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# TEMPERATURE CONTROLLER

# R - 720

USER'S GUIDE

# List of contents

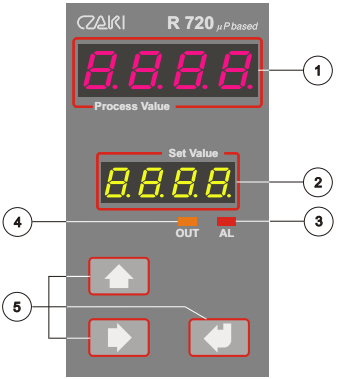
# 1.Introduction

R-720 type temperature controller is a general-purpose single-channel microprocessor unit that performs followings features:

- easily adapted to most often applied types thermocouples and thermoresistores;
- PID or ON/OFF with histeresis control algorithm selected by the user ;
- the value of setting value (SV) could be described in function of time;
- autotuning that setting parameters of proces control itself;
- an alarm output relay is operated by five programmable modes;
- configuration by a front panel keyboard or by a serial port interface
- double four digit LED display and two lamps that informs about states of outputs
- high power relay output or output for SSR;
- low EMC emission;
- signalization of sensor damaged;

# 2. Front panel description

Controller R-720 has double display and three push-button keyboard placed on the temperature controller front wall. Appereance of the front panel is shown in the figure below:




1 - process temperature display (PV)
2 - set temperature display (SV)
3 - alarm indicator
4 - output indicator
5 - keyboard

Fig. 1 Wiew of front wall

| Key | Controller work mode | Action |
|---|---|---|
| **Up** | 1. NORMAL mode, holding time >4s.<br>2. MENU mode:<br>- during moving at menu structure<br>- during changing parameter value | - enter to MENU PANEL mode<br>- back off about one level in menu structure<br>- increment about one parameter value |
| **Shift** | 1. NORMAL mode, holding time >4s.<br>2. MENU mode:<br>- during moving at menu structure<br>- during changing parameter value | - change displayed value between SV or PWM<br>- rewrap next MENU PANEL positions<br>- change of modified figure |
| **Enter** | 1. NORMAL mode<br>2. MENU mode | - modify set temperature (SV)<br>- confirm choose |

Tab. 1 Key functions

# 3. Connection diagram

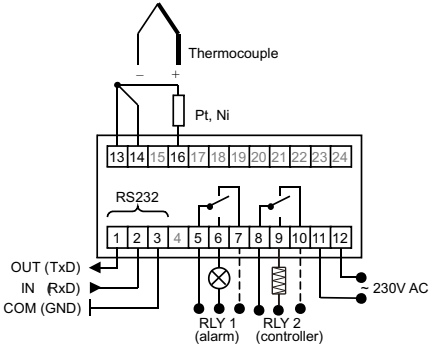



Fig.2 RS-232 version

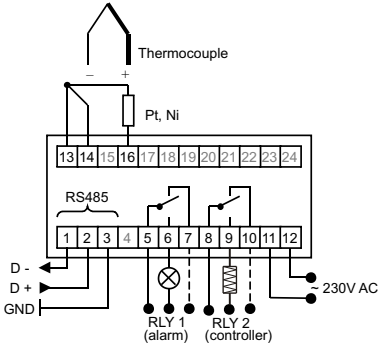



Fig. 3 RS-485 version

| R720 | | DB 9* | DB 25* |
|---|---|---|---|
| TxD | 1 | 2 | 3 |
| RxD | 2 | 3 | 2 |
| GND | 3 | 5 | 7 |

* PC serial socket

Tab. 2 Connection between controller and PC computer

# 4.Operation

Controller R-720 can work in two modes:

1. NORMAL - controller executes all charged control and alarm functions. Upper display shows measured temperature, bottom display shows (despide of choose) set temperature (SV) or average power (PWM) expressed in percentages.
2. MENU - in this mode R-720 realized all normal mode functions and also makes possible to modify parameters.

R-720 supports two kinds of menu. MENU PANEL, controlled by keyboard at the front of controller and MENU TERMINAL, accessible via serial interface RS-232 or RS-485 and terminal application.

R-720 offers several types of algorithms of steering the objects, the user can choose suitable for it or use autotuning function. This function makes easily setting the right value of parameters in PID algorithm.

R-720 offers followings types of algorithm:

- ON/OFF ,
- ON/OFF with hysteresis,
- P,
- PI,
- PID,
- temperature profile in time function,

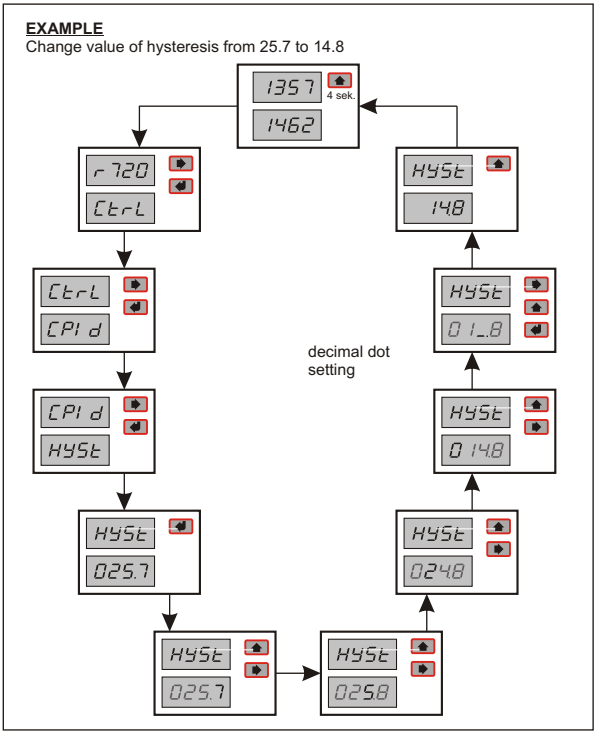
Choice between algorithms users makes by setting parameters like in table 3.

| Type of control | P_bn | t_in | t_di | HYSt |
|---|---|---|---|---|
| On/Off | = 0 | | | = 0 |
| On/Off with hysteresis | = 0 | | | □ 0 |
| P | □ 0 | = 0 | = 0 | |
| PI | □ 0 | □ 0 | = 0 | |
| PID | □ 0 | □ 0 | □ 0 | |

Tab. 3

**EXAMPLE**

Change value of hysteresis from 25.7 to 14.8



## List of parameters and their symbols.

| Symbol on display | Range of value | Factory settings | Meaning |
|---|---|---|---|
| P_bn | 0.0 ... 100.0 [%] | 99.9 [%] | proportional gain |
| t_ in | 0 ... 3200 [s] | 1000 [s] | integral time |
| t_di | 0 ... 1000 [s] | 0 [s] | derative time |
| t_CY | 1 ... 360 [s] | 10 [s] | pulse repetition period |
| HYSt | 0.0 ... 100.0 [°C] | 1.0 [°C] | hysteresis |
| APId | On/OFF | On | turn on control process; don't apply to time profile |
| t_0 | 00:00:00 ... 23:59:59 | 00:00:00 | starting time of time profile |
| SU_0 | -99.9 ... 1800 [°C] | 100.0 [°C] | beginning SV value, of time profile |
| ACP0 | On/OFF | On | activating starting point of time profile |
| t_ 1 | 00:00:00 ... 23:59:59 | 01:00:00 | first point of time profile |
| SU_ 1 | -99.9 ... 1800 [°C] | 200.0 [°C] | SV value of first point of time profile |
| ACP 1 | On/OFF | On | activating first point of time profile |
| t_2 | 00:00:00 ... 23:59:59 | 02:00:00 | second point of time profile |
| SU_2 | -99.9 ... 1800 [°C] | 300.0 [°C] | SV value of second point of time profile |
| ACP2 | On/OFF | On | activating second point of time profile |
| t_3 | 00:00:00 ... 23:59:59 | 03:00:00 | third point of time profile |

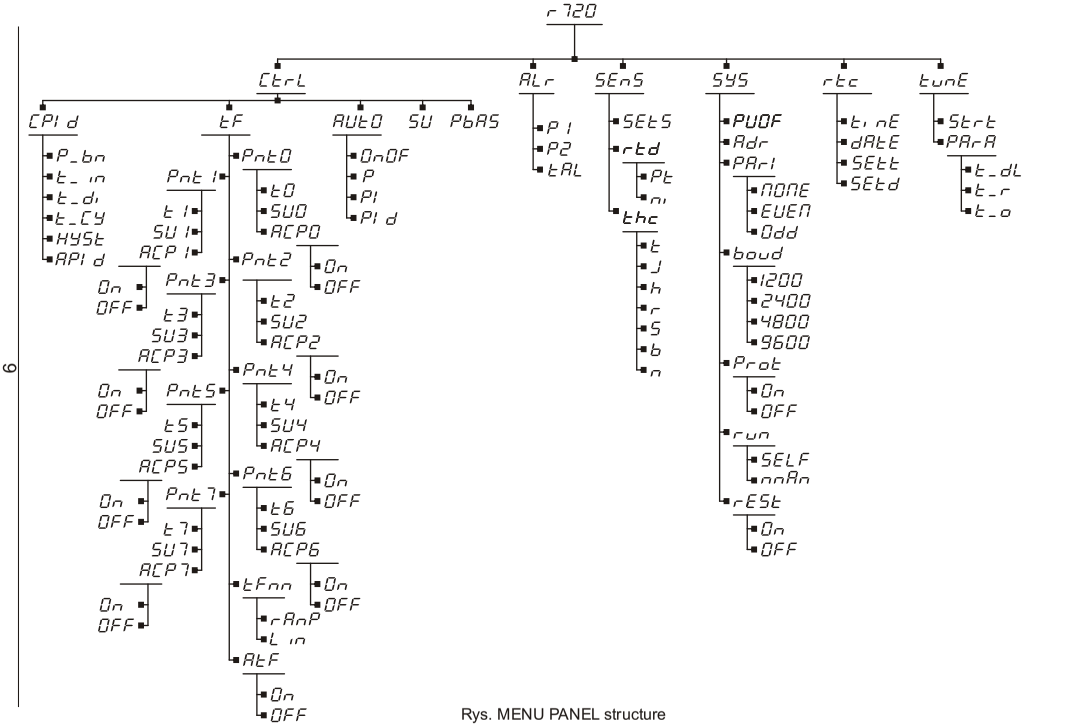
Tab. 4.0

| | | | |
|---|---|---|---|
| SU_3 | -99.9 ... 1800 [°C] | 400.0 [°C] | third point SV value, for time profile |
| ACP3 | On/OFF | On | activating third point of time profile |
| t_4 | 00:00:00 ... 23:59:59 | 04:00:00 | fourth point of time profile |
| SU_4 | -99.9 ... 1800 [°C] | 500.0 [°C] | fourth point SV value, for time profile |
| ACP4 | On/OFF | On | activating fourth point of time profile |
| t_5 | 00:00:00 ... 23:59:59 | 05:00:00 | fifth point of time profile |
| SU_5 | -99.9 ... 1800 [°C] | 600.0 [°C] | SV value of fifth point of time profile |
| ACP5 | On/OFF | On | activating fifth point of time profile |
| t_6 | 00:00:00 ... 23:59:59 | 06:00:00 | sixth point of time profile |
| SU_6 | -99.9 ... 1800 [°C] | 700.0 [°C] | SV value of sixth point of time profile |
| ACP6 | On/OFF | On | activating sixth point of time profile |
| t_7 | 00:00:00 ... 23:59:59 | 07:00:00 | seventh point of time profile |
| SU_7 | -99.9 ... 1800 [°C] | 800.0 [°C] | SV value of seventh point of time profile |
| ACP7 | On/OFF | On | activating seventh point of time profile |
| AtF | On/OFF | OFF | activating time profile program |
| tFnn | RAMP,LINEAR | RAMP | time profile work mode |
| SU | -99.9 ... 1800 [°C] | 100.0 [°C] | set temperature |

Tab. 4.1

| | | | |
|---|---|---|---|
| PbAS | 10 .. 100.0 [%] | 100.0 [%] | maximum value of PWM |
| P 1 | -99.9 ... 1800 [°C] | 50 [°C] | first level |
| P2 | -99.9 ... 1800 [°C] | 100 [°C] | second level |
| tAL | 0 ... 5 | 0 | alarm mode |
| SEtS | T,J,K,R,S,B,N, Pt100,Ni100 | K | selected sensor type |
| rtd | Pt100,Ni100 | - | thermoresistive sensors |
| thc | T,J,K,R,S,B,N | - | thermocouple sensors |
| PUOF | -10.0 ... 10.0 [°C] | 0.0 [°C] | offset |
| Adr | 0 ... 99 | 0 | meter address |
| PAr1 | even,odd,none | none | parity control |
| boud | 1200,2400, 4800,9600 | 2400 | serial transmission speed |
| Prot | On/OFF | OFF | settings protection |
| run | SELF, MAN | MAN | starting control process after power up |
| rESt | On/OFF | OFF | reset (restore factory settings) |

Tab. 4.2




Rys. MENU PANEL structure

# 5. Algorithms of control

## 5.1 Algorithm ON/OFF type and ON/OFF with hysteresis.

This algorithm is the simplest type of all control algorithms. This is algorithm without correction, it means, that output signal may have two values only: 0 or 100%.

This kind of control algorithm is suitalbe for the objects with small interference influence.

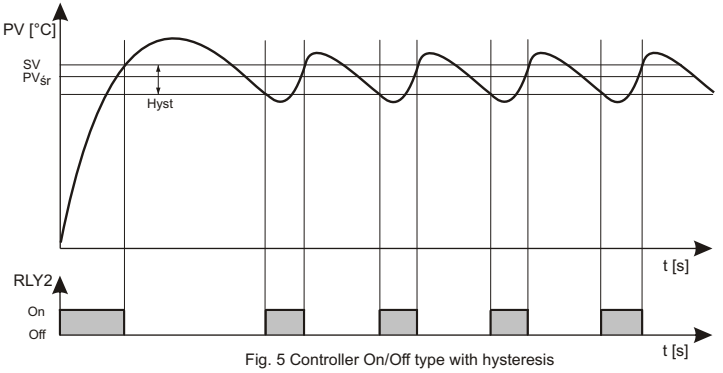



Fig. 5 Controller On/Off type with hysteresis

In case of the object with high delay values, that algorithm will be accompanied with overshoot.

In case of R-720 controller proportional amplification is expressed in percentages of difference between set temperature value (SV) and bottom value of measuring range (individual for each sensor type, see tab. 6)
Increasing proportional amplification is going to increase a controller sensivity for object temperature changes.
Increasing proportional amplification is going, also, to narrow the linear zone (PR).

**EXAMPLE**

set temperature value SV: 400 °C
process value PV = 200 °C
PWM base value PbAS = 80.0 %
amplification P_bn: 60.0 %
integral element t_in = 0 s
derivative element t_di = 0 s
pulse repetition period t_cy = 10 s
Termopara K, zakres pracy: -100 ... 1200 °C
LR = -100 °C

proportional range:

PR = (SV - LR) · P_bn

PR = (400.0 + 100.0) · 60% = 300.0 °C

$$PWM = \frac{SV - PV}{PR} \cdot PbAS$$

dla PV = 200 °C

$$PWM = \frac{400.0 - 200.0}{300.0} \cdot 80.0$$

PWM = 53.3 %

time of relay turn on, t_on:

t_on = t_cy · PWM
t_on = 10 · 53.3%
t_on = 5.33 s

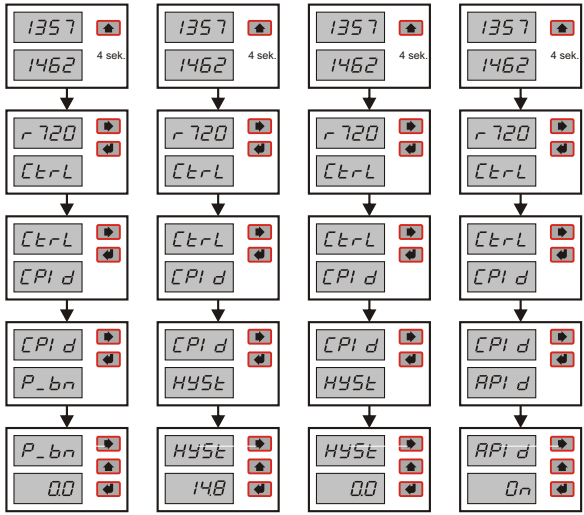
**Integration time-constant (t_in).**

The integral element eliminates static component error.
Use this parameter causes that object temperature (PV) will establish at set value level (SV).
Increase of t_in parameter slows down the process of reaching the steady state (SV) of object temperature (PV).

*To choose on/off algorithm must set controller parameters as following:*

*P_bn=0.0, Hyst=0.0, APID = On => On/Off without hysteresis ;*

*P_bn=0.0, Hyst=X, APID = On => On/Off with hysteresis value x;*




## 5.2 Algorithm P, PI, PID

Temperature control basing on quasi-linear algorithm proportinal (P) integral (I) and derative (D) makes possible:

- elimination temperature static error;
- smaller interference influence;
- sterowanie mocą średnią elementu grzejnego;

Proportional amplification P_bn is a basic parameter of PID algorithm, it affects in equal degree on all parameters of control algorithm.

**Derivation time-constant (t_di).**

The derivative element influences on value of average power between sampling the temperature. If temperature grows up, then derivative element reduces power, the growth temperature slows down. If temperature falls down, derivative element increases heater power. Influence of derivative upon heater power is the higer, the higer is the value of derivative time (t_di).

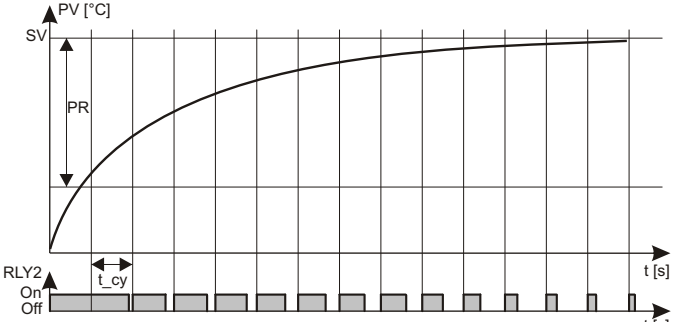



Fig. 6 Control based on proportional algorithm (P)

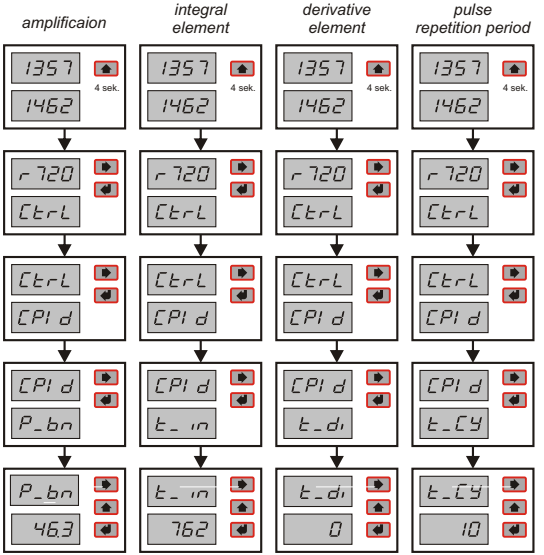
**Pulse repetition period (t_cy).**

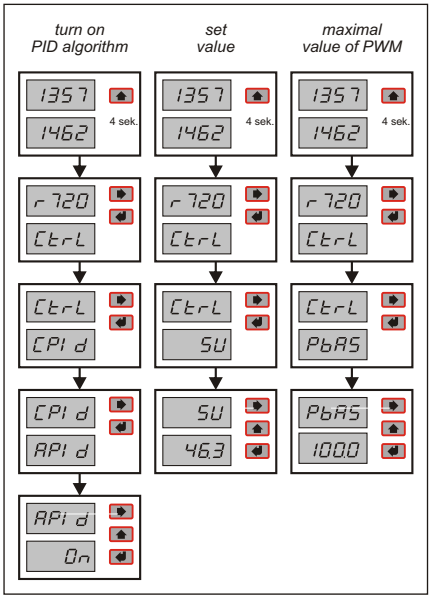
This parameter (t_cy) should be several times shorter than object time-constant.

Too big value of t_cy is going to unstable the control process.

Too small value of t_cy can shorts the time of life relay contacts.

*To use the PI, PID algorithms user must set seven parameters:*



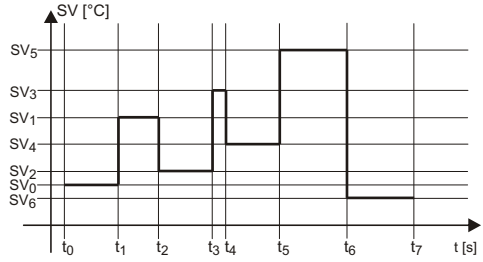



## 5.3 Time profile

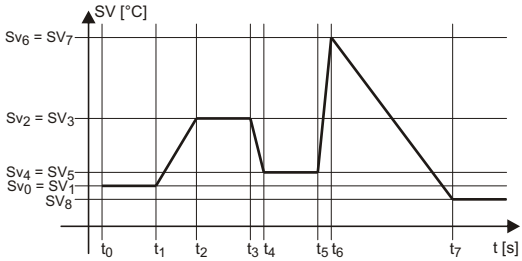
Time profile is based on real time clock and makes possible modifying set temperature value (SV) in function of time. SV could be self-modifying in two modes: RAMP or LINEAR, it is possible to programm up to eight temperature-time points.

RAMP work mode realizes algorith of jump of SV value, see fig.7. After time profile starting control output is switched off and controller is waiting as long as the value of system time reaches value of first time point. In that moment control process will be started. (Realized chosen algorithm P, PI, PID, ON/OFF).

LINEAR mode makes possible only ON/OFF i ON/OFF with hysteresis algorithm of control. Similarly like in mode RAMP, we cam programme eight temperature-time points. But the value of temperature set (SV) will be shaped across value of linear function (see fig.8).



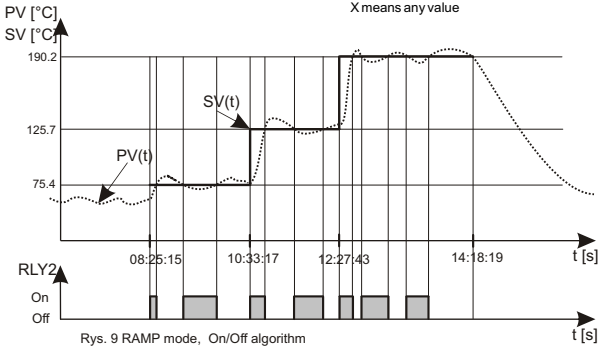

Rys.7 RAMP mode




Rys.8 LINEAR mode

**EXAMPLE:**
RAMP mode and On/Off control algorithm.

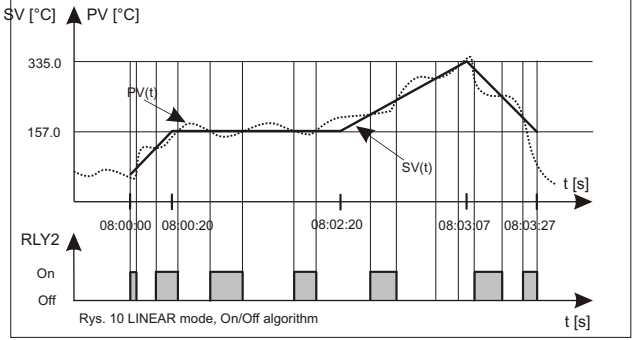
P_bn=0.0, Hyst = 0.0;
SV0= 75.4 °C, t0=08:25:15, ACP0=on;
SV1=125.7 °C, t1=10:38:17, ACP1=on;
SV2=190.2 °C, t2=12:27:43, ACP2=on;
SV3=X, t3=14:18:19, ACP3=on;
SV4=X, t4=X, ACP4=off;
SV5=X, t5=X, ACP5=off;
SV6=X, t6=X, ACP6=off;
SV7=X, t7=X, ACP7=off;
X means any value




Rys. 9 RAMP mode, On/Off algorithm

**PRZYKŁAD:** LINEAR mode and ON/Off control algorithm.

P_bn=0.0, Hyst = 0.0;
SV0= 25.0 °C, t_0=08:00:00, ACP0=on;
SV1=157.0 °C, t_1=08:00:20, ACP1=on;
SV2=157.0 °C, t_2=08:02:20, ACP2=on;
SV3=335.0 °C, t_3=08:03:07, ACP3=on;
SV4=157.0 °C, t4= 08:03:27, ACP4=0n;
SV5=X, t5=X, ACP5=off;
SV6= X, t6=X, ACP6=off;
SV7=X, t7=X, ACP7=off;
X means any value

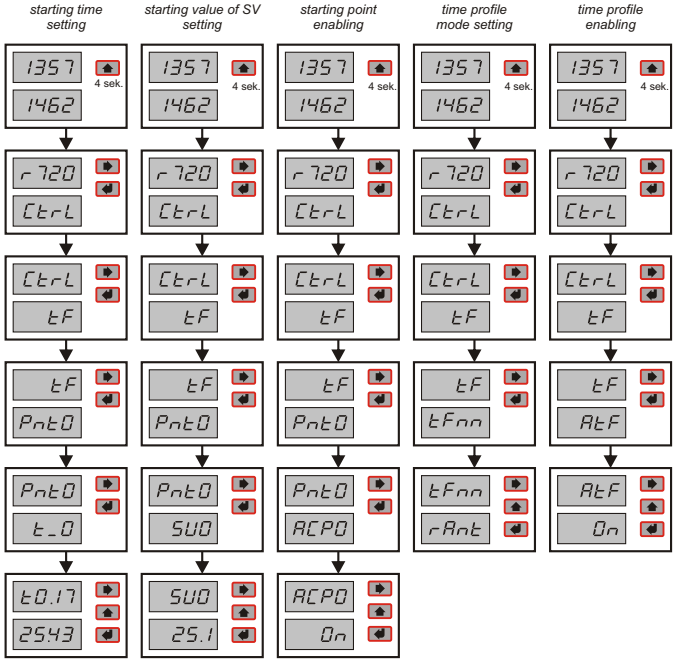



Rys. 10 LINEAR mode, On/Off algorithm

*Programming time characteristics consists in determining the number of its points. (state On of variable ACPx activates x point, state Off deactivates that point - max.8 points) and determining time tx and set value SVx for point Px of characteristics.*

***Example***

*If all points are being used (ACP0..ACP7 = On) and user will decided that five points of characteristics will be enough for him. In that case user shold set parameter ACP5 at Off state, and thats all. All remaining points will be deactivated automatically.*



# 6. Alarm

The R-703 controller is equiped with level alarm, wich can work in one of five modes of work. Could be used by user to monitoring the control process, informing about corrent state of process and possible risk of overheating.

Alarm can be used also as additional control output working in On/Off mode or On/Off with hysteresis mode.

Mode of alarm output ilustrates fig. 11 below.

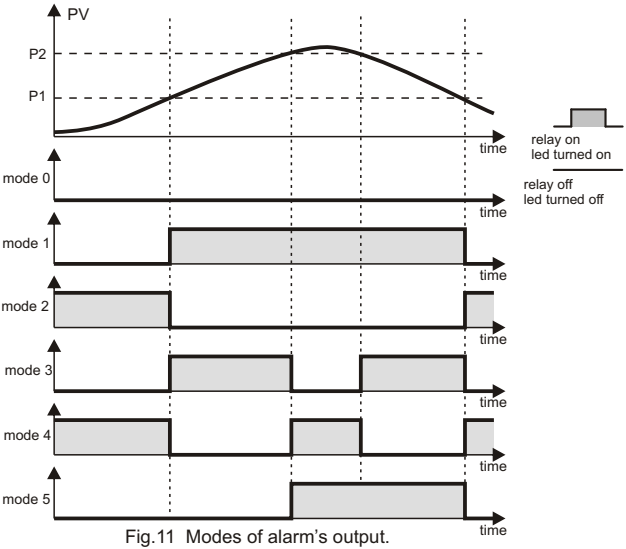



Fig.11 Modes of alarm's output.

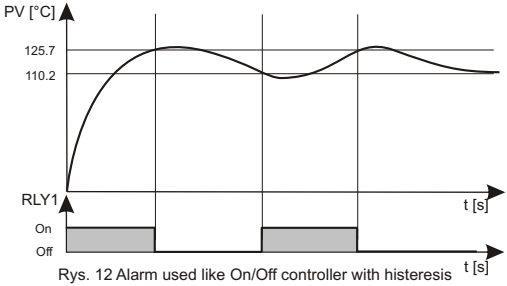
***Attention!!!***

*Value od alarm's level should be P1<P2, in other time alarm didn't work property.*

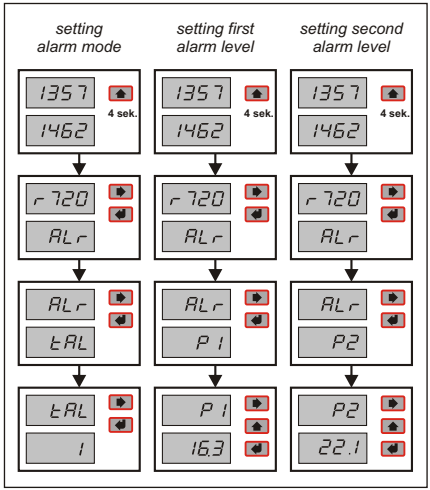
Example.

Figure below presents On/Off with hysteresis algorithm controller uses alarms relay output. )

Alarm settings: P1 =110.2 °C, P2=125.7 °C, Tal=5.




Rys. 12 Alarm used like On/Off controller with histeresis (used normal close relay contacts)



# 7. Autotuning

Process of tuning, implemented in R-720 can be used to firtst order objects with delay (Fig. 13), which time constant is bigger than 100 seconds and smaller than 3600 seconds. If in the tunning proccess R-720 notices that object is too slow or too fast to identify, the process will be aborted and user will be informed about it.

The process od autotunig based on studying the response of the object to the unit step. 100% of powers is delivered to the object and is holding at that level to the time when PV walue (measuring temperature) will be reached SV value (temperature set). In the time of experiment is measuring the object delay, the time of temperature growing and the value of overshoot of PV. Based on collected data, parameters of object will be calculated.

After end of tuning all parameters of the object will be saved in nonvolatile memory and it is possible to use them in any time.

To use parameters appointed in the process of autotuning, user should access MENU PANEL into the AUTO position and there (depending on the wanted control algorithm: P, PI, PID) choose right option.

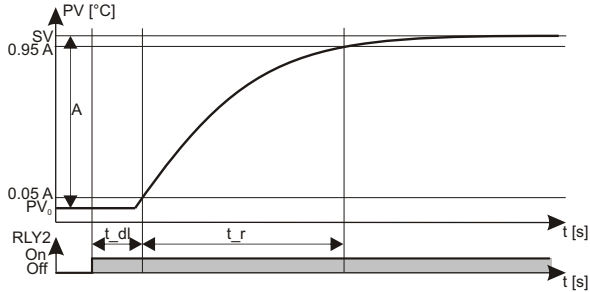
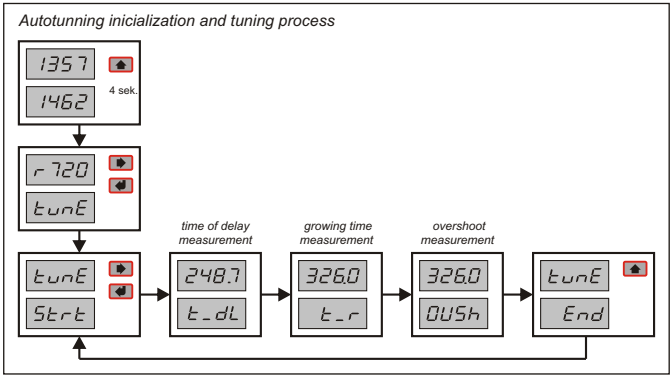
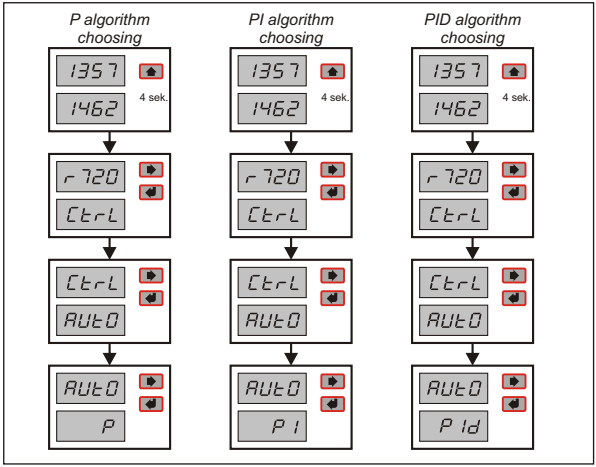


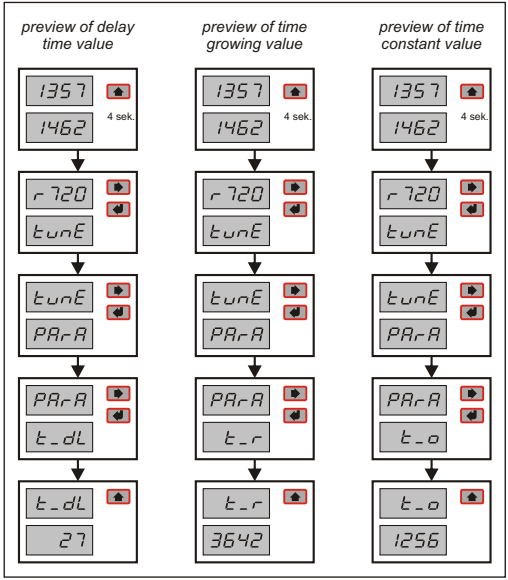

Fig. 13 Step response of first order object with delay.




After selecting one of control algorithm, values created in autotuning process are staying recalculated and copied to control variables(P_bn, T_in, T_di, T_cy). It is possible to modyfiy them later, when control process won't be satisfacted enough.



In time of autotuning process user must keep special careful when the identified object is a part of greater system. In that situation and when overshoot over SVvalue is very high, it is possible to damage components of that system.




***ATTENTION!***

*Parameters of control created in the autotuning process can be using as long as the object is still in the same unchagned conditions whih ruled while tuning. In other way created values can run away from reality. As a result of it control process can run in the incorrect way.*

*If parameters of object will change (location, diemensions), the autotuning process must be doing again.*

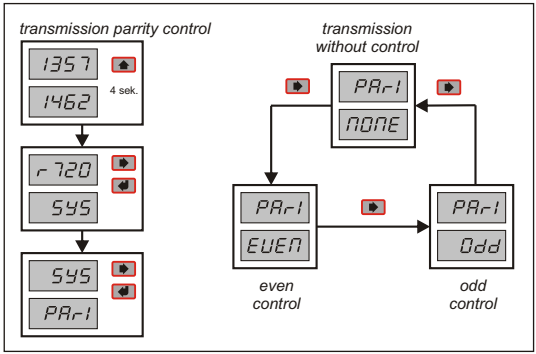
In the moment of buying R-720 controller is equipped with default values of parameters of tuning. (See tab.4.0)

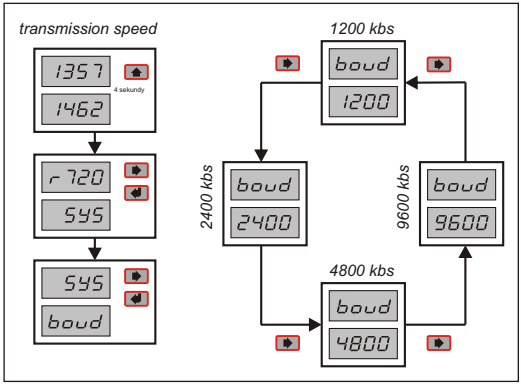
# 8. Communication

R-720 is equipped with RS-232 serial port (or RS485 in option) interface making possible co-operation with the computer. Serial port working with four different transmission speed. Przy pomocy łącza szeregowego można sterować regulatorem, odczytywać i zmieniać jego niektóre parametry. Via serial interface is also accessible MENU TERMINAL, which makes possible easier configuration and more comfortable in use that MENU PANEL.

Data between computer and controller are transmitted ASCII code and contains 8 data bits and one stop bit. For correct work user should set up:

- **Transmission speed (boud)**. It is possible one of four transmission speed: 1200, 2400, 4800 i 9600 kbps ;
- **Parrity control (PArI)**. Options: even, odd, none






- **Controller address**. Addressing makes possible to work several devices connected to one serial port (RS-485 interface only).

Number of address range is from 0 to 99.

If user uses to communicate terminal application on the computer and MENU TERMINAL, it is recomended to turn off local echo.

**ATTENTION!**

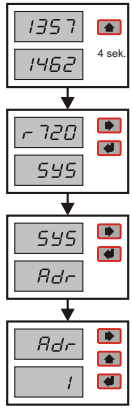
*In case, when transmission parameters are modyfying using MENU TERMINAL, user shold remember that changes will be updated after MENU will bo closed. After than paramaters od transmission must be changes in terminal application on the computer.*

## 8.1 Communication protocol

Serial interface enables programming controller without using MENU PANEL. To read value of one parameter, user should use special data format presented at fig.14.

Addressing makes possible changes values of paramaters only in users intresting controller.

In case when address will be equal 00 data will be interpreted by all contected controllers. Protocol don't recognizes big and small letters. All parameters values, listed below, could be read and write, apart PV value which can be read only.Wszystkie wymienione poniżej




Read command (read measuring temperature by controller of 01 address example)

| 0 | 1 | T | ? | □ |
|---|---|---|---|---|
| adres | | kod | | <CR> |

R-720 example answer : **+0022.8**
(exactly: **<LF>**, '**+0022.8**', **<CR>**, **<LF>** )

Write command
(write set temperature value example)

| 0 | 1 | Z | + | 1 | 2 | 5 | . | 0 | □ |
|---|---|---|---|---|---|---|---|---|---|
| adres | | kod | +/- | nowa wartość | | | | | <CR> |

Write command
(write integral element vaule example)

| 0 | 1 | I | 8 | 0 | 0 | □ |
|---|---|---|---|---|---|---|
| adres | | kod | nowa wartość | | | <CR> |

R-720 example answer: **done**
(exactly: **<LF>**, '**done**', **<CR>**, **<LF>** )

Fig. 14 Command format

## 8.2 List of command

| Command code | Description | Atributs | |
|---|---|---|---|
| | | R | W |
| **T, t** | temperature value (PV) | + | - |
| **Z, z** | set temperature value (SV) | + | + |
| **P, p** | proportional amplifiaction (P_bn) | + | + |
| **I, i** | integral element (t_in) | + | + |
| **D, d** | derivative element (t_di) | + | + |
| **C, c** | pulse repetition period (t_cy) | + | + |
| **H, h** | hysteresis (Hyst) | + | + |
| **B, b** | maximum value of PWM | + | + |
| **S, s** | sensor type * | + | + |
| **A, a** | alarm works mode (tAL) | + | + |
| **X, x** | first alarm threshold (P1) | + | + |
| **Y, y** | second alarm threshold (P2) | + | + |

Tab. 5

* 1 - thermocuple J 4 - thermocuple R 7 - termopara N
2 - thermocuple K 5 - thermocuple B 8 - Pt100
3 - thermocuple T 6 - thermocuple S 9 - Ni100

**EXAMPLES**
Reading temperatue from controller about address 23 => 23T?<CR>
Reading temperatue from controller about any address => 00T?<CR>
Setting SV value = 395.6 for controller about address 7 => 07Z+395.6<CR>
Entering to MENU TERMINAL of controller about adress 17 => 17<CR>
Entering to MENU TERMINAL of controller about unknow address => 00<CR>

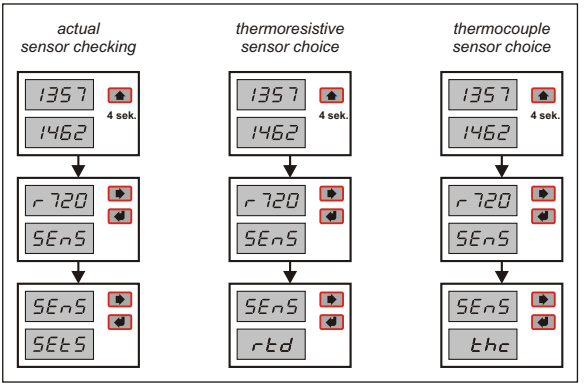
# 9. Sensor

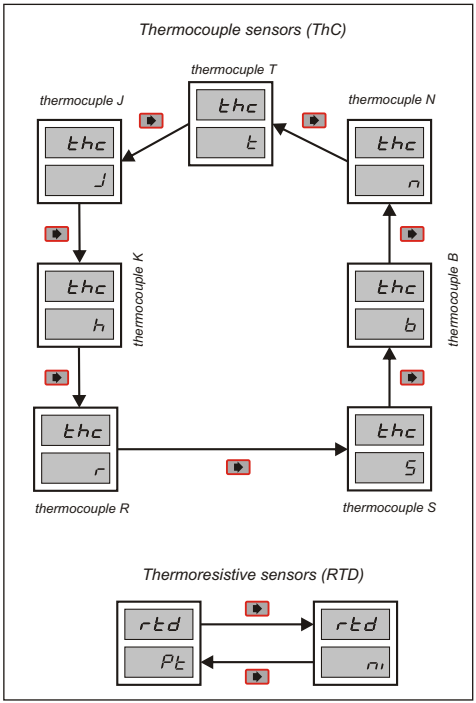
R-720 is a universal controller, which co-operate with all sensors offered by Czaki Thermo-Product, and most of others. Controller can co-operate with termoresistive sensors: ( PN-EN60751+A2 norm):

- Pt100 => -99.9 ... +850.0 °C;
- Ni100 => -60.0 ... +180.0 °C;

and thermoelements (PN-EN60584 norm):

- J (Fe-CuNi) => -99.9 ... +1000 °C;
- K (NiCr-NiAl) => -99.9 ... +1200 °C;
- T (Cu-CuNi) => 0.0 ... +230.0 °C;
- R (PtRh13-Pt) => +200.0 ... +1600 °C;
- B (PtRh30-PtRh6) => +400.0 ... +1800 °C;
- S (PtRh10-Pt) => +200.0 ... +1600 °C;
- N (NiCrSi-NiSiMg) => -99.9 ... +1300 °C;



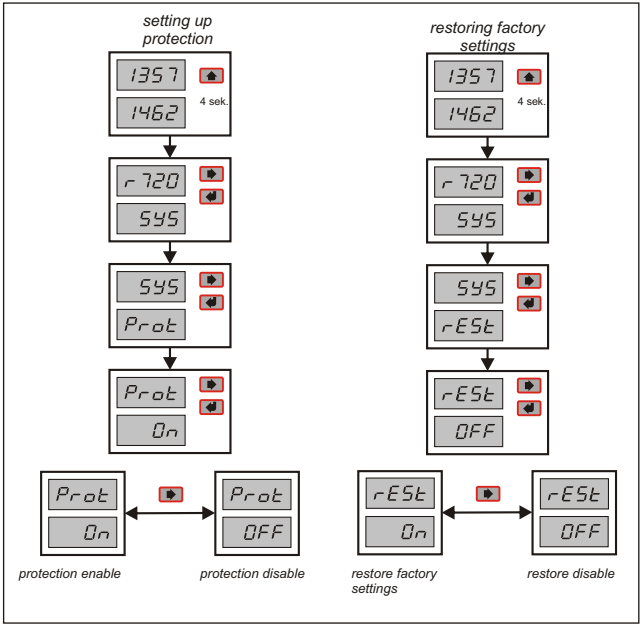



## 10. Protection

Controller offers the possibility of blocking set the parameters of work, to make impossible the access unauthorised personel. All parameters values are protected, this is safe mode. In that case (safe mode) there is no possible to use MENU TERMINAL and MENU PANEL. Protection could be clear only if controler will be powered up with pressing UP key.

# 11. Reset

This option restores factory settings of parameters fron scheudle 4. After set up this option user should leave menu and then waiting for controller inicialization. After this controller is ready to work with factory settings.



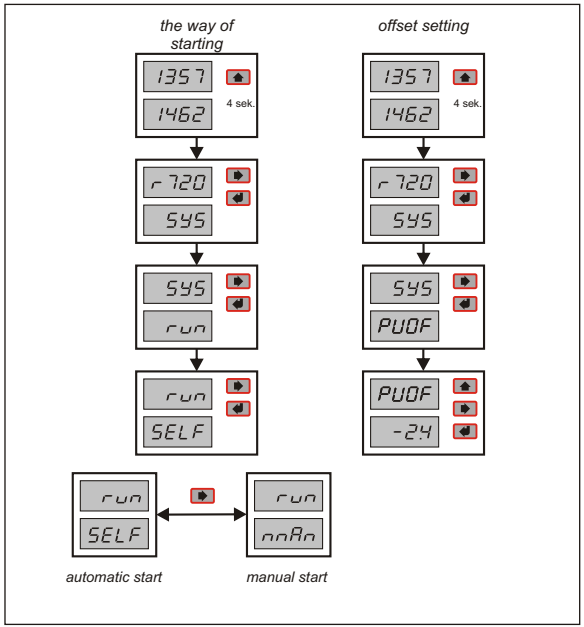

# 12. Starting

Controller R-720 can starts process of control automaticlly after powred up or in time when user starts it manual. The way of starting defines parameter **run**. It could be SELF or MAN. In case of MAN option,

after power control output will be disconnected and controller will be waiting for pressing ENTER key.

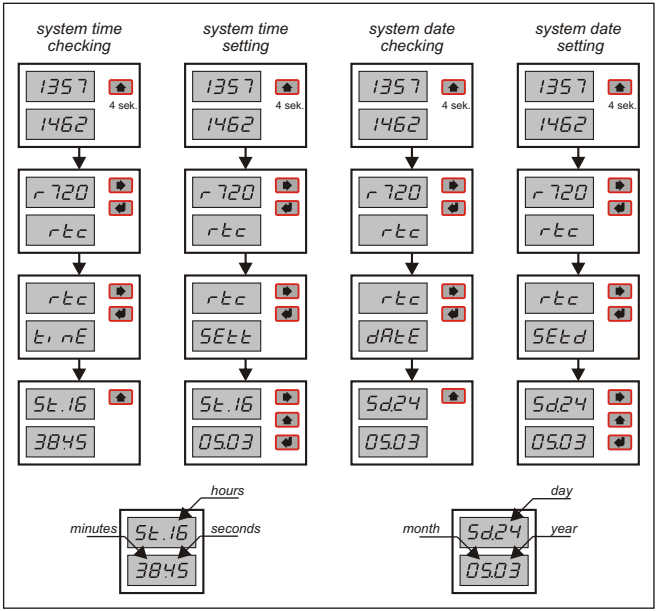
## 13. Offset

Offset is setting in case of solid difference between real temperature and measure temperature. This parameter can compensate, for example, the influence of wiring resistance when is used two-wire thermoresistance sensors or thermocouples from poor class.



# 14. System time

R-720 is equipped with real time clock, which is used in the time profile. This clock is setting up in factory, but user could modify it settings. It is recomended to check it settings from time to time.



# 15. Technical data

| | |
|---|---|
| **Working temperature range** | J (Fe - CuNi) [-99.9 .. +1000] °C<br>K (NiCr - NiAl) [-99.9 .. +1200] °C<br>T (Cu-CuNi) [-99.9 .. +230.0] °C<br>R (PtRh13 - Pt) [+200.0 .. +1600] °C<br>S (PtRh10 - Pt) [+200.0 .. +1600] °C<br>B (PtRh30 - PtRh6) [+400.0 .. +1800] °C<br>N (NiCrSi - NiSi) [-99.9 .. +1300] °C<br>Pt100 [-99.9 .. +850.0] °C<br>Ni100 [-60.0 .. +180.0] °C |
| **Resolution of temperature measurement** | 0.1 °C dla T < 1000 °C<br>1 °C dla T □ 1000 °C |
| **Temperature measurement error** | < 0.3 °C ± 2 cyfry dla T < 200.0 °C<br>< 0.7 °C ± 1 cyfra dla 200.0 °C <T < 500.0 °C<br>< 1.5 °C ± 1 cyfra dla 500.0 °C <T < 1000 °C<br>< 2 °C ± 1 cyfra dla T > 1000 °C |
| **Cold junction temperature measurement error** | 1 °C |
| **Reading temperature period** | 1 sec |
| **Ranges of parameters' set.** | as described within tab. 4 |
| **Type of outputs** | mechanical relay |
| **Max. current of relay** | 5 A |
| **Max. switching voltage** | 250 V AC, 24DC |
| **Max. switching power** | 1000 VA |
| **Max. frequency switching** | 600 cycle/h at nominal duty<br>72 000 cycle/h without duty |
| **Protection rating** | IP 40 from front wall<br>IP 20 from rear (conectors) wall |
| **Power supply** | 230V +10% -20% 50..60Hz, 3VA |
| **Ambient temperature** | 0 ..50 °C |
| **Relative humidity** | < 80% |
| **Weight** | ca. 0.4 kg |
| **Dimensions h** × **w** × **d** | 96 × 48 × 140 mm |
| **Mounting window dimensions** | 91 × 44 mm |

Tab. 6

# 16. Errors

| Message | Kind of error | Cause |
|---|---|---|
|   | Temperature below measurement range | too low input signal value |
|   | Temperature over measurement range | too high input signal value, or no sensor |
|   | EEPROM memory writing error | memory damaged |
|   | EEPROM memory reading error | memory damaged |
|   | Tunning error | too high or too low value of time constant of controlled object |

Tab. 7 List of errors

**NOTES**

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