0B	0 ÷ 100	MV control signal value [%] for outputs 1, 2 and 3	**R**
0x0C (12)	0 ÷ 65535	device status: - type of built-in **mA/V** analogue output (bit 0, bit=1=V), - **BIN** input status (bit 1, bit=1=active input=closed), *chapter 7.1*, - presence of Ethernet and RS485 modules (bits 4, 5, bit=1=available), - LED display type (bit 7, bit=1=small=AR663.B), *chap.7d,* - USB connection status (bit 8, bit=1=connected),	**R**
0x0D ÷ 0x0F	0	not used or reserved	**R**
0x10 ÷ 0x16	-1999 ÷ 19999	current measured values (in order: input 1, input 2, measurement difference 1-2, sum of measurements 1+2, average value of measurements 1 and 2, greater value of measurements 1 and 2, smaller value of measurements 1 and 2), in code U2 (16-bit), without comma, (for thermometric inputs, resolution 0.1°C)	**R**
0x17 ÷ 0x1E	0	not used or reserved	**R**
0x1F (31)	0 ÷ 65535	connection status of the Ethernet interface and the MODBUS-RTU and	**R**

		MQTT protocols: - LAN connection status, link-up (bit 0, bit=1=connected), - connection with the MQTT broker status (bits 1, 2, bit1=bit2=1=connected), - TCP port status for MODBUS-TCP (bits 6, 7, 8, it6=bit7=1=connected),	
0x20 ÷ 0x22	0 ÷ 65535	unique MAC hardware address of the Ethernet interface (EUI-48)	**R**
Configuration parameters (the collective list of parameters can be found in *chapter 8, Table 8*)			
Register (parameter) address = **35** + parameter index from *Table 8* (e.g. address=35 for parameter 0: mP1), Register (parameter) value = value from *Table 8* (e.g. 0 for 0: Pt)			**R/W**

12. OWN NOTES