PID controller with relay output

Aim of the work

Getting to know features of the PID controller with relay output, its applicability and how does it operate.

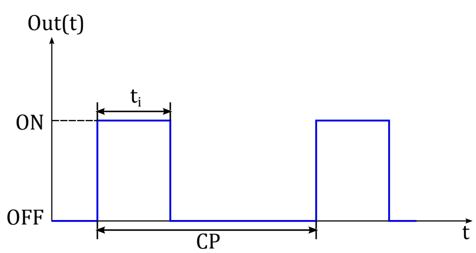
1 Equipment

Controller E5EN

- Controller type: PID;
- Sensor: temperature (thermocouple type K voltage $0 \dots 50\ mV\ DC$);
- Output signals: reverse characteristics (for heating).

Controller parameters can be observed and set using settings menu.

Output of the controller ($u(t)$) is a discrete signal with values {ON, OFF}, pulse length (u=ON) t_i range is $0 < t_i < CP$, where CP is a pulse period.



Mean value of the signal

$$u(\%) = \frac{t_i}{CP} \cdot 100\% \quad (1)$$

$$U_{rms} = U_m \sqrt{\frac{t_i}{CP}} = U_m \sqrt{\frac{u\ [\%]}{100}} \quad (2)$$

Power supply and Object

See description of Lab 1. “Thermal Process Identification”.

Signals recording

- Software oscilloscope Velleman PCSU1000 (PCLab2000) and the amplifier.

Work flow

Check settings of the controller, assemble the circuit, read and calculate parameters.

2 Controller tuning

Get to know the modes and menus of the controller.

In menu **Initial Settings Level** set the next parameters to the controller:

***in-t*=6** % Thermocouple type

***Cntl*=PID** % Control action

***õrEV*=õr-r** % Characteristic of the controller

3 Assembling

✓ Check if power supply is turned off.

✓ Connect object with a controller as it shown in Fig. 1

- Use the controller output signal u to commutate the power supply signal, thus power supply output is $U = \{0, U_m\}$. The amplitude of the signal U_m can be changed by the knob.

  Caution! Use protected wires! $U_m = 0 \dots 240\ V$!

- Output of the power supply is connected to the object and a lamp 220 V.
- Connect the output of the object U_{tp} to the input of the controller and through the signal amplifier to the oscilloscope.

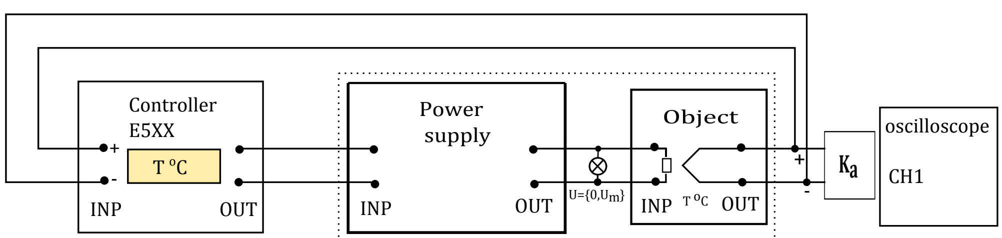


Figure 1: Assembling diagram: PID Control

✓ Turn on the object fan!

✓ Make sure that **offset** of the signal **is minimal** (turn amplifier potentiometer to leftmost position ↶). Connect amplifier with PC via USB port.

4 Controller P-mode

In oscilloscope software PCLab2000 select **Transient Recorder** Mode

✓ Set the 0,2 V/div for the CH1, and 50 s/div as registration speed.

✓ Set the initial level of the signal almost at the bottom of the screen using "Position" slider.

Set the next controller parameters:

✓ Period of the controller output signal (Control Period) CP = 5 s in **Initial Settings Level**.

✓ P-mode tuning (Proportional) in **Adjustment Level**:

> ***P***=40 $°C$ % Proportional Band (PB)
>
> ***I***=0 % Integral Time (T_i)
>
> ***D***=0 % Derivative Time (T_d)
>
> ***õ*FR** 0 % Manual Reset Value. If you have it in menu after the PID parameters.

✓ Setpoint $SV = 180\ °C$ in **Operational Level**.

✓ Start register the signal using "**Single**" button.

✓ Set the power supply voltage $U_m = 180\ V$.

✓ Observe the process PV, wait for process stabilization (PV = const). Do not stop the registration of the signal!

4.1 Readings and Calculations

1. What is the $T_{max}[°C]$ or $T_{min}[°C]$ reached during the process?
2. At the end of each process (steady-state) take the readings of

   Set Point SV ($°C$),

   Process Value PV ($°C$),

   Manipulated Value MV or u[%].

3. Using obtained data calculate an output signal u[%] caused by the *offset* or e.

For the more precise observations of the U_{tp} signal:

✓ Change the sensitivity of oscilloscope 20 mV/div - signal will increase;

✓ Shift the signal level to the first (from the bottom) division on the screen ≈ 6 divisions of Output Offset $\curvearrowright$.

5 Controller PI-mode

✓ Add "I" parameter to the controller. Set $T_i = 70\ s$.

✓ Wait for process stabilization ($PV \approx SV =$ const).

✓ See Sec. Readings and Calculations 4.1, take all the readings.

✓ Stop recording the signal

5.1 Add text to the figure:

- Lab No., Object No.;
- Student name(s),
- Controller mode (P/PI/PID),
- Process mode,
- Date.

✓ Save figure.

✓ Make sure that signal level is on the second division (from the bottom) of the screen. Shift the signal level Output Offset ↷ if necessary.

✓ Start signal recording using "**Single**" button.

✓ Make the following experiments with different types of disturbances. During the each mode make the measurements, see Sec. Readings and Calculations 4.1.

5.2 Tests

Step disturbance in the feedback loop

- Turn off the fan of the object, wait for the end of the effect, read data;
- Turn on the fan of the object, wait for the end of the effect, read data.

Step change of the set point

- Observe and record the step response on SV 180 $°C \to$ 200 $°C$, wait for the end of the effect, read data;

✓ Save figure with an added data as listed above, see Sec. 5.1. Start recording the new graph.

- Observe and record the step response SV 200 $°C \to$ 180 $°C$, wait for the end of the effect, read data.

Step disturbance from the output of the actuator

- Make a disturbance on the power supply output $+40\ V$ ($U_m = 180\ V \rightarrow 220\ V$), wait for the end of the effect, read data;
- Change the disturbance direction $-40\ V$ ($U_m = 220 \rightarrow 180\ V$), wait for the end of the effect, read data.

✓ Save figure with an added data as listed above, see Sec. 5.1.

6 Controller PID-mode

✓ Add derivative parameter $T_d = 20\ s$.

✓ Repeat tests (1)-(3) from Sec. 5.2 .

✓ Observe a process. Save figure.

6.1 Completion of the work

Set source voltage $U_{in} = 0\ V$. (**Caution!** $U_m = 0 \ldots 250\ V!$)

✓ Disconnect the object, power source and controller.

✓ Disconnect the amplifier from PC USB port.

7 Calculations

1. Evaluate results, what impact has each parameter on the process control?
2. Find the process "Power supply + Object" steady-state characteristic. Input of the system is a controller output signal $u(\%)$, see Eq. (2), output - object temperature $T(°C)$, see Lab No. 1 "Thermal Process Identification".

   (a) Find the gain

$$K_p = \frac{dT}{du}. \tag{3}$$

Report should consist of:

- Experiment results (graphs),
- Calculations.