PID setting

Abstract

The application note describes settings of parameters in PID controllers in control systems made by the company AMiT. It also includes recommended default values for PID controller settings in selected technologies.

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File: ap0042_en_01.pdf

Attachments:

File content: –

–	None

Contents

Revision history

Version	Date	Changes
001	04. 08. 2010	New document.

Related documentation

1. Help tab in the DetStudio development environment
   file: DetStudioHelp.chm
2. Source code for sample project TP_Px – Steam transfer station
   file: tp_px_xxx_dso.zip
3. Source code for sample project TV_x_x – Air conditioning
   file: tv_x_x_xxx_dso.zip
4. Source code for sample project TM_1_x – Room regulation
   file: tm_1_x_xxx_dso.zip
5. Application note AP0034 – Boiler cascade control
   file: ap0034_en_xxx.pdf
6. Application note AP0036 – Use of function blocks for DM-FCx
   file: ap00036_en_xx.pdf

1 PID controller

The PID controller includes proportional, integration and derivative terms that act through the action variables on the system controlled in order to maintain the controlled variable at the determined value and to make the regulation deviation zero or as small as possible. In a request for optimal PID controller setting, there may be (and are indeed) multiple goals, often even contradictory goals. These may include e.g. monitoring a requested value, suppressing malfunction causes, white noise insensitivity, response stability, etc. Therefore, setting a PID controller may be a certain compromise of individual requirements. We often encounter e.g. settings that have to deal with a requirement of fast PID controller response to changes in the control circuit while maintaining minimum over-control with good response stability. In most cases, using a PI type controller is fully sufficient (the derivative term is deactivated). Temperature control is a typical example. The following chart states the influence of individual PID controller parameters on its control activity. The chart shows the contradiction in settings in a requirement for fast and stable responses.

The influence of increasing constant values on response speed and stability:

Constant	**Response speed**	**Response stability**
Proportional (K)	increases	decreases
Integration (Ti)	decreases	increases
Derivative (Td)	Increases	Decreases

1.1 Influence of PID parameters on control

The resulting action variable (action) is calculated on the basis of the proportional, integration and derivative PID controller constants. Constants influence the course of the control process together. In control systems by AMiT, the action of the PID controller is calculated according to the following formula:

$$y = K \cdot \left(x + \frac{1}{T_i} \int_0^t x \cdot dt + T_d \cdot \frac{dx}{dy} \right)$$

In order to explain the PID controller in simple terms, its functionality is demonstrated in the following example.

The controller’s task is to regulate the temperature of a soldering microgun. It will therefore supply power. In order for the controller to know what amount of power to supply, it will also measure temperature. The setpoint temperature is the temperature which the soldering gun needs to be heated to.

1.1.1 Proportional constant (K)

The controller subtracts the value of temperature measured from the setpoint temperature and multiplies the difference (the regulation deviation) by the constant (proportional constant (K). The result is the power the soldering gun heats up to (e.g. in percent). Therefore, if the temperature measured is much lower than the setpoint temperature, the power is high. The more the temperature measured approaches the setpoint temperature, the lower the power. If the temperature measured is the same as the setpoint temperature, the power is zero. The aforementioned formula for PID controller shows that the PID controller multiplies the deviation with the proportional constant K. If this constant’s value is zero, the PID controller will not work. The power is still zero, regardless of the deviation. If we set the constant value to 1, the power will be e.g. 10 % at temperature difference 10 °C.

In most cases, using only the proportional controller leads to an occurrence of a permanent regulation deviation.

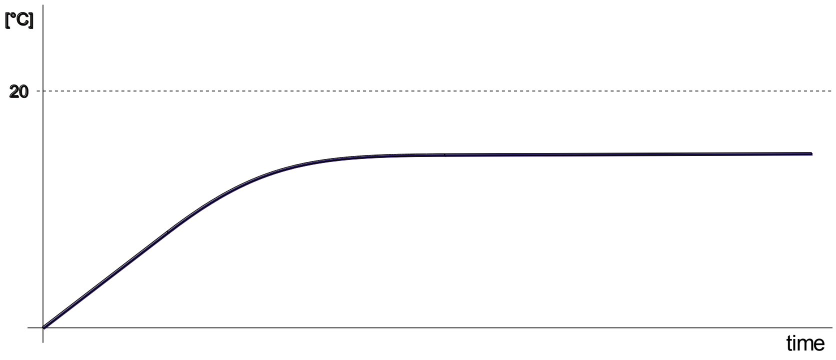

Fig. 1 – P controller with a small constant K

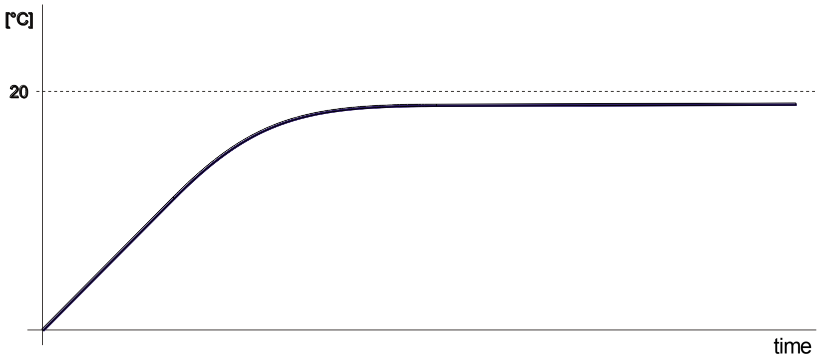

Fig. 2 – P controller with an acceptably set constant K

The permanent regulation deviation can be decreased by increasing the constant K. However, there is danger that the regulation circuit is going to get destabilized, i.e. the regulated variable keeps growing unlimitedly with or without oscillation up to the point of automatic stop or device damage.

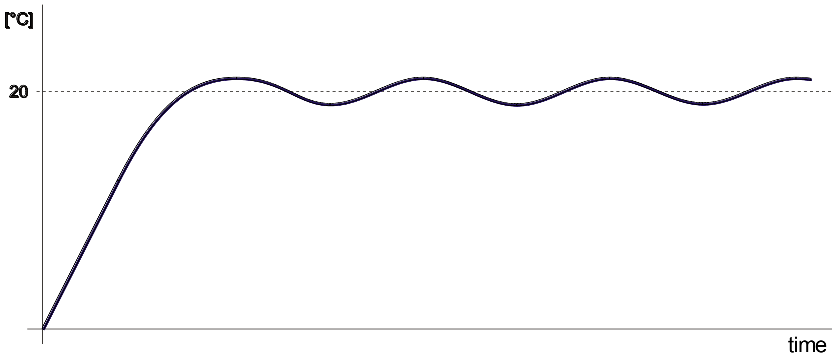

Fig. 3 – P controller with a high constant K

In order to remove the permanent regulation deviation, the controller activity usually features an integration behaviour term (if the regulated system itself does not have integration character).

1.1.2 Integration constant (Ti)

The integration part of a PID controller multiplies the regulation deviation by the constant and adds it to its value. That means that if the temperature measured is lower than setpoint, the integration term is going to grow. If temperature measured is higher than setpoint, the integration term is going to decrease. The higher the regulation deviation, the faster the change in the integration term. If the controller is only integration, the soldering gun first heats up a little and the power gradually increases. As soon as the setpoint temperature is exceeded, the power decreases. After the temperature stabilizes at the setpoint value, the integration term will be set to the power necessary for maintaining steady temperature (we supply the same power to cool the soldering gun).

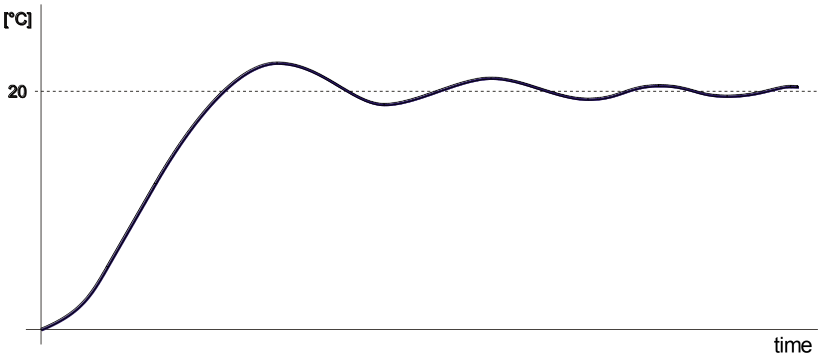

Fig. 4 The influence of the integration constant in the PI controller (the Ti constant is too low)

If we decrease the portion of integration term in the PID controller (by increasing the Ti constant), we reduce oscillation of the regulation circuit. If the portion of the integration term increases (by decreasing the Ti constant), the regulation circuit oscillation increases as well. It can be mitigated to a certain extent by adding the derivative term.

1.1.3 Derivative constant (Td)

The derivative term of the PID controller multiplies the rate of deviation change by the constant Td. If the temperature measured decreases, the derivative term increases the power. Therefore, the faster the temperature measured decreases, the higher is the power the derivative term of the PID controller will use for heating. If the temperature measured increases, the derivative term of a PID controller decreases the power. That manifests very well at the moment when we begin working with the heated soldering gun. The temperature begins to drop and the derivative term immediately responds by increasing the power. On the other hand, if the temperature increase becomes too steep, the derivative term of a PID controller decreases the power.

If we decrease the derivative term rate in the PID controller (by decreasing the Td constant), the controller responds more slowly to changes in setpoint values in the regulation circuit.

If we increase the derivative term rate in the PID controller (by increasing the Td constant), the controller’s response to changes in setpoint values in the regulation circuit will become faster.

2 Controller design procedure

2.1 Determining system parameters

Parameters are best determined from the transient system characteristics measured. We measure 2 responses to the system input jump and determine parameters by averaging the two measurements:

1. Jump 0 % .. 50 % action (e.g. opening a valve)
2. Jump 50 % .. 100 % action (e.g. opening a valve)

Before the measurement, we must make sure that the system is idle, i.e. That the variable regulated does not change. The variable regulated should stabilize again at the end of the measurement.
The system gain is then given by the formula:

$$K_S = \frac{\Delta y}{\Delta u}$$

where

Δy is the difference between temperatures at the beginning and end of measurement

Δu is the difference between input values at the beginning and end of measurement, i.e. 50 %

The time constant T_S is determined as the time in which the output reaches 63 % of its stabilized value. The time constant measured in this way is higher than the actual time constant of the system because the system is slower e.g. due to the influence of the regulation valve. However, this time constant determination is sufficient for determining the controller time constant. Consequently, the controller will also be “slower”, which is suitable.

Note:
*The measured output of the system is mostly filtered using a 1st order filter (module **`Filtr1R`**), in order to eliminate white noise. The filter time constant should be much lower (by at least 1 degree) than the system time constant in order not to disrupt the regulation. The measurement “delay” has generally bad influence on the regulation process.*

2.2 Determining controller parameters

The integration time constant T_I is selected the same as the measured system time constant T_S.
The gain is given by the formula:

$$K_R = \frac{1}{K_S}$$

Controller parameters determined in this way should provide that the resulting controlled system will have a slightly overdamped character. That means that the resulting response to the jump of value requested will have no overshoot. The system can be even more dampened by decreasing the gain,

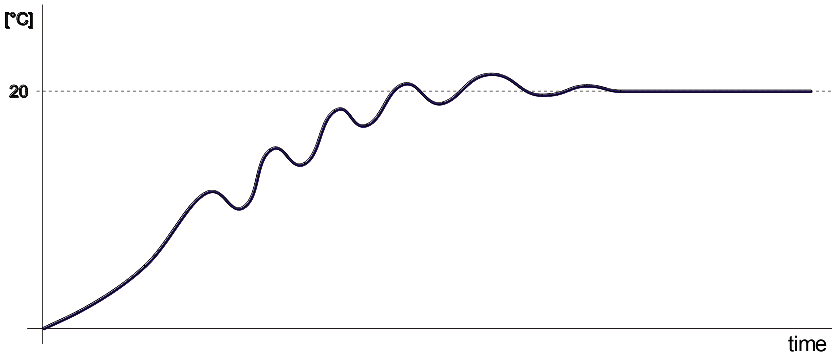

Fig. 5 – Constant K too low

By increasing the gain, the control process accelerates but the dampening decreases, so the resulting response may oscillate slightly. Significant increase in gain may increase the oscillation up to the point the system becomes unstable.

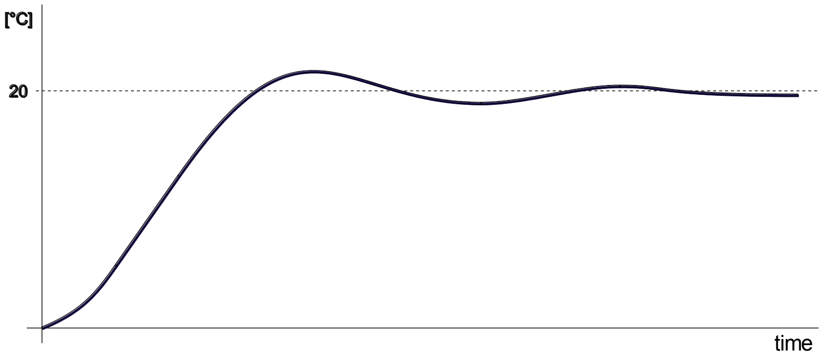

Fig. 6 – Constant K too high

The integration time constant usually does not need any further attunement. Below are examples of responses of the resulting controlled system depending on the size of the selected integration time constant of the controller.

Fig. 7 – Constants determined correctly

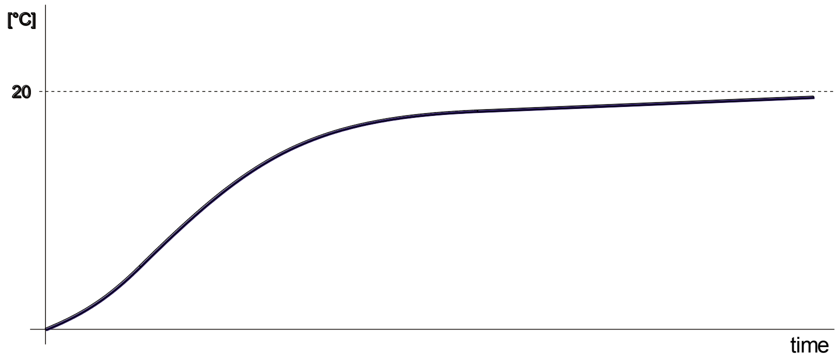

Fig. 8 – Double integration time constant (takes long to “pull up”)

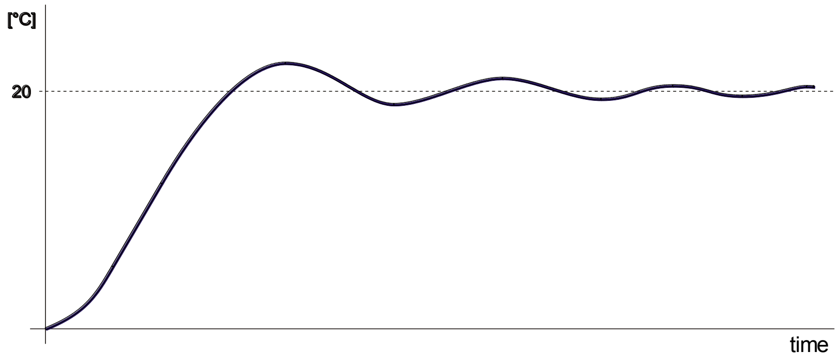

Fig. 9 – A half integration time constant (undesirable overshoot)

3 Recommended default values of PID controllers

3.1 Air conditioning

3.1.1 Hot water air heater

K = 4.0
T_i = 150 s
T_d = 0 s

Note:
The value of the proportional constant depends on the heater power with respect to the medium heated.

3.2 Heating

3.2.1 Controlled heating branch

K = 1.0
T_i = 200 s
T_d = 0 s

3.2.2 Boiler cascade

K = 1.0
T_i = 300 s
T_d = 0 s

Note:
More information is available in the Application Note AP0034 – Boiler Cascade Control.

3.2.3 Steam exchanger

K = 2.0
T_i = 200 s
T_d = 0 s

Note:
In a steam exchanger control, we must usually monitor the take-off on the secondary exchanger side and to step-decrease its action in its step changes (turning off heating of DHW, turning off air conditioning). The solution example is included in sample projects of steam transfer stations TP_PQ and TP_P2.

4 Technical support

All information on working with the PID module in control systems by AMiT will be provided by the technical support department of the company AMiT. Do not hesitate to contact the technical support via e-mail using the following address: **support@amit.cz**.

5 Warning