SIEMENS

SIMATIC

S7-1200, S7-1500
PID control

Function Manual

12/2014

A5E35300227-AA

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

⚠ DANGER

indicates that death or severe personal injury **will** result if proper precautions are not taken.

⚠ WARNING

indicates that death or severe personal injury **may** result if proper precautions are not taken.

⚠ CAUTION

indicates that minor personal injury can result if proper precautions are not taken.

NOTICE

indicates that property damage can result if proper precautions are not taken.

If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

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Note the following:

⚠ WARNING

Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

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Preface

Purpose of the documentation

This documentation will support you in configuring and programming control tasks with the S7-1200 and S7-1500 automation systems.

Basic knowledge required

The following knowledge is required in order to understand the documentation:

- General knowledge of automation technology
- Knowledge of the industrial automation system SIMATIC
- Experience of working with STEP 7 (TIA Portal)

Validity of the documentation

This documentation applies to the use of SW controllers on the CPUs of automation systems S7-1200 and S7-1500 together with STEP 7 (TIA Portal). Additional SW controllers that are not covered in this documentation are available for the use of S7-300 and S7-400 with STEP 7 (TIA Portal). Section Overview of software controller (Page 39) gives a complete overview of all SW controllers in STEP 7 (TIA Portal) and their possible applications.

Conventions

Please observe notes marked as follows:

Note

The notes contain important information on the product described in the documentation, on the handling of the product or on part of the documentation to which particular attention should be paid.

Additional assistance

- Information on the offers of our Technical Support are available in the appendix Service & Support (Page 493).
- The range of technical documentation for the individual SIMATIC products and automation systems is available on the Internet (http://www.siemens.com/simatic-tech-doku-portal).
- The online catalog and the ordering system are available on the Internet (http://mall.automation.siemens.com).

Table of contents

Documentation guide

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Introduction

This modular documentation of the SIMATIC products covers diverse topics concerning your automation system.

The complete documentation for the S7-1200 and S7-1500 systems consists of the respective system manuals, function manuals and device manuals.

Furthermore, the information system of the TIA Portal (online help) offers you assistance in configuring and programming your automation system.

Overview of the documentation on the topic of PID control

The table below includes additional documentation which supplements this description on the topic of PID control.

Table 1- 1 Documentation on the topic of PID control

Topic	Documentation	Most important contents
STEP 7 (TIA Portal)	STEP 7 online help	Configuring and programming with the engineering software
System description	System manual S7-1500 Automation System (http://support.automation.siemens.com/WW/view/en/59191792)	• Application planning • Installation • Wiring • Commissioning
	System manual S7 -1200 Programmable controller (http://support.automation.siemens.com/WW/view/en/91696622)	• Application planning • Installation • Wiring • Commissioning • Programming concepts • Communication • Technical specifications
	System manual ET 200SP Distributed I/O system (http://support.automation.siemens.com/WW/view/en/58649293)	• Application planning • Installation • Connecting • Commissioning

SIMATIC manuals

All current manuals for the SIMATIC products are available for download free of charge from the Internet (http://www.siemens.com/automation/service&support).

My Documentation Manager

The My Documentation Manager is used to combine entire manuals or only parts of these to your own manual.
You can export the manual as PDF file or in a format that can be edited later.

You can find My Documentation Manager on the Internet (http://support.automation.siemens.com/WW/view/en/38715968).

Applikations & Tools

Applications & Tools supports you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus in individual products.

You can find Applications & Tools on the Internet (http://support.automation.siemens.com/WW/view/en/20208582).

CAx Download Manager

The CAx Download Manager is used to access the current product data for your CAx or CAe systems.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find the CAx Download Manager on the Internet (http://support.automation.siemens.com/WW/view/en/42455541).

Principles for control

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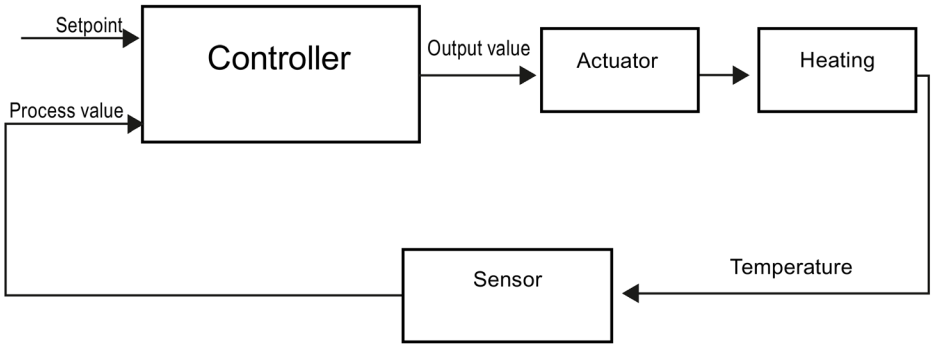
2.1 Controlled system and actuators

Controlled system

Room temperature control by means of a heating system is a simple example of a controlled system. A sensor measures the room temperature and transfers the value to a controller. The controller compares the current room temperature with a setpoint and calculates an output value (manipulated variable) for heating control.



A properly set PID controller reaches this setpoint as quickly as possible and then holds it a constant value. After a change in the output value, the process value often changes only with a time delay. The controller has to compensate for this response.

Actuators

The actuator is an element of the controlled system and is influenced by the controller. Its function modifies mass and energy flows.

The table below provides an overview of actuator applications.

Application	Actuator
Liquid and gaseous mass flow	Valve, shutter, gate valve
Solid mass flow, e.g., bulk material	Articulated baffle, conveyor, vibrator channel
Flow of electrical power	Switching contact, contactor, relay, thyristor
	Variable resistor, variable transformer, transistor

Actuators are distinguished as follows:

- Proportional actuators with constant actuating signal

  These elements set degrees of opening, angular positions or positions in proportion to the output value. The output value has an analog effect on the process within the control range.

  Actuators in this group include spring-loaded pneumatic drives, as well as motorized drives with position feedback for which a position control system is formed.

  An continuous controller, such as PID_Compact, generates the output value.

- Proportional actuators with pulse-width modulated signal

  These actuators are used to generate the output of pulses with a length proportional to the output value within the sampling time intervals. The actuator - e.g. a heating resistor or cooling apparatus - is switched on in isochronous mode for durations that differ depending on the output value.

  The actuating signal can assume unipolar "On" or "Off" states, or represent bipolar states such as "open/close", "forward/backward", "accelerate/brake".

  The output value is generated by a two-step controller such as PID_Compact with pulse-width modulation.

- Actuators with integral action and three-step actuating signal

  Actuators are frequently operated by motors with an on period that is proportional to the actuator travel of the choke element. This includes elements such as valves, shutters, and gate valves. In spite of their different design, all of these actuators follow the effect of an integral action at the input of the controlled system.

  A step controller, such as PID_3Step. generates the output value.

2.2 Controlled systems

The properties of a controlled system can hardly be influenced as these are determined by the technical requirements of the process and machinery. Acceptable control results can only be achieved by selecting a suitable controller type for the specific controlled system and adapting the controller to the time response of the controlled system. Therefore, it is is indispensable for the configuration of the proportional, integral and derivative actions of the controller to have precise knowledge of the type and parameters of the controlled system.

Controlled system types

Controlled systems are classified based on their time response to step changes of the output value.

We distinguish between the following controlled systems:

- Self-regulating controlled systems
  - Proportional-action controlled systems
  - PT1 controlled systems
  - PT2 controlled systems
- Non-self-regulating controlled systems
- Controlled systems with and without dead time

Self-regulating controlled systems

Proportional-action controlled systems

In proportional-action controlled systems, the process value follows the output value almost immediately. The ratio between the process value and output value is defined by the proportional Gain of the controlled system.

Examples:

- Gate valve in a piping system
- Voltage dividers
- Step-down function in hydraulic systems

PT1 controlled systems

In a PT1 controlled system, the process value initially changes in proportion to the change of the output value. The rate of change of the process value is reduced as a function of the time until the end value is reached, i.e., it is delayed.

Examples:

- Spring damping system
- Charge of RC elements
- Water container that is heated with steam.

The time constants are often identical for heating and cooling processes, or for charging and discharge characteristics. With different time constants, controlling is clearly more complex.

PT2 controlled systems

In a PT2 controlled system, the process value does not immediately follow a step change of the output value, i.e., it increases in proportion to the positive rate of rise and then approaches the setpoint at a decreasing rate of rise. The controlled system shows a proportional response characteristic with second order delay element.

Examples:

- Pressure control
- Flow rate control
- Temperature control

Non-self-regulating controlled systems

Non-self-regulating controlled systems have an integral response. The process value approaches an infinite maximum value.

Example:

- Liquid flow into a container

Controlled systems with dead time

A dead time always represents the runtime or transport time that has to expire before a change to the system input can be measured at the system output.

In controlled systems with dead time, the process value change is delayed by the amount of the dead time.

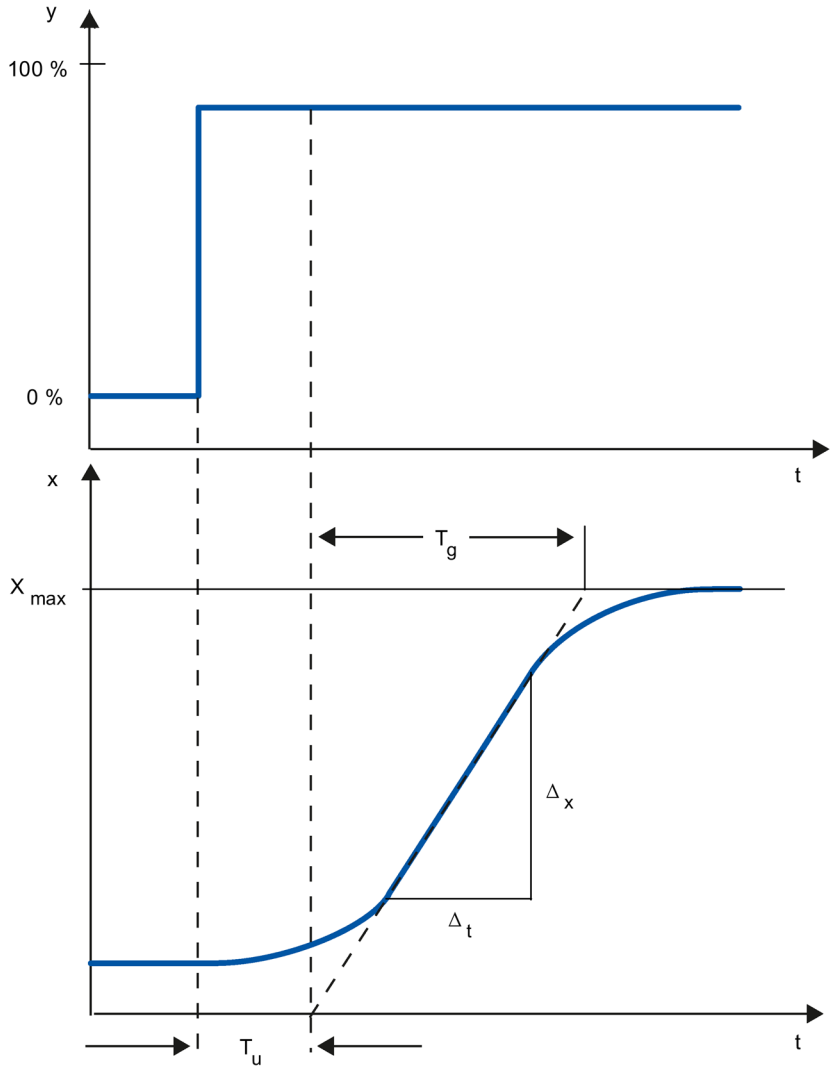
Example:

- Conveyor

2.3 Characteristic values of the control section

Determining the time response from the step response

Time response of the controlled system can be determined based on the time characteristic of process value x following a step change of output value y. Most controlled systems are self-regulating controlled systems.



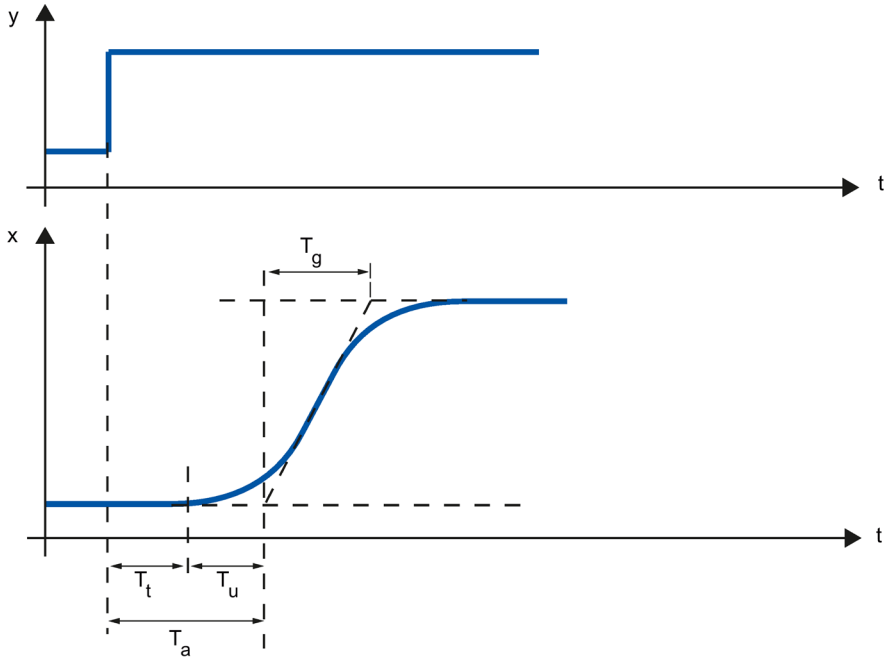
The time response can be determined by approximation using the variables Delay time T_u, Recovery time T_g and Maximum value X_{max}. The variables are determined by applying tangents to the maximum value and the inflection point of the step response. In many situations, it is not possible to record the response characteristic up to the maximum value because the process value cannot exceed specific values. In this case, the rate of rise v_{max} is used to identify the controlled system ($v_{max} = \Delta_x/\Delta_t$).

The controllability of the controlled system can be estimated based on the ratio T_u/T_g, or $T_u \times v_{max}/X_{max}$. Rule:

Process type	T_u / T_g	Suitability of the controlled system for controlling
I	< 0,1	can be controlled well
II	0.1 to 0.3	can still be controlled
III	> 0,3	difficult to control

Influence of the dead time on the controllability of a controlled system

A controlled system with dead time and recovery reacts as follows to a jump of the output value.



T_t	Dead time
T_u	Delay time
T_g	Recovery time
y	Output value
x	Process value

The controllability of a self-regulating controlled system with dead time is determined by the ratio of T_t to T_g. T_t must be small compared to T_g. Rule:

$T_t/T_g \leq 1$

Response rate of controlled systems

Controlled systems can be judged on the basis of the following values:

T_u < 0.5 min, T_g < 5 min = fast controlled system

T_u > 0.5 min, T_g > 5 min = slow controlled system

Parameters of certain controlled systems

Physical quantity	Controlled system	Delay time T_u	Recovery time T_g	Rate of rise v_{max}
Temperature	Small electrically heated furnace	0.5 to 1 min	5 to 15 min	Up to 60 K/min.
	Large electrically heated annealing furnace	1 to 5 min	10 to 20 min	Up to 20 K/min.
	Large gas-heated annealing furnace	0.2 to 5 min	3 to 60 min	1 to 30 K/min
	Distillation tower	1 to 7 min	40 to 60 min	0.1 to 0.5° C/s
	Autoclaves (2.5 m^3)	0.5 to 0.7 min	10 to 20 min	Not specified
	High-pressure autoclaves	12 to 15 min	200 to 300 min	Not specified
	Steam superheater	30 s to 2.5 min	1 to 4 min	2°C/s
	Injection molding machines	0.5 to 3 min	3 to 30 min	5 to 20 K/min
	Extruders	1 to 6 min	5 to 60 min	
	Packaging machines	0.5 to 4 min	3 to 40 min	2 to 35 K/min
	Room heating	1 to 5 min	10 to 60 min	1° C/min
Flow rate	Pipeline with gas	0 to 5 s	0.2 to 10 s	Not relevant
	Pipeline with liquid	None	None	
Pressure	Gas pipeline	None	0.1 s	Not relevant
	Drum boiler with gas or oil firing	None	150 s	Not relevant
	Drum boiler with impact grinding mills	1 to 2 min	2 to 5 min	Not relevant
Vessel level	Drum boiler	0.6 to 1 min	Not specified	0.1 to 0.3 cm/s
Speed	Small electric drive	None	0.2 to 10 s	Not relevant
	Large electric drive	None	5 to 40 s	Not relevant
	Steam turbine	None	Not specified	50 min^{-1}
Voltage	Small generators	None	1 to 5 s	Not relevant
	Large generators	None	5 to 10 s	Not relevant

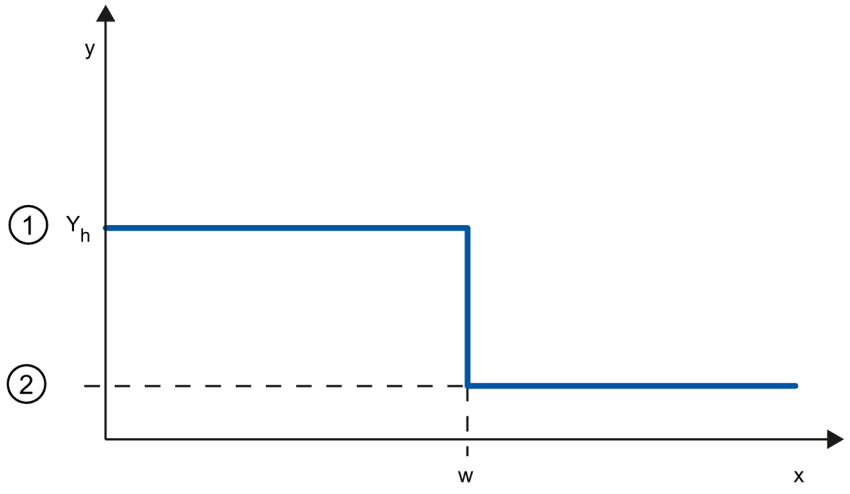
2.4 Pulse controller

Two-step controllers without feedback

Two-step controllers have the state "ON" and "OFF" as the switching function. This corresponds to 100% or 0% output. This behavior generates a sustained oscillation of process value x around setpoint w.

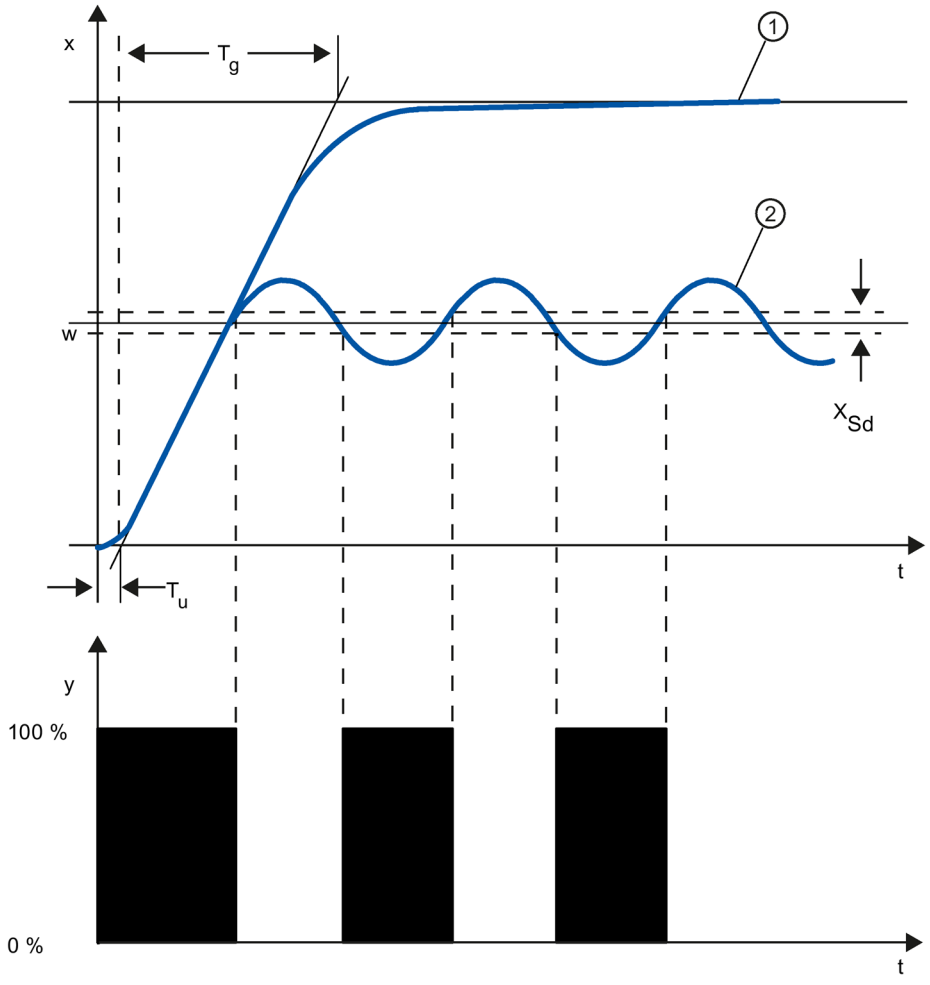
The amplitude and duration of the oscillation increase in proportion to the ratio between the delay time T_u and recovery time T_g of the controlled system. These controllers are used mainly for simple temperature control systems (such as electrically directly heated furnaces) or as limit-value signaling units.

The following diagram shows the characteristic of a two-step controller



①	ON
②	OFF
Y_h	Control range
w	Setpoint

The following diagram shows the control function of a two-step controller



①	Response characteristic without controller
②	Response characteristic with two-step controller
T_u	Delay time
T_g	Recovery time
X_{Sd}	Switching difference

Two-step controllers with feedback

The behavior of two-step controllers in the case of controlled systems with larger delay times, such as furnaces where the functional space is separated from the heating, can be improved by the use of electronic feedback.

The feedback is used to increase the switching frequency of the controller, which reduces the amplitude of the process value. In addition, the control-action results can be improved substantially in dynamic operation. The limit for the switching frequency is set by the output level. It should not exceed 1 to 5 switches per minute at mechanical actuators, such as relays and contactors. In the case of voltage and current outputs with downstream thyristor or Triac controllers high switching frequencies can be selected that exceed the limit frequency of the controlled system by far.

Since the switching pulses can no longer be determined at the output of the controlled system, results comparable with those of continuous controllers are obtained.

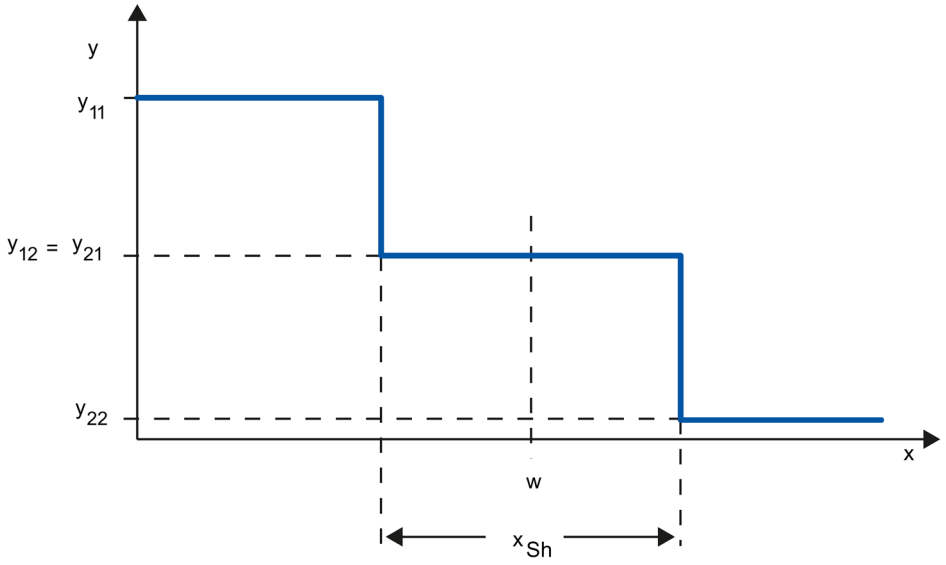
The output value is generated by pulse-width modulation of the output value of a continuous controller.

Two-step controllers with feedback are used for temperature control in furnaces, at processing machines in the plastics, textile, paper, rubber and foodstuff industries as well as for heating and cooling devices.

Three-step controllers

Three-step controllers are used for heating / cooling. These controllers have two switching points as their output. The control-action results are optimized through electronic feedback structures. Fields of applications for such controllers are heating, low-temperature, climatic chambers and tool heating units for plastic-processing machines.

The following diagram shows the characteristic of a three-step controller

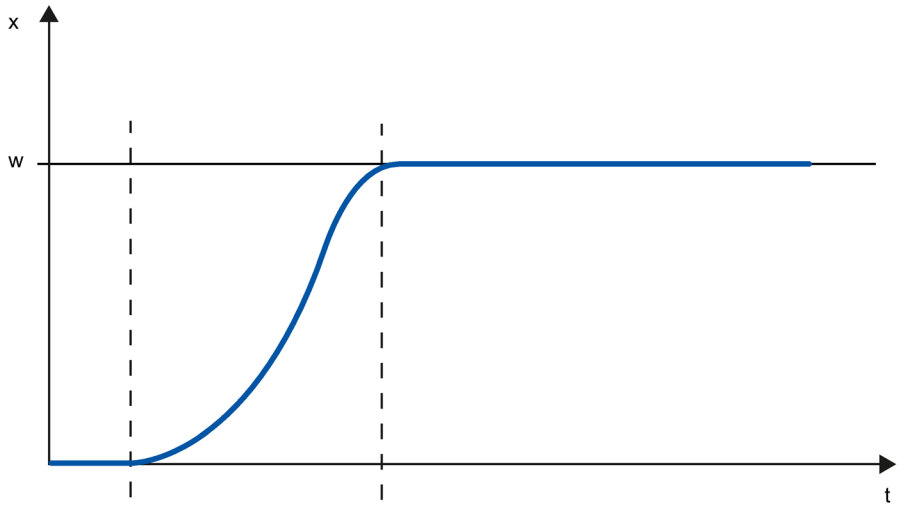


y	Output value, e.g. y11 = 100% heating y12 = 0% heating y21 = 0% cooling y22 = 100% cooling
x	Physical quantity of the process value, e.g., temperature in° C
w	Setpoint
x_{Sh}	Distance between Switching Point 1 and Switching Point 2

2.5 Response to setpoint changes and disturbances

Response to setpoint changes

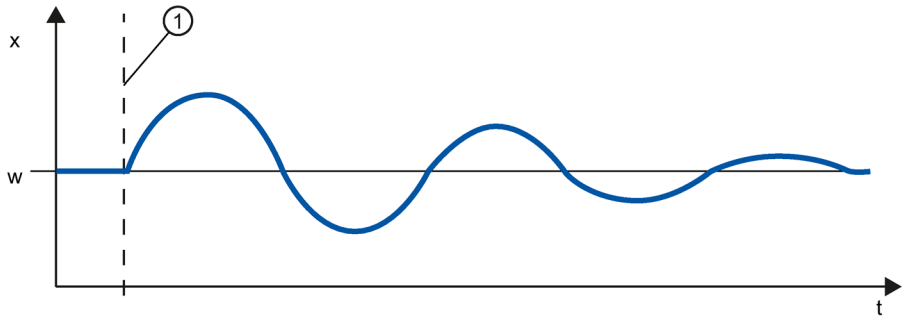
The process value should follow a setpoint change as quickly as possible. The response to setpoint changes is improved by minimizing fluctuation of the process value and the time required to reach the new setpoint.



x	Process value
w	Setpoint

Response to disturbances

The setpoint is influenced by disturbance variables. The controller has to eliminate the resulting control deviations in the shortest time possible. The response to disturbances is improved by minimizing fluctuation of the process value and the time required to reach the new setpoint.



x	Process value
w	Setpoint
①	Influencing a disturbance variable

Disturbance variables are corrected by a controller with integral action. A persistent disturbance variable does not reduce control quality because the control deviation is relatively constant. Dynamic disturbance variables have a more significant impact on control quality because of control deviation fluctuation. The control deviation is eliminated again only by means of the slow acting integral action.

A measurable disturbance variable can be included in the controlled system. This inclusion would significantly accelerated the response of the controller.

2.6 Control Response at Different Feedback Structures

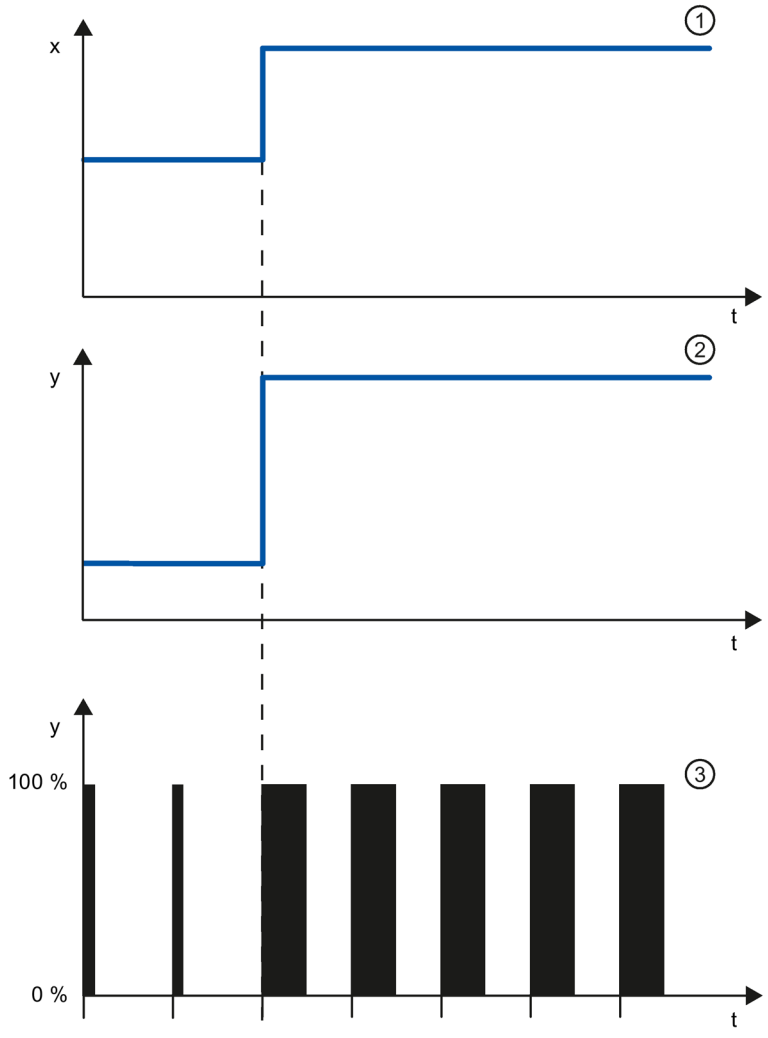
Control behavior of controllers

A precise adaptation of the controller to the time response of the controlled system is decisive for the controller's precise settling to the setpoint and optimum response to disturbance variables.

The feedback circuit can have a proportional action (P), proportional-derivative action (PD), proportional-integral action (PI), or proportional-integral-derivative action (PID).

If step functions are to be triggered by control deviations, the step responses of the controllers differ depending on their type.

Step response of a proportional action controller



① Control deviation
② Output value of a continuous controller
③ Output value of a pulse controller

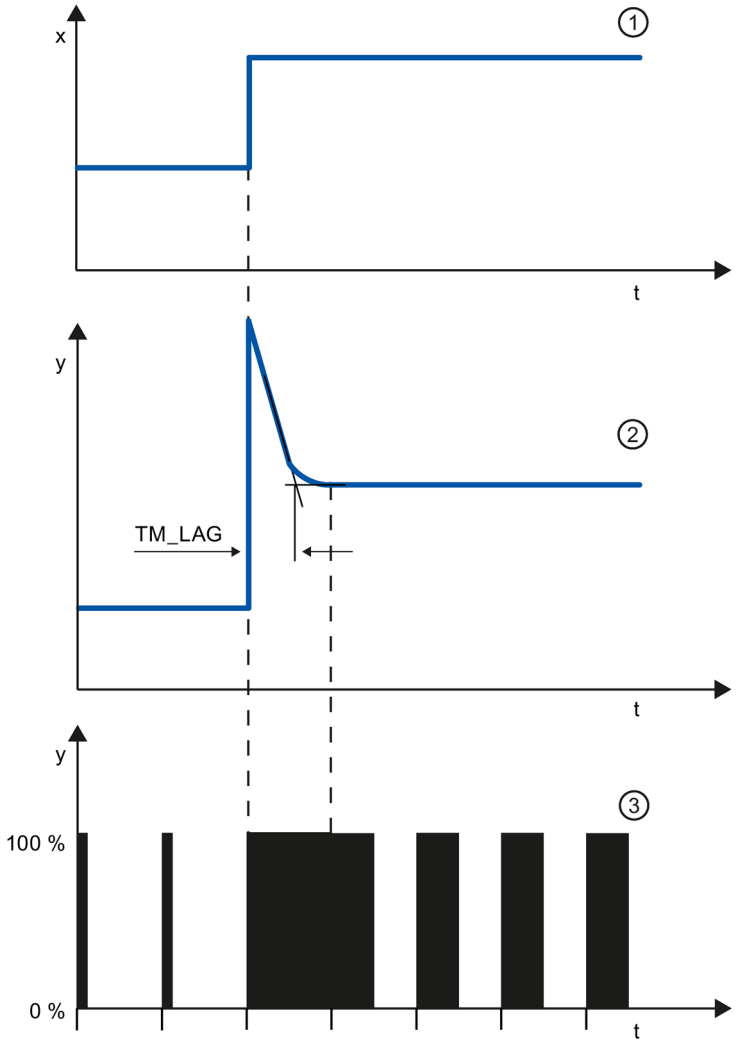
Equation for proportional action controller

Output value and control deviation are directly proportional, meaning:

Output value = proportional gain × control deviation

$y = GAIN \times x$

Step response of a PD-action controller



①	Control deviation
②	Output value of a continuous controller
③	Output value of a pulse controller
TM_LAG	Delay of the Derivative action

Equation for PD-action controller

The following applies for the step response of the PD-action controller in the time range:

$$y = GAIN \cdot X_W \cdot \left(1 + \frac{TD}{TM\_LAG} \cdot e^{\frac{-t}{TM\_LAG}} \right)$$

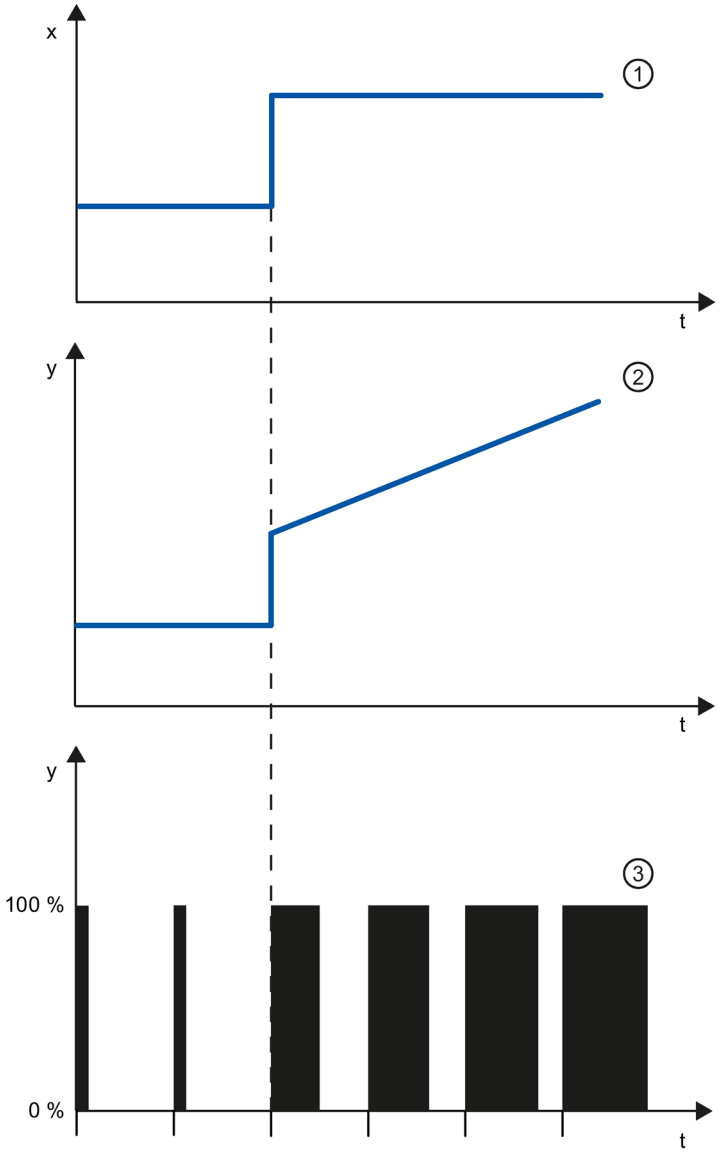
t = time interval since the step of the control deviation

The derivative action generates a output value as a function of the rate of change of the process value. A derivative action by itself is not suitable for controlling because the output value only follows a step of the process value. As long as the process value remains constant, the output value will no longer change.

The response to disturbances of the derivative action is improved in combination with a proportional action. Disturbances are not corrected completely. The good dynamic response is advantageous. A well attenuated, non-oscillating response is achieved during approach and setpoint change.

A controller with derivative action is not appropriate if a controlled system has pulsing measured quantities, for example, in the case of pressure or flow control systems.

Step response of a PI-action controller



① Control deviation
② Output value of a continuous controller
③ Output value of a pulse controller

An integral action in the controller adds the control deviation as a function of the time. This means that the controller corrects the system until the control deviation is eliminated. A sustained control deviation is generated at controllers with proportional action only. This effect can be eliminated by means of an integral action in the controller.

In practical experience, a combination of the proportional, integral and derivative actions is ideal, depending on the requirements placed on the control response. The time response of the individual components can be described by the controller parameters proportional gain GAIN, integral action time TI (integral action), and derivative action time TD (derivative action).

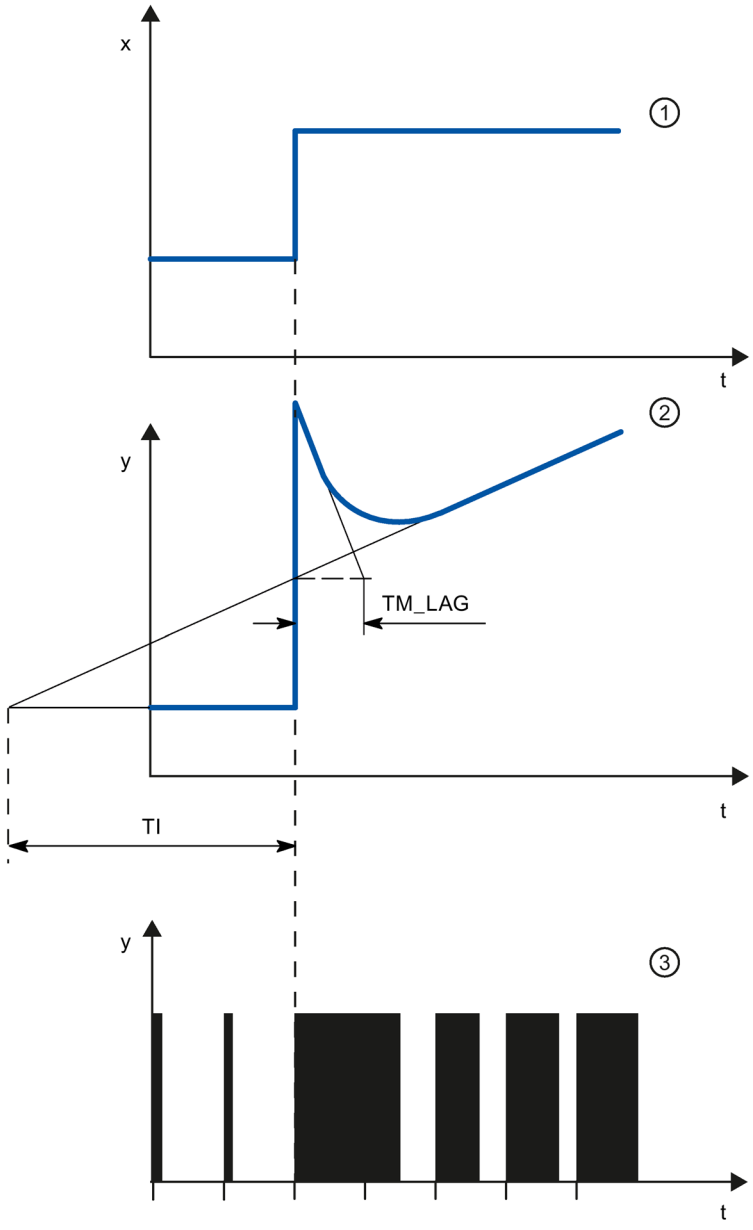
Equation for PI-action controller

The following applies for the step response of the PI-action controller in the time range:

$$y = GAIN \cdot X_W \cdot \left(1 + \frac{1}{TI \cdot t}\right)$$

t = time interval since the step of the control deviation

Step response of a PID controller



①	Control deviation
②	Output value of a continuous controller
③	Output value of a pulse controller
TM_LAG	Delay of the Derivative action
T_i	Integral action time

Equation for PID controller

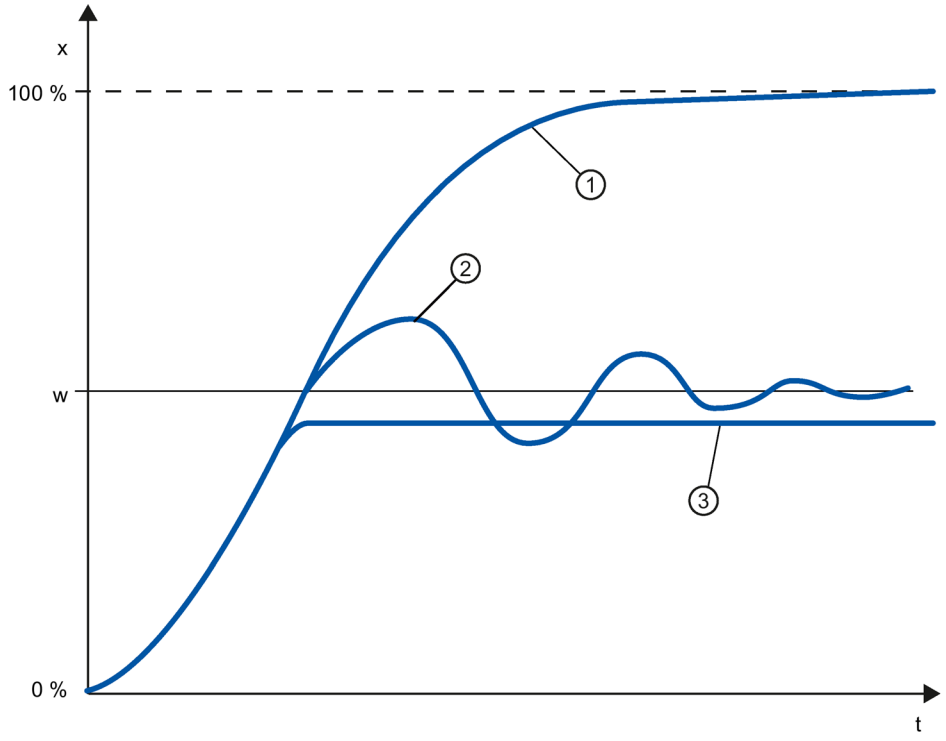
The following applies for the step response of the PID controller in the time range:

$$y = GAIN \cdot X_w \cdot \left(1 + \frac{1}{TI \cdot t} + \frac{TD}{TM\_LAG} \cdot e^{\frac{-t}{TM\_LAG}} \right)$$

t = time interval since the step of the control deviation

Response of a controlled system with different controller structures

Most of the controller systems occurring in process engineering can be controlled by means of a controller with PI-action response. In the case of slow controlled system with a large dead time, for example temperature control systems, the control result can be improved by means of a controller with PID action.



①	No controller
②	PID controller
③	PD-action controller
w	Setpoint
x	Process value

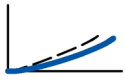
Controllers with PI and PID action have the advantage that the process value does not have any deviation from the setpoint value after settling. The process value oscillates over the setpoint during approach.

2.7 Selection of the controller structure for specified controlled systems

Selection of the Suitable Controller Structures

To achieve optimum control results, select a controller structure that is suitable for the controlled system and that you can adapt to the controlled system within specific limits.

The table below provides an overview of suitable combinations of a controller structure and controlled system.

Controlled system		Controller structure			
		P	PD	PI	PID
	With dead time only	Unsuitable	Unsuitable	Suitable	Unsuitable
	PT1 with dead time	Unsuitable	Unsuitable	Well suited	Well suited
	PT2 with dead time	Unsuitable	Suited conditionally	Well suited	Well suited
	Higher order	Unsuitable	Unsuitable	Suited conditionally	Well suited
	Not self-regulating	Well suited	Well suited	Well suited	Well suited

The table below provides an overview of suitable combinations of a controller structure and physical quantity.

Physical quantity	Controller structure			
	P	PD	PI	PID
	Sustained control deviation		No sustained control deviation	
Temperature	For low performance requirements and proportional action controlled systems with $T_u/Tg < 0,1$	Well suited	The most suitable controller structures for high performance requirements (except for specially adapted special controllers)	
Pressure	Suitable, if the delay time is inconsiderable	Unsuitable	The most suitable controller structures for high performance requirements (except for specially adapted special controllers)	
Flow rate	Unsuitable, because required GAIN range is usually too large	Unsuitable	Suitable, but integral action controller alone often better	Hardly required

2.8 PID parameter settings

Rule of Thumb for the Parameter Setting

Controller structure	Setting
P	GAIN ≈ v_{max} × T_u [° C]
PI	GAIN ≈ 1.2 × v_{max} × T_u [° C] TI ≈ 4 × T_u [min]
PD	GAIN ≈ 0.83 × v_{max} × T_u [° C] TD ≈ 0.25 × v_{max} × T_u [min] TM_LAG ≈ 0.5 × TD[min]
PID	GAIN ≈ 0.83 × v_{max} × T_u [° C] TI ≈ 2 × T_u [min] TD ≈ 0.4 × T_u [min] TM_LAG ≈ 0.5 × TD[min]
PD/PID	GAIN ≈ 0.4 × v_{max} × T_u [° C] TI ≈ 2 × T_u [min] TD ≈ 0.4 × T_u [min] TM_LAG ≈ 0.5 × TD[min]

Instead of $v_{max} = \Delta_x / \Delta_t$, you can use X_{max} / T_g.

In the case of controllers with PID structure the setting of the integral action time and differential-action time is usually coupled with each other.

The ratio TI / TD lies between 4 and 5 and is optimal for most controlled systems.

Non-observance of the differential-action time TD is uncritical at PD controllers.

In the case of PI and PID controllers, control oscillations occur if the integral action time TI has been select by more than half too small.

An integral action time that is too large slows down the settling times of disturbances. One cannot expect that the control loops operate "optimally" after the first parameter settings. Experience shows that adjusting is always necessary, when a system exists that is "difficult to control" with $T_u / T_g > 0.3$.

Configuring a software controller

3

3.1 Overview of software controller

For the configuration of a software controller, you need an instruction with the control algorithm and a technology object. The technology object for a software controller corresponds with the instance DB of the instruction. The configuration of the controller is saved in the technology object. In contrast to the instance DBs of other instructions, technology objects are not stored for the program resources, but rather under CPU > Technology objects.

Technology objects and instructions

CPU	Library	Instruction	Technology object	Description
S7-1200	Compact PID	PID_Compact V1.X	PID_Compact V1.X	Universal PID controller with integrated tuning
S7-1200		PID_3Step V1.X	PID_3Step V1.X	PID controller with integrated tuning for valves
S7-1500 S7-1200 V4.x		PID_Compact V2.X	PID_Compact V2.X	Universal PID controller with integrated tuning
S7-1500 S7-1200 V4.x		PID_3Step V2.X	PID_3Step V2.X	PID controller with integrated tuning for valves
S7-1500 ≥ V1.7 S7-1200 ≥ V4.1		PID_Temp V1.0	PID_Temp V1.0	Universal PID temperature controller with integrated tuning
S7-1500/300/400	PID basic functions	CONT_C	CONT_C	Continuous controller
S7-1500/300/400		CONT_S	CONT_S	Step controller for actuators with integrating behavior
S7-1500/300/400		PULSEGEN	-	Pulse generator for actuators with proportional behavior
S7-1500/300/400		TCONT_CP	TCONT_CP	Continuous temperature controller with pulse generator
S7-1500/300/400		TCONT_S	TCONT_S	Temperature controller for actuators with integrating behavior
S7-300/400	PID Self Tuner	TUN_EC	TUN_EC	Optimization of a continuous controller
S7-300/400		TUN_ES	TUN_ES	Optimization of a step controller

CPU	Library	Instruction	Technology object	Description
S7-300/400	Standard PID Control (PID Professional optional package)	PID_CP	PID_CP	Continuous controller with pulse generator
S7-300/400		PID_ES	PID_ES	Step controller for actuators with integrating behavior
S7-300/400		LP_SCHED	-	Distribute controller calls
S7-300/400	Modular PID Control (PID Professional optional package)	A_DEAD_B	-	Filter interfering signal from control deviation
S7-300/400		CRP_IN	-	Scale analog input signal
S7-300/400		CRP_OUT	-	Scale analog output signal
S7-300/400		DEAD_T	-	Delay output of input signal
S7-300/400		DEADBAND	-	Suppress small fluctuations to the process value
S7-300/400		DIF	-	Differentiate input signals over time
S7-300/400		ERR_MON		Monitor control deviation
S7-300/400		INTEG	-	Integrate input signals over time
S7-300/400		LAG1ST	-	First-order delay element
S7-300/400		LAG2ND	-	Second-order delay element
S7-300/400		LIMALARM	-	Report limit values
S7-300/400		LIMITER	-	Limiting the manipulated variable
S7-300/400		LMNGEN_C	-	Determine manipulated variable for continuous controller
S7-300/400		LMNGEN_S	-	Determine manipulated variable for step controller
S7-300/400		NONLIN	-	Linearize encoder signal
S7-300/400		NORM	-	Scale process value physically
S7-300/400		OVERRIDE	-	Switch manipulated variable from 2 PID controllers to 1 actuator
S7-300/400		PARA_CTL	-	Switch parameter sets
S7-300/400		PID	-	PID algorithm
S7-300/400		PUSLEGEN_M	-	Generate pulse for proportional actuators
S7-300/400		RMP_SOAK	-	Specify setpoint according to ramp / soak
S7-300/400		ROC_LIM	-	Limit rate of change
S7-300/400		SCALE_M	-	Scale process value
S7-300/400		SP_GEN	-	Specify setpoint manually
S7-300/400		SPLT_RAN	-	Split manipulated variable range
S7-300/400		SWITCH	-	Switch analog values
S7-300/400		LP_SCHED_M	-	Distribute controller calls

3.2 Steps for the configuration of a software controller

All SW-controllers are configured according to the same scheme:

Step	Description
1	Add technology object (Page 42)
2	Configure technology object (Page 43)
3	Call instruction in the user program (Page 45)
4	Download technology object to device (Page 46)
5	Commission software controller (Page 47)
6	Save optimized PID parameters in the project (Page 48)
7	Comparing values (Page 50)
8	Display instances of a technology object (Page 77)

3.3 Add technology objects

Add technology object in the project navigator

When a technology object is added, an instance DB is created for the instruction of this technology object. The configuration of the technology object is stored in this instance DB.

Requirement

A project with a CPU has been created.

Procedure

To add a technology object, proceed as follows:

1. Open the CPU folder in the project tree.
2. Open the "Technology objects" folder.
3. Double-click "Add new object".
   The "Add new object" dialog box opens.
4. Click on the "PID" button.
   All available PID-controllers for this CPU are displayed.
5. Select the instruction for the technology object, for example, PID_Compact.
6. Enter an individual name for the technology object in the "Name" input field.
7. Select the "Manual" option if you want to change the suggested data block number of the instance DB.
8. Click "Further information" if you want to add own information to the technology object.
9. Confirm with "OK".

Result

The new technology object has been created and stored in the project tree in the "Technology objects" folder. The technology object is used if the instruction for this technology object is called in a cyclic interrupt OB.

Note

You can select the "Add new and open" check box at the bottom of the dialog box. This opens the configuration of the technology object after adding has been completed.

3.4 Configure technology objects

The properties of a technology object on a S7-1200 CPU can be configured in two ways.

- In the Inspector window of the programming editor
- In the configuration editor

The properties of a technology object on a S7-300/400 CPU can only be configured in the configuration editor.

Inspector window of the programming editor

In the Inspector window of the programming editor you can only configure the parameters required for operation.

The offline values of the parameters are also shown in online mode. You can only change the online values in the commissioning window.

To open the Inspector window of the technology object, follow these steps:

1. Open the "Program blocks" folder in the project tree.
2. Double click the block (cyclic interrupt OB) in which you open the instruction of the SW-controller.
   The block is opened in the work area.
3. Click on the instruction of the SW-controller.
4. In the Inspector window, select the "Properties" and "Configuration" tabs consecutively.

Configuration window

For each technology object, there is a specific configuration window in which you can configure all properties.

To open the configuration window of the technology object, follow these steps:

1. Open the "Technology objects" folder in the project tree.
2. Open the technology object in the project tree.
3. Double-click the "Configuration" object.

Symbols

Icons in the area navigation of the configuration and in the Inspector window show additional details about the completeness of the configuration:

	**The configuration contains default values and is complete**. The configuration exclusively contains default values. With these default values the use of the technology object is possible without further changes.
	**The configuration contains values defined by the user and is complete** All input fields of the configuration contain valid values and at least one default setting was changed.
	**The configuration is incomplete or faulty** At least one input field or a collapsible list contains no or one invalid value. The corresponding field or the drop-down list box has a red background. When clicked the roll-out error message indicates the cause of the error.

The properties of a technology object are described in detail in the chapter for the technology object.

3.5 Call instruction in the user program

The instruction of the software controller must be called in a cyclic interrupt OB. The sampling time of the software controller is determined by the interval between the calls in the cyclic interrupt OB.

Requirement

The cyclic interrupt OB is created and the cycle time of the cyclic interrupt OB is correctly configured.

Procedure

Proceed as follows to call the instruction in the user program:

1. Open the CPU folder in the project tree.
2. Open the "Program blocks" folder.
3. Double-click the cyclic interrupt OB.
   The block is opened in the work area.
4. Open the "Technology" group in the "Instructions" window and the "PID Control" folder.
   The folder contains all instructions for software controllers that can be configured on the CPU.
5. Select the instruction and drag it to your cyclic interrupt OB.
   The "Call options" dialog box opens.
6. Select a technology object or type the name for a new technology object from the "Name" list.

Result

If the technology object does not exist yet, it is added. The instruction is added in the cyclic interrupt OB. The technology object is assigned to this call of the instruction.

3.6 Downloading technology objects to device

A new or modified configuration of the technology object must be downloaded to the CPU for the online mode. The following characteristics apply when downloading retentive data:

- **Software (changes only)**
  - S7-1200, S7-1500:
    Retentive data is retained.
  - S7-300/400:
    Retentive data is updated immediately. CPU does not change to Stop.
- **Download PLC program to device and reset**
  - S7-1200, S7-1500:
    Retentive data is updated at the next change from Stop to RUN. The PLC program can only be downloaded completely.
  - S7-300/400:
    Retentive data is updated at the next change from Stop to RUN.

Downloading retentive data to an S7-1200 or S7-1500 CPU

Note

The download and reset of the PLC program during ongoing system operation can result in serious damages or injuries in the case of malfunctions or program errors.

Make sure that dangerous states cannot occur before you download and reset the PLC program.

Proceed as follows to download the retentive data:

1. Select the entry of the CPU in the project tree.
2. Select the command "Download and reset PLC program" from the "Online" menu.
   - If you have not established an online connection yet, the "Extended download" dialog opens. In this case, set all required parameters for the connection and click "Download".
   - If the online connection has been defined, the project data is compiled, if necessary, and the dialog "Load preview" opens. This dialog displays messages and recommends actions necessary for download.
3. Check the messages.

   As soon as download is possible, the "Download" button becomes active.
4. Click on "Download".

   The complete PLC program is downloaded and the "Load results" dialog opens. This dialog displays the status and the actions after the download.
5. If the modules are to restart immediately after the download, select the check box "Start all".
6. Close the dialog "Download results" with "Finish".

Result

The complete PLC program is downloaded to the device. Blocks that only exist online in the device are deleted. By downloading all affected blocks and by deleting any blocks in the device that are not required, you avoid inconsistencies between the blocks in the user program.

The messages under "Info > General" in the Inspector window indicate whether the download was successful.

3.7 Commissioning software controller

Procedure

To open the "Commissioning" work area of the technology object, follow these steps:

1. Open the "Technology objects" folder in the project tree.
2. Open the technology object in the project tree.
3. Double-click the "Commissioning" object.

The commissioning functions are specific for each controller and are described there.

3.8 Save optimized PID parameter in the project

The software controller is optimized in the CPU. Through this, the values in the instance-DB on the CPU no longer agree with those in the project.

To update the PID parameter in the project with the optimized PID parameters, proceed as follows:

Requirement

- An online connection to the CPU is established and the CPU is in "RUN" mode.
- The functions of the commissioning window have been enabled by means of the "Start" button.

Procedure

1. Open the CPU folder in the project tree.
2. Open the "Technology objects" folder.
3. Open a technology object.
4. Double click on "Commissioning".
5. Click on the  icon "Upload PID parameters".
6. Save the project.

Result

The currently active PID parameters are stored in the project data. When reloading the project data in the CPU, the optimized parameters are used.

3.9 Comparing values

3.9.1 Comparison display and boundary conditions

The "Compare values" function provides the following options:

- Comparison of configured start values of the project with the start values in the CPU and the actual values
- Direct editing of actual values and the start values of the project
- Immediate detection and display of input errors with suggested corrections
- Backup of actual values in the project
- Transfer of start values of the project to the CPU as actual values

Icons and operator controls

The following icons and operator controls are available:

Icon	Function
	Start value PLC matches the configured Start value project
	Start value PLC does not match the configured Start value project
	The comparison of the Start value PLC with the configured Start value project cannot be performed
	At least one of the two comparison values has a process-related or syntax error.
	Transfers actual values to the offline project
	Transfers updated start values in the project to the CPU (initialize setting values)
	Opens the "Compare values" dialog

Boundary conditions

The "Compare values" function is available for S7-1200 and S7-1500 without limitations.

The following limitation applies to S7-300 and S7-400:

In monitoring mode, an S7-300/S7-400 cannot transfer the start values to the CPU. These values cannot be displayed online with "Compare values".

The actual values of the technology object are displayed and can be changed directly.

3.9.2 Comparing values

The procedure is shown in the following using "PID Parameters" as an example.

Requirements

- A project with a software controller is configured.
- The project is downloaded to the CPU.
- The configuration dialog is open in the project navigator.

Procedure

1. Open the desired software controller in the project navigation.
2. Double-click the "Configuration" object.
3. Navigate within the configuration window to the "PID Parameters" dialog.
4. Click the  icon to activate monitoring mode.

   The icons and operator controls (Page 49) of the "Compare values" function are shown behind the parameters.
5. Click the desired parameter in the input box and change the parameter values manually by entering them directly.
   - If the background of the input box is gray, this value is a read-only value and cannot be changed.
   - To change the values in the "PID Parameters" dialog, enable manual entry by selecting the "Enable manual entry" check box beforehand.
6. Click the  icon to open the dialog for the start values.

   This dialog indicates two values of the parameter:
   - Start value in CPU: The start value in the CPU is shown in the top part.
   - Start value in the project: The configured start value in the project is shown in the bottom part.
7. Enter the desired value in the input box for the project.

Error detection

The input of incorrect values is detected. Corrections are suggested in this case.

If you enter a value with incorrect syntax, a rollout containing the corresponding error message opens below the parameter. The incorrect value is not applied.

If you enter a value that is incorrect for the process, a dialog opens containing the error message and a suggested correction:

- Click "No" to accept this suggested correction and correct your input.
- Click "OK" to apply the incorrect value.

NOTICE
Malfunctions of the controller
Values incorrect for the process can result in controller malfunctions.

Backing up actual values

Click the  icon to transfer the actual controller values to the start values of your configured project.

Transferring project values to the CPU

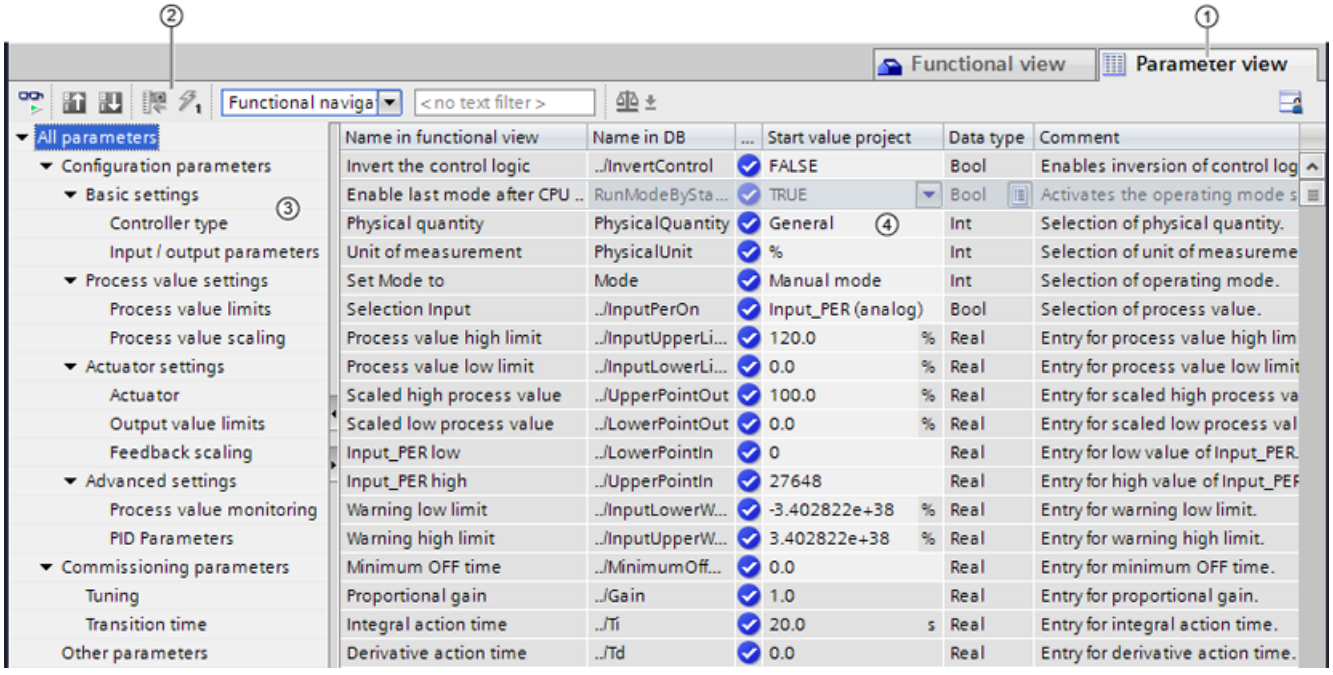
Click the  icon to transfer the configured values of your project to the CPU.

⚠ CAUTION
Prevent personal injury and property damage!
Downloading and resetting of the user program while the plant is operating may result in significant property damage and severe personal injuries in the event of malfunctions or program errors.
Make sure that dangerous states cannot occur before you download and reset the user program.

3.10 Parameter view

3.10.1 Introduction to the parameter view

The Parameter view provides you with a general overview of all relevant parameters of a technology object. You obtain an overview of the parameter settings and can easily change them in offline and online mode.



① "Parameter view" tab

② Toolbar (Page 55)

③ Navigation (Page 56)

④ Parameter table (Page 57)

Function scope

The following functions are available for analyzing the parameters of the technology objects and for enabling targeted monitoring and modification.

Display functions:

- Display of parameter values in offline and online mode
- Display of status information of the parameters
- Display of value deviations and option for direct correction
- Display of configuration errors
- Display of value changes as a result of parameter dependencies
- Display of all memory values of a parameter: Start value PLC, Start value project, Monitor value
- Display of the parameter comparison of the memory values of a parameter

Operator control functions:

- Navigation for quickly changing between the parameters and parameter structures.
- Text filter for faster searches for particular parameters.
- Sorting function for customizing the order of parameters and parameter groups to requirements.
- Memory function for backing up structural settings of the Parameter view.
- Monitoring and modifying of parameter values online.
- Function for saving a snapshot of parameter values of the CPU in order to capture momentary situations and to respond to them.
- Function for applying a snapshot of parameter values as start values.
- Download of modified start values to the CPU.
- Comparison functions for comparing parameter values with one another.

Validity

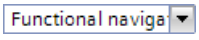
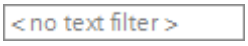
The Parameter view described here is available for the following technology objects:

- PID_Compact
- PID_3Step
- PID_Temp
- CONT_C (S7-1500 only)
- CONT_S (S7-1500 only)
- TCONT_CP (S7-1500 only)
- TCONT_S (S7-1500 only)
- TO_Axis_PTO (S7-1200 Motion Control)
- TO_Positioning_Axis (S7-1200 Motion Control)
- TO_CommandTable_PTO (S7-1200 Motion Control)
- TO_CommandTable (S7-1200 Motion Control)

3.10.2 Structure of the parameter view

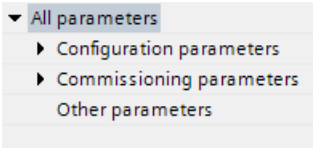
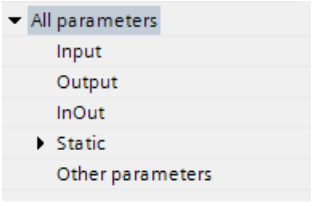
3.10.2.1 Toolbar

The following functions can be selected in the toolbar of the parameter view.

Icon	Function	Explanation
	Monitor all	Starts the monitoring of visible parameters in the active Parameter view (online mode).
	Create snapshot of monitor values and accept setpoints of this snapshot as start values	Applies the current monitor values to the “Snapshot” column and updates the start values in the project. Only in online mode for PID_Compact and PID_3Step.
	Initialize setpoints	Transfers the start values updated in the project to the CPU. Only in online mode for PID_Compact and PID_3Step.
	Create snapshot of monitor values	Applies the current monitor values to the “Snapshot” column. Only in online mode.
	Modify all selected parameters immediately and once	This command is executed once and as quickly as possible without reference to any particular point in the user program. Only in online mode.
	Select navigation structure	Toggles between functional navigation and data navigation.
	Text filter...	After entry of a character string: Display of all parameters containing the specified string in one of the currently visible columns.
	Selection of compare values	Selection of parameter values that are to be compared with one another in online mode (Start value project, Start value PLC, Snapshot) Only in online mode.
	Save window settings	Saves your display settings for the Parameter view (e.g., selected navigation structure, activated table columns, etc.)

3.10.2.2 Navigation

Within the "Parameter view" tab, the following alternative navigation structures can be selected.

Navigation		Explanation
Functional navigation		In the functional navigation, the structure of the parameters is based on the structure in the configuration dialog ("Functional view" tab), commissioning dialog, and diagnostics dialog. The last group "Other parameters" contains all other parameters of the technology object.
Data navigation		In the data navigation, the structure of the parameters is based on the structure in the instance DB / technology DB. The last group "Other parameters" contains the parameters that are not contained in the instance DB / technology DB.

You can use the "Select navigation structure" drop-down list to toggle the navigation structure.

3.10.2.3 Parameter table

The table below shows the meaning of the individual columns of the parameter table. You can show or hide the columns as required.

- Column "Offline" = X: Column is visible in offline mode.
- Column "Online" = X: Column is visible in online mode (online connection to the CPU).

Column	Explanation	Offline	Online
Name in functional view	Name of the parameter in the functional view. The display field is empty for parameters that are not configured via the technology object.	X	X
Full name in DB	Complete path of the parameter in the instance DB / technology DB. The display field is empty for parameters that are not contained in the instance DB / technology DB.	X	X
Name in DB	Name of the parameter in the instance DB / technology DB. If the parameter is part of a structure or UDT, the prefix ". ./" is added. The display field is empty for parameters that are not contained in the instance DB / technology DB.	X	X
Status of configuration	Display of the completeness of the configuration using status symbols. see Status of configuration (offline) (Page 68)	X	
Compare result	Result of the "Compare values" function. This column is shown if there is an online connection and the "Monitor all" button is selected.		X
Start value project	Configured start value in the project. Error indication if entered values have a syntax or process-related error.	X	X
Default value	Value that is pre-assigned to the parameter. The display field is empty for parameters that are not contained in the instance DB / technology DB.	X	X
Snapshot	Snapshot of the current values in the CPU (monitor values). Error indication if values have a process-related error.	X	X
Start value PLC	Start value in the CPU. This column is shown if there is an online connection and the "Monitor all" button is selected. Error indication if values have a process-related error.		X
Monitor value	Current value in the CPU. This column is shown if there is an online connection and the "Monitor all" button is selected. Error indication if values have a process-related error.		X
Modify value	Value that is to be used to change the monitor valuet. This column is shown if there is an online connection and the "Monitor all" button is selected. Error indication if entered values have a syntax or process-related error.		X

Column	Explanation	Offline	Online
Selection for transmission 	Selection of the Modify values that are to be transmitted using the "Modify all selected parameters immediately and once" button. This column is displayed together with the "Modify value" column.		X
Minimum value	Minimum process-related value of the parameter. If the minimum value is dependent on other parameters, it is defined: • Offline: By the Start value project. • Online: By the Monitor values.	X	X
Maximum value	Maximum process-related value of the parameter. If the maximum value is dependent on other parameters, it is defined: • Offline: By the Start value project. • Online: By the Monitor values.	X	X
Setpoint	Designates the parameter as a setpoint. These parameters can be initialized online.	X	X
Data type	Data type of the parameter. The display field is empty for parameters that are not contained in the instance DB / technology DB.	X	X
Retain	Designates the value as a retentive value. The values of retentive parameters are retained even after the voltage supply is switched off.	X	X
Accessible from HMI	Indicates whether the HMI can access this parameter during runtime.	X	X
Visible in HMI	Indicates whether the parameter is visible in the selection list of the HMI by default.	X	X
Comment	Brief description of the parameter.	X	X

See also

Comparing values (Page 49)

3.10.3 Opening the parameter view

Requirement

The technology object has been added in the project tree, i.e., the associated instance DB / technology DB of the instruction has been created.

Procedure

1. Open the "Technology objects" folder in the project tree.
2. Open the technology object in the project tree.
3. Double-click the "Configuration" object.
4. Select the "Parameter view" tab in the top right corner.

Result

The Parameter view opens. Each displayed parameter is represented by one row in the parameter table.

The displayable parameter properties (table columns) vary depending on whether you are working with the Parameter view in offline or online mode.

In addition, you can selectively display and hide individual table columns.

See also

Default setting of the parameter view (Page 60)

3.10.4 Default setting of the parameter view

Default settings

To enable you to work efficiently with the Parameter view, you can customize the parameter display and save your settings.

The following customizations are possible and can be saved:

- Show and hide columns
- Change column width
- Change order of the columns
- Toggle navigation
- Select parameter group in the navigation
- Selection of compare values

Show and hide columns

To show or hide columns in the parameter table, follow these steps:

1. Position the cursor in the header of the parameter table.
2. Select the "Show/Hide" command in the shortcut menu.
   The selection of available columns is displayed.
3. To show a column, select the check box for the column.
4. To hide a column, clear the check box for the column.

or

1. Position the cursor in the header of the parameter table.
2. Select the "Show all columns" command in the shortcut menu if all columns of the offline or online mode are to be displayed.

Some columns can only be displayed in online mode: see Parameter table (Page 57).

Change column width

To customize the width of a column so that all texts in the rows can be read, follow these steps:

1. Position the cursor in the header of the parameter table to the right of the column to be customized until the shape of the cursor changes to a cross.
2. Then double-click this location.

or

1. Open the shortcut menu on the header of the parameter table.
2. Click
   - "Optimize column width" or
   - "Optimize width of all columns".

If the column width setting is too narrow, the complete content of individual fields are shown if you hover the cursor briefly over the relevant field.

Change order of the columns

The columns of the parameter table can be arranged in any way.

To change the order of the columns, follow these steps:

1. Click on the column header and use a drag-and-drop operation to move it to the desired location.

   When you release the mouse button, the column is anchored to the new position.

Toggle navigation

To toggle the display form of the parameters, follow these steps:

1. Select the desired navigation in the “Select navigation structure” drop-down list.
   - Data navigation
   - Functional navigation

See also Navigation (Page 56).

Select parameter group in the navigation

Within the selected navigation, you choose between the “All parameters” display or the display of a subordinate parameter group of your choice.

1. Click the desired parameter group in the navigation.

   The parameter table only displays the parameters of the parameter group.

Selection of compare values (online)

To set the compare values for the “Compare values” function, follow these steps:

1. Select the desired compare values in the “Selection of compare values” drop-down list.
   - Start value project / Start value PLC
   - Start value project / Snapshot
   - Start value PLC / Snapshot

The “Start value project / Start value PLC” option is set by default.

Saving the default setting of the Parameter view

To save the above customizations of the Parameter view, follow these steps:

1. Customize the Parameter view according to your requirements.
2. Click the “Save window settings” button at the top right of the Parameter view.

3.10.5 Working with the parameter view

3.10.5.1 Overview

The following table provides an overview of the functions of the Parameter view in online and offline mode described in the following.

- Column "Offline" = X: This function is possible in offline mode.
- Column "Online" = X: This function is possible in online mode.

Function/action	Offline	Online
Filtering the parameter table (Page 63)	X	X
Sorting the parameter table (Page 64)	X	X
Transferring parameter data to other editors (Page 64)	X	X
Indicating errors (Page 65)	X	X
Editing start values in the project (Page 66)	X	X
Status of configuration (offline) (Page 68)	X	
Monitoring values online in the parameter view (Page 69)		X
Create snapshot of monitor values (Page 70)		X
Modifying values (Page 71)		X
Comparing values (Page 73)		X
Applying values from the online program as start values (Page 75)		X
Initializing setpoints in the online program (Page 76)		X

3.10.5.2 Filtering the parameter table

You can filter the parameters in the parameter table in the following ways:

- With the text filter
- With the subgroups of the navigation

Both filter methods can be used simultaneously.

With the text filter

Texts that are visible in the parameter table can be filtered. This means only texts in displayed parameter rows and columns can be filtered.

1. Enter the desired character string for filtering in the “Text filter...” input box.

   The parameter table displays only the parameters containing the character string.

The text filtering is reset.

- When another parameter group is selected in the navigation.
- When navigation is changed from data navigation to functional navigation, or vice versa.

With the subgroups of the navigation

1. Click the desired parameter group in the navigation, e.g., "Static".

   The parameter table only shows the static parameters. You can select further subgroups for some groups of the navigation.

2. Click “All parameters” in the navigation if all parameters are to be shown again.

3.10.5.3 Sorting the parameter table

The values of the parameters are arranged in rows. The parameter table can be sorted by any displayed column.

- In columns containing numerical values, sorting is based on the magnitude of the numerical value.
- In text columns, sorting is alphabetical.

Sorting by column

1. Position the cursor in the header cell of the desired column.

   The background of this cell turns blue.
2. Click the column header.

Result

The entire parameter table is sorted by the selected column. A triangle with tip facing up appears in the column header.

Clicking the column header again changes the sorting as follows:

- Symbol "▲": Parameter table is sorted in ascending order.
- Symbol "▼": Parameter table is sorted in descending order.
- No symbol: The sorting is removed again. The parameter table assumes the default display.

The "../" prefix in the "Name in DB" column is ignored when sorting.

3.10.5.4 Transferring parameter data to other editors

After selecting an entire parameter row of the parameter table, you can use the following:

- Drag-and-drop
- <Ctrl+C>/<Ctrl+V>
- Copy/Paste via shortcut menu

Transfer parameters to the following editors of the TIA Portal:

- Program editor
- Watch table
- Signal table for trace function

The parameter is inserted with its full name: See information in "Full name in DB" column.

3.10.5.5 Indicating errors

Error indication

Parameter assignment errors that result in compilation errors (e.g., limit violation) are indicated in the Parameter view.

Every time a value is input in the Parameter view, a check is made for process-related and syntax errors and the result is indicated.

Bad values are indicated by:

- Red error symbol in the "Status of configuration" (offline mode) or "Compare result" (online mode, depending on the selected comparison type) columns

and/or

- Table field with red background

  If you click the bad field, a roll-out error message appears with information of the permissible value range or the required syntax (format)

Compilation error

From the error message of the compiler, you can directly open the Parameter view (functional navigation) containing the parameter causing the error in situations where the parameter is not displayed in the configuration dialog.

3.10.5.6 Editing start values in the project

With the Parameter view, you can edit the start values in the project in offline mode and online mode.

- You make value changes in the “Start value project” column of the parameter table.
- In the “Status of configuration” column of the parameter table, the progress of the configuration is indicated by the familiar status symbols from the configuration dialog of the technology object.

Boundary conditions

- If other parameters depend on the parameter whose start value was changed, the start value of the dependent parameters are also adapted.
- If a parameter of a technology object is not editable, it is also not editable in the parameter view. The ability to edit a parameter can also depend on the values of other parameters.

Defining new start values

To define start values for parameters in the Parameter view, follow these steps:

1. Open the Parameter view of the technology object.
2. Enter the desired start values in the "Start value project" column. The value must match the data type of the parameter and must not exceed the value range of the parameter. The limits of the value range can be seen in the “Maximum value” and “Minimum value” columns.

The "Status of configuration" column indicates the progress of the configuration with colored symbols.

See also Status of configuration (offline) (Page 68)

Following adaptation of the start values and downloading of the technology object to the CPU, the parameters take the defined value at startup if they are not declared as retentive (“Retain” column).

Error indication

When a start value is input, a check is made for process-related and syntax errors and the result is indicated.

Bad start values are indicated by:

- Red error symbol in the "Status of configuration" (offline mode) or "Compare result" (online mode, depending on the selected comparison type) columns

and/or

- Red background in the “Start value project” field
  If you click on the bad field, a roll-out error message appears with information of the permissible value range or the necessary syntax (format)

Correcting bad start values

1. Correct bad start values using information from the roll-out error message.

   Red error symbol, red field background, and roll-out error message are no longer displayed.

The project cannot be successfully compiled unless the start values are error-free.

3.10.5.7 Status of configuration (offline)

The status of the configuration is indicated by icons:

- In the “Status of configuration” column in the parameter table
- In the navigation structure of the functional navigation and data navigation

Symbol in “Status of configuration” column

Symbol	Meaning
	The start value of the parameter corresponds to the default value and is valid. A start value has not yet been defined by the user.
	The start value of the parameter contains a value defined by the user. The start value is different than the default value. The start value is error-free and valid.
	The start value of the parameter is invalid (syntax or process-related error). The input box has a red background. When clicked, the roll-out error message indicates the cause of the error.
	Only for S7-1200 Motion Control: The start value of the parameter is valid but contains warnings. The input box has a yellow background.

Symbol in the navigation

The symbols in the navigation indicate the progress of the configuration in the same way as in the configuration dialog of the technology object.

See also

Configure technology objects (Page 43)

3.10.5.8 Monitoring values online in the parameter view

You can monitor the values currently taken by the parameters of the technology object in the CPU (monitor values) directly in the Parameter view.

Requirements

- There is an online connection.
- The technology object is downloaded to the CPU.
- The program execution is active (CPU in "RUN").
- The Parameter view of the technology object is open.

Procedure

1. Start the monitoring by clicking  .

   As soon as the Parameter view is online, the following columns are additionally displayed:

   – Compare result
   – Start value PLC
   – Monitor value
   – Modify value
   – Selection for transmission

   The "Monitor value" column shows the current parameter values on the CPU.

   Meaning of the additional columns: see Parameter table (Page 57)

2. Stop the monitoring by clicking  again.

Display

All columns that are only available online have an orange background:

- Values in light-orange cells can be changed.
- Values in cells with a dark orange background cannot be changed.

3.10.5.9 Create snapshot of monitor values

You can back up the current values of the technology object on the CPU (monitor values) and display them in the Parameter view.

Requirements

- There is an online connection.
- The technology object is downloaded to the CPU.
- The program execution is active (CPU in "RUN").
- The Parameter view of the technology object is open.
- The “Monitor all” button is selected.

Procedure

To show the current parameter values, follow these steps:

1. In the Parameter view, click the “Create snapshot of monitor values" icon .

Result

The current monitor values are transferred once to the "Snapshot" column of the parameter table.

You can analyze the values "frozen" in this way while the monitor values continue to be updated in the "Monitor values" column.

3.10.5.10 Modifying values

With the Parameter view, you can modify values of the technology object in the CPU.

You can assign values to the parameter once (Modify value) and modify them immediately. The modify request is executed as quickly as possible without reference to any particular point in the user program.

DANGER

Danger when modifying:

Changing the parameter values while the plant is operating may result in severe damage to property and personal injury in the event of malfunctions or program errors.

Make sure that dangerous states cannot occur before you use the "Modify" function.

Requirements

- There is an online connection.
- The technology object is downloaded to the CPU.
- The program execution is active (CPU in "RUN").
- The Parameter view of the technology object is open.
- The “Monitor all” button  is selected.
- The parameter can be modified (associated field in the "Modify value" column has a light-orange background).

Procedure

To modify parameters immediately, follow these steps:

1. Enter the desired modify values in the “Modify values” column of the parameter table.
2. Check whether the check box for modifying is selected in the "Select for transmission" column.

   The modify values and associated check boxes of dependent parameters are automatically adapted at the same time.
3. Click the “Modify all selected parameters immediately and once” icon  .

The selected parameters are modified once and immediately with the specified values and can be monitored in the "Modify values" column. The check boxes for modifying in the "Selection for transmission" column are automatically cleared after the modify request is complete.

Error indication

When a start value is input, a check is made immediately for process-related and syntax errors and the result is indicated.

Bad start values are indicated by:

- Red background in the “Modify value” field

and

- If you click the bad field, a roll-out error message appears with information of the permissible value range or the necessary syntax (format)

Bad modify values

- Modify values with process-related errors can be transmitted.
- Modify values with syntax errors **cannot** be transmitted.

3.10.5.11 Comparing values

You can use comparison functions to compare the following memory values of a parameter:

- Start value project
- Start value PLC
- Snapshot

Requirements

- There is an online connection.
- The technology object is downloaded to the CPU.
- The program execution is active (CPU in "RUN").
- The Parameter view of the technology object is open.
- The “Monitor all” button is selected.

Procedure

To compare the start values on the various target systems, follow these steps:

1. Click the "Selection of compare values" icon .

   A selection list containing the comparison options opens:

   – Start value project - Start value PLC (default setting)

   – Start value project - Snapshot

   – Start value PLC - Snapshot

2. Select the desired comparison option.

   The selected comparison option is executed as follows:

   – A scales symbol appears in the header cells of the two columns selected for comparison.

   – Symbols are used in the "Compare result" column to indicate the result of the comparison of the selected columns.

Symbol in "Compare result" column

Symbol	Meaning
	The compare values are equal and error-free.
	The compare values are not equal and error-free.
	At least one of the two compare values has a process-related or syntax error.
	The comparison cannot be performed. At least one of the two compare values is not available (e.g., snapshot).

Symbol in the navigation

The symbols are shown in the same way in the navigation if the comparison result applies to at least one of the parameters below the displayed navigation structure.

3.10.5.12 Applying values from the online program as start values

In order to apply optimized values from the CPU to the project as start values, you create a snapshot of the monitor values. Values of the snapshot marked as a "Setpoint" are then applied to the project as start values.

Requirements

- The technology object is of type "PID_Compact" or "PID_3Step".
- There is an online connection.
- The technology object is downloaded to the CPU.
- The program execution is active (CPU in "RUN").
- The Parameter view of the technology object is open.
- The “Monitor all” button is selected.

Procedure

To apply optimized values from the CPU, follow these steps:

1. Click the "Create snapshot of monitor values and accept setpoints of this snapshot as start values" icon .

Result

The current monitor values are applied to the "Snapshot" column and their setpoints are copied to the "Start value project" column as new start values.

Note

Applying values of individual parameters

You can also apply the values of individual parameters that are not marked as a setpoint from the "Snapshot" column to the "Start values project" column. To do so, copy the values and insert them into the "Start value project" column using the "Copy" and "Paste" commands in the shortcut menu.

3.10.5.13 Initializing setpoints in the online program

You can initialize all parameters that are marked as a "Setpoint" in the Parameter view with new values in the CPU in one step. In so doing, the start values are downloaded from the project to the CPU. The CPU remains in "RUN" mode.

To avoid data loss on the CPU during a cold restart or warm restart, you must also download the technology object to the CPU.

DANGER

Danger when changing parameter values

Changing the parameter values while the plant is operating may result in severe damage to property and personal injury in the event of malfunctions or program errors.

Make sure that dangerous states cannot occur before you reinitialize the setpoints.

Requirements

- The technology object is of type "PID_Compact" or "PID_3Step".
- There is an online connection.
- The technology object is downloaded to the CPU.
- The program execution is active (CPU in "RUN").
- The Parameter view of the technology object is open.
- The “Monitor all” button  is selected.
- The parameters marked as a "Setpoint" have a "Start value project" that is free of process-related and syntax errors

Procedure

To initialize all setpoints, follow these steps:

1. Enter the desired values in the "Start value project" column.

   Ensure that the start start values are free of process-related and syntax errors.
2. Click the "Initialize setpoints" icon .

Result

The setpoints in the CPU are initialized with the start values from the project.

3.11 Display instance DB of a technology object.

An instance DB, in which the parameter and static variables are saved, is created for each technology object.

Procedure

To display the instance DB of a technology object, proceed as follows:

1. Open the CPU folder in the project tree.
2. Open the "Technology objects" folder.
3. Highlight a technology object.
4. Select the command "Open DB editor" in the shortcut menu.

Using PID_Compact 4

4.1 Technology object PID_Compact

The technology object PID_Compact provides a continuous PID controller with integrated optimization. You can alternatively configure a pulse controller. Both manual and automatic mode are possible.

PID-Compact continuously acquires the measured process value within a control loop and compares it with the required setpoint. From the resulting control deviation, the instruction PID_Compact calculates an output value by which the process value is adapted as quickly and stable as possible to the setpoint. The output value for the PID controller consists of three actions:

- **P** action

  The proportional action of the output value increases in proportion to the control deviation.

- **I** action

  The integral action of the output value increases until the control deviation has been balanced.

- **D** action

  The derivative action increases with the rate of change of control deviation. The process value is corrected to the setpoint as quickly as possible. The derivative action will be reduced again if the rate of change of control deviation drops.

The instruction PID_Compact calculates the proportional, integral and derivative parameters for your controlled system during pretuning. Fine tuning can be used to tune the parameters further. You do not need to manually determine the parameters.

Additional information

- Overview of software controller (Page 39)
- Add technology objects (Page 42)
- Configure technology objects (Page 43)
- Configuring PID_Compact V2 (Page 80)
- Configuring PID_Compact V1 (Page 98)

4.2 PID_Compact V2

4.2.1 Configuring PID_Compact V2

4.2.1.1 Basic settings

Introduction

Configure the following properties of the "PID_Compact" technology object under "Basic settings" in the Inspector window or in the configuration window:

- Physical quantity
- Control logic
- Start-up behavior after reset
- Setpoint (only in the Inspector window)
- Process value (only in the Inspector window)
- Output value (only in the Inspector window)

Setpoint, process value and output value

You can only configure the setpoint, process value and output value in the Inspector window of the programming editor. Select the source for each value:

- Instance DB

  The value saved in the instance DB is used.

  Value must be updated in the instance DB by the user program.

  There should be no value at the instruction.

  Change via HMI possible.

- Instruction

  The value connected to the instruction is used.
  The value is written to the instance DB each time the instruction is called.

  No change via HMI possible.

Controller type

Physical quantity

Select the physical quantity and unit of measurement for setpoint, process value, and disturbance variable in the "Controller type" group. Setpoint, process value, and disturbance variable is displayed in this unit of measurement.

Control logic

An increase of the output value is generally intended to cause an increase in the process value. This is referred to as a normal control logic.

PID_Compact does not work with negative proportional gain. Select the check box "Invert control logic" to reduce the process value with a higher output value.

Examples

- Opening the drain valve will reduce the level of a container's contents.
- Increasing cooling will reduce the temperature.

Startup characteristics

1. To switch to "Inactive" mode after CPU restart, clear the "Activate Mode after CPU restart" check box.

   To switch to the operating mode saved in the Mode parameter after CPU restart, select the "Activate Mode after CPU restart" check box.

2. In the "Set Mode to" drop-down list, select the mode that is to be enabled after a complete download to the device.

   After a complete download to the device, PID_Compact starts in the selected operating mode. With each additional restart, PID_Compact starts in the mode that was last saved in Mode.

Example

You have selected the "Activate Mode after CPU restart" check box and the entry "Pretuning" in the "Set Mode to" list. After a complete download to the device, PID_Compact starts in the "Pretuning" mode. If pretuning is still active, PID_Compact starts in "Pretuning" mode again after restart of the CPU. If pretuning was successfully completed and automatic mode is active, PID_Compact starts in "Automatic mode" after restart of the CPU.

Setpoint

Procedure

Proceed as follows to define a fixed setpoint:

1. Select "Instance DB".
2. Enter a setpoint, e.g. 80° C.
3. Delete any entry in the instruction.

Proceed as follows to define a variable setpoint:

1. Select "Instruction".
2. Enter the name of the REAL variable in which the setpoint is saved.

   Program-controlled assignment of various values to the REAL variable is possible, for example for the time controlled change of the setpoint.

Process value

PID_Compact will scale the value of the analog input to the physical quantity if you use the analog input value directly.

You will need to write a program for processing if you wish first to process the analog input value. The process value is, for example, not directly proportional to the value at the analog input. The processed process value must be in floating point format.

Procedure

Proceed as follows to use the analog input value without processing:

1. Select the entry "Input_PER" in the drop-down list "Input".
2. Select "Instruction" as source.
3. Enter the address of the analog input.

Proceed as follows to use the processed process value in floating point format:

1. Select the entry "Input" in the drop-down list "Input".
2. Select "Instruction" as source.
3. Enter the name of the variable in which the processed process value is saved.

Output value

PID_Compact offers three output values. Your actuator will determine which output value you use.

- Output_PER

  The actuator is triggered via an analog output and controlled with a continuous signal, e.g. 0...10V, 4...20mA.

- Output

  The output value needs to be processed by the user program, for example because of nonlinear actuator response.

- Output_PWM

  The actuator is controlled via a digital output. Pulse width modulation creates minimum ON and minimum OFF times.

Procedure

Proceed as follows to use the analog output value:

1. Select the entry "Output_PER (analog)" in the drop-down list "Output".
2. Select "Instruction".
3. Enter the address of the analog output.

Proceed as follows to process the output value using the user program:

1. Select the entry "Output" in the drop-down list "Output".
2. Select "Instance DB".

   The calculated output value is saved in the instance data block.
3. For the preparation of the output value, use the output parameter Output.
4. Transfer the processed output value to the actuator via a digital or analog CPU output.

Proceed as follows to use the digital output value:

1. Select the entry "Output_PWM" in the drop-down list "Output".
2. Select "Instruction".
3. Enter the address of the digital output.

4.2.1.2 Process value settings

Scaling the process value

If you have configured the use of Input_PER in the basic setting, you must convert the value of the analog input to the physical quantity of the process value. The current configuration is displayed in the Input_PER display.

Input_PER will be scaled using a low and high value pair if the process value is directly proportional to the value of the analog input.

Procedure

To scale the process value, follow these steps:

1. Enter the low pair of values in the "Scaled low process value" and "Low" input fields.
2. Enter the high pair of values in the "Scaled high process value" and "High" input boxes.

Default settings for the value pairs are stored in the hardware configuration. To use the value pairs from the hardware configuration, follow these steps:

1. Select the PID_Compact instruction in the programming editor.
2. Interconnect Input_PER with an analog input in the basic settings.
3. Click the "Automatic setting" button in the process value settings.

The existing values will be overwritten with the values from the hardware configuration.

Process value limits

You must specify an appropriate absolute high limit and low limit for the process value as limit values for your controlled system. As soon as the process value violates these limits, an error occurs (ErrorBits = 0001h). Tuning is canceled when the process value limits are violated. You can configure how PID_Compact reacts to an error in automatic mode in the output value settings.

4.2.1.3 Advanced settings

Monitoring process value

Configure a warning high and low limit for the process value in the "Process value monitoring" configuration window. If one of the warning limits is exceeded or undershot during operation, a warning will be displayed at the PID_Compact instruction:

- At the InputWarning_H output parameter if the warning high limit has been exceeded
- At the InputWarning_L output parameter if the warning low limit has been undershot

The warning limits must be within the process value high and low limits.

The process value high and low limits will be used if you do not enter values.

Example

Process value high limit = 98 °C; warning high limit = 90 °C

Warning low limit = 10 °C; process value low limit = 0 °C

PID_Compact will respond as follows:

Process value	InputWarning_H	InputWarning_L	Error-Bits	Operating mode
> 98 °C	TRUE	FALSE	0001h	Inactive or Substitute output value with error monitoring
≤ 98 °C and > 90 °C	TRUE	FALSE	0000h	Automatic mode
≤ 90 °C and ≥ 10 °C	FALSE	FALSE	0000h	Automatic mode
< 10 °C and ≥ 0 °C	FALSE	TRUE	0000h	Automatic mode
< 0 °C	FALSE	TRUE	0001h	Inactive or Substitute output value with error monitoring

In the output value settings, you can specify the reaction of PID_Compact when the process value high limit or low limit is violated.

See also

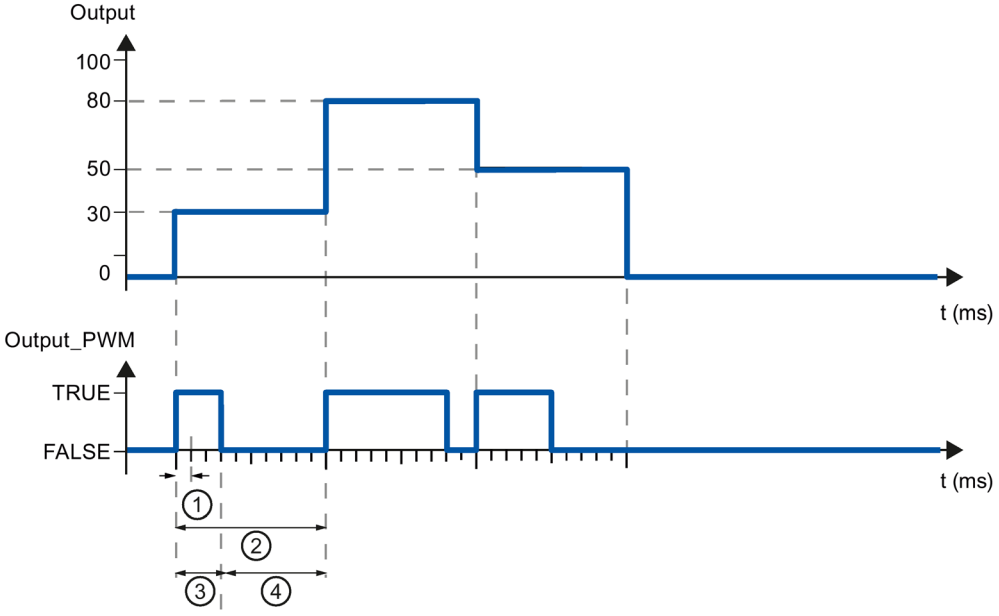
Parameters State and Mode V2 (Page 267)

PWM limits

The value at the output parameter Output is transformed into a pulse sequence that is output at output parameter Output_PWM by means of a pulse width modulation. Output is calculated in the PID algorithm sampling time, Output_PWM is output in the PID_Compact sampling time.

The PID algorithm sampling time is determined during pretuning or fine tuning. If manually setting the PID parameters, you will also need to configure the PID algorithm sampling time. The PID_Compact sampling time is equivalent to the cycle time of the calling OB.

The pulse duration is proportional to the value at Output and is always an integer multiple of the PID_Compact sampling time.



① PID_Compact sampling time
② PID algorithm sampling time
③ Pulse duration
④ Break time

The "Minimum ON time" and the "Minimum OFF time" are rounded to an integer multiple of the PID_Compact sampling time.

A pulse or a break is never shorter than the minimum ON or OFF time. The inaccuracies this causes are added up and compensated in the next cycle.

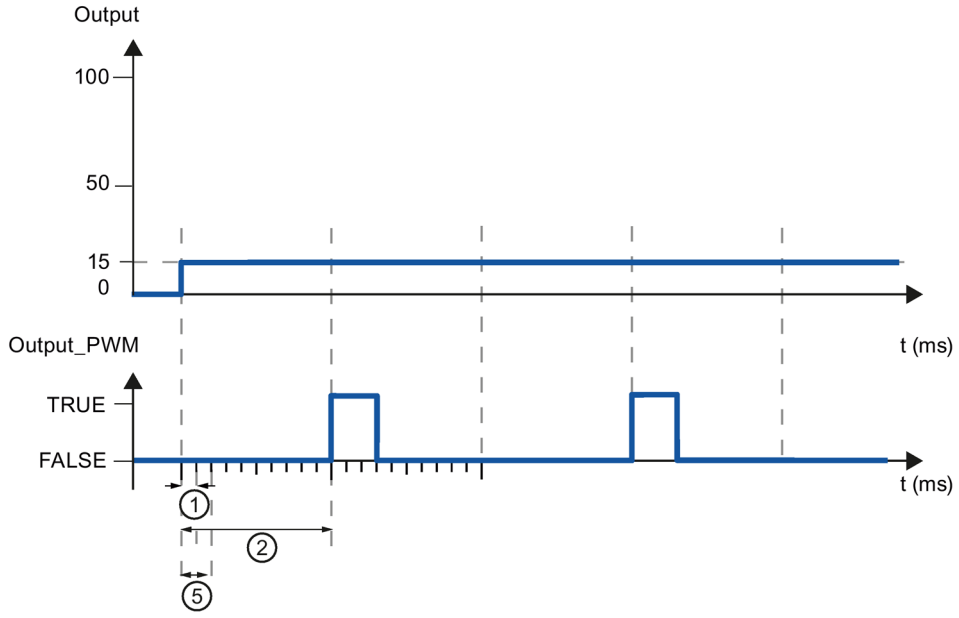
Example

PID_Compact sampling time = 100 ms

PID algorithm sampling time = 1000 ms

Minimum ON time = 200 ms

Output is a constant 15%. The smallest pulse that PID_Compact can output is 20%. In the first cycle, no pulse is output. In the second cycle, the pulse not output in the first cycle is added to the pulse of the second cycle.



① PID_Compact sampling time
② PID algorithm sampling time
⑤ Minimum ON time

In order to minimize operation frequency and conserve the actuator, extend the minimum ON and OFF times.

If you are using "Output" or "Output_PER", you must configure the value 0.0 for the minimum ON and OFF times.

Note

The minimum ON and OFF times only affect the output parameter Output_PWM and are not used for any pulse generators integrated in the CPU.

Output value

Output value limits

In the "Output value limits" configuration window, configure the absolute limits of your output value in percent. Absolute output value limits are not violated in neither manual mode nor automatic mode. If an output value outside the limits is specified in manual mode, the effective value is limited in the CPU to the configured limits.

The output value limits must match the control logic.

The valid output value limit values depend on the Output used.

Output	-100.0 to 100.0%
Output_PER	-100.0 to 100.0%
Output_PWM	0.0 to 100.0%

Reaction to error

NOTICE
Your system may be damaged. If you output "Current value while error pending " or "Substitute output value while error pending" in the event of an error, PID_Compact remains in automatic mode. This may cause a violation of the process value limits and damage your system. It is essential to configure how your controlled system reacts in the event of an error to protect your system from damage.

PID_Compact is preset so that the controller stays active in most cases in the event of an error. If errors occur frequently in controller mode, this default reaction has a negative effect on the control response. In this case, check the Errorbits parameter and eliminate the cause of the error.

PID_Compact generates a programmable output value in response to an error:

- Zero (inactive)

  PID_Compact outputs 0.0 as output value for all errors and switches to "Inactive" mode. The controller is only reactivated by a falling edge at Reset or a rising edge at ModeActivate.

- Current value while error is pending

  If the following errors occur in **automatic mode**, PID_Compact returns to automatic mode as soon as the errors are no longer pending.

  If one or more of the following errors occur, PID_Compact stays in automatic mode:

  – 0001h: The "Input" parameter is outside the process value limits.

  – 0800h: Sampling time error

  – 40000h: Invalid value at Disturbance parameter.

  If one or more of the following errors occur in **automatic mode**, PID_Compact switches to "Substitute output value with error monitoring" mode and outputs the last valid output value:

  – 0002h: Invalid value at Input_PER parameter.

  – 0200h: Invalid value at Input parameter.

  – 0400h: Calculation of output value failed.

  – 1000h: Invalid value at Setpoint parameter.

  If an error occurs in **manual mode**, PID_Compact continues using the manual value as the output value. If the manual value is invalid, the substitute output value is used. If the manual value and substitute output value are invalid, the output value low limit is used.

  If the following error occurs during a **pretuning or fine tuning**, PID_Compact remains in active mode:

  – 0020h: Pretuning is not permitted during fine tuning.

  When any other error occurs, PID_Compact cancels the tuning and switches to the mode from which tuning was started.

  As soon as no errors are pending, PID_Compact returns to automatic mode.

- Substitute output value while error is pending

  PID_Compact outputs the substitute output value.

  If the following error occurs, PID_Compact stays in "Substitute output value with error monitoring" mode and outputs the output value low limit:

  – 20000h: Invalid value at SubstituteOutput tag.

  For all other errors, PID_Compact reacts as described for "Current value while error is pending".

See also

Parameters State and Mode V2 (Page 267)

PID parameters

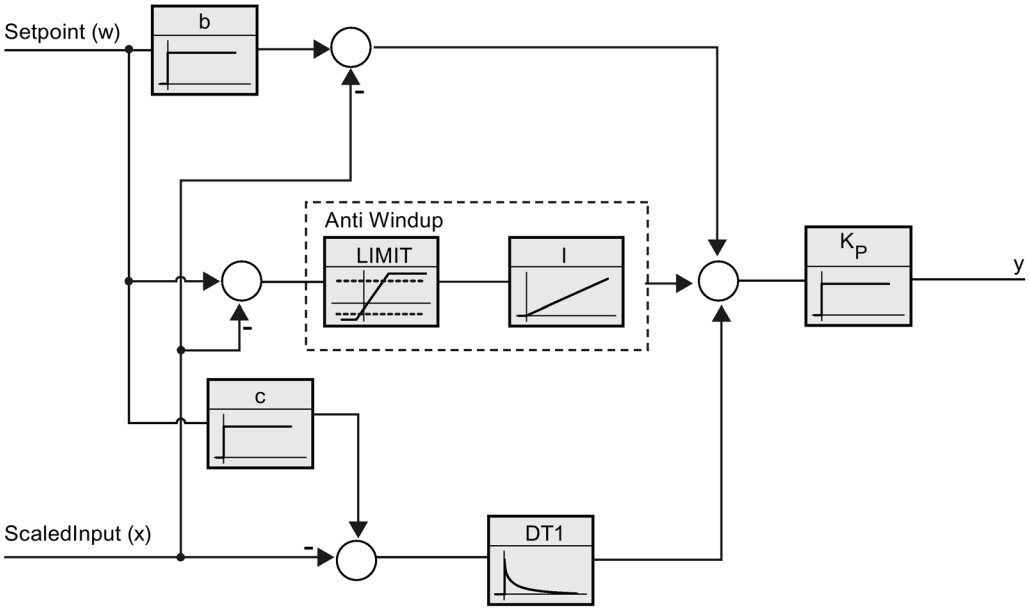
The PID parameters are displayed in the "PID Parameters" configuration window. The PID parameters will be adapted to your controlled system during controller tuning. You do not need to enter the PID parameters manually.

The PID algorithm operates according to the following equation:

$$y = K_p \left[(b \cdot w - x) + \frac{1}{T_I \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c \cdot w - x) \right]$$

Symbol	Description
y	Output value of the PID algorithm
K_p	Proportional gain
s	Laplace operator
b	Proportional action weighting
w	Setpoint
x	Process value
T_I	Integral action time
a	Derivative delay coefficient (derivative delay T1 = a × T_D)
T_D	Derivative action time
c	Derivative action weighting

The diagram below illustrates the integration of the parameters into the PID algorithm:



All PID parameters are retentive. If you enter the PID parameters manually, you must completely download PID_Compact.

Downloading technology objects to device (Page 46)

Proportional gain

The value specifies the proportional gain of the controller. PID_Compact does not work with a negative proportional gain. Control logic is inverted under Basic settings > Controller type.

Integral action time

The integral action time determines the time behavior of the integral action. The integral action is deactivated with integral action time = 0.0.

Derivative action time

The derivative action time determines the time behavior of the derivative action. Derivative action is deactivated with derivative action time = 0.0.

Derivative delay coefficient

The derivative delay coefficient delays the effect of the derivative action.

Derivative delay = derivative action time × derivative delay coefficient

- 0.0: Derivative action is effective for one cycle only and therefore almost not effective.
- 0.5: This value has proved useful in practice for controlled systems with **one** dominant time constant.
- > 1.0: The greater the coefficient, the longer the effect of the derivative action is delayed.

Proportional action weighting

The proportional action may weaken with changes to the setpoint.

Values from 0.0 to 1.0 are applicable.

- 1.0: Proportional action for setpoint change is fully effective
- 0.0: Proportional action for setpoint change is not effective

The proportional action is always fully effective when the process value is changed.

Derivative action weighting

The derivative action may weaken with changes to the setpoint.

Values from 0.0 to 1.0 are applicable.

- 1.0: Derivative action is fully effective upon setpoint change
- 0.0: Derivative action is not effective upon setpoint change

The derivative action is always fully effective when the process value is changed.

PID algorithm sampling time

The controlled system needs a certain amount of time to respond to changes in the output value. It is therefore not advisable to calculate the output value in every cycle. The sampling time of the PID algorithm represents the time between two calculations of the output value. It is calculated during tuning and rounded to a multiple of the cycle time. All other functions of PID_Compact are executed at every call.

If you use Output_PWM, the accuracy of the output signal is determined by the ratio of the PID algorithm sampling time to the cycle time of the OB. The PID algorithm sampling time corresponds to the time period of the pulse width modulation. The cycle time should be at least 10 times the PID algorithm sampling time.

Rule for tuning

Select whether PI or PID parameters are to be calculated in the "Controller structure" drop-down list.

- **PID**

  Calculates PID parameters during pretuning and fine tuning.

- **PI**

  Calculates PI parameters during pretuning and fine tuning.

- **User-defined**

  The drop-down list displays "User-defined" if you have configured different controller structures for pretuning and fine tuning via a user program.

4.2.2 Commissioning PID_Compact V2

4.2.2.1 Pretuning

The pretuning determines the process response to a jump change of the output value and searches for the point of inflection. The PID parameters are calculated from the maximum rate of rise and dead time of the controlled system. You obtain the best PID parameters when you perform pretuning and fine tuning.

The more stable the process value is, the easier it is to calculate the PID parameters and the more precise the result will be. Noise on the process value can be tolerated as long as the rate of rise of the process value is significantly higher compared to the noise. This is most likely the case in operating modes "Inactive" and "manual mode". The PID parameters are backed up before being recalculated.

Requirement

- The "PID_Compact" instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- Reset = FALSE
- PID_Compact is in one of the following modes: "Inactive", "Manual mode", or "Automatic mode".
- The setpoint and the process value lie within the configured limits (see "Process value monitoring" configuration).
- The difference between setpoint and process value is greater than 30% of the difference between process value high limit and process value low limit.
- The distance between the setpoint and the process value is > 50% of the setpoint.

Procedure

To perform pretuning, follow these steps:

1. Double-click the "PID_Compact > Commissioning" entry in the project tree.
2. Select the entry "Pretuning" in the "Tuning mode" drop-down list.
3. Click the "Start" icon.
   - An online connection will be established.
   - Value recording is started.
   - Pretuning is started.
   - The "Status" field displays the current steps and any errors that may have occurred. The progress bar indicates the progress of the current step.

Note

Click the "Stop" icon when the progress bar has reached 100% and it can be assumed the controller tuning function is blocked. Check the configuration of the technology object and, if necessary, restart controller tuning.

Result

If pretuning was performed without an error message, the PID parameters have been tuned. PID_Compact switches to automatic mode and uses the tuned parameters. The tuned PID parameters will be retained during power OFF and a restart of the CPU.

If pretuning is not possible, PID_Compact responds with the configured reaction to errors.

See also

Parameters State and Mode V2 (Page 267)

4.2.2.2 Fine tuning

Fine tuning generates a constant, limited oscillation of the process value. The PID parameters are tuned for the operating point from the amplitude and frequency of this oscillation. All PID parameters are recalculated from the results. PID parameters from fine tuning usually have better master control and disturbance characteristics than PID parameters from pretuning. You obtain the best PID parameters when you perform pretuning and fine tuning.

PID_Compact automatically attempts to generate an oscillation greater than the noise of the process value. Fine tuning is only minimally influenced by the stability of the process value. The PID parameters are backed up before being recalculated.

Requirement

- The PID_Compact instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- Reset = FALSE
- The setpoint and the process value lie within the configured limits.
- The control loop has stabilized at the operating point. The operating point is reached when the process value corresponds to the setpoint.
- No disturbances are expected.
- PID_Compact is in one of the following operating modes: Inactive, automatic mode, or manual mode.

Process depends on initial situation

Fine tuning can be started from the following operating modes: "Inactive", "automatic mode", or "manual mode". Fine tuning proceeds as follows when started from:

- Automatic mode

  Start fine tuning from automatic mode if you wish to improve the existing PID parameters through tuning.

  PID_Compact controls the system using the existing PID parameters until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start.

- Inactive or manual mode

  If the requirements for pretuning are met, pretuning is started. The determined PID parameters will be used for control until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start. If pretuning is not possible, PID_Compact responds with the configured reaction to errors.

  An attempt is made to reach the setpoint with the minimum or maximum output value if the process value for pretuning is already too near the setpoint. This can produce increased overshoot.

Procedure

To perform fine tuning, follow these steps:

1. Select the entry "Fine tuning" in the "Tuning mode" drop-down list.
2. Click the "Start" icon.
   - An online connection will be established.
   - Value recording is started.
   - The process of fine tuning is started.
   - The "Status" field displays the current steps and any errors that may have occurred. The progress bar indicates the progress of the current step.

Note

Click the "Stop" icon in the "Tuning mode" group when the progress bar has reached 100% and it is to be assumed that tuning is blocked. Check the configuration of the technology object and, if necessary, restart controller tuning.

Result

If no errors occurred during fine tuning, the PID parameters have been tuned. PID_Compact switches to automatic mode and uses the tuned parameters. The tuned PID parameters will be retained during power OFF and a restart of the CPU.

If errors occurred during "fine tuning", PID_Compact responds with the configured response to errors.

See also

Parameters State and Mode V2 (Page 267)

4.2.2.3 "Manual" mode

The following section describes how you can use the "manual mode" operating mode in the commissioning window of the "PID_Compact" technology object. Manual mode is also possible when an error is pending.

Requirement

- The "PID_Compact" instruction is called in a cyclic interrupt OB.
- An online connection to the CPU has been established and the CPU is in the "RUN" mode.

Procedure

Use "Manual mode" in the commissioning window if you want to test the controlled system by specifying a manual value. To define a manual value, follow these steps:

1. Click the "Start" icon.
2. Select the "Manual mode" check box in the "Online status of controller" area.

   PID_Compact operates in manual mode. The most recent current output value remains in effect.
3. Enter the manual value in the "Output" field as a % value.
4. Click the icon.

Result

The manual value is written to the CPU and immediately goes into effect.

Clear the "Manual mode" check box if the output value is to be specified again by the PID controller. The switchover to automatic mode is bumpless.

See also

Parameters State and Mode V2 (Page 267)

4.3 PID_Compact V1

4.3.1 Configuring PID_Compact V1

4.3.1.1 Basic settings

Introduction

Configure the following properties of the "PID_Compact" technology object under "Basic settings" in the Inspector window or in the configuration window:

- Physical quantity
- Control logic
- Start-up behavior after reset
- Setpoint (only in the Inspector window)
- Process value (only in the Inspector window)
- Output value (only in the Inspector window)

Setpoint, process value and output value

You can only configure the setpoint, process value and output value in the Inspector window of the programming editor. Select the source for each value:

- Instance DB

  The value saved in the instance DB is used.

  Value must be updated in the instance DB by the user program.

  There should be no value at the instruction.

  Change via HMI possible.

- Instruction

  The value connected to the instruction is used.
  The value is written to the instance DB each time the instruction is called.

  No change via HMI possible.

Controller type

Physical quantity

Select the unit of measurement and physical quantity for the setpoint and process value in the "Controller type" group. The setpoint and process value will be displayed in this unit.

Control logic

An increase of the output value is generally intended to cause an increase in the process value. This is referred to as a normal control logic.

PID_Compact does not work with negative proportional gain. Select the check box "Invert control logic" to reduce the process value with a higher output value.

Examples

- Opening the drain valve will reduce the level of a container's contents.
- Increasing cooling will reduce the temperature.

Start-up behavior after reset

To change straight to the last active mode after restarting the CPU, select the "Enable last mode after CPU restart" check box.

PID_Compact will remain in "Inactive" mode if the check box is cleared.

Setpoint

Procedure

Proceed as follows to define a fixed setpoint:

1. Select "Instance DB".
2. Enter a setpoint, e.g. 80° C.
3. Delete any entry in the instruction.

Proceed as follows to define a variable setpoint:

1. Select "Instruction".
2. Enter the name of the REAL variable in which the setpoint is saved.

   Program-controlled assignment of various values to the REAL variable is possible, for example for the time controlled change of the setpoint.

Process value

PID_Compact will scale the value of the analog input to the physical quantity if you use the analog input value directly.

You will need to write a program for processing if you wish first to process the analog input value. The process value is, for example, not directly proportional to the value at the analog input. The processed process value must be in floating point format.

Procedure

Proceed as follows to use the analog input value without processing:

1. Select the entry "Input_PER" in the drop-down list "Input".
2. Select "Instruction" as source.
3. Enter the address of the analog input.

Proceed as follows to use the processed process value in floating point format:

1. Select the entry "Input" in the drop-down list "Input".
2. Select "Instruction" as source.
3. Enter the name of the variable in which the processed process value is saved.

Output value

PID_Compact offers three output values. Your actuator will determine which output value you use.

- Output_PER

  The actuator is triggered via an analog output and controlled with a continuous signal, e.g. 0...10V, 4...20mA.

- Output

  The output value needs to be processed by the user program, for example because of nonlinear actuator response.

- Output_PWM

  The actuator is controlled via a digital output. Pulse width modulation creates minimum ON and minimum OFF times.

Procedure

Proceed as follows to use the analog output value:

1. Select the entry "Output_PER (analog)" in the drop-down list "Output".
2. Select "Instruction".
3. Enter the address of the analog output.

Proceed as follows to process the output value using the user program:

1. Select the entry "Output" in the drop-down list "Output".
2. Select "Instance DB".

   The calculated output value is saved in the instance data block.
3. For the preparation of the output value, use the output parameter Output.
4. Transfer the processed output value to the actuator via a digital or analog CPU output.

Proceed as follows to use the digital output value:

1. Select the entry "Output_PWM" in the drop-down list "Output".
2. Select "Instruction".
3. Enter the address of the digital output.

4.3.1.2 Process value settings

Configure the scaling of your process value and specify the process value absolute limits In the "Process value settings" configuration window.

Scaling the process value

If you have configured the use of Input_PER in the basic settings, you will need to convert the value of the analog input into the physical quantity of the process value. The current configuration will be displayed in the Input_PER display.

Input_PER will be scaled using a low and high value pair if the process value is directly proportional to the value of the analog input.

1. Enter the low pair of values in the "Scaled low process value" and "Low" input fields.
2. Enter the high pair of values in the "Scaled high process value" and "High" input boxes.

Default settings for the value pairs are saved in the hardware configuration. Proceed as follows to use the value pairs from the hardware configuration:

1. Select the instruction PID_Compact in the programming editor.
2. Connect Input_PER with an analog input in the basic settings.
3. Click on the "Automatic setting" button in the process value settings.

The existing values will be overwritten with the values from the hardware configuration.

Monitoring process value

Specify the absolute high and low limit of the process value. As soon as these limits are violated during operation, the controller switches off and the output value is set to 0%. You must enter reasonable limits for your controlled system. Reasonable limits are important during optimization to obtain optimal PID parameters.

The default for the "High limit process value" is 120 %. At the I/O input, the process value can be a maximum of 18% higher than the standard range (overrange). An error is no longer reported for a violation of the "High limit process value". Only a wire-break and a short-circuit are recognized and the PID_Compact switches to "Inactive" mode.

⚠ WARNING

If you set very high process value limits (for example $-3.4*10^{38}...+3.4*10^{38}$), process value monitoring will be disabled. Your system may then be damaged if an error occurs.

See also

Monitoring process value (Page 103)

PWM limits (Page 104)

Output value limits (Page 106)

PID parameters (Page 107)

4.3.1.3 Advanced settings

Monitoring process value

Configure a warning high and low limit for the process value in the "Process value monitoring" configuration window. If one of the warning limits is exceeded or undershot during operation, a warning will be displayed at the PID_Compact instruction:

- At the InputWarning_H output parameter if the warning high limit has been exceeded
- At the InputWarning_L output parameter if the warning low limit has been undershot

The warning limits must be within the process value high and low limits.

The process value high and low limits will be used if you do not enter values.

Example

Process value high limit = 98° C; warning high limit = 90° C

Warning low limit = 10° C; process value low limit = 0° C

PID_Compact will respond as follows:

Process value	InputWarning_H	InputWarning_L	Operating mode
> 98° C	TRUE	FALSE	Inactive
≤ 98° C and > 90° C	TRUE	FALSE	Automatic mode
≤ 90° C and ≥ 10° C	FALSE	FALSE	Automatic mode
< 10° C and ≥ 0° C	FALSE	TRUE	Automatic mode
< 0° C	FALSE	TRUE	Inactive

See also

Process value settings (Page 102)

PWM limits (Page 104)

Output value limits (Page 106)

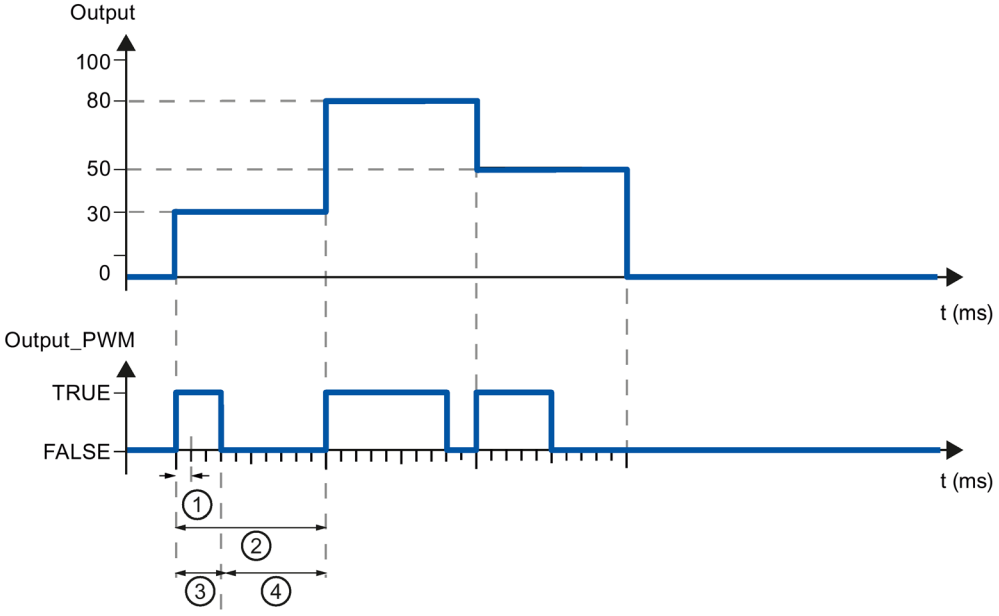
PID parameters (Page 107)

PWM limits

The value at the output parameter Output is transformed into a pulse sequence that is output at output parameter Output_PWM by means of a pulse width modulation. Output is calculated in the PID algorithm sampling time, Output_PWM is output in the PID_Compact sampling time.

The PID algorithm sampling time is determined during pretuning or fine tuning. If manually setting the PID parameters, you will also need to configure the PID algorithm sampling time. The PID_Compact sampling time is equivalent to the cycle time of the calling OB.

The pulse duration is proportional to the value at Output and is always an integer multiple of the PID_Compact sampling time.



① PID_Compact sampling time
② PID algorithm sampling time
③ Pulse duration
④ Break time

The "Minimum ON time" and the "Minimum OFF time" are rounded to an integer multiple of the PID_Compact sampling time.

A pulse or a break is never shorter than the minimum ON or OFF time. The inaccuracies this causes are added up and compensated in the next cycle.

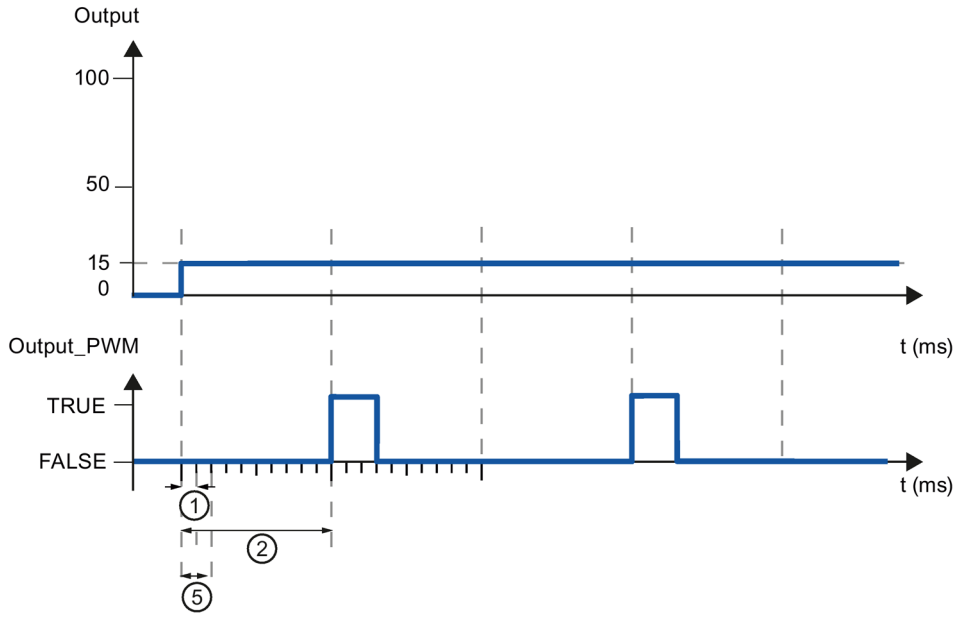
Example

PID_Compact sampling time = 100 ms

PID algorithm sampling time = 1000 ms

Minimum ON time = 200 ms

Output is a constant 15%. The smallest pulse that PID_Compact can output is 20%. In the first cycle, no pulse is output. In the second cycle, the pulse not output in the first cycle is added to the pulse of the second cycle.



① PID_Compact sampling time
② PID algorithm sampling time
⑤ Minimum ON time

In order to minimize operation frequency and conserve the actuator, extend the minimum ON and OFF times.

If you are using "Output" or "Output_PER", you must configure the value 0.0 for the minimum ON and OFF times.

Note

The minimum ON and OFF times only affect the output parameter Output_PWM and are not used for any pulse generators integrated in the CPU.

See also

Process value settings (Page 102)

Monitoring process value (Page 103)

Output value limits (Page 106)

PID parameters (Page 107)

Output value limits

In the "Output value limits" configuration window, configure the absolute limits of your output value in percent. Absolute output value limits are not violated in neither manual mode nor in automatic mode. If a output value outside the limits is specified in manual mode, the effective value is limited in the CPU to the configured limits.

The valid output value limit values depend on the Output used.

Output	-100.0 to 100.0
Output_PER	-100.0 to 100.0
Output_PWM	0.0 to 100.0

PID_Compact sets the output value to 0.0 if an error occurs. 0.0 must therefore always be within the output value limits. You will need to add an offset to Output and Output_PER in the user program if you want an output value low limit of greater than 0.0.

See also

Process value settings (Page 102)

Monitoring process value (Page 103)

PWM limits (Page 104)

PID parameters (Page 107)

PID parameters

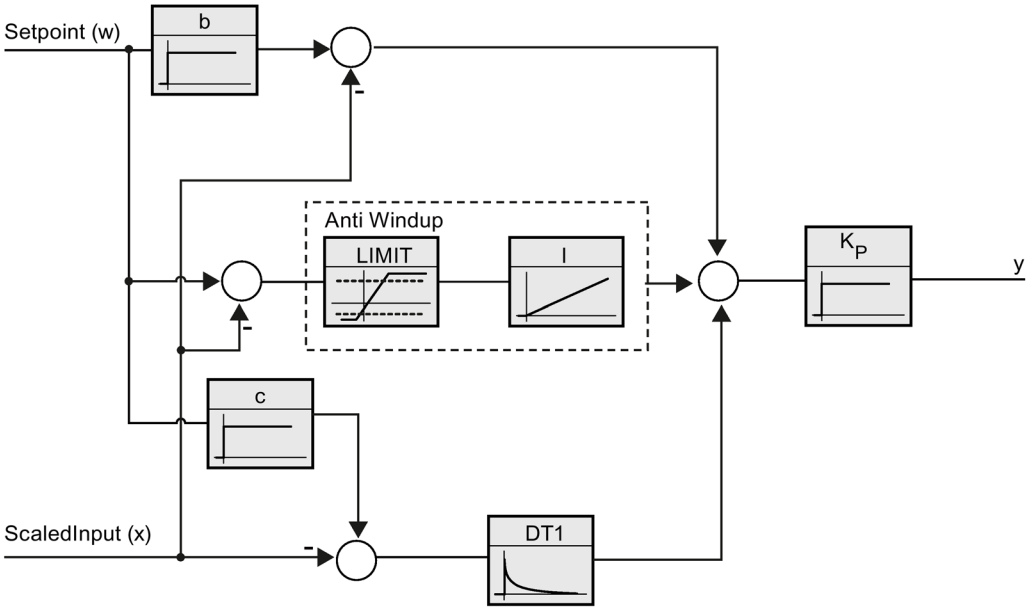
The PID parameters are displayed in the "PID Parameters" configuration window. The PID parameters will be adapted to your controlled system during controller tuning. You do not need to enter the PID parameters manually.

The PID algorithm operates according to the following equation:

$$y = K_p \left[(b \cdot w - x) + \frac{1}{T_I \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c \cdot w - x) \right]$$

Symbol	Description
y	Output value of the PID algorithm
K_p	Proportional gain
s	Laplace operator
b	Proportional action weighting
w	Setpoint
x	Process value
T_I	Integral action time
a	Derivative delay coefficient (derivative delay T1 = a × T_D)
T_D	Derivative action time
c	Derivative action weighting

The diagram below illustrates the integration of the parameters into the PID algorithm:



All PID parameters are retentive. If you enter the PID parameters manually, you must completely download PID_Compact.

Proportional gain

The value specifies the proportional gain of the controller. PID_Compact does not work with a negative proportional gain. Control logic is inverted under Basic settings > Controller type.

Integral action time

The integral action time determines the time behavior of the integral action. The integral action is deactivated with integral action time = 0.0.

Derivative action time

The derivative action time determines the time behavior of the derivative action. Derivative action is deactivated with derivative action time = 0.0.

Derivative delay coefficient

The derivative delay coefficient delays the effect of the derivative action.

Derivative delay = derivative action time × derivative delay coefficient

- 0.0: Derivative action is effective for one cycle only and therefore almost not effective.
- 0.5: This value has proved useful in practice for controlled systems with **one** dominant time constant.
- > 1.0: The greater the coefficient, the longer the effect of the derivative action is delayed.

Proportional action weighting

The proportional action may weaken with changes to the setpoint.

Values from 0.0 to 1.0 are applicable.

- 1.0: Proportional action for setpoint change is fully effective
- 0.0: Proportional action for setpoint change is not effective

The proportional action is always fully effective when the process value is changed.

Derivative action weighting

The derivative action may weaken with changes to the setpoint.

Values from 0.0 to 1.0 are applicable.

- 1.0: Derivative action is fully effective upon setpoint change
- 0.0: Derivative action is not effective upon setpoint change

The derivative action is always fully effective when the process value is changed.

PID algorithm sampling time

The controlled system needs a certain amount of time to respond to changes in the output value. It is therefore not advisable to calculate the output value in every cycle. The sampling time of the PID algorithm represents the time between two calculations of the output value. It is calculated during tuning and rounded to a multiple of the cycle time. All other functions of PID_Compact are executed at every call.

If you use Output_PWM, the accuracy of the output signal is determined by the ratio of the PID algorithm sampling time to the cycle time of the OB. The PID algorithm sampling time corresponds to the time period of the pulse width modulation. The cycle time should be at least 10 times the PID algorithm sampling time.

Rule for tuning

Select whether PI or PID parameters are to be calculated in the "Controller structure" drop-down list.

- **PID**

  Calculates PID parameters during pretuning and fine tuning.

- **PI**

  Calculates PI parameters during pretuning and fine tuning.

- **User-defined**

  The drop-down list displays "User-defined" if you have configured different controller structures for pretuning and fine tuning via a user program.

See also

Downloading technology objects to device (Page 46)

4.3.2 Commissioning PID_Compact V1

4.3.2.1 Commissioning

The commissioning window helps you commission the PID controller. You can monitor the values for the setpoint, process value and output value along the time axis in the trend view. The following functions are supported in the commissioning window:

- Controller pretuning
- Controller fine tuning

  Use fine tuning for fine adjustments to the PID parameters.
- Monitoring the current closed-loop control in the trend view
- Testing the controlled system by specifying a manual output value

All functions require an online connection to the CPU to have been established.

Basic handling

- Select the desired sampling time in the "Sampling time" drop-down list.

  All values in the commissioning window are updated in the selected update time.
- Click the "Start" icon in the measuring group if you want to use the commissioning functions.

  Value recording is started. The current values for the setpoint, process value and output value are entered in the trend view. Operation of the commissioning window is enabled.
- Click the "Stop" icon if you want to end the commissioning functions.

  The values recorded in the trend view can continue to be analyzed.

Closing the commissioning window will terminate recording in the trend view and delete the recorded values.

See also

Pretuning (Page 111)

Fine tuning (Page 113)

"Manual" mode (Page 115)

4.3.2.2 Pretuning

The pretuning determines the process response to a jump change of the output value and searches for the point of inflection. The tuned PID parameters are calculated as a function of the maximum slope and dead time of the controlled system.

The more stable the process value is, the easier it is to calculate the PID parameters and the more precise the result will be. Noise on the process value can be tolerated as long as the rate of rise of the process value is significantly higher compared to the noise. The PID parameters are backed up before being recalculated.

Requirement

- The "PID_Compact" instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- PID_Compact is in "inactive" or "manual" mode.
- The setpoint may not be changed during controller tuning. PID_Compact will otherwise be deactivated.
- The setpoint and the process value lie within the configured limits (see "Process value monitoring" configuration).
- The difference between setpoint and process value is greater than 30% of the difference between process value high limit and process value low limit.
- The distance between the setpoint and the process value is > 50% of the setpoint.

Procedure

To perform pretuning, follow these steps:

1. Double-click the "PID_Compact > Commissioning" entry in the project tree.
2. Select the entry "Pretuning" in the "Tuning mode" drop-down list.
3. Click the "Start" icon.
   - An online connection will be established.
   - Value recording is started.
   - Pretuning is started.
   - The "Status" field displays the current steps and any errors that may have occurred. The progress bar indicates the progress of the current step.

   Note

   Click the "Stop" icon when the progress bar has reached 100% and it is to be assumed the controller tuning function is blocked. Check the configuration of the technology object and, if necessary, restart controller tuning.

Result

If pretuning was performed without an error message, the PID parameters have been tuned. PID_Compact switches to automatic mode and uses the tuned parameters. The tuned PID parameters will be retained during power OFF and a restart of the CPU.

If pretuning is not possible, PID_Compact will change to "Inactive" mode.

See also

Parameters State and sRet.i_Mode V1 (Page 287)

Commissioning (Page 110)

Fine tuning (Page 113)

"Manual" mode (Page 115)

4.3.2.3 Fine tuning

Fine tuning generates a constant, limited oscillation of the process value. The PID parameters are optimized for the operating point from the amplitude and frequency of this oscillation. All PID parameters are recalculated on the basis of the findings. PID parameters from fine tuning usually have better master control and disturbance behavior than PID parameters from pretuning.

PID_Compact automatically attempts to generate an oscillation greater than the noise of the process value. Fine tuning is only minimally influenced by the stability of the process value. The PID parameters are backed up before being recalculated.

Requirement

- The PID_Compact instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- The setpoint and the process value lie within the configured limits (see "Process value monitoring" configuration).
- The control loop has stabilized at the operating point. The operating point is reached when the process value corresponds to the setpoint.
- No disturbances are expected.
- The setpoint may not be changed during controller tuning.
- PID_Compact is in inactive mode, automatic mode or manual mode.

Process depends on initial situation

Fine tuning can be started in "inactive", "automatic" or "manual" mode. Fine tuning proceeds as follows when started in:

- Automatic mode

  Start fine tuning in automatic mode if you wish to improve the existing PID parameters using controller tuning.

  PID_Comact will regulate using the existing PID parameters until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start.

- Inactive or manual mode

  If the requirements for pretuning are met, pretuning is started. The PID parameters established will be used for adjustment until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start. If pretuning is not possible, PID_Compact will change to "Inactive" mode.

  An attempt is made to reach the setpoint with a minimum or maximum output value if the process value for pretuning is already too near the setpoint. This can produce increased overshoot.

Procedure

Proceed as follows to carry out "fine tuning":

1. Select the entry "Fine tuning" in the "Tuning mode" drop-down list.
2. Click the "Start" icon.
   - An online connection will be established.
   - Value recording is started.
   - The process of fine tuning is started.
   - The "Status" field displays the current steps and any errors that may have occurred. The progress bar indicates the progress of the current step.

Note

Click the "Stop" icon in the "Tuning mode" group when the progress bar has reached 100% and it is to be assumed the controller tuning function is blocked. Check the configuration of the technology object and, if necessary, restart controller tuning.

Result

The PID parameters will have been optimized if fine tuning has been executed without errors. PID_Compact changes to automatic mode and uses the optimized parameters. The optimized PID parameters will be retained during power OFF and a restart of the CPU.

If errors occurred during "fine tuning", PID_Compact will change to "inactive" mode.

See also

Parameters State and sRet.i_Mode V1 (Page 287)

Commissioning (Page 110)

Pretuning (Page 111)

"Manual" mode (Page 115)

4.3.2.4 "Manual" mode

The following section describes how you can use the "Manual" operating mode in the commissioning window of the "PID Compact" technology object.

Requirement

- The "PID_Compact" instruction is called in a cyclic interrupt OB.
- An online connection to the CPU has been established and the CPU is in the "RUN" mode.
- The functions of the commissioning window have been enabled via the "Start" icon.

Procedure

Use "Manual mode" in the commissioning window if you want to test the process by specifying a manual value. To define a manual value, proceed as follows:

1. Select the check box "Manual mode" in the "Online status of the controller" area.

   PID_Compact operates in manual mode. The most recent current output value remains in effect.
2. Enter the manual value in the "Output" field as a % value.
3. Click the control icon .

Result

The manual value is written to the CPU and immediately goes into effect.

Note

PID_Compact continues to monitor the process value. If the process value limits are exceeded, PID_Compact is deactivated.

Clear the "Manual mode" check box if the output value is to be specified again by the PID controller. The change to automatic mode is bumpless.

See also

Parameters State and sRet.i_Mode V1 (Page 287)

Commissioning (Page 110)

Pretuning (Page 111)

Fine tuning (Page 113)

Using PID_3Step

5

5.1 Technology object PID_3Step

The technology object PID_3Step provides a PID controller with tuning for valves or actuators with integral response.

You can configure the following controllers:

- Three-point step controller with position feedback
- Three-point step controller without position feedback
- Valve controller with analog output value

PID_3Step continuously acquires the measured process value within a control loop and compares it with the setpoint. From the resulting control deviation, PID_3Step calculates an output value through which the process value reaches the setpoint as quickly and steadily as possible. The output value for the PID controller consists of three actions:

- **P** action

  The proportional action of the output value increases in proportion to the control deviation.

- **I** action

  The integral action of the output value increases until the control deviation has been balanced.

- **D** action

  The derivative action increases with the rate of change of control deviation. The process value is corrected to the setpoint as quickly as possible. The derivative action will be reduced again if the rate of change of control deviation drops.

The instruction PID_3Step calculates the proportional, integral and derivative parameters for your controlled system during pretuning. Fine tuning can be used to tune the parameters further. You do not need to manually determine the parameters.

Additional information

- Overview of software controller (Page 39)
- Add technology objects (Page 42)
- Configure technology objects (Page 43)
- Configuring PID_3Step V2 (Page 118)
- Configuring PID_3Step V1 (Page 139)

5.2 PID_3Step V2

5.2.1 Configuring PID_3Step V2

5.2.1.1 Basic settings

Introduction

Configure the following properties of the "PID_3Step" technology object under "Basic settings" in the Inspector window or in the configuration window:

- Physical quantity
- Control logic
- Start-up behavior after reset
- Setpoint (only in the Inspector window)
- Process value (only in the Inspector window)
- Output value (only in the Inspector window)
- Position feedback (only in the Inspector window)

Setpoint, process value, output value and position feedback

You can only configure the setpoint, process value, output value and position feedback in the Inspector window of the programming editor. Select the source for each value:

- Instance DB

  The value saved in the instance DB is used.

  Value must be updated in the instance DB by the user program.

  There should be no value at the instruction.

  Change via HMI possible.

- Instruction

  The value connected to the instruction is used.
  The value is written to the instance DB each time the instruction is called.

  No change via HMI possible.

Controller type

Physical quantity

Select the physical quantity and unit of measurement for setpoint, process value, and disturbance variable in the "Controller type" group. Setpoint, process value, and disturbance variable is displayed in this unit of measurement.

Control logic

An increase of the output value is generally intended to cause an increase in the process value. This is referred to as a normal control logic.

PID_3Step does not work with negative proportional gain. Select the check box "Invert control logic" to reduce the process value with a higher output value.

Examples

- Opening the drain valve will reduce the level of a container's contents.
- Increasing cooling will reduce the temperature.

Startup characteristics

1. To switch to "Inactive" mode after CPU restart, clear the "Activate Mode after CPU restart" check box.

   To switch to the operating mode saved in the Mode parameter after CPU restart, select the "Activate Mode after CPU restart" check box.

2. In the "Set Mode to" drop-down list, select the mode that is to be enabled after a complete download to the device.

   After a complete download to the device, PID_3Step starts in the selected operating mode. With each additional restart, PID_3Step starts in the mode that was last saved in Mode.

Example

You have selected the "Activate Mode after CPU restart" check box and the entry "Pretuning" in the "Set Mode to" list. After a complete download to the device, PID_3Step starts in the "Pretuning" mode. If pretuning is still active, PID_3Step starts in "Pretuning" mode again after restart of the CPU. If pretuning was successfully completed and automatic mode is active, PID_3Step starts in "Automatic mode" after restart of the CPU.

Setpoint

Procedure

Proceed as follows to define a fixed setpoint:

1. Select "Instance DB".
2. Enter a setpoint, e.g. 80° C.
3. Delete any entry in the instruction.

Proceed as follows to define a variable setpoint:

1. Select "Instruction".
2. Enter the name of the REAL variable in which the setpoint is saved.

   Program-controlled assignment of various values to the REAL variable is possible, for example for the time controlled change of the setpoint.

Process value

PID_3Step will scale the value of the analog input to the physical quantity if you use the analog input value directly.

You will need to write a program for processing if you wish first to process the analog input value. The process value is, for example, not directly proportional to the value at the analog input. The processed process value must be in floating point format.

Procedure

Proceed as follows to use the analog input value without processing:

1. Select the entry "Input_PER" in the drop-down list "Input".
2. Select "Instruction" as source.
3. Enter the address of the analog input.

Proceed as follows to use the processed process value in floating point format:

1. Select the entry "Input" in the drop-down list "Input".
2. Select "Instruction" as source.
3. Enter the name of the variable in which the processed process value is saved.

Position feedback

Position feedback configuration depends upon the actuator used.

- Actuator without position feedback
- Actuator with digital endstop signals
- Actuator with analog position feedback
- Actuator with analog position feedback and endstop signals

Actuator without position feedback

Proceed as follows to configure PID_3Step for an actuator without position feedback:

1. Select the entry "No Feedback" in the drop-down list "Feedback".

Actuator with digital endstop signals

Proceed as follows to configure PID_3Step for an actuator with endstop signals:

1. Select the entry "No Feedback" in the drop-down list "Feedback".
2. Activate the "Actuator endstop signals" check box.
3. Select "Instruction" as source for Actuator_H and Actuator_L.
4. Enter the addresses of the digital inputs for Actuator_H and Actuator_L.

Actuator with analog position feedback

Proceed as follows to configure PID_3Step for an actuator with analog position feedback:

1. Select the entry "Feedback" or "Feedback_PER" in the drop-down list "Feedback".
   - Use the analog input value for Feedback_PER. Configure Feedback_PER scaling in the actuator settings.
   - Process the analog input value for Feedback using your user program.
2. Select "Instruction" as source.
3. Enter the address of the analog input or the variable of your user program.

Actuator with analog position feedback and endstop signals

Proceed as follows to configure PID_3Step for an actuator with analog position feedback and endstop signals:

1. Select the entry "Feedback" or "Feedback_PER" in the drop-down list "Feedback".
2. Select "Instruction" as source.
3. Enter the address of the analog input or the variable of your user program.
4. Activate the "Actuator endstop signals" check box.
5. Select "Instruction" as source for Actuator_H and Actuator_L.
6. Enter the addresses of the digital inputs for Actuator_H and Actuator_L.

Output value

PID_3Step offers an analog output value (Output_PER) and digital output values (Output_UP, Output_DN). Your actuator will determine which output value you use.

- Output_PER

  The actuator is triggered via an analog output and controlled with a continuous signal, e.g. 0...10V, 4...20mA.

- Output_UP, Output_DN

  The actuator is controlled via two digital outputs.

Procedure

Proceed as follows to use the analog output value:

1. Select the entry "Output (analog)" in the drop-down list "Output".
2. Select "Instruction".
3. Enter the address of the analog output.

Proceed as follows to use the digital output value:

1. Select the entry "Output (digital)" in the drop-down list "Output".
2. Select "Instruction" for Output_UP and Output_DN.
3. Enter the addresses of the digital outputs.

Proceed as follows to process the output value using the user program:

1. Select the entry corresponding to the actuator in the drop-down list "Output".
2. Select "Instruction".
3. Enter the name of the variable you are using to process the output value.
4. Transfer the processed output value to the actuator by means of an analog or digital CPU output.

5.2.1.2 Process value settings

Scaling the process value

If you have configured the use of Input_PER in the basic setting, you must convert the value of the analog input to the physical quantity of the process value. The current configuration is displayed in the Input_PER display.

Input_PER will be scaled using a low and high value pair if the process value is directly proportional to the value of the analog input.

Procedure

To scale the process value, follow these steps:

1. Enter the low pair of values in the "Scaled low process value" and "Low" text boxs.
2. Enter the high pair of values in the "Scaled high process value" and "High" input boxes.

Default settings for the value pairs are stored in the hardware configuration. To use the value pairs from the hardware configuration, follow these steps:

1. Select the PID_3Step instruction in the programming editor.
2. Interconnect Input_PER with an analog input in the basic settings.
3. Click the "Automatic setting" button in the process value settings.

The existing values will be overwritten with the values from the hardware configuration.

Process value limits

You must specify an appropriate absolute high limit and low limit for the process value as limit values for your controlled system. As soon as the process value violates these limits, an error occurs (ErrorBits = 0001h). Tuning is canceled when the process value limits are violated. You can specify how PID_3Step responds to errors in automatic mode in the actuator settings.

5.2.1.3 Actuator settings

Actuator

Actuator-specific times

Configure the motor transition time and the minimum ON and OFF times to prevent damage to the actuator. You can find the specifications in the actuator data sheet.

The motor transition time is the time in seconds the motor requires to move the actuator from the closed to the opened state. You can measure the motor transition time during commissioning.

The motor transition time is retentive. If you enter the motor transition time manually, you must completely download PID_3Step.

Downloading technology objects to device (Page 46)

If you are using "Output_UP" or "Output_DN", you can reduce the switching frequency with the minimum on and minimum OFF time.

The on or off times calculated are totaled in automatic mode and only become effective when the sum is greater than or equal to the minimum on or OFF time.

Manual_UP = TRUE or Manual_DN = TRUE in manual mode operates the actuator for at least the minimum ON or OFF time.

Reaction to error

PID_3Step is preset so that the controller stays active in most cases in the event of an error. If errors occur frequently in controller mode, this default reaction has a negative effect on the control response. In this case, check the Errorbits parameter and eliminate the cause of the error.

NOTICE
Your system may be damaged. If you output "Current value while error pending" or "Substitute output value while error pending" in the event of an error, PID_3Step remains in automatic mode even if the process value limits are violated. This may damage your system. It is essential to configure how your controlled system reacts in the event of an error to protect your system from damage.

PID_3Step generates a programmable output value in response to an error:

- Current value

  PID_3Step is switched off and no longer modifies the actuator position.

- Current value for error while error is pending

  The controller functions of PID_3Step are switched off and the position of the actuator is no longer changed.

  If the following errors occur in automatic mode, PID_3Step returns to automatic mode as soon as the errors are no longer pending.

  – 0002h: Invalid value at Input_PER parameter.

  – 0200h: Invalid value at Input parameter.

  – 0400h: Calculation of output value failed.

  – 1000h: Invalid value at Setpoint parameter.

  – 2000h: Invalid value at Feedback_PER parameter.

  – 4000h: Invalid value at Feedback parameter.

  – 8000h: Error during digital position feedback.

  – 20000h: Invalid value at SavePosition tag.

  If one or more of the following errors occur, PID_3Step stays in automatic mode:

  – 0001h: The Input parameter is outside the process value limits.

  – 0800h: Sampling time error

  – 40000h: Invalid value at Disturbance parameter.

  PID_3Step remains in manual mode if an error occurs in manual mode.

  If an error occurs during tuning or transition time measurement, PID_3Step switches to the mode in which tuning or transition time measurement was started. Only in the event of the following error is tuning not aborted:

  – 0020h: Pretuning is not permitted during fine tuning.

- Substitute output value

  PID_3Step moves the actuator to the substitute output value and then switches off.

- Substitute output value while error is pending

  PID_3Step moves the actuator to the substitute output value. When the substitute output value is reached, PID_3Step reacts as it does with "Current value for while error is pending".

Enter the substitute output value in "%".

Only substitute output values 0% and 100% can be approached precisely in the case of actuators without analog position feedback. A substitute output value not equal to 0% or 100% is approached via an internally simulated position feedback. This procedure does not, however, allow the exact approach of substitute output value.

All substitute output values can be approached precisely with actuators with analog position feedback.

Scaling position feedback

Scaling position feedback

If you have configured the use of Feedback_PER in the basic settings, you will need to convert the value of the analog input into %. The current configuration will be displayed in the "Feedback" display.

Feedback_PER is scaled using a low and high value pair.

1. Enter the low pair of values in the "Low endstop" and "Low" input boxes.
2. Enter the high pair of values in the "High endstop" and "High" input boxes.

"Low endstop" must be less than "High endstop"; "Low" must be less than "High".

The valid values for "High endstop" and "Low endstop" depend upon:

- No Feedback, Feedback, Feedback_PER
- Output (analog), Output (digital)

Output	Feedback	Low endstop	High endstop
Output (digital)	No Feedback	Cannot be set (0.0%)	Cannot be set (100.0%)
Output (digital)	Feedback	-100.0% or 0.0%	0.0% or +100.0%
Output (digital)	Feedback_PER	-100.0% or 0.0%	0.0% or +100.0%
Output (analog)	No Feedback	Cannot be set (0.0%)	Cannot be set (100.0%)
Output (analog)	Feedback	-100.0% or 0.0%	0.0% or +100.0%
Output (analog)	Feedback_PER	-100.0% or 0.0%	0.0% or +100.0%

Output value limits

Limiting the output value

You can exceed or undershoot the output value limits during the transition time measurement and with mode = 10. The output value is limited to these values in all other modes.

Enter the absolute output value limits in the "Output value high limit" and "Output value low limit" input boxes. The output value limits must be within "Low endstop" and "High endstop".

If no Feedback is available and Output (digital) is set, you cannot limit the output value. Output_UP and Output_DN are then reset upon Actuator_H = TRUE or Actuator_L = TRUE. If no endstop signals are available, Output_UP and Output_DN are reset after a travel time of 150% of the motor actuating time.

5.2.1.4 Advanced settings

Monitoring process value

Configure a warning high and low limit for the process value in the "Process value monitoring" configuration window. If one of the warning limits is exceeded or undershot during operation, a warning will be displayed at the PID_3Step instruction:

- At the InputWarning_H output parameter if the warning high limit has been exceeded
- At the InputWarning_L output parameter if the warning low limit has been undershot

The warning limits must be within the process value high and low limits.

The process value high and low limits will be used if you do not enter values.

Example

Process value high limit = 98° C; warning high limit = 90° C

Warning low limit = 10° C; process value low limit = 0° C

PID_3Step will respond as follows:

Process value	InputWarning_H	InputWarning_L	Error-Bits	Operating mode
> 98° C	TRUE	FALSE	0001h	As configured
≤ 98° C and > 90° C	TRUE	FALSE	0000h	Automatic mode
≤ 90° C and ≥ 10° C	FALSE	FALSE	0000h	Automatic mode
< 10° C and ≥ 0° C	FALSE	TRUE	0000h	Automatic mode
< 0° C	FALSE	TRUE	0001h	As configured

In the actuator settings, you can configure the response of PID_3Step when the process value high limit or low limit is violated.

PID parameters

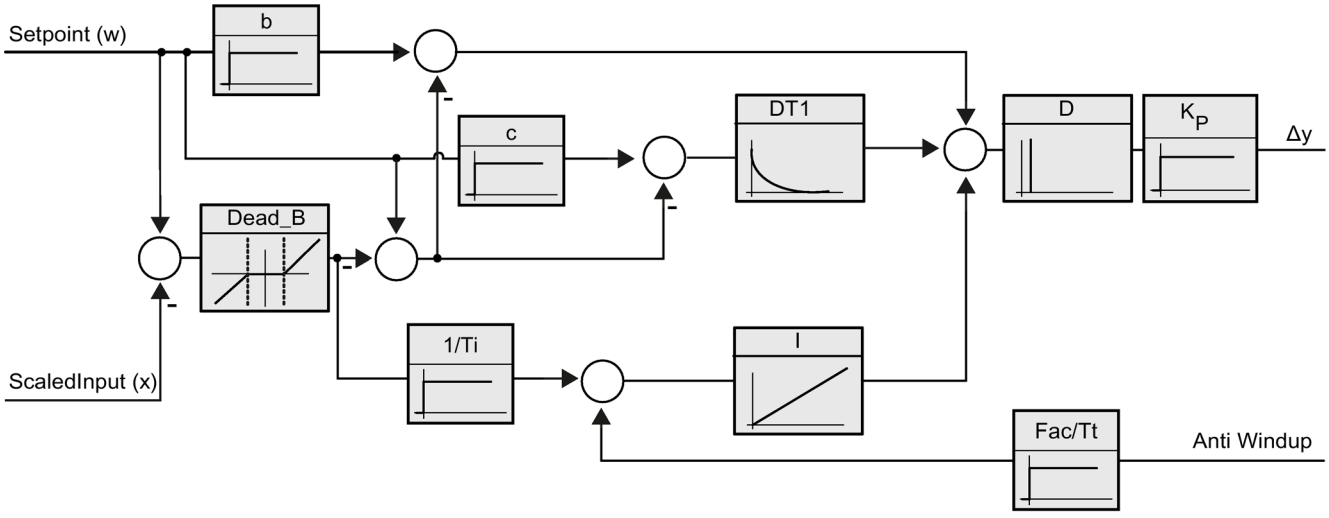
The PID parameters are displayed in the "PID Parameters" configuration window. The PID parameters will be adapted to your controlled system during controller tuning. You do not need to enter the PID parameters manually.

The PID algorithm operates according to the following equation:

$$\Delta y = K_p \cdot s \cdot \left[(b \cdot w - x) + \frac{1}{T_I \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c \cdot w - x) \right]$$

Symbol	Description
Δy	Output value of the PID algorithm
K_p	Proportional gain
s	Laplace operator
b	Proportional action weighting
w	Setpoint
x	Process value
T_I	Integral action time
a	Derivative delay coefficient (derivative delay T1 = a × T_D)
T_D	Derivative action time
c	Derivative action weighting

The diagram below illustrates the integration of the parameters into the PID algorithm:



All PID parameters are retentive. If you enter the PID parameters manually, you must completely download PID_3Step.

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Proportional gain

The value specifies the proportional gain of the controller. PID_3Step does not work with a negative proportional gain. Control logic is inverted under Basic settings > Controller type.

Integral action time

The integral action time determines the time behavior of the integral action. The integral action is deactivated with integral action time = 0.0.

Derivative action time

The derivative action time determines the time behavior of the derivative action. Derivative action is deactivated with derivative action time = 0.0.

Derivative delay coefficient

The derivative delay coefficient delays the effect of the derivative action.

Derivative delay = derivative action time × derivative delay coefficient

- 0.0: Derivative action is effective for one cycle only and therefore almost not effective.
- 0.5: This value has proved useful in practice for controlled systems with **one** dominant time constant.
- > 1.0: The greater the coefficient, the longer the effect of the derivative action is delayed.

Proportional action weighting

The proportional action may weaken with changes to the setpoint.

Values from 0.0 to 1.0 are applicable.

- 1.0: Proportional action for setpoint change is fully effective
- 0.0: Proportional action for setpoint change is not effective

The proportional action is always fully effective when the process value is changed.

Derivative action weighting

The derivative action may weaken with changes to the setpoint.

Values from 0.0 to 1.0 are applicable.

- 1.0: Derivative action is fully effective upon setpoint change
- 0.0: Derivative action is not effective upon setpoint change

The derivative action is always fully effective when the process value is changed.

PID algorithm sampling time

The controlled system needs a certain amount of time to respond to changes in the output value. It is therefore not advisable to calculate the output value in every cycle. The sampling time of the PID algorithm represents the time between two calculations of the output value. It is calculated during tuning and rounded to a multiple of the PID_3Step sampling time. All other functions of PID_3Step are executed at every call.

Deadband width

The deadband suppresses the noise component in the steady controller state. The deadband width specifies the size of the deadband. The deadband is off if the deadband width is 0.0.

5.2.2 Commissioning PID_3Step V2

5.2.2.1 Pretuning

The pretuning determines the process response to a pulse of the output value and searches for the point of inflection. The tuned PID parameters are calculated as a function of the maximum slope and dead time of the controlled system. You obtain the best PID parameters when you perform pretuning and fine tuning.

The more stable the process value is, the easier it is to calculate the PID parameters and the more precise the result will be. Noise on the process value can be tolerated as long as the rate of rise of the process value is significantly higher compared to the noise. This is most likely the case in operating modes "Inactive" and "manual mode". The PID parameters are backed up before being recalculated.

The setpoint is frozen during pretuning.

Requirement

- The PID_3Step instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- Reset = FALSE
- The motor transition time has been configured or measured.
- PID_3Step is in one of the following modes: "Inactive", "Manual mode", or "Automatic mode".
- The setpoint and the process value lie within the configured limits (see "Process value settings" configuration).

Procedure

To perform pretuning, follow these steps:

1. Double-click the "PID_3Step > Commissioning" entry in the project tree.
2. Select the entry "Pretuning" in the "Tuning mode" drop-down list in the working area "Tuning".
3. Click the "Start" icon.
   - An online connection will be established.
   - Value recording is started.
   - Pretuning is started.
   - The "Status" field displays the current steps and any errors that may have occurred. The progress bar indicates the progress of the current step.

Note

Click the "Stop" icon when the progress bar has reached 100% and it is to be assumed the controller tuning function is blocked. Check the configuration of the technology object and, if necessary, restart controller tuning.

Result

If pretuning was performed without an error message, the PID parameters have been tuned. PID_3Step switches to automatic mode and uses the tuned parameters. The tuned PID parameters will be retained during power OFF and a restart of the CPU.

If pretuning is not possible, PID_3Step responds with the configured reaction to errors.

5.2.2.2 Fine tuning

Fine tuning generates a constant, limited oscillation of the process value. The PID parameters are tuned for the operating point from the amplitude and frequency of this oscillation. All PID parameters are recalculated from the results. PID parameters from fine tuning usually have better master control and disturbance characteristics than PID parameters from pretuning. You obtain the best PID parameters when you perform pretuning and fine tuning.

PID_3Step automatically attempts to generate an oscillation greater than the noise of the process value. Fine tuning is only minimally influenced by the stability of the process value. The PID parameters are backed up before being recalculated.

The setpoint is frozen during fine tuning.

Requirement

- The PID_3Step instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- Reset = FALSE
- The motor transition time has been configured or measured.
- The setpoint and the process value lie within the configured limits (see "Process value settings" configuration).
- The control loop has stabilized at the operating point. The operating point is reached when the process value corresponds to the setpoint.
- No disturbances are expected.
- PID_3Step is in inactive mode, automatic mode or manual mode.

Process depends on initial situation

Fine tuning proceeds as follows when started from:

- Automatic mode

  Start fine tuning from automatic mode if you wish to improve the existing PID parameters through tuning.

  PID_3Step controls the system using the existing PID parameters until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start.

- Inactive or manual mode

  Pretuning is always started first. The determined PID parameters will be used for control until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start.

Procedure

To perform fine tuning, follow these steps:

1. Select the entry "Fine tuning" in the "Tuning mode" drop-down list.
2. Click the "Start" icon.
   - An online connection will be established.
   - Value recording is started.
   - The process of fine tuning is started.
   - The "Status" field displays the current steps and any errors that may have occurred. The progress bar indicates the progress of the current step.

Note

Click the "Stop" icon in the "Tuning mode" group when the progress bar has reached 100% and it is to be assumed the controller tuning function is blocked. Check the configuration of the technology object and, if necessary, restart controller tuning.

Result

If no errors occurred during fine tuning, the PID parameters have been tuned. PID_3Step switches to automatic mode and uses the tuned parameters. The tuned PID parameters will be retained during power OFF and a restart of the CPU.

If errors occurred during fine tuning, PID_3Step responds with the configured response to errors.

5.2.2.3 Commissioning with manual PID parameters

Requirement

- The PID_3Step instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- Reset = FALSE
- The motor transition time has been configured or measured.
- PID_3Step is in "inactive" mode.
- The setpoint and the process value lie within the configured limits (see "Process value settings" configuration).

Procedure

Proceed as follows to commission PID_3Step with manual PID parameters:

1. Double-click on "PID_3Step > Configuration" in the project tree.
2. Click on "Advanced settings > PID Parameters" in the configuration window.
3. Select the check box "Enable direct input".
4. Enter the PID parameters.
5. Double-click the "PID_3Step > Commissioning" entry in the project tree.
6. Establish an online connection to the CPU.
7. Load the PID parameters to the CPU.
8. Click the "Start PID_3Step" icon.

Result

PID_3Step changes to automatic mode and controls using the current PID parameters.

See also

PID parameters (Page 128)

5.2.2.4 Measuring the motor transition time

Introduction

PID_3Step requires the motor transition time to be as accurate as possible for good controller results. The data in the actuator documentation contains average values for this type of actuator. The value for the specific actuator used may differ.

You can measure the motor transition time during commissioning if you are using actuators with position feedback or endstop signals. The output value limits are not taken into consideration during the motor transition time measurement. The actuator can travel to the high or the low endstop.

The motor transition time cannot be measured if neither position feedback nor endstop signals are available.

Actuators with analog position feedback

Proceed as follows to measure motor transition time with position feedback:

Requirement

- Feedback or Feedback_PER has been selected in the basic settings and the signal has been connected.
- An online connection to the CPU has been established.

1. Select the "Use position feedback" check box.
2. Enter the position to which the actuator is to be moved in the "Target position" input field.

   The current position feedback (starting position) will be displayed. The difference between "Target position" and "Position feedback" must be at least 50% of the valid output value range.
3. Click the "Start" icon.

Result

The actuator is moved from the starting position to the target position. Time measurement starts immediately and ends when the actuator reaches the target position. The motor transition time is calculated according to the following equation:

Motor transition time = (output value high limit – output value low limit) × Measuring time / AMOUNT (target position – starting position).

The progress and status of transition time measurement are displayed. The transition time measured is saved in the instance data block on the CPU and displayed in the "Measured transition time" field. When the transition time measurement is ended and ActivateRecoverMode = TRUE, PID_3Step switches to the operating mode from which the transition time measurement was started. If the transition time measurement is ended and ActivateRecoverMode = FALSE, PID_3Step changes to "Inactive" mode.

Note

Click on the icon  "Upload measured transition time" to load the motor transition time measured to the project.

Actuators with endstop signals

Proceed as follows to measure the transition time of actuators with endstop signals:

Requirement

- The "Endstop signals" check box in the basic settings has been selected and Actuator_H and Actuator_L are connected.
- An online connection to the CPU has been established.

Proceed as follows to measure motor transition time with endstop signals:

1. Select the "Use actuator endstop signals" check box.
2. Select the direction in which the actuator is to be moved.
   - Open - Close - Open

     The actuator is moved first to the high endstop, then to the low endstop and then back to the high endstop.
   - Close - Open - Close

     The actuator is moved first to the low endstop, then to the high endstop and then back to the low endstop.
3. Click the "Start" icon.

Result

The actuator is moved in the selected direction. Time measurement will start once the actuator has reached the first endstop and will end when the actuator reaches this endstop for the second time. The motor transition time is equal to the time measured divided by two.

The progress and status of transition time measurement are displayed. The transition time measured is saved in the instance data block on the CPU and displayed in the "Measured transition time" field. When the transition time measurement is ended and ActivateRecoverMode = TRUE, PID_3Step switches to the operating mode from which the transition time measurement was started. If the transition time measurement is ended and ActivateRecoverMode = FALSE, PID_3Step changes to "Inactive" mode.

Cancelling transition time measurement

PID_3Step switches to "Inactive" mode if you cancel transition time measurement by pressing the Stop button.

5.3 PID_3Step V1

5.3.1 Configuring PID_3Step V1

5.3.1.1 Basic settings

Introduction

Configure the following properties of the "PID_3Step" technology object under "Basic settings" in the Inspector window or in the configuration window:

- Physical quantity
- Control logic
- Start-up behavior after reset
- Setpoint (only in the Inspector window)
- Process value (only in the Inspector window)
- Output value (only in the Inspector window)
- Position feedback (only in the Inspector window)

Setpoint, process value, output value and position feedback

You can only configure the setpoint, process value, output value and position feedback in the Inspector window of the programming editor. Select the source for each value:

- Instance DB

  The value saved in the instance DB is used.

  Value must be updated in the instance DB by the user program.

  There should be no value at the instruction.

  Change via HMI possible.

- Instruction

  The value connected to the instruction is used.
  The value is written to the instance DB each time the instruction is called.

  No change via HMI possible.

Controller type

Physical quantity

Select the unit of measurement and physical quantity for the setpoint and process value in the "Controller type" group. The setpoint and process value will be displayed in this unit.

Control logic

An increase of the output value is generally intended to cause an increase in the process value. This is referred to as a normal control logic.

PID_3Step does not work with negative proportional gain. Select the check box "Invert control logic" to reduce the process value with a higher output value.

Examples

- Opening the drain valve will reduce the level of a container's contents.
- Increasing cooling will reduce the temperature.

Start-up behavior after reset

To change straight to the last active mode after restarting the CPU, select the "Enable last mode after CPU restart" check box.

PID_3Step will remain in "Inactive" mode if the check box is cleared.

Setpoint

Procedure

Proceed as follows to define a fixed setpoint:

1. Select "Instance DB".
2. Enter a setpoint, e.g. 80° C.
3. Delete any entry in the instruction.

Proceed as follows to define a variable setpoint:

1. Select "Instruction".
2. Enter the name of the REAL variable in which the setpoint is saved.

   Program-controlled assignment of various values to the REAL variable is possible, for example for the time controlled change of the setpoint.

Process value

PID_3Step will scale the value of the analog input to the physical quantity if you use the analog input value directly.

You will need to write a program for processing if you wish first to process the analog input value. The process value is, for example, not directly proportional to the value at the analog input. The processed process value must be in floating point format.

Procedure

Proceed as follows to use the analog input value without processing:

1. Select the entry "Input_PER" in the drop-down list "Input".
2. Select "Instruction" as source.
3. Enter the address of the analog input.

Proceed as follows to use the processed process value in floating point format:

1. Select the entry "Input" in the drop-down list "Input".
2. Select "Instruction" as source.
3. Enter the name of the variable in which the processed process value is saved.

Position feedback

Position feedback configuration depends upon the actuator used.

- Actuator without position feedback
- Actuator with digital endstop signals
- Actuator with analog position feedback
- Actuator with analog position feedback and endstop signals

Actuator without position feedback

Proceed as follows to configure PID_3Step for an actuator without position feedback:

1. Select the entry "No Feedback" in the drop-down list "Feedback".

Actuator with digital endstop signals

Proceed as follows to configure PID_3Step for an actuator with endstop signals:

1. Select the entry "No Feedback" in the drop-down list "Feedback".
2. Activate the "Actuator endstop signals" check box.
3. Select "Instruction" as source for Actuator_H and Actuator_L.
4. Enter the addresses of the digital inputs for Actuator_H and Actuator_L.

Actuator with analog position feedback

Proceed as follows to configure PID_3Step for an actuator with analog position feedback:

1. Select the entry "Feedback" or "Feedback_PER" in the drop-down list "Feedback".
   - Use the analog input value for Feedback_PER. Configure Feedback_PER scaling in the actuator settings.
   - Process the analog input value for Feedback using your user program.
2. Select "Instruction" as source.
3. Enter the address of the analog input or the variable of your user program.

Actuator with analog position feedback and endstop signals

Proceed as follows to configure PID_3Step for an actuator with analog position feedback and endstop signals:

1. Select the entry "Feedback" or "Feedback_PER" in the drop-down list "Feedback".
2. Select "Instruction" as source.
3. Enter the address of the analog input or the variable of your user program.
4. Activate the "Actuator endstop signals" check box.
5. Select "Instruction" as source for Actuator_H and Actuator_L.
6. Enter the addresses of the digital inputs for Actuator_H and Actuator_L.

Output value

PID_3Step offers an analog output value (Output_PER) and digital output values (Output_UP, Output_DN). Your actuator will determine which output value you use.

- Output_PER

  The actuator is triggered via an analog output and controlled with a continuous signal, e.g. 0...10V, 4...20mA.

- Output_UP, Output_DN

  The actuator is controlled via two digital outputs.

Procedure

Proceed as follows to use the analog output value:

1. Select the entry "Output (analog)" in the drop-down list "Output".
2. Select "Instruction".
3. Enter the address of the analog output.

Proceed as follows to use the digital output value:

1. Select the entry "Output (digital)" in the drop-down list "Output".
2. Select "Instruction" for Output_UP and Output_DN.
3. Enter the addresses of the digital outputs.

Proceed as follows to process the output value using the user program:

1. Select the entry corresponding to the actuator in the drop-down list "Output".
2. Select "Instruction".
3. Enter the name of the variable you are using to process the output value.
4. Transfer the processed output value to the actuator by means of an analog or digital CPU output.

5.3.1.2 Process value settings

Configure the scaling of your process value and specify the process value absolute limits In the "Process value settings" configuration window.

Scaling the process value

If you have configured the use of Input_PER in the basic settings, you will need to convert the value of the analog input into the physical quantity of the process value. The current configuration will be displayed in the Input_PER display.

Input_PER will be scaled using a low and high value pair if the process value is directly proportional to the value of the analog input.

1. Enter the low pair of values in the "Scaled low process value" and "Low" input fields.
2. Enter the high pair of values in the "Scaled high process value" and "High" input boxes.

Default settings for the value pairs are saved in the hardware configuration. Proceed as follows to use the value pairs from the hardware configuration:

1. Select the instruction PID_3Step in the programming editor.
2. Connect Input_PER to an analog input in the basic settings.
3. Click on the "Automatic setting" button in the process value settings.

   The existing values will be overwritten with the values from the hardware configuration.

Monitoring process value

Specify the absolute high and low limit of the process value. You must enter reasonable limits for your controlled system. Reasonable limits are important during optimization to obtain optimal PID parameters. The default for the "High limit process value" is 120 %. At the I/O input, the process value can be a maximum of 18% higher than the standard range (overrange). This setting ensures that an error is no longer signaled due to a violation of the "Process value high limit". Only a wire-break and a short-circuit are recognized and PID_3Step reacts according to the configured reaction to error.

NOTICE
Your system may be damaged.
If you set very high process value limits (for example $-3.4*10^{38}...+3.4*10^{38}$), process value monitoring will be disabled. Your system may then be damaged if an error occurs. You need to configure useful process value limits for your controlled system.

5.3.1.3 Actuator settings

Actuator-specific times

Configure the motor transition time and the minimum ON and OFF times to prevent damage to the actuator. You can find the specifications in the actuator data sheet.

The motor transition time is the time in seconds the motor requires to move the actuator from the closed to the opened state. The maximum time that the actuator is moved in one direction is 110% of the motor transition time. You can measure the motor transition time during commissioning.

If you are using "Output_UP" or "Output_DN", you can reduce the switching frequency with the minimum on and minimum OFF time.

The on or off times calculated are totaled in automatic mode and only become effective when the sum is greater than or equal to the minimum on or OFF time.

A rising edge at Manual_UP or Manual_DN in manual mode will operate the actuator for at least the minimum on or OFF time.

Reaction to error

PID_3Step is preset so that the controller stays active in most cases in the event of an error. If errors occur frequently in controller mode, this default reaction has a negative effect on the control response. In this case, check the Errorbits parameter and eliminate the cause of the error.

PID_3Step generates a programmable output value in response to an error:

- Current value

  PID_3Step is switched off and no longer modifies the actuator position.

- Current value for error while error is pending

  The controller functions of PID_3Step are switched off and the position of the actuator is no longer changed.

  If the following errors occur in automatic mode, PID_3Step returns to automatic mode as soon as the errors are no longer pending.

  – 0002h: Invalid value at Input_PER parameter.
  – 0200h: Invalid value at Input parameter.
  – 0800h: Sampling time error
  – 1000h: Invalid value at Setpoint parameter.
  – 2000h: Invalid value at Feedback_PER parameter.
  – 4000h: Invalid value at Feedback parameter.
  – 8000h: Error during digital position feedback.

  If one of these error occurs in manual mode, PID_3Step remains in manual mode.

  If an error occurs during the tuning or transition time measurement, PID_3Step is switched off.

- Substitute output value

  PID_3Step moves the actuator to the substitute output value and then switches off.

- Substitute output value while error is pending

  PID_3Step moves the actuator to the substitute output value. When the substitute output value is reached, PID_3Step reacts as it does with "Current value for while error is pending".

Enter the substitute output value in "%".

Only substitute output values 0% and 100% can be approached precisely in the case of actuators without analog position feedback. The actuator is moved in one direction at 110% of the motor transition time to ensure the high or low endstop is reached. There endstop signals take priority. A substitute output value not equal to 0% or 100% is approached via an internally simulated position feedback. This procedure does not, however, allow the exact approach of substitute output value.

All substitute output values can be approached precisely with actuators with analog position feedback.

Scaling position feedback

If you have configured the use of Feedback_PER in the basic settings, you will need to convert the value of the analog input into %. The current configuration will be displayed in the "Feedback" display.

Feedback_PER is scaled using a low and high value pair.

1. Enter the low pair of values in the "Low endstop" and "Low" input boxes.
2. Enter the high pair of values in the "High endstop" and "High" input boxes.

"Low endstop" must be less than "High endstop"; "Low" must be less than "High".

The valid values for "High endstop" and "Low endstop" depend upon:

- No Feedback, Feedback, Feedback_PER
- Output (analog), Output (digital)

Output	Feedback	Low endstop	High endstop
Output (digital)	No Feedback	Cannot be set (0.0%)	Cannot be set (100.0%)
Output (digital)	Feedback	-100.0% or 0.0%	0.0% or +100.0%
Output (digital)	Feedback_PER	-100.0% or 0.0%	0.0% or +100.0%
Output (analog)	No Feedback	Cannot be set (0.0%)	Cannot be set (100.0%)
Output (analog)	Feedback	-100.0% or 0.0%	0.0% or +100.0%
Output (analog)	Feedback_PER	-100.0% or 0.0%	0.0% or +100.0%

Limiting the output value

You can only exceed or undershoot the output value limits during the transition time measurement. The output value is limited to these values in all other modes.

Enter the absolute output value limits in the "Output value high limit" and "Output value low limit" input boxes. The output value limits must be within "Low endstop" and "High endstop".

If no Feedback is available and Output (digital) is set, you cannot limit the output value. The digital outputs are reset with Actuator_H = TRUE or Actuator_L = TRUE, or after a travel time amounting to 110% of the motor transition time.

5.3.1.4 Advanced settings

Monitoring process value

Configure a warning high and low limit for the process value in the "Process value monitoring" configuration window. If one of the warning limits is exceeded or undershot during operation, a warning will be displayed at the PID_3Step instruction:

- At the InputWarning_H output parameter if the warning high limit has been exceeded
- At the InputWarning_L output parameter if the warning low limit has been undershot

The warning limits must be within the process value high and low limits.

The process value high and low limits will be used if you do not enter values.

Example

Process value high limit = 98° C; warning high limit = 90° C

Warning low limit = 10° C; process value low limit = 0° C

PID_3Step will respond as follows:

Process value	InputWarning_H	InputWarning_L	Operating mode
> 98° C	TRUE	FALSE	Inactive
≤ 98° C and > 90° C	TRUE	FALSE	Automatic mode
≤ 90° C and ≥ 10° C	FALSE	FALSE	Automatic mode
< 10° C and ≥ 0° C	FALSE	TRUE	Automatic mode
< 0° C	FALSE	TRUE	Inactive

PID parameters

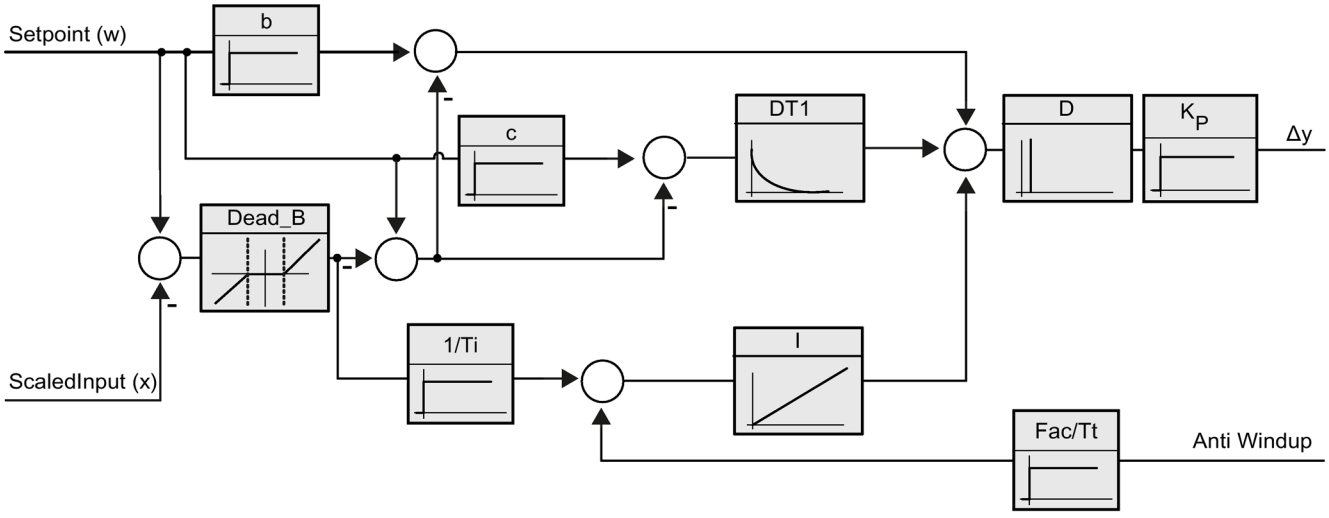
The PID parameters are displayed in the "PID Parameters" configuration window. The PID parameters will be adapted to your controlled system during controller tuning. You do not need to enter the PID parameters manually.

The PID algorithm operates according to the following equation:

$$\Delta y = K_p \cdot s \cdot \left[(b \cdot w - x) + \frac{1}{T_I \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c \cdot w - x) \right]$$

Symbol	Description
Δy	Output value of the PID algorithm
K_p	Proportional gain
s	Laplace operator
b	Proportional action weighting
w	Setpoint
x	Process value
T_I	Integral action time
a	Derivative delay coefficient (derivative delay T1 = a × T_D)
T_D	Derivative action time
c	Derivative action weighting

The diagram below illustrates the integration of the parameters into the PID algorithm:



All PID parameters are retentive. If you enter the PID parameters manually, you must completely download PID_3Step.

Proportional gain

The value specifies the proportional gain of the controller. PID_3Step does not work with a negative proportional gain. Control logic is inverted under Basic settings > Controller type.

Integral action time

The integral action time determines the time behavior of the integral action. The integral action is deactivated with integral action time = 0.0.

Derivative action time

The derivative action time determines the time behavior of the derivative action. Derivative action is deactivated with derivative action time = 0.0.

Derivative delay coefficient

The derivative delay coefficient delays the effect of the derivative action.

Derivative delay = derivative action time × derivative delay coefficient

- 0.0: Derivative action is effective for one cycle only and therefore almost not effective.
- 0.5: This value has proved useful in practice for controlled systems with **one** dominant time constant.
- > 1.0: The greater the coefficient, the longer the effect of the derivative action is delayed.

Proportional action weighting

The proportional action may weaken with changes to the setpoint.

Values from 0.0 to 1.0 are applicable.

- 1.0: Proportional action for setpoint change is fully effective
- 0.0: Proportional action for setpoint change is not effective

The proportional action is always fully effective when the process value is changed.

Derivative action weighting

The derivative action may weaken with changes to the setpoint.

Values from 0.0 to 1.0 are applicable.

- 1.0: Derivative action is fully effective upon setpoint change
- 0.0: Derivative action is not effective upon setpoint change

The derivative action is always fully effective when the process value is changed.

PID algorithm sampling time

The controlled system needs a certain amount of time to respond to changes in the output value. It is therefore not advisable to calculate the output value in every cycle. The sampling time of the PID algorithm represents the time between two calculations of the output value. It is calculated during tuning and rounded to a multiple of the PID_3Step sampling time. All other functions of PID_3Step are executed at every call.

Deadband width

The deadband suppresses the noise component in the steady controller state. The deadband width specifies the size of the deadband. The deadband is off if the deadband width is 0.0.

See also

Downloading technology objects to device (Page 46)

5.3.2 Commissioning PID_3Step V1

5.3.2.1 Commissioning

You can monitor the setpoint, process value and output value over time in the "Tuning" working area. The following commissioning functions are supported in the curve plotter:

- Controller pretuning
- Controller fine tuning
- Monitoring the current closed-loop control in the trend view

All functions require an online connection to the CPU to have been established.

Basic handling

- Select the desired sampling time in the "Sampling time" drop-down list.

  All values in the tuning working area are updated in the selected update time.
- Click the "Start" icon in the measuring group if you want to use the commissioning functions.

  Value recording is started. The current values for the setpoint, process value and output value are entered in the trend view. Operation of the commissioning window is enabled.
- Click the "Stop" icon if you want to end the commissioning functions.

  The values recorded in the trend view can continue to be analyzed.
- Closing the commissioning window will terminate recording in the trend view and delete the recorded values.

5.3.2.2 Pretuning

The pretuning determines the process response to a pulse of the output value and searches for the point of inflection. The tuned PID parameters are calculated as a function of the maximum slope and dead time of the controlled system.

The more stable the process value is, the easier it is to calculate the PID parameters and the more precise the result will be. Noise on the process value can be tolerated as long as the rate of rise of the process value is significantly higher compared to the noise. The PID parameters are backed up before being recalculated.

The setpoint is frozen during pretuning.

Requirement

- The PID_3Step instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- PID_3Step is in "inactive" or "manual" mode.
- The setpoint and the process value lie within the configured limits (see "Process value settings" configuration).

Procedure

To perform pretuning, follow these steps:

1. Double-click the "PID_3Step > Commissioning" entry in the project tree.
2. Select the entry "Pretuning" in the "Tuning mode" drop-down list in the working area "Tuning".
3. Click the "Start" icon.
   - An online connection will be established.
   - Value recording is started.
   - Pretuning is started.
   - The "Status" field displays the current steps and any errors that may have occurred. The progress bar indicates the progress of the current step.

   Note

   Click the "Stop" icon when the progress bar has reached 100% and it is to be assumed the controller tuning function is blocked. Check the configuration of the technology object and, if necessary, restart controller tuning.

Result

If pretuning was performed without an error message, the PID parameters have been tuned. PID_3Step switches to automatic mode and uses the tuned parameters. The tuned PID parameters will be retained during power OFF and a restart of the CPU.

If pretuning is not possible, PID_3Step changes to "Inactive" mode.

5.3.2.3 Fine tuning

Fine tuning generates a constant, limited oscillation of the process value. The PID parameters are optimized for the operating point from the amplitude and frequency of this oscillation. All PID parameters are recalculated on the basis of the findings. PID parameters from fine tuning usually have better master control and disturbance behavior than PID parameters from pretuning.

PID_3Step automatically attempts to generate an oscillation greater than the noise of the process value. Fine tuning is only minimally influenced by the stability of the process value. The PID parameters are backed up before being recalculated.

The setpoint is frozen during fine tuning.

Requirement

- The PID_3Step instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- The motor transition time has been configured or measured.
- The setpoint and the process value lie within the configured limits (see "Process value settings" configuration).
- The control loop has stabilized at the operating point. The operating point is reached when the process value corresponds to the setpoint.
- No disturbances are expected.
- PID_3Step is in inactive mode, automatic mode or manual mode.

Process depends on initial situation

Fine tuning proceeds as follows when started in:

- Automatic mode

  Start fine tuning in automatic mode if you wish to improve the existing PID parameters using controller tuning.

  PID_3Step will regulate using the existing PID parameters until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start.

- Inactive or manual mode

  Pretuning is always started first. The PID parameters established will be used for adjustment until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start.

Procedure

Proceed as follows to carry out "fine tuning":

1. Select the entry "Fine tuning" in the "Tuning mode" drop-down list.
2. Click the "Start" icon.
   - An online connection will be established.
   - Value recording is started.
   - The process of fine tuning is started.
   - The "Status" field displays the current steps and any errors that may have occurred. The progress bar indicates the progress of the current step.

Note

Click the "Stop" icon in the "Tuning mode" group when the progress bar has reached 100% and it is to be assumed the controller tuning function is blocked. Check the configuration of the technology object and, if necessary, restart controller tuning.

Result

The PID parameters will have been optimized if fine tuning has been executed without errors. PID_3Step changes to automatic mode and uses the optimized parameters. The optimized PID parameters will be retained during power OFF and a restart of the CPU.

If errors occurred during fine tuning, PID_3Step will change to "inactive" mode.

5.3.2.4 Commissioning with manual PID parameters

Procedure

Proceed as follows to commission PID_3Step with manual PID parameters:

1. Double-click on "PID_3Step > Configuration" in the project tree.
2. Click on "Advanced settings > PID Parameters" in the configuration window.
3. Select the check box "Enable direct input".
4. Enter the PID parameters.
5. Double-click on "PID_3Step > Commissioning" in the project tree.
6. Establish an online connection to the CPU.
7. Load the PID parameters to the CPU.
8. Click on the "Activate controller" icon.

Result

PID_3Step changes to automatic mode and controls using the current PID parameters.

5.3.2.5 Measuring the motor transition time

Introduction

PID_3Step requires the motor transition time to be as accurate as possible for good controller results. The data in the actuator documentation contains average values for this type of actuator. The value for the specific actuator used may differ.

You can measure the motor transition time during commissioning if you are using actuators with position feedback or endstop signals. The output value limits are not taken into consideration during the motor transition time measurement. The actuator can travel to the high or the low endstop.

The motor transition time cannot be measured if neither position feedback nor endstop signals are available.

Actuators with analog position feedback

Proceed as follows to measure motor transition time with position feedback:

Requirement

- Feedback or Feedback_PER has been selected in the basic settings and the signal has been connected.
- An online connection to the CPU has been established.

1. Select the "Use position feedback" check box.
2. Enter the position to which the actuator is to be moved in the "Target position" input field.

   The current position feedback (starting position) will be displayed. The difference between "Target position" and "Position feedback" must be at least 50% of the valid output value range.
3. Click the  "Start transition time measurement" icon.

Result

The actuator is moved from the starting position to the target position. Time measurement starts immediately and ends when the actuator reaches the target position. The motor transition time is calculated according to the following equation:

Motor transition time = (output value high limit – output value low limit) × Measuring time / AMOUNT (target position – starting position).

The progress and status of transition time measurement are displayed. The transition time measured is saved in the instance data block on the CPU and displayed in the "Measured transition time" field. PID_3Step will change to "Inactive" mode once transition time measurement is complete.

Note

Click on the icon  "Upload measured transition time" to load the motor transition time measured to the project.

Actuators with endstop signals

Proceed as follows to measure the transition time of actuators with endstop signals:

Requirement

- The "Endstop signals" check box in the basic settings has been selected and Actuator_H and Actuator_L are connected.
- An online connection to the CPU has been established.

Proceed as follows to measure motor transition time with endstop signals:

1. Select the "Use actuator endstop signals" check box.
2. Select the direction in which the actuator is to be moved.
   - Open - Close - Open

     The actuator is moved first to the high endstop, then to the low endstop and then back to the high endstop.
   - Close - Open - Close

     The actuator is moved first to the low endstop, then to the high endstop and then back to the low endstop.
3. Click the  "Start transition time measurement" icon.

Result

The actuator is moved in the selected direction. Time measurement will start once the actuator has reached the first endstop and will end when the actuator reaches this endstop for the second time. The motor transition time is equal to the time measured divided by two.

The progress and status of transition time measurement are displayed. The transition time measured is saved in the instance data block on the CPU and displayed in the "Measured transition time" field. PID_3Step will change to "Inactive" mode once transition time measurement is complete.

Cancelling transition time measurement

PID_3Step will change to "Inactive" mode immediately if you cancel transition time measurement. The actuator will stop being moved. You can reactive PID-3Step in the curve plotter.

Using PID_Temp

6

6.1 Technology object PID_Temp

The PID_Temp technology object provides a continuous PID controller with integrated tuning. PID_Temp is especially designed for temperature control and is suited for heating or heating/cooling applications. Two outputs are available for this purpose, one each for heating and cooling. PID_Temp can also be used for other control tasks. PID_Temp is cascadable and can be used in manual or automatic mode.

PID_Temp continuously acquires the measured process value within a control loop and compares it with the set setpoint. From the resulting control deviations, the instruction PID_Temp calculates the output value for heating and/or cooling which is used to adjust the process value to the setpoint. The output values for the PID controller consist of three actions:

- Proportional action

  The proportional action of the output value increases in proportion to the control deviation.

- Integral action

  The integral action of the output value increases until the control deviation has been balanced.

- Derivative action

  The derivative action increases with the rate of change of control deviation. The process value is corrected to the setpoint as quickly as possible. The derivative action will be reduced again if the rate of change of control deviation drops.

The instruction PID_Temp calculates the proportional, integral and derivative parameters for your controlled system during "pretuning". "Fine tuning" can be used to tune the parameters further. You do not need to manually determine the parameters.

Either a fixed cooling factor or two PID parameter sets can be used for heating-and-cooling applications.

Additional information

- Overview of software controller (Page 39)
- Add technology objects (Page 42)
- Configure technology objects (Page 43)
- Configuring PID_Temp (Page 160)

6.2 Configuring PID_Temp

6.2.1 Basic settings

6.2.1.1 Introduction

Configure the following properties of the "PID_Temp" technology object under "Basic settings" in the Inspector window or in the configuration window:

- Physical quantity
- Start-up behavior after reset
- Source and input of the setpoint (only in the Inspector window)
- Selection of the process value
- Source and input of the process value (only in the Inspector window)
- Selection of the heating output value
- Source and input of the heating output value (only in the Inspector window)
- Activation and selection of the cooling output value
- Source and input of the cooling output value (only in the Inspector window)
- Activation of PID_Temp as master or slave of a cascade
- Number of slaves
- Selection of the master (only in the Inspector window)

Setpoint, process value, heating output value and cooling output value

You can select the source and enter values or tags for the setpoint, process value, heating output value and cooling output value in the Inspector window of the programming editor.

Select the source for each value:

- Instance DB:

  The value saved in the instance DB is used. The value must be updated by the user program in the instance DB. There should be no value at the instruction. Can be changed using HMI.

- Instruction:

  The value connected to the instruction is used. The value is written to the instance DB each time the instruction is called. Cannot be changed using HMI.

6.2.1.2 Controller type

Physical quantity

Select the unit of measurement and physical quantity for the setpoint and the process value in the "Controller type" group. The setpoint and the process value are displayed in this unit.

Startup characteristics

1. To switch to "Inactive"mode after CPU restart, clear the "Activate Mode after CPU restart"check box.

   To switch to the operating mode saved in the Mode parameter after CPU restart, select the "Activate Mode after CPU restart" check box.

2. In the "Set Mode to" drop-down list, select the mode that is to be enabled after a complete download to the device.

   After a complete "Download to device", PID_Temp starts in the selected operating mode. With each additional restart, PID_Temp starts in the mode that was last saved in Mode.

   When selecting pretuning or fine tuning, you also have to set or reset the Heat.EnableTuning and Cool.EnableTuning tags in order to choose between tuning for heating and tuning for cooling.

Example:

You have selected the "Activate Mode after CPU restart" check box and the "Pretuning" entry in the "Set Mode to" list. After a complete "Download to device", PID_Temp starts in the "Pretuning" mode. If pretuning is still active, PID_Temp starts in "Pretuning" mode again after restart of the CPU (heating/cooling depends on the tags Heat.EnableTuning and Cool.EnableCooling). If pretuning was successfully completed and automatic mode is active, PID_Temp starts in "Automatic mode" after restart of the CPU.

6.2.1.3 Setpoint

Procedure

Proceed as follows to define a fixed setpoint:

1. Select "Instance DB".
2. Enter a setpoint, e.g. 80° C.
3. Delete any entry in the instruction.

Proceed as follows to define a variable setpoint:

1. Select "Instruction".
2. Enter the name of the REAL tag in which the setpoint is saved.

   Program-controlled assignment of various values to the REAL tag is possible, for example for the time-controlled change of the setpoint.

6.2.1.4 Process value

PID_Temp will scale the value of the analog input to the physical quantity if you use the analog input value directly.

You will need to write a program for processing if you wish first to process the analog input value. The process value is, for example, not directly proportional to the value at the analog input. The processed process value must be in floating point format.

Procedure

Proceed as follows to use the analog input value without processing:

1. Select the entry "Input_PER" in the drop-down list "Input".
2. Select "Instruction" as source.
3. Enter the address of the analog input.

Proceed as follows to use the processed process value in floating point format:

1. Select the entry "Input" in the drop-down list "Input".
2. Select "Instruction" as source.
3. Enter the name of the variable in which the processed process value is saved.

6.2.1.5 Heating and cooling output value

The PID_Temp instruction provides a PID controller with integrated tuning for temperature processes. PID_Temp is suitable for heating or heating-and-cooling applications.

PID_Temp provides the following output values. Your actuator will determine which output value you use.

- OutputHeat

  Heating output value (floating-point format): The output value for heating needs to be processed by the user program, for example, because of non-linear actuator response.

- OutputHeat_PER

  Analog heating output value: The actuator for heating is triggered via an analog output and controlled with a continuous signal, e.g. 0...10 V, 4...20 mA.

- OutputHeat_PWM

  Pulse-width modulated heating output value: The actuator for heating is controlled via a digital output. Pulse width modulation creates variable ON and OFF times.

- OutputCool

  Cooling output value (floating-point format): The output value for cooling needs to be processed by the user program, for example because of non-linear actuator response.

- OutputCool_PER

  Analog cooling output value: The actuator for cooling is triggered via an analog output and controlled with a continuous signal, e.g. 0...10 V, 4...20 mA.

- OutputCool_PWM

  Pulse-width modulated cooling output value: The actuator for cooling is controlled via a digital output. Pulse width modulation creates variable ON and OFF times.

The cooling output is only available if it was activated via the "Activate cooling" check box.

- If the check box is cleared, the output value of the PID algorithm (PidOutputSum) is scaled and output at the outputs for heating.
- If the check box is selected, positive output values of the PID algorithm (PidOutputSum) are scaled and output at the outputs for heating. Negative output values of the PID algorithm are scaled and output at the outputs for cooling. You can choose between two methods for output value calculation at the output settings.

Note

Note:

- The OutputHeat_PWM, OutputHeat_PER, OutputCool_PWM, OutputCool_PER outputs are only calculated if you select these correspondingly from the drop-down list.
- The OutputHeat output is always calculated.
- The OutputCool output is calculated if the check box for cooling is selected.
- The "Activate cooling" check box is only available if the controller is not configured as a master in a cascade.

Procedure

Proceed as follows to use the analog output value:

1. Select the entry "OutputHeat_PER" or "OutputCool_PER" in the drop-down list "OutputHeat" or "OutputCool".
2. Select "Instruction".
3. Enter the address of the analog output.

Proceed as follows to use the pulse-width modulated output value:

1. Select the entry "OutputHeat_PWM" or "OutputCool_PWM" in the drop-down list "OutputHeat" or "OutputCool".
2. Select "Instruction".
3. Enter the address of the digital output.

Proceed as follows to process the output value using the user program:

1. Select the entry "OutputHeat" or "OutputCool" in the drop-down list "OutputHeat" or "OutpuCool".
2. Select "Instruction".
3. Enter the name of the variable you are using to process the output value.
4. Transfer the processed output value to the actuator by means of an analog or digital CPU output.

6.2.1.6 Cascade

If a PID_Temp instance receives its setpoint from a higher-level master controller and outputs its output value in turn to a subordinate slave controller, this PID_Temp instance is both a master controller and a slave controller simultaneously. Both configurations listed below then have to be carried out for such a PID_Temp instance. This is the case, for example, for the middle PID_Temp instance in a cascade control system with three concatenated measured variables and three PID_Temp instances.

Configuring a controller as master in a cascade

A master controller specifies the setpoint of a slave controller through its output.

In order to use PID_Temp as master in a cascade, you have to deactivate the cooling in the basic settings. In order to configure this PID_Temp instance as a master controller in a cascade, activate the "Controller is master" check box. The selection of the output value for heating is set automatically to OutputHeat.

OutputHeat_PWM and OutputHeat_PER cannot be used at a master in a cascade.

Subsequently specify the number of directly subordinate slave controllers that receive their setpoint from this master controller.

If no own scaling function is used when assigning the OutputHeat parameter of the master to the Setpoint parameter of the slave, it may be necessary to adapt the output value limits and the output scaling of the master to the setpoint/process value range of the slave. This can be done in the output settings of the master in the "OutputHeat / OutputCool" section.

Configuring a controller as a slave in a cascade

A slave controller receives its setpoint (Setpoint parameter) from the output of its master controller (OutputHeat parameter).

In order to configure this PID_Temp instance as a slave controller in a cascade, activate the "Controller is slave" check box in the basic settings.

Subsequently select the PID_Temp instance that is to be used as the master controller for this slave controller in the Inspector window of the programming editor. The Master and Setpoint parameters of the slave controller are interconnected with the selected master controller through this selection (the existing interconnections at these parameters are overwritten). This interconnection allows the exchange of information and the setpoint specification between master and slave. If required, the interconnection can be changed subsequently at the Setpoint parameter of the slave controller in order, for example, to insert an additional filter. The interconnection at the parameter master may not be changed subsequently.

The "Controller is master" check box has to be selected and the number of slaves has to be configured correctly at the selected master controller. The master controller has to be called before the slave controller in the same cyclic interrupt OB.

Additional information

Additional information about program creation, configuration and commissioning when PID_Temp is used in cascade control systems is available under Cascade control with PID_Temp (Page 194).

6.2.2 Process value settings

6.2.2.1 Process value limits

You must specify an appropriate absolute high limit and low limit for the process value as limit values for your controlled system. As soon as the process value violates these limits, an error occurs (ErrorBits = 0001h). Tuning is canceled when the process value limits are violated. You can specify how PID_Temp responds to errors in automatic mode in the output settings.

6.2.2.2 Scale process value

If you have configured the use of Input_PER in the basic settings, you will need to convert the value of the analog input into the physical quantity of the process value. The current configuration is displayed in the Input_PER display.

Input_PER is scaled using a low and high value pair if the process value is directly proportional to the value of the analog input.

Procedure

To scale the process value, follow these steps:

1. Enter the low pair of values in the "Scaled low process value" and "Low" input fields.
2. Enter the high pair of values in the "Scaled high process value" and "High" input fields.

Default settings for the value pairs are saved in the hardware configuration. Proceed as follows to use the value pairs from the hardware configuration:

1. Select the instruction PID_Temp in the programming editor.
2. Interconnect Input_PER with an analog input in the basic settings.
3. Click on the "Automatic setting" button in the process value settings.

The existing values are overwritten with the values from the hardware configuration.

6.2.3 Output settings

6.2.3.1 Basic settings output

Method for heating and cooling

If cooling is activated in the basic settings, two methods are available for calculating the PID output value:

- PID parameter changeover (Config.AdvancedCooling = TRUE):

  Output value calculation for cooling is carried out by means of a separate PID parameter set. The PID algorithm decides on the basis of the calculated output value and the control deviation whether the PID parameters are used for heating or cooling. This method is suitable if the heating and cooling actuators have different time responses and different gains.

  Pretuning and fine tuning for cooling are only available if this method is selected.

- Cooling factor (Config.AdvancedCooling = FALSE):

  Output value calculation for cooling is effected with the PID parameters for heating under consideration of the configurable cooling factor Config.CoolFactor. This method is suitable if the heating and cooling actuators have a similar time response but different gains. If this method is selected, pretuning and fine tuning for cooling as well as the PID parameter set for cooling are not available. Only the tunings for heating can be carried out.

Cooling factor

If the cooling factor is selected as the method for heating/cooling, this factor is used in the calculation of the output value for cooling. This allows different gains of heating and cooling actuators to be used.

The cooling factor is not set automatically or adjusted during tuning. You have to configure the correct cooling factor manually by using the ratio "Heating actuator gain/Cooling actuator gain".

Example: Cooling factor = 2.0 means that the heating actuator gain is twice as high as the cooling actuator gain.

The cooling factor is only effective and can only be changed if "Cooling factor" is selected as the method for heating/cooling.

Reaction to error

NOTICE
Your system may be damaged. If you output "Current value while error is pending " or "Substitute output value while error is pending" in the event of an error, PID_Temp remains in automatic mode or in manual mode. This may cause a violation of the process value limits and damage your system. It is essential to configure how your controlled system reacts in the event of an error to protect your system from damage.

PID_Temp is preset so that the controller stays active in most cases in the event of an error.

If errors occur frequently in controller mode, this default reaction has a negative effect on the control response. In this case, check the ErrorBits parameter and eliminate the cause of the error.

PID_Temp generates a programmable output value in response to an error:

- Zero (inactive)

  At all errors, PID_Temp switches to the "Inactive" operating mode and outputs the following:

  – 0.0 as PID output value (PidOutputSum)

  – 0.0 as output value for heating (OutputHeat) and output value for cooling (OutputCool)

  – 0 as analog output value for heating (OutputHeat_PER) and analog output value for cooling (OutputCool_PER)

  – FALSE as PWM output value for heating (OutputHeat_PWM) and PWM output value for cooling (OutputCool_PWM)

  This is independent of the configured output value limits and the scaling. The controller is only reactivated by a falling edge at Reset or a rising edge at ModeActivate.

- Current value while error is pending

  The error response depends on the error occurring and the operating mode.

  If one or more of the following errors occur in automatic mode, PID_Temp stays in automatic mode:

  – 0000001h: The Input parameter is outside the process value limits.

  – 0000800h: Sampling time error

  – 0040000h: Invalid value at Disturbance parameter.

  – 8000000h: Error during the calculation of the PID parameters.

  If one or more of the following errors occur in automatic mode, PID_Temp switches to "Substitute output value with error monitoring" mode and outputs the last valid PID output value (PidOutputSum):

  – 0000002h: Invalid value at Input_PER parameter.

  – 0000200h: Invalid value at Input parameter.

  – 0000400h: Calculation of output value failed.

  – 0001000h: Invalid value at Setpoint or SubstituteSetpoint parameter.

  The values at the outputs for heating and cooling resulting from the PID output value are produced by the configured output scaling.

  As soon as the errors are no longer pending, PID_Temp switches back to automatic mode.

  If an error occurs during manual mode, PID_Temp remains in manual mode and continues to use the manual value as the PID output value.

  If the manual value is invalid, the configured substitute output value is used.

  If the manual value and substitute output value are invalid, the low limit of the PID output value for heating (Config.Output.Heat.PidLowerLimit) is used.

  If the following error occurs during pretuning or fine tuning, PID_Temp remains in active mode:

  – 0000020h: Pretuning is not permitted during fine tuning.

  When any other error occurs, PID_Temp cancels the tuning and switches to the mode from which tuning was started.

- Substitute output value while error is pending

  PID_Temp behaves as described at "Current value while error is pending", but outputs the configured substitute output value (SubstituteOutput) as a PID output value (PidOutputSum) in "Substitute output value with error monitoring" operating mode.

  The values at the outputs for heating and cooling resulting from the PID output value are produced by the configured output scaling.

  In the case of controllers with activated cooling output (Config.ActivateCooling = TRUE), enter:

  – A positive substitute output value to output the value at the outputs for heating.

  – A negative substitute output value to output the value at the outputs for cooling.

  If the following error occurs, PID_Temp stays in "Substitute output value with error monitoring" mode and outputs the low limit of the PID output value for heating (Config.Output.Heat.PidLowerLimit):

  – 0020000h: Invalid value at SubstituteOutput tag.

6.2.3.2 Output value limits and output value scaling

Depending on the operating mode, the PID output value (PidOutputSum) is calculated automatically by the PID algorithm or by the manual value (ManualValue) or the configured substitute output value (SubstituteOutput).

The PID output value is limited depending on the configuration:

- If the cooling is deactivated in the basic settings (Config.ActivateCooling = FALSE), the value is limited to the high limit of the PID output value (heating) (Config.Output.Heat.PidUpperLimit) and the low limit of the PID output value (heating) (Config.Output.Heat.PidLowerLimit).

  You can configure both limits at the horizontal axis of the scaling characteristic line in the "OutputHeat / OutputCool" section. These are displayed in the "OutputHeat_PWM / OutputCool_PWM" and "OutputHeat_PER / OutputCool_PER" sections, but cannot be changed.

- If the cooling is activated in the basic settings (Config.ActivateCooling = TRUE), the value is limited to the high limit of the PID output value (Config.Output.Heat.PidUpperLimit) and the low limit of the PID output value (cooling) (Config.Output.Cool.PidLowerLimit).

  You can configure both limits at the horizontal axis of the scaling characteristic line in the "OutputHeat / OutputCool" section. These are displayed in the "OutputHeat_PWM / OutputCool_PWM" and "OutputHeat_PER / OutputCool_PER" sections, but cannot be changed.

  The low limit of the PID output value (heating) (Config.Output.Heat.PidLowerLimit) and the high limit of the PID output value (cooling) (Config.Output.Cool.PidUpperLimit) cannot be changed and have to be assigned the value 0.0.

The PID output value is scaled and output at the outputs for heating and cooling. Scaling can be specified separately for each output and is specified across 2 value pairs each, consisting of a limit value of the PID output value and a scaling value:

Output	Value pair	Parameter
OutputHeat	Value pair 1	High limit of PID output value (heating) Config.Output.Heat.PidUpperLimit, Scaled upper output value (heating) Config.Output.Heat.UpperScaling
	Value pair 2	Low limit of PID output value (heating) Config.Output.Heat.PidLowerLimit, Scaled lower output value (heating) Config.Output.Heat.LowerScaling
OutputHeat_PWM	Value pair 1	High limit of PID output value (heating) Config.Output.Heat.PidUpperLimit, Scaled upper PWM output value (heating) Config.Output.Heat.PwmUpperScaling
	Value pair 2	Low limit of PID output value (heating) Config.Output.Heat.PidLowerLimit, Scaled lower PWM output value (heating) Config.Output.Heat.PwmLowerScaling
OutputHeat_PER	Value pair 1	High limit of PID output value (heating) Config.Output.Heat.PidUpperLimit, Scaled upper analog output value (heating) Config.Output.Heat.PerUpperScaling
	Value pair 2	Low limit of PID output value (heating) Config.Output.Heat.PidLowerLimit, Scaled lower analog output value (heating) Config.Output.Heat.PerLowerScaling
OutputCool	Value pair 1	Low limit of PID output value (cooling) Config.Output.Cool.PidLowerLimit, Scaled upper output value (cooling) Config.Output.Cool.UpperScaling
	Value pair 2	High limit of PID output value (cooling) Config.Output.Cool.PidUpperLimit, Scaled lower output value (cooling) Config.Output.Cool.LowerScaling
OutputCool_PWM	Value pair 1	Low limit of PID output value (cooling) Config.Output.Cool.PidLowerLimit, Scaled upper PWM output value (cooling) Config.Output.Cool.PwmUpperScaling
	Value pair 2	High limit of PID output value (cooling) Config.Output.Cool.PidUpperLimit, Scaled lower output value (cooling) Config.Output.Cool.PwmLowerScaling

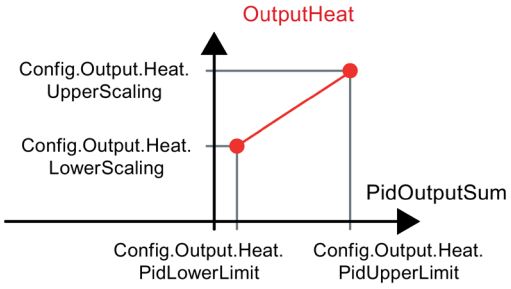
Output	Value pair	Parameter
OutputCool_PER	Value pair 1	Low limit of PID output value (cooling) Config.Output.Cool.PidLowerLimit, Scaled upper analog output value (cooling) Config.Output.Cool.PerUpperScaling
	Value pair 2	High limit of PID output value (cooling) Config.Output.Cool.PidUpperLimit, Scaled low analog output value (cooling) Config.Output.Cool.PerLowerScaling

The low limit of PID output value (heating) (Config.Output.Heat.PidLowerLimit) has to have the value 0.0, if the cooling is activated (Config.ActivateCooling = TRUE).

The high limit of PID output value (cooling) Config.Output.Cool.PidUpperLimit) must always have the value 0.0.

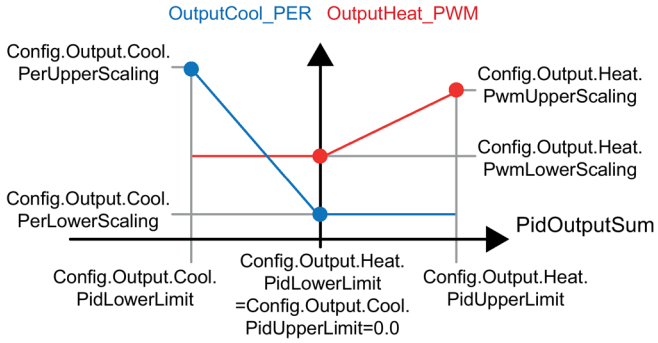
Example:

Output scaling when the OutputHeat output is used (cooling deactivated. The low limit of PID output value (heating) (Config.Output.Heat.PidLowerLimit) may be unequal to 0.0):



Example:

Output scaling when the OutputHeat_PWM and OutputCool_PER outputs are used (cooling activated. The low limit of PID output value (heating) (Config.Output.Heat.PidLowerLimit) must be 0.0):



With the exception of the "Inactive" operating mode, the value at an output always lies between its scaled upper output value and the scaled lower output value, for example for OutputHeat always between the scaled upper output value (heating)

(Config.Output.Heat.UpperScaling) and the scaled lower output value (heating) (Config.Output.Heat.LowerScaling).

If you want to limit the value at the associated output, you therefore have to adapt these scaling values as well.

You can configure the scaling values of an output at the vertical axes of the scaling characteristic line. Each output has two separate scaling values. These can only be changed for OutputHeat_PWM, OutputCool_PWM, OutputHeat_PER and OutputCool_PER if the corresponding output is selected in the basic settings. The cooling has to be activated additionally in the basic settings at all the outputs for cooling.

The trend view in the commissioning dialog box only records the values of OutputHeat and OutputCool, irrespective of the selected output in the basic settings. Therefore, if necessary, adapt the scaling values for OutputHeat/OutputCool if you use OutputHeat_PWM, or OutputHeat_PER or OutputCool_PWM if you use OutputCool_PER and want to use the trend view in the commissioning dialog.

6.2.4 Advanced settings

6.2.4.1 Process value monitoring

Configure a warning high and low limit for the process value in the "Process value monitoring" configuration window. If one of the warning limits is exceeded or undershot during operation, a warning is displayed at the PID_Temp instruction:

- At the InputWarning_H output parameter if the warning high limit has been exceeded
- At the InputWarning_L output parameter if the warning low limit has been undershot

The warning limits must be within the process value high and low limits.

The process value high and low limits are used if you do not enter values.

Example

Process value high limit = 98° C; warning high limit = 90° C

Warning low limit = 10° C; process value low limit = 0° C

PID_Temp will respond as follows:

Process value	InputWarning_H	InputWarning_L	ErrorBits
> 98 °C	TRUE	FALSE	0001h
≤ 98° C and > 90° C	TRUE	FALSE	0000h
≤ 90° C and ≥ 10° C	FALSE	FALSE	0000h
< 10° C and ≥ 0° C	FALSE	TRUE	0000h
< 0° C	FALSE	TRUE	0001h

You can configure the response of PID_Temp when the process value high limit or low limit is violated in the output settings.

6.2.4.2 PWM limits

The PID output value PidOutputSum is scaled and transformed via a pulse width modulation into a pulse train that is output at the output parameter OutputHeat_PWM or OutputCool_PWM. The "Sampling time of PID algorithm" represents the time between two calculations of the PID output value. The sampling time is used as time period of the pulse width modulation.

During heating, the PID output value is always calculated in the "Sampling time of PID algorithm for heating".

Calculation of the PID output value during cooling depends on the type of cooling selected in "Basic settings Output":

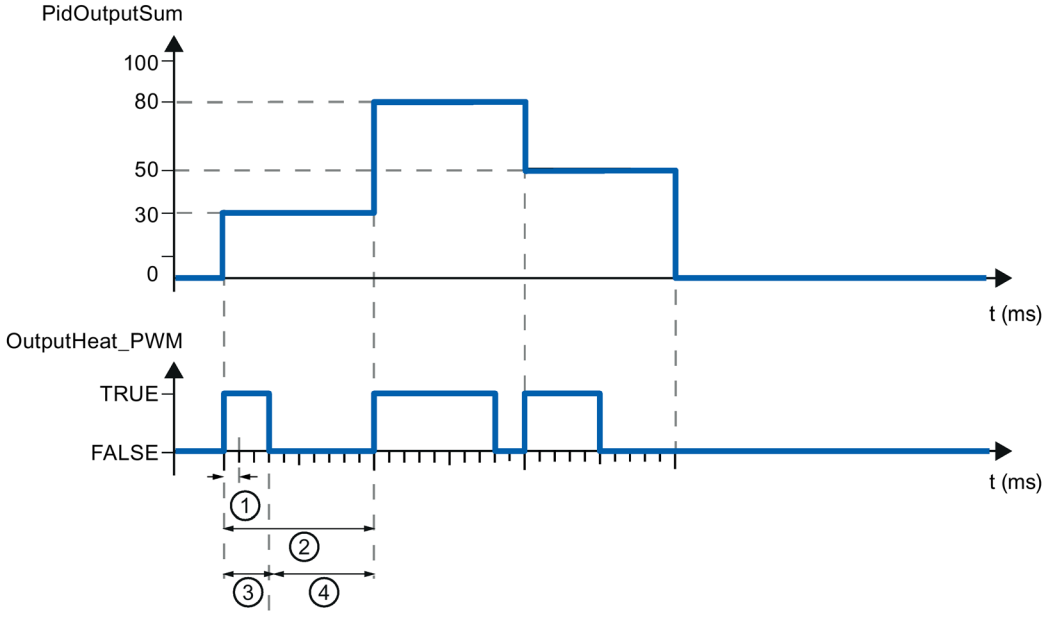
- If the cooling factor is used, the "Sampling time of PID algorithm for heating" applies.
- If the PID parameter changeover is used, the "Sampling time of PID algorithm for cooling" applies.

OutputHeat_PWM and OutputCool_PWM are output in the sampling time PID_Temp (corresponds to the cycle time of the calling OB).

The PID algorithm sampling time for heating or cooling is determined during pretuning or fine tuning. If you set the PID parameters manually, you will also need to configure the PID algorithm sampling time for heating or cooling. The PID_Temp sampling time is equivalent to the cycle time of the calling OB.

The pulse duration is proportional to the PID output value and is always an integer multiple of the PID_Temp sampling time.

Example for OutputHeat_PWM



① PID_Temp sampling time
② PID algorithm sampling time for heating
③ Pulse duration
④ Break time

The "Minimum ON time" and the "Minimum OFF time" can be set separately for heating and cooling, rounded to an integer multiple of the PID_Temp sampling time.

A pulse or a break is never shorter than the minimum ON or OFF time. The inaccuracies this causes are added up and compensated in the next cycle.

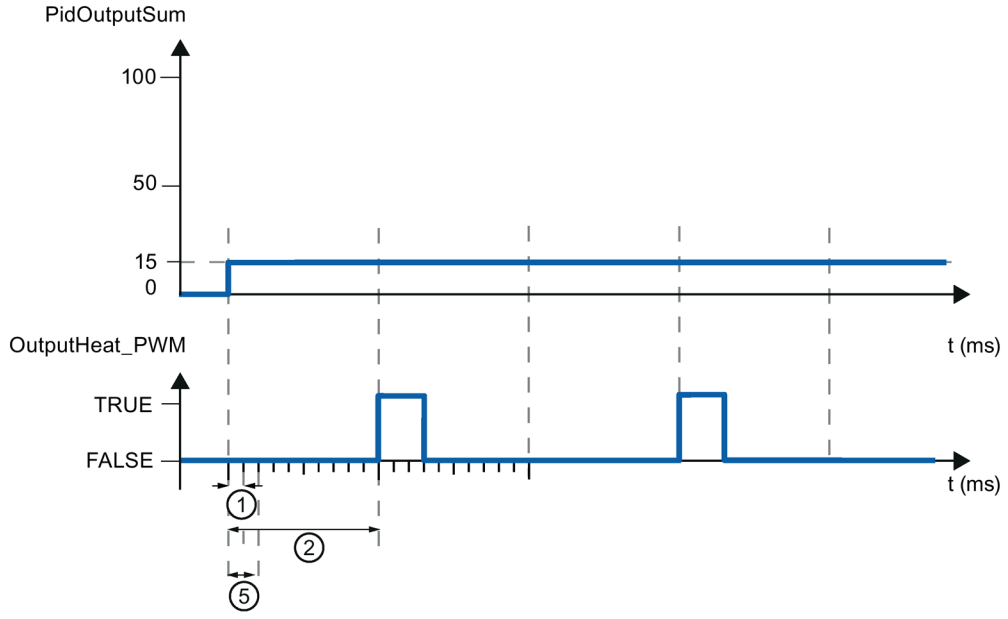
Example for OutputHeat_PWM

PID_Temp sampling time = 100 ms

PID algorithm sampling time = 1000 ms

Minimum ON time = 200 ms

The PID output value PidOutputSum amounts to 15% constantly. The smallest pulse that PID_Temp can output corresponds to 20%. In the first cycle, no pulse is output. In the second cycle, the pulse not output in the first cycle is added to the pulse of the second cycle.



① PID_Temp sampling time
② PID algorithm sampling time for heating
⑤ Minimum ON time

In order to minimize operation frequency and conserve the actuator, extend the minimum ON and OFF times.

If you have selected OutputHeat/OutputCool or OutputHeat_PER/OutputCool_PER as the output in the basic settings, the minimum ON time and the minimum OFF time are not evaluated and cannot be changed.

If the "Sampling time of PID algorithm" (Retain.CtrlParams.Heat.Cycle or Retain.CtrlParams.Cool.Cycle) and thus the period duration of the pulse width modulation is very high when OutputHeat_PWM or OutputCool_PWM is used, you can specify a deviating shorter period duration at the parameters Config.Output.Heat.PwmPeriode or Config.Output.Cool.PwmPeriode in order to improve smoothness of the process value (see also PwmPeriode tag (Page 431)).

Note

The minimum ON and OFF times only affect the output parameters OutputHeat_PWM or OutputCool_PWM and are not used for any pulse generators integrated in the CPU.

6.2.4.3 PID parameters

The PID parameters are displayed in the "PID Parameters" configuration window.

If cooling is activated in the basic settings and PID parameter changeover is selected as the method for heating/cooling in the output settings, two parameter sets are available: One for heating and one for cooling.

In this case, the PID algorithm decides on the basis of the calculated output value and the control deviation whether the PID parameters for heating or cooling are used.

If cooling is deactivated or the cooling factor is selected as the method for heating/cooling, the parameter set for heating is always used.

During tuning, the PID parameters are adapted to the controlled system with the exception of the deadband width that has to be configured manually.

PID_Temp is a PIDT1 controller with anti-windup and weighting of the proportional and derivative actions.

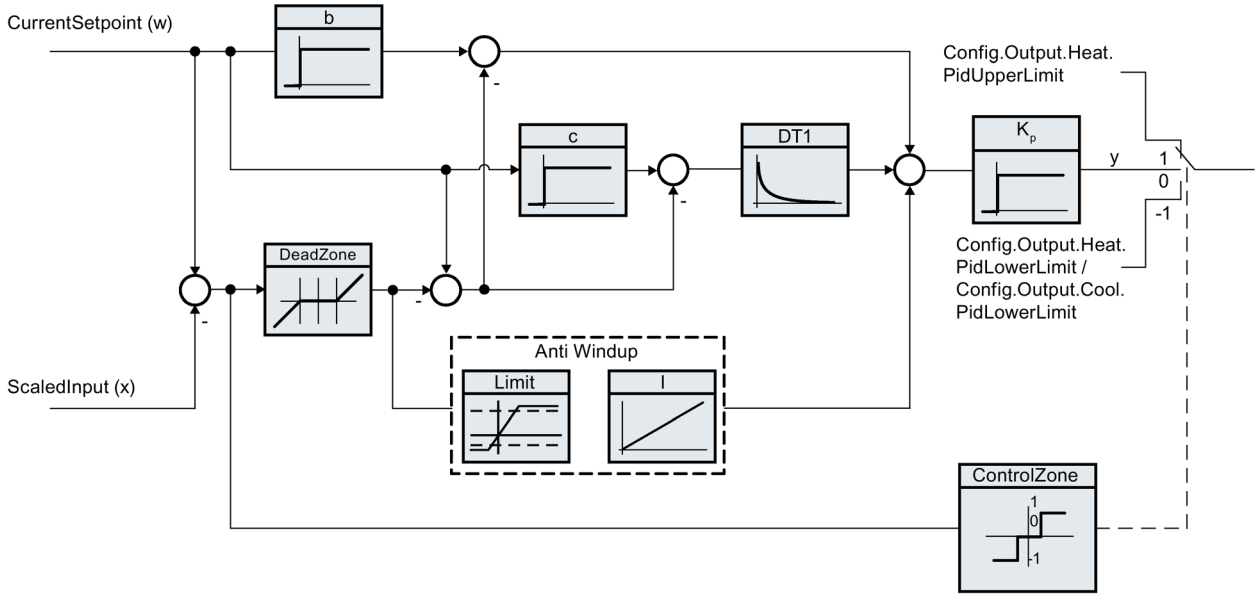
The PID algorithm operates according to the following equation (control zone and deadband deactivated):

$$y = K_p \left[(b \cdot w - x) + \frac{1}{T_I \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c \cdot w - x) \right]$$

Symbol	Description	Associated parameters of the PID_Temp instruction
y	Output value of the PID algorithm	-
K_p	Proportional gain	Retain.CtrlParams.Heat.Gain Retain.CtrlParams.Cool.Gain CoolFactor
s	Laplace operator	-
b	Proportional action weighting	Retain.CtrlParams.Heat.PWeighting Retain.CtrlParams.Cool.PWeighting
w	Setpoint	CurrentSetpoint
x	Process value	ScaledInput

Symbol	Description	Associated parameters of the PID_Temp instruction
T_I	Integral action time	Retain.CtrlParams.Heat.Ti Retain.CtrlParams.Cool.Ti
T_D	Derivative action time	Retain.CtrlParams.Heat.Td Retain.CtrlParams.Cool.Td
a	Coefficient for derivative-action delay (Derivative delay T1 = a × T_D)	Retain.CtrlParams.Heat.TdFiltRatio Retain.CtrlParams.Cool.TdFiltRatio
c	Derivative action weighting	Retain.CtrlParams.Heat.DWeighting Retain.CtrlParams.Cool.DWeighting
DeadZone	Deadband width	Retain.CtrlParams.Heat.DeadZone Retain.CtrlParams.Cool.DeadZone
ControlZone	Control zone width	Retain.CtrlParams.Heat.ControlZone Retain.CtrlParams.Cool.ControlZone

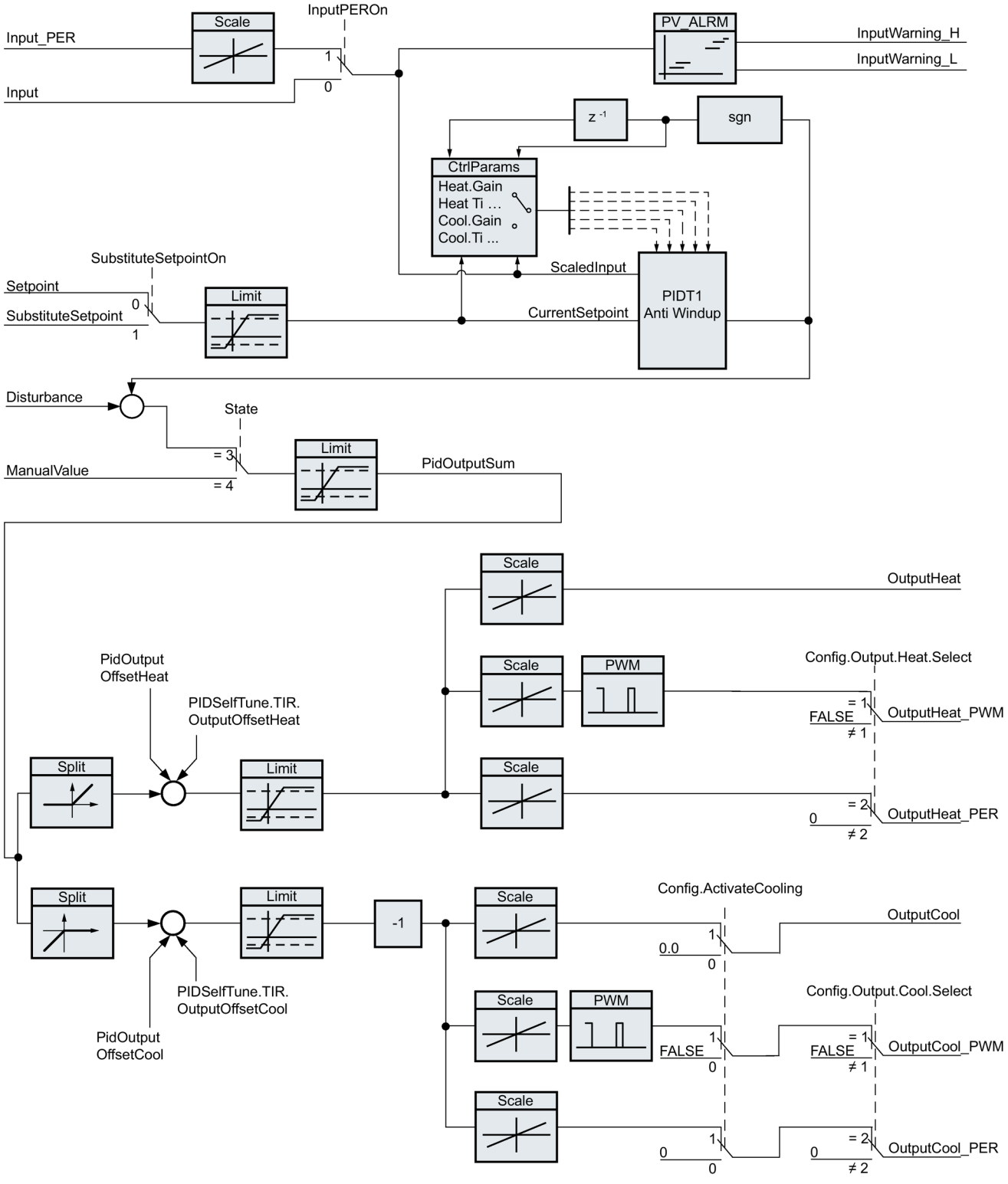
The diagram below illustrates the integration of the parameters into the PID algorithm:



All PID parameters are retentive. If you enter the PID parameters manually, you must completely download PID_Temp (Downloading technology objects to device (Page 46)).

PID_Temp block diagram

The following block diagram shows how the PID algorithm is integrated in the PID_Temp.



Proportional gain

The value specifies the proportional gain of the controller. PID_Temp does not operate with a negative proportional gain and only supports the normal control direction, meaning that an increase in the process value is achieved by an increase in the PID output value (PidOutputSum).

Integral action time

The integral action time determines the time behavior of the integral action. The integral action is deactivated with integral action time = 0.0.

Derivative action time

The derivative action time determines the time behavior of the derivative action. Derivative action is deactivated with derivative action time = 0.0.

Derivative delay coefficient

The derivative delay coefficient delays the effect of the derivative action.

Derivative delay = derivative action time × derivative delay coefficient

- 0.0: Derivative action is effective for one cycle only and therefore almost not effective.
- 0.5: This value has proved useful in practice for controlled systems with one dominant time constant.
- > 1.0: The greater the coefficient, the longer the effect of the derivative action is delayed.

Proportional action weighting

The proportional action may weaken with changes to the setpoint.

Values from 0.0 to 1.0 are applicable.

- 1.0: Proportional action for setpoint change is fully effective
- 0.0: Proportional action for setpoint change is not effective

The proportional action is always fully effective when the process value is changed.

Derivative action weighting

The derivative action may weaken with changes to the setpoint.

Values from 0.0 to 1.0 are applicable.

- 1.0: Derivative action is fully effective upon setpoint change
- 0.0: Derivative action is not effective upon setpoint change

The derivative action is always fully effective when the process value is changed.

PID algorithm sampling time

The controlled system needs a certain amount of time to respond to changes in the output value. It is therefore not advisable to calculate the output value in every cycle. The sampling time of "PID algorithm" represents the time between two calculations of the PID output value. It is calculated during tuning and rounded to a multiple of the PID_Temp sampling time (cycle time of the cyclic interrupt OB). All other functions of PID_Temp are executed at every call.

If you use OutputHeat_PWM or OutputCool_PWM, the sampling time of the PID algorithm is used as the period duration of the pulse width modulation. The accuracy of the output signal is determined by the ratio of the PID algorithm sampling time to the cycle time of the OB. The cycle time should be a maximum of one tenth of the PID algorithm sampling time.

The sampling time of the PID algorithm that is used as the period duration of the pulse width modulation at OutputCool_PWM depends on the method for heating/cooling selected in "Basic settings Output":

- If the cooling factor is used, the "sampling time of the PID algorithm for heating" also applies to OutputCool_PWM.
- If the PID parameter changeover is used, the "sampling time PID algorithm for cooling" applies as the period duration for OutputCool_PWM.

If the sampling time of the PID algorithm and thus the period duration of the pulse width modulation is very high when OutputHeat_PWM or OutputCool_PWM is used, you can specify a deviating shorter period duration at the parameters Config.Output.Heat.PwmPeriode or Config.Output.Cool.PwmPeriode in order to improve smoothness of the process value.

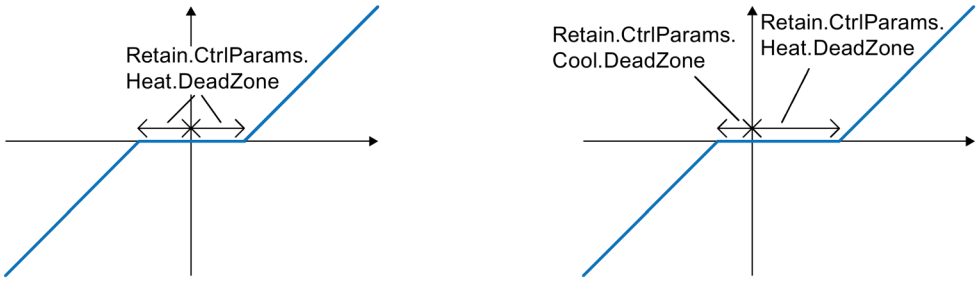
Deadband width

If the process value is affected by noise, the noise can also have an effect on the output value. The output value may fluctuate considerably when controller gain is high and the derivative action is activated. If the process value lies within the deadband around the setpoint, the control deviation is suppressed so that the PID algorithm does not react and unnecessary fluctuations of the output value are reduced.

The deadband width for heating is not set automatically during tuning. You have to correctly configure the deadband width manually. The deadband is deactivated by setting the deadband width = 0.0.

If cooling is activated in the basic settings and PID parameter changeover is selected as the method for heating/cooling in the output settings, the deadband lies between "Setpoint - deadband width (heating)" and "Setpoint + deadband width (cooling)".

If cooling is deactivated in the basic settings or the cooling factor is used, the deadband lies symmetrically between "Setpoint - deadband width (heating)" and "Setpoint + deadband width (heating)".



Deadband with deactivated cooling or cooling factor (left) or activated cooling and PID parameter changeover (right). The x / horizontal axis displays the control deviation = setpoint - process value. The y / vertical axis shows the output signal of the deadband that is passed to the PID algorithm.

Control zone width

If the process value exits the control zone around the setpoint, the minimum or maximum output value is output. This means that the process value reaches the setpoint faster.

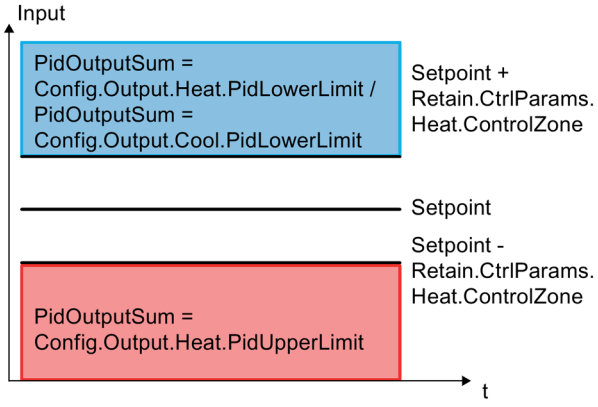
If the process value lies within the control zone around the setpoint, the output value is calculated by the PID algorithm.

The control zone width for heating or cooling is only set automatically during the pretuning, if "PID (temperature)" is selected as the controller structure for cooling or heating.

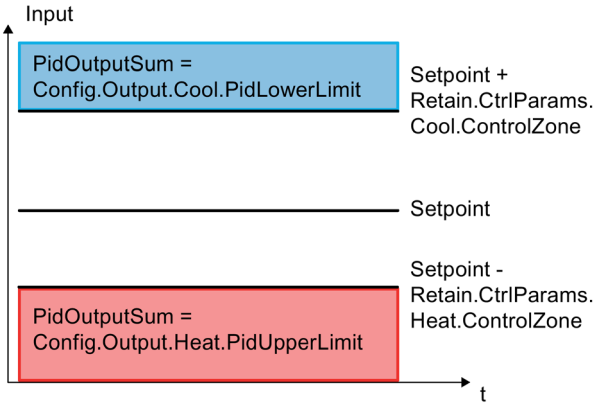
The control zone is deactivated by setting the control zone width = 3.402822e+38.

If cooling is deactivated in the basic settings or the cooling factor is used, the control zone lies symmetrically between "Setpoint - control zone width (heating)" and "Setpoint + control zone width (heating)".

If cooling is activated in the basic settings and PID parameter changeover is selected as the method for heating/cooling in the output settings, the control zone lies between "Setpoint - control zone width (heating)" and "Setpoint + control zone width (cooling)".



Control zone with deactivated cooling or cooling factor.



Control zone with activated cooling and PID parameter changeover.

Rule for tuning

Select whether PI or PID parameters are to be calculated in the "Controller structure" drop-down list. You can specify the rules for tuning for heating and for tuning for cooling separately.

- PID (temperature)

  Calculates PID parameters during pretuning and fine tuning.

  Pretuning is designed for temperature processes and results in a slower and rather asymptotic control response with smaller overshoots than with the "PID" option. Fine tuning is identical to the "PID" option.

  The control zone width is determined automatically during pretuning only if this option is selected.

- PID

  Calculates PID parameters during pretuning and fine tuning.

- PI

  Calculates PI parameters during pretuning and fine tuning.

- User-defined

  The drop-down list displays "User-defined" if you have configured different controller structures for pretuning and fine tuning via a user program or the parameter view.

6.3 Commissioning PID_Temp

6.3.1 Commissioning

The commissioning window helps you commission the PID controller. You can monitor the values for the setpoint, process value and the output values for heating and cooling along the time axis in the trend view. The following functions are supported in the commissioning window:

- Controller pretuning
- Controller fine tuning

  Use fine tuning for fine adjustments to the PID parameters.
- Monitoring the current closed-loop control in the trend view
- Testing the controlled system by specifying a manual PID output value and a substitute setpoint
- Saving the actual values of the PID parameters to an offline project.

All functions require an online connection to the CPU.

The online connection to the CPU is established, if it does not exist already, and operation of the commissioning window is enabled by means of the "Monitor all" or "Start" buttons of the trend view.

Operation of the trend view

- Select the desired sampling time in the "Sampling time" drop-down list.

  All the values of the trend view are updated in the selected sampling time.
- Click the "Start" icon in the Measurement group if you want to use the trend view.

  Value recording is started. The current values for the setpoint, process value and output values for heating and cooling are entered in the trend view.
- Click the "Stop" icon if you want to end the trend view.

  The values recorded in the trend view can continue to be analyzed.

Closing the commissioning window will terminate recording in the trend view and delete the recorded values.

6.3.2 Pretuning

The pretuning determines the process response to a jump change of the output value and searches for the point of inflection. The tuned PID parameters are calculated as a function of the maximum slope and dead time of the controlled system. You obtain the best PID parameters when you perform pretuning and fine tuning.

The more stable the process value is, the easier it is to calculate the PID parameters and the more precise the result will be. Noise on the process value can be tolerated as long as the rate of rise of the process value is significantly higher compared to the noise. This is most likely the case in operating modes "Inactive" and "manual mode". The PID parameters are backed up before being recalculated.

PID_Temp offers different pretuning types depending on the configuration:

- Pretuning heating

  A jump is output at the output value heating, the PID parameters for heating are calculated and then the setpoint is used as the control variable in automatic mode.

- Pretuning heating and cooling

  A jump is output at the output value heating.

  As soon as the process value is near the setpoint, a jump to the output value cooling is output.

  The PID parameters for heating (Retain.CtrlParams.Heat structure) and cooling (Retain.CtrlParams.Cool structure) are calculated and then the setpoint is used as the control variable in automatic mode.

- Pretuning cooling

  A jump is output at the output value cooling.

  The PID parameters for cooling are calculated and then the setpoint is used as the control variable in automatic mode.

If you want to tune the PID parameters for heating and cooling, you can expect improved control response by carrying out "Pretuning heating" and subsequently "Pretuning cooling" than by carrying out "Pretuning heating and cooling". However, carrying out pretuning in two steps takes more time.

General requirements

- The PID_Temp instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- Reset = FALSE
- PID_Temp is in one of the following modes: "Inactive", "Manual mode", or "Automatic mode".
- The setpoint and the process value lie within the configured limits (see Process value monitoring (Page 174) configuration).

Requirements for pretuning heating

- The difference between setpoint and process value is greater than 30% of the difference between process value high limit and process value low limit.
- The distance between the setpoint and the process value is greater than 50% of the setpoint.
- The setpoint is greater than the process value.

Requirements for pretuning heating and cooling

- The cooling output in the "Basic settings" is activated (Config.ActivateCooling = TRUE).
- The PID parameter changeover in the "Basic settings of output value" is activated (Config.AdvancedCooling = TRUE).
- The difference between setpoint and process value is greater than 30% of the difference between process value high limit and process value low limit.
- The distance between the setpoint and the process value is greater than 50% of the setpoint.
- The setpoint is greater than the process value.

Requirements for pretuning cooling

- The cooling output in the "Basic settings" is activated (Config.ActivateCooling = TRUE).
- The PID parameter changeover in the "Basic settings of output value" is activated (Config.AdvancedCooling = TRUE).
- "Pretuning heating" or "Pretuning heating and cooling" has been carried out successfully (PIDSelfTune.SUT.ProcParHeatOk = TRUE). The same setpoint should be used for all tunings.
- The difference between setpoint and process value is smaller than 5% of the difference between process value high limit and process value low limit.

Procedure

To perform pretuning, follow these steps:

1. Double-click the "PID_Temp > Commissioning" entry in the project tree.
2. Activate the "Monitor all" button or start the trend view.

   An online connection will be established.
3. Select the desired pretuning entry from the "Tuning mode" drop-down list.
4. Click the "Start" icon.
   - Pretuning is started.
   - The "Status" field displays the current steps and any errors that may have occurred. The progress bar indicates the progress of the current step.

Note

Click the "Stop" icon when the progress bar ("Progress" tag) has not changed for a long period and it is to be assumed that the tuning function is blocked. Check the configuration of the technology object and, if necessary, restart controller tuning.

Result

If pretuning was performed without an error message, the PID parameters have been tuned. PID_Temp switches to automatic mode and uses the tuned parameters. The tuned PID parameters will be retained during power OFF and a restart of the CPU.

If pretuning is not possible, PID_Temp responds with the configured reaction to errors.

6.3.3 Fine tuning

Fine tuning generates a constant, limited oscillation of the process value. The PID parameters are tuned for the operating point from the amplitude and frequency of this oscillation. The PID parameters are recalculated from the results. PID parameters from fine tuning usually have better master control and disturbance characteristics than PID parameters from pretuning. You obtain the best PID parameters when you perform pretuning and fine tuning.

PID_Temp automatically attempts to generate an oscillation greater than the noise of the process value. Fine tuning is only minimally influenced by the stability of the process value. The PID parameters are backed up before being recalculated.

PID_Temp offers different fine tuning types depending on the configuration:

- Fine tuning heating:

  PID_Temp generates an oscillation of the process value with periodic changes at the output value heating and calculates the PID parameters for heating.

- Fine tuning cooling:

  PID_Temp generates an oscillation of the process value with periodic changes at the output value cooling and calculates the PID parameters for cooling.

Temporary tuning offset for heating/cooling controllers

If PID_Temp is used as a heating/cooling controller (Config.ActivateCooling = TRUE), the PID output value (PidOutputSum) at the setpoint has to fulfill the following requirements so that process value oscillation can be generated and fine tuning can be carried out successfully:

- Positive PID output value for fine tuning heating
- Negative PID output value for fine tuning cooling

If this condition is not fulfilled, you can specify a temporary offset for fine tuning that is output at the opposing output.

- Offset for cooling output (PIDSelfTune.TIR.OutputOffsetCool) at fine tuning heating.

  Before starting tuning, enter a negative tuning offset cooling that is smaller than the PID output value (PidOutputSum) at the setpoint in the stationary state.

- Offset for heating output (PIDSelfTune.TIR.OutputOffsetHeat) at fine tuning cooling

  Before starting tuning, enter a positive tuning offset heating that is greater than the PID output value (PidOutputSum) at the setpoint in the stationary state.

The defined offset is balanced by the PID algorithm so that the process value remains at the setpoint. The height of the offset allows the PID output value to be adapted correspondingly so that it fulfills the requirement mentioned above.

In order to avoid greater overshoots of the process value at specification of the offset, this can also be increased in several steps.

If PID_Temp exits the fine tuning mode, the tuning offset is reset.

Example: Specification of an offset for fine tuning cooling

- Without offset
  - Setpoint = Process value (ScaledInput) = 80 °C
  - PID output value (PidOutputSum) = 30.0
  - Output value heating (OutputHeat) = 30.0
  - Output value cooling (OutputCool) = 0.0

    Oscillation of the process value around the setpoint cannot be generated with the cooling output alone. Fine tuning would fail here.
- With offset for heating output (PIDSelfTune.TIR.OutputOffsetHeat) = 80.0
  - Setpoint = Process value (ScaledInput) = 80 °C
  - PID output value (PidOutputSum) = -50.0
  - Output value heating (OutputHeat) = 80.0
  - Output value cooling (OutputCool) = -50.0

    Thanks to the specification of an offset for the heating output, the cooling output can now generate oscillation of the process value around the setpoint. Fine tuning can now be carried out successfully.

General requirements

- The PID_Temp instruction is called in a cyclic interrupt OB.
- ManualEnable = FALSE
- Reset = FALSE
- The setpoint and the process value lie within the configured limits (see "Process value settings" configuration).
- The control loop has stabilized at the operating point. The operating point is reached when the process value corresponds to the setpoint.
- No disturbances are expected.
- PID_Temp is in inactive mode, automatic mode or manual mode.

Requirements for fine tuning heating

- Heat.EnableTuning = TRUE
- Cool.EnableTuning = FALSE
- If PID_Temp is configured as a heating-and-cooling controller (Config.ActivateCooling = TRUE), the heating output has to be active at the operating point where tuning is to be carried out.

  PidOutputSum > 0.0 (see tuning offset)

Requirements for fine tuning cooling

- Heat.EnableTuning = FALSE
- Cool.EnableTuning = TRUE
- The cooling output is activated (Config.ActivateCooling = TRUE).
- The PID parameter changeover is activated (Config.AdvancedCooling = TRUE).
- The cooling output has to be active at the operating point where tuning is to be carried out.

  PidOutputSum < 0.0 (see tuning offset)

Process depends on initial situation

Fine tuning can be started from the following operating modes: "Inactive", "automatic mode", or "manual mode".

Fine tuning proceeds as follows when started from:

- Automatic mode with PIDSelfTune.TIR.RunIn = FALSE (default)

  Start fine tuning from automatic mode if you wish to improve the existing PID parameters through tuning.

  PID_Temp controls the system using the existing PID parameters until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start.

- Inactive, manual mode or automatic mode with PIDSelfTune.TIR.RunIn = TRUE

  An attempt is made to reach the setpoint with the minimum or maximum output value (two-point control):

  – With minimum or maximum output value heating at fine tuning heating.
  – With minimum or maximum output value cooling at fine tuning cooling.

  This can produce increased overshoot. When the setpoint is reached, fine tuning is started.

  If the setpoint cannot be reached, PID_Temp does not abort tuning automatically.

Procedure

To perform fine tuning, follow these steps:

1. Double-click the "PID_Temp > Commissioning" entry in the project tree.
2. Activate the "Monitor all" button or start the trend view.

   An online connection will be established.
3. Select the desired fine tuning entry from the "Tuning mode" drop-down list.
4. If required (see tuning offset), specify a tuning offset and wait until the stationary state is reached again.
5. Click the "Start" icon.
   - The process of fine tuning is started.
   - The "Status" field displays the current steps and any errors that may have occurred.

     The progress bar indicates the progress of the current step.

Note

Click the "Stop" icon in the "Tuning mode" group if the progress bar ("Progress" tag) has not changed for a long period and it is to be assumed that the tuning function is blocked. Check the configuration of the technology object and, if necessary, restart controller tuning.

In the following phases in particular, tuning is not aborted automatically if the setpoint cannot be reached.

- "Attempting to reach setpoint for heating with two-point control."
- "Attempting to reach setpoint for cooling with two-point control."

Result

If no errors occurred during fine tuning, the PID parameters have been tuned. PID_Temp switches to automatic mode and uses the tuned parameters. The tuned PID parameters will be retained during power OFF and a restart of the CPU.

If errors occurred during fine tuning, PID_Temp responds with the configured response to errors.

6.3.4 "Manual" mode

The following section describes how you can use "Manual mode" in the commissioning window of the "PID_Temp" technology object.

Manual mode is also possible when an error is pending.

Requirement

- The "PID_Temp" instruction is called in a cyclic interrupt OB.
- An online connection to the CPU has been established.
- The CPU is in "RUN" mode.

Procedure

If you want to test the controlled system by specifying a manual value, use "Manual mode" in the commissioning window.

To define a manual value, follow these steps:

1. Double-click the "PID_Temp > Commissioning" entry in the project tree.
2. Activate the "Monitor all" button or start the trend view.

   An online connection will be established.
3. Select the "Manual mode" check box in the "Online status of controller" area.

   PID_Temp operates in manual mode. The most recent current output value remains in effect.
4. Enter the manual value in the editable field as a % value.

   If cooling is activated in the basic settings, enter the manual value as follows:

   – Enter a positive manual value to output the value at the outputs for heating.

   – Enter a negative manual value to output the value at the outputs for cooling.
5. Click the icon.

Result

The manual value is written to the CPU and immediately goes into effect.

Clear the "Manual mode" check box if the output value is to be specified again by the PID controller.

The switchover to automatic mode is bumpless.

6.3.5 Substitute setpoint

The following section describes how you can use the substitute setpoint in the commissioning window of the "PID_Temp" technology object.

Requirement

- The "PID_Temp" instruction is called in a cyclic interrupt OB.
- An online connection to the CPU has been established.
- The CPU is in "RUN" mode.

Procedure

If you want to use a different value as the setpoint than that specified at the "Setpoint" parameter (for example to tune a slave in a cascade), use the substitute setpoint in the commissioning window.

Proceed as follows to specify a substitute setpoint:

1. Double-click the "PID_Temp > Commissioning" entry in the project tree.
2. Activate the "Monitor all" button or start the trend view.

   An online connection will be established.
3. Select the "Subst.Setpoint" check box in the "Online status of controller" section.

   The substitute setpoint (SubstituteSetpoint tag) is initialized with the most recently updated setpoint and now used.
4. Enter the substitute setpoint in the editable field.
5. Click the icon.

Result

The substitute setpoint is written to the CPU and immediately goes into effect.

Clear the "Subst.Setpoint" check box if the value at the "Setpoint" parameter is to be used again as setpoint.

The switchover is not bumpless.

6.3.6 Cascade commissioning

Information about cascade commissioning with PID_Temp is available under Commissioning (Page 200).

6.4 Cascade control with PID_Temp

6.4.1 Introduction

In cascade control, several control loops are nested within each other. In the process, slaves receive their setpoint (Setpoint) from the output value (OutputHeat) of the respective higher-level master.

A prerequisite for establishing a cascade control system is that the controlled system can be divided into subsystems, each with its own measured variable.

Setpoint specification for the controlled variable is carried out at the outmost master.

The output value of the innermost slave is applied to the actuator and thus acts on the controlled system.

The following major advantages result from the use of a cascade control system in comparison with a single-loop control system:

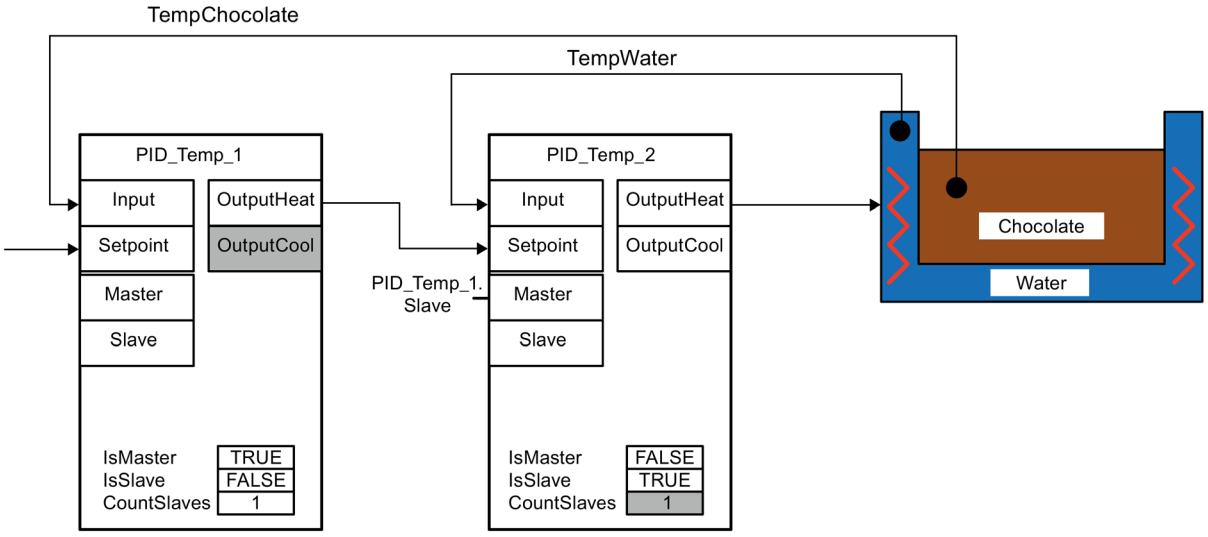
- Thanks to the additional subordinate control loops, disturbances which occur there are corrected quickly. Their influence on the controlled variable is reduced considerably. The disturbance behavior is thus improved.
- The subordinate control loops act in linearizing form. The negative effects of such non-linearities on the controlled variable are thus moderated.

PID_Temp offers the following functionality especially for use in cascade control systems:

- Specification of a substitute setpoint
- Exchange of status information between master and slave (for example, current operating mode)
- Different Anti-Wind-Up modes (response of the master to limitation of its slave)

Example

The following block diagram shows a cascade control system with PID_Temp using the simplified example of a chocolate melting unit:



The PID_Temp_1 master compares the process value of the chocolate temperature (TempChocolate) with the setpoint specification by the user at the Setpoint parameter. Its output value OutputHeat forms the setpoint of the slave PID_Temp_2.

PID_Temp_2 attempts to regulate the process value of the water-bath temperature (TempWater) to this setpoint. The output value of PID_Temp_2 acts directly on the actuator of the controlled system (heating of the water bath) and thus influences the water-bath temperature. The water-bath temperature in turn has an effect on the chocolate temperature.

See also

Program creation (Page 196)

6.4.2 Program creation

Observe the following points during program creation:

- Number of PID_Temp instances

  The number of different PID_Temp instances called up in a cyclic interrupt OB has to agree with the number of concatenated measured variables in the process.

  There are two concatenated measured variables in the example: TempChocolate and TempWater. Therefore two PID_Temp instances are required.

- Call sequence

  A master has to be called before its slaves in the same cyclic interrupt OB.

  The outermost master at which the user setpoint is specified is called first.

  The slave whose setpoint is specified by the outermost master is called next, etc.

  The innermost slave that acts on the actuator of the process with its output value is called last.

  In the example, PID_Temp_1 is called before PID_Temp_2.

- Interconnection of the measured variables

  The outermost master is interconnected with the outermost measured variable that is to be regulated to the user setpoint.

  The innermost slave is interconnected with the innermost measured variable that is influenced directly by the actuator.

  Interconnection of the measured variables with PID_Temp is carried out with the parameters Input or Input_PER.

  In the example, the outermost measured variable TempChocolate is interconnected with PID_Temp_1 and the innermost measured variable TempWater with PID_Temp_2.

- Interconnection of the output value of the master to the setpoint of the slave

  The output value (OutputHeat) of a master has to be assigned to the setpoint (Setpoint) of its slave.

  This interconnection can be carried out in the programming editor or automatically in the Inspector window of the slave in the basic settings via the selection of the master.

  If required, you can insert your own filter or scaling functions, for example in order to adapt the output value range of the master to the setpoint/process value range of the slave.

  In the example, OutputHeat of PID_Temp_1 is assigned to Setpoint of PID_Temp_2.

- Interconnection of the interface for information exchange between master and slave

  The "Slave" parameter of a master has to be assigned to the "Master" parameter of all its directly subordinate slaves (which receive their setpoint from this master). The assignment should be carried out via the interface of the Slave in order to allow the interconnection of a master with several slaves and the display of the interconnection in the Inspector window of the slave in the basic settings.

  This interconnection can be carried out in the programming editor or automatically in the Inspector window of the slave in the basic settings via the selection of the master.

  The Anti-Wind-Up functionality and the evaluation of the slave operating modes at the master can only function correctly if this interconnection is carried out.

  In the example, the "Slave" parameter of PID_Temp_1 is assigned to the "Master" parameter of PID_Temp_2.

Program code of the example using SCL (without assignment of the output value of the slave to the actuator):

```
"PID_Temp_1"(Input:="TempChocolate");

"PID_Temp_2"(Input:="TempWater", Master := "PID_Temp_1".Slave, Setpoint :=
"PID_Temp_1".OutputHeat);
```

See also

PID_Temp ActivateRecoverMode tag (Page 427)

6.4.3 Configuration

You can carry out the configuration via your user program, the configuration editor or the Inspector window of the PID_Temp call.

When using PID_Temp in a cascade control system, ensure the correct configuration of the settings specified below.

If a PID_Temp instance receives its setpoint from a superior master controller and outputs its output value in turn to a subordinate slave controller, this PID_Temp instance is both a master controller and a slave controller simultaneously. Both configurations listed below have to be carried out for such a PID_Temp instance. This is the case, for example, for the middle PID_Temp instance in a cascade control system with three concatenated measured variables and three PID_Temp instances.

Configuration of a master

Setting in the configuration editor or Inspector window	DB parameter	Explanation
Basic settings → Cascade: Activate "Controller is master" check box	Config.Cascade.IsMaster = TRUE	Activates this controller as a master in a cascade
Basic settings → Cascade: Number of slaves	Config.Cascade.CountSlaves	Number of directly subordinate slaves that receive their setpoint directly from this master
Basic settings → Input/output parameters: Selection of the output value (heating) = OutputHeat	Config.Output.Heat.Select = 0	The master only uses the output parameter OutputHeat. OutputHeat_PWM and OutputHeat_PER are deactivated.
Basic settings → Input/output parameters: Clear "Activate cooling" check box	Config.ActivateCooling = FALSE	The cooling has to be deactivated at a master.

Setting in the configuration editor or Inspector window	DB parameter	Explanation
Output settings → Output limits and scaling → OutputHeat / OutputCool: Low limit of PID output value (heating), High limit of PID output value (heating), Scaled lower output value (heating), Scaled upper output value (heating)	Config.Output.Heat.PidLowerLimit, Config.Output.Heat.PidUpperLimit, Config.Output.Heat.LowerScaling, Config.Output.Heat.UpperScaling	If no own scaling function is used when assigning OutputHeat of the master to Setpoint of the slave, it may be necessary to adapt the output value limits and the output scaling of the master to the setpoint/process value range of the slave.
This tag is not available in the Inspector window or in the function view of the configuration editor. You can change it via the parameter view of the configuration editor.	Config.Cascade.AntiWindUpMode	The Anti-Wind-Up mode determines how the integral action of this master is treated if directly subordinate slaves reach their output value limits. Options are: • AntiWindUpMode = 0: The AntiWindUp functionality is deactivated. The master does not react to the limitation of its slaves. • AntiWindUpMode = 1 (default): The integral action of the master is reduced in the relationship "Slaves in limitation/Number of slaves". This reduces the effects of the limitation on the control behavior. • AntiWindUpMode = 2: The integral action of the master is held as soon as a slave is in limitation.

Configuration of a slave

Setting in the configuration editor or Inspector window	DB parameter	Explanation
Basic settings → Cascade: Select the "Controller is slave" check box	Config.Cascade.IsSlave = TRUE	Activates this controller as a slave in a cascade

6.4.4 Commissioning

After compiling and loading of the program, you can start commissioning of the cascade control system.

Begin with the innermost slave at commissioning (implementation of tuning or change to automatic mode with existing PID parameters) and continue outwards until the outermost master has been reached.

In the above example, commissioning starts with PID_Temp_2 and is continued with PID_Temp_1.

Tuning the slave

Tuning of PID_Temp requires a constant setpoint. Therefore, activate the substitute setpoint of a slave (SubstituteSetpoint and SubstituteSetpointOn tags) to tune the slave or set the associated master to manual mode by using a corresponding manual value. This ensures that the setpoint of the slave remains constant during tuning.

Tuning the master

In order for a master to influence the process or to carry out tuning, all the downstream slaves have to be in automatic mode and their substitute setpoint has to be deactivated. A master evaluates these conditions through the interface for information exchange between master and slave (Master parameter and Slave parameter) and displays the current state at the AllSlaveAutomaticState and NoSlaveSubstituteSetpoint tags. Corresponding status messages are output in the commissioning editor.

Status message in the commissioning editor of the master	DB parameter of the master	Correction
One or more slaves are not in automatic mode.	AllSlaveAutomaticState = FALSE, NoSlaveSubstituteSetpoint = TRUE	First, carry out commissioning of all downstream slaves. Ensure that the following conditions are fulfilled before carrying out tuning or activating manual mode or automatic mode of the master: • All downstream slaves are in automatic mode (state = 3). • All downstream slaves have deactivated the substitute setpoint (SubstituteSetpointOn = FALSE).
One or more slaves have activated the substitute setpoint.	AllSlaveAutomaticState = TRUE, NoSlaveSubstituteSetpoint = FALSE	
One or more slaves are not in automatic mode and have activated the substitute setpoint.	AllSlaveAutomaticState = FALSE, NoSlaveSubstituteSetpoint = FALSE	

If pretuning or fine tuning is started for a master, PID_Temp aborts tuning in the following cases and displays an error with ErrorBits = DW#16#0200000:

- One or more slaves are not in automatic mode (AllSlaveAutomaticState = FALSE)
- One or more slaves have activated the substitute setpoint (NoSlaveSubstituteSetpoint = FALSE).

The subsequent operating mode changeover depends on ActivateRecoverMode.

6.4.5 Substitute setpoint

In order to specify a setpoint, PID_Temp offers a substitute setpoint at the SubstituteSetpoint tags in addition to the Setpoint parameter. This can be activated by setting SubstituteSetpointOn = TRUE or by selecting the corresponding check box in the commissioning editor.

The substitute setpoint allows you to specify the setpoint temporarily directly at the slave, for example during commissioning or tuning.

In this case, the interconnection of the output value of the master with the setpoint of the slave that is required for normal operation of the cascade control system does not have to be changed in the program

In order for a master to influence the process or to carry out tuning, the substitute setpoint has to be deactivated at all downstream slaves.

You can monitor the currently effective setpoint as it is used by the PID algorithm for calculation at the CurrentSetpoint tags.

6.4.6 Operating modes and fault response

The master or slave of a PID_Temp instance does not change the operating mode of this PID_Temp instance.

If a fault occurs at one of its slaves, the master remains in its current operating mode.

If a fault occurs at its master, the slave remains in its current operating mode. However, further operation of the slave then depends on the fault and the configured fault response of the master since the output value of the master is used as the setpoint of the slave:

- If ActivateRecoverMode = TRUE is configured at the master. and the fault does not prevent the calculation of OutputHeat, the fault does not have any effect on the slave.
- If ActivateRecoverMode = TRUE is configured at the master and the fault prevents the calculation of OutputHeat, the master outputs the last output value or the configured substitute output value SubstituteOutput, depending on SetSubstituteOutput. This is then used by the slave as the setpoint.

  PID_Temp is preconfigured so that the substitute output value 0.0 is output in this case (ActivateRecoverMode = TRUE, SetSubstituteOutput = TRUE, SubstituteOutput = 0.0). Configure a suitable substitute output value for your application or activate the use of the last valid PID output value (SetSubstituteOutput = FALSE).
- If ActivateRecoverMode = FALSE is configured at the master, the master changes to the "Inactive" mode when a fault occurs and outputs OutputHeat = 0.0. The slave then uses 0.0 as the setpoint.

The fault response is located in the output settings in the configuration editor.

6.5 Multi-zone controlling with PID_Temp

Introduction

In a multi-zone control system, several sections, so-called zones, of a plant are controlled simultaneously to different temperatures. A multi-zone control system is characterized by the mutual influence of the temperature zones through thermal coupling, i.e. the process value of one zone can influence the process value of a different zone through thermal coupling. The strength that this influence has depends on the structure of the plant and the selected operating points of the zones.

Example: Extrusion plant as it is used, for example, in plastics processing.

The substance mixture that passes through the extruder has to be controlled to different temperatures for optimal processing. For example, different temperatures can be required at the filling point of the extruder than at the outlet nozzle. The individual temperature zones mutually influence each other through thermal coupling.

When PID_Temp is used in multi-zone control systems, each temperature zone is controlled by a separate PID_Temp instance.

Observe the following explanations if you want to use the PID_Temp in a multi-zone control system.

Separate pretuning for heating and cooling

Initial commissioning of a plant as a rule begins with the carrying out of pretuning in order to carry out initial setting of the PID parameters and control to the operating point. The pretuning for multi-zone control systems is often carried out simultaneously for all zones.

PID_Temp offers the possibility of carrying out pretuning for heating and cooling in one step (Mode = 1, Heat.EnableTuning = TRUE, Cool.EnableTuning = TRUE) for controllers with activated cooling and PID parameter changeover as the method for heating/cooling (Config.ActivateCooling = TRUE, Config.AdvancedCooling = TRUE).

However, it is advisable not to use this tuning for simultaneous pretuning of several PID_Temp instances in a multi-zone control system. Instead, first carry out the pretuning for heating (Mode = 1, Heat.EnableTuning = TRUE, Cool.EnableTuning = FALSE) and the pretuning for cooling (Mode = 1, Heat.EnableTuning = FALSE, Cool.EnableTuning = TRUE) separately.

Pretuning for cooling should not be started until all zones have completed pretuning for heating and have reached their operating points.

This reduces mutual influencing through thermal coupling between the zones during tuning.

Adapting the delay time

If PID_Temp is used in a multi-zone control system with strong thermal couplings between the zones, you should ensure that the adaption of the delay time is deactivated for pretuning with PIDSelfTune.SUT.AdaptDelayTime = 0. Otherwise, the determination of the delay time can be incorrect if the cooling of a zone is prevented by the thermal influence of other zones during the adapting of the delay time (heating is deactivated in this phase).

Temporary deactivation of cooling

PID_Temp offers the possibility of deactivating cooling temporarily in automatic mode for controllers with active cooling (Config.ActivateCooling = TRUE) by setting DisableCooling = TRUE.

This ensures that this controller does not cool in automatic mode during commissioning while the controllers of other zones have not yet completed tuning of heating. The tuning could otherwise be influenced negatively by the thermal coupling between the zones.

Procedure

You can proceed as follows during the commissioning of multi-zone control systems with relevant thermal couplings:

1. Set DisableCooling = TRUE for all controllers with activated cooling.
2. Set PIDSelfTune.SUT.AdaptDelayTime = 0 for all controllers.
3. Specify the desired setpoints (Setpoint parameter) and start pretuning for heating (Mode = 1, Heat.EnableTuning = TRUE, Cool.EnableTuning = FALSE) simultaneously for all controllers.
4. Wait until all the controllers have completed pretuning for heating.
5. Set DisableCooling = FALSE for all controllers with activated cooling.
6. Wait until the process values of all the zones are steady and close to the respective setpoint.

   If the setpoint cannot be reached permanently for a zone, the heating or cooling actuator is too weak.
7. Start pretuning for cooling (Mode = 1, Heat.EnableTuning = FALSE, Cool.EnableTuning = TRUE) for all controllers with activated cooling.

Note

Limit violation of the process value

If the cooling is deactivated in automatic mode with DisableCooling = TRUE, this can cause the process value to exceed the setpoint and the process value limits while DisableCooling = TRUE. Observe the process values and intervene, if appropriate, if you use DisableCooling.

Note

Multi-zone control systems

For multi-zone control systems, the thermal couplings between the zones can result in increased overshoots, permanent or temporary violation of limits and permanent or temporary control deviations during commissioning or operation. Observe the process values and be ready to intervene. Depending on the system, it can be necessary to deviate from the procedure described above.

Synchronization of several fine tuning processes

If fine tuning is started from automatic mode with PIDSelfTune.TIR.RunIn = FALSE, PID_Temp tries to reach the setpoint with PID controlling and the current PID parameters. The actual tuning does not start until the setpoint is reached. The time required to reach the setpoint can be different for the individual zones of a multi-zone control system.

If you want to carry out fine tuning for several zones simultaneously, PID_Temp offers the possibility to synchronize these by waiting with the further tuning steps after the setpoint has been reached.

Procedure

This ensures that all the controllers have reached their setpoint when the actual tuning steps start. This reduces mutual influencing through thermal coupling between the zones during tuning.

Proceed as follows for controllers for whose zones you want to carry out fine tuning simultaneously:

1. Set PIDSelfTune.TIR.WaitForControlIn = TRUE for all controllers.

   These controllers have to be in automatic mode with PIDSelfTune.TIR.RunIn = FALSE.
2. Specify the desired setpoints (Setpoint parameters) and start fine tuning for all controllers.
3. Wait until PIDSelfTune.TIR.ControlInReady = TRUE at all controllers.
4. Set PIDSelfTune.TIR.FinishControlIn = TRUE for all controllers.

All controllers then start the actual tuning simultaneously.

Using PID basic functions

7

7.1 CONT_C

7.1.1 Technology object CONT_C

The technology object CONT_C provides a continual PID-controller for automatic and manual mode. It corresponds to the instance data block of the instruction CONT_C. You can configure a pulse controller using the PULSEGEN instruction.

The proportional, integral (INT) and differential components (DIF) are switched parallel to each other and can be turned on and off individually. With this, P-, I, PI-, PD- and PID-controller can be set.

S7-1500
All parameters and tags of the technology object are retentive and can only be changed during download to the device if you completely download CONT_C.

See also

Overview of software controller (Page 39)

Add technology objects (Page 42)

Configure technology objects (Page 43)

CONT_C (Page 433)

Downloading technology objects to device (Page 46)

7.1.2 Configure controller difference CONT_C

Use process value periphery

To use the process value in the periphery format at the PV_PER input parameter, follow these steps:

1. Select the "Enable I/O" check box.
2. If the process value is available as a physical size, enter the factor and offset for the scaling in percent.
   The process value is then determined according to the following formula:
   PV = PV_PER × PV_FAC + PV_OFF

Use internal process values

To use the process value in the floating-point format at the PV_IN input parameter, follow these steps:

1. Clear the "Enable I/O" check box.

Control deviation

Set a dead zone range under the following requirement:

- The process value signal is noisy.
- The controller gain is high.
- The derivative action is activated.

The noise component of the process value causes strong deviations of the output value in this case. The dead zone suppresses the noise component in the steady controller state. The dead zone range specifies the size of the dead zone. With a dead zone range of 0.0, the dead zone is turned off.

See also

How CONT_C works (Page 434)

7.1.3 Configure the controller algorithm CONT_C

General

To determine which components of the control algorithm are activated, proceed as follows:

1. Select an entry from the "Controller structure" list.
   You can only specify required parameters for the selected controller structure.

Proportional action

1. If the controller structure contains a proportional action, enter the "proportional gain".

Integral action

1. If the controller structure contains an integral action, enter the integral action time.
2. To give the integral action an initialization value, select the check box "Initialize integral action" and enter the initialization value.
3. In order to permanently set the integral action to this initialization value, select the "Integral action hold" check box.

Derivative action

1. If the controller structure contains a derivative action, enter the derivative action time, the derivative action weighting and the delay time.

See also

How CONT_C works (Page 434)

7.1.4 Configure the output value CONT_C

General

You can set CONT_C in the manual or automatic mode.

1. To set a manual manipulated value, activate the option "Activate manual mode" option check box.
   You can specify a manual manipulated value on the input parameter MAN.

Manipulated value limits

The manipulated value is limited at the top and bottom so that it can only accept valid values. You cannot turn off the limitation. Exceeding the limits is displayed through the output parameters QLMN_HLM and QLMN_LLM.

1. Enter a value for the high and low manipulated value limits.
   If the manipulated value is a physical size, the units for the high and low manipulated value limits must match.

Scaling

The manipulated value can be scaled for output as a floating point and periphery value through a factor and an offset according to the following formula.

Scaled manipulated value = manipulated value x factor + offset

Default is a factor of 1.0 and an offset of 0.0.

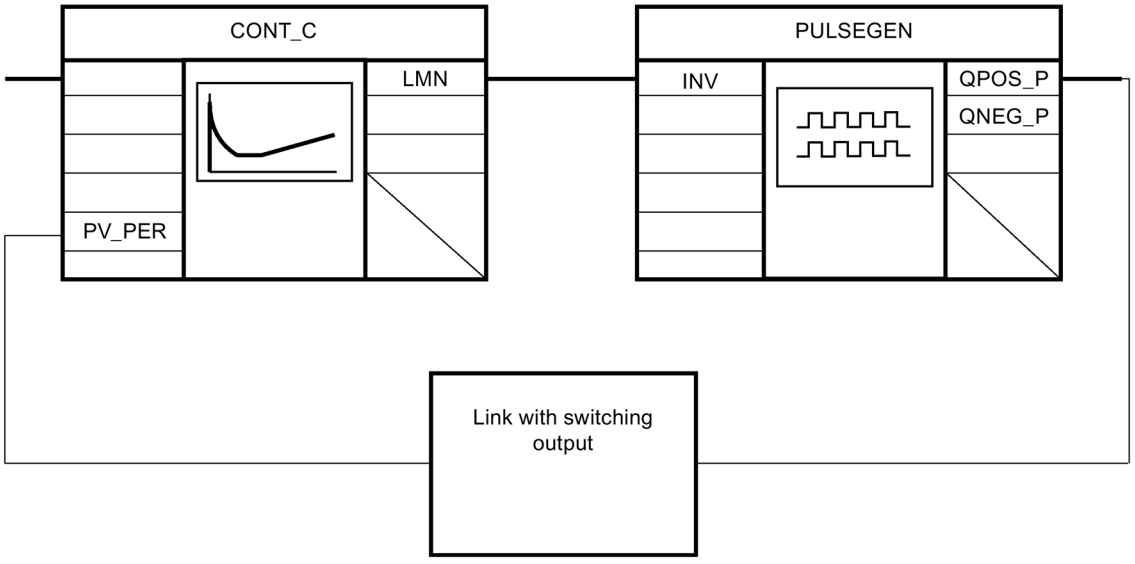
1. Enter a value for the factor and offset.

See also

How CONT_C works (Page 434)

7.1.5 Programming a pulse controller

With the continuous controller CONT_C and the pulse shaper PULSEGEN, you can implement a fixed setpoint controller with a switching output for proportional actuators. The following figure shows the signal flow of the control loop.



The continuous controller CONT_C forms the output value LMN that is converted by the pulse shaper PULSEGEN into pulse/break signals QPOS_P or QNEG_P.

See also

PULSEGEN (Page 444)

7.1.6 Commissioning CONT_C

Requirements

- The instruction and the technology object are loaded on the CPU.

Procedure

In order to manually determine the optimal PID parameter, proceed as follows:

1. Click the "Start" icon.

   If there is no online connection, this will be established. The current values for the setpoint, process value and output value are recorded.
2. Enter new PID parameters in the "P", "I", "D" and "Delay time" fields.
3. Click on the icon "Send parameter to CPU" in the "Tuning" group.
4. Select the "Change setpoint" check box in the "Current values" group.
5. Enter a new setpoint and click in the "Current Values" group on the icon .
6. Clear the "Manual mode" check box.

   The controller works with the new PID parameters and controls the new setpoint.
7. Check the quality of the PID parameter to check the curve points.
8. Repeat steps 2 to 6 until you are satisfied with the controller results.

7.2 CONT_S

7.2.1 Technology object CONT_S

The technology object CONT_S provides a step controller for actuators with integrating behavior and is used to control technical temperature processes with binary output value output signals. The technology object corresponds to the instance data block of the CONT_S instruction. The operating principle is based on the PI control algorithm of the sampling controller. The step controller operates without a position feedback signal. Both manual and automatic mode are possible.

S7-1500
All parameters and tags of the technology object are retentive and can only be changed during download to the device if you completely download CONT_S.

See also

Overview of software controller (Page 39)

Add technology objects (Page 42)

Configure technology objects (Page 43)

CONT_S (Page 439)

Downloading technology objects to device (Page 46)

7.2.2 Configure controller difference CONT_S

Use process value periphery

To use the process value in the periphery format at the PV_PER input parameter, follow these steps:

1. Select the "Enable I/O" check box.
2. If the process value is available as a physical quantity, enter the factor and offset for the scaling in percent.
   The process value is then determined according to the following formula:
   PV = PV_PER × PV_FAC + PV_OFF

Use internal process values

To use the process value in the floating-point format at the PV_IN input parameter, follow these steps:

1. Clear the "Enable I/O" check box.

Control deviation

Set a deadband range under the following requirement:

- The process value signal is noisy.
- The controller gain is high.
- The derivative action is activated.

The noise component of the process value causes strong deviations of the manipulated variable in this case. The deadband suppresses the noise component in the steady controller state. The deadband range specifies the size of the deadband. With a deadband range of 0.0, the deadband is turned off.

See also

Mode of operation CONT_S (Page 440)

7.2.3 Configuring control algorithm CONT_S

PID algorithm

1. Enter the "proportional amplification" for the P-component.
2. Enter the integration time for the time behavior of the I-component.
   With an integration time of 0.0, the I-component is switched off.

See also

Mode of operation CONT_S (Page 440)

7.2.4 Configure manipulated value CONT_S

General

You can set CONT_S in the manual or automatic mode.

1. To set a manual manipulated value, activate the "Activate manual mode" option check box.
   Enter a manual manipulated value for the input parameters LMNUP and LMNDN.

Pulse generator

1. Enter the minimum impulse duration and minimum pause duration.
   The values must be greater than or equal to the cycle time for the input parameter CYCLE. The frequency of operation is reduced through this.
2. Enter the motor setting time.
   The value must be greater than or equal to the cycle time of the input parameter CYCLE.

See also

Mode of operation CONT_S (Page 440)

7.2.5 Commissioning CONT_S

Requirements

- The instruction and the technology object have been loaded to the CPU.

Procedure

To manually determine the optimal PID parameters, proceed as follows:

1. Click the "Start" icon.

   If there is no online connection, this will be established. The current values for the setpoint, process value and output value are recorded.
2. In the fields "P" and "I", enter a new proportional value and a new integration time.
3. Click on the icon "Send parameter to CPU" in the "Tuning" group.
4. Select the "Change setpoint" check box in the "Current values" group.
5. Enter a new setpoint and click in the "Current Values" group on the icon .
6. Clear the "Manual mode" check box.

   The controller works with the new parameters and controls the new setpoint.
7. Check the quality of the PID parameter to check the curve points.
8. Repeat steps 2 to 6 until you are satisfied with the controller results.

7.3 TCONT_CP

7.3.1 Technology object TCONT_CP

The technology object TCONT_CP provides a continual temperature controller with pulse generator. It corresponds to the instance data block of the instruction TCONT_CP. The operation is based on the PID control algorithm of the sampling controller. Both manual and automatic mode are possible.

The instruction TCONT_CP calculates the proportional, integral and derivative parameters for your controlled system during pretuning. "Fine tuning" can be used to tune the parameters further. You can also enter the PID parameters manually.

S7-1500
All parameters and tags of the technology object are retentive and can only be changed during download to the device if you completely download TCONT_CP.

See also

Overview of software controller (Page 39)

Add technology objects (Page 42)

Configure technology objects (Page 43)

TCONT_CP (Page 455)

Downloading technology objects to device (Page 46)

7.3.2 Configure TCONT_CP

7.3.2.1 Controller difference

Use process value periphery

To use the input parameter PV_PER, proceed as follows:

1. Select the entry "Periphery" from the "Source" list.
2. Select the "sensor type".
   Depending on the sensor type, the process value is scaled according to different formulas.
   - Standard
     Thermoelements; PT100/NI100

     PV = 0.1 × PV_PER × PV_FAC + PV_OFFS
   - Cooling;
     PT100/NI100

     PV = 0.01 × PV_PER × PV_FAC + PV_OFFS
   - Current/voltage

     PV = 100/27648 × PV_PER × PV_FAC + PV_OFFS
3. Enter the factor and offset for the scaling of the process value periphery.

Use internal process values

To use the input parameter PV_IN, proceed as follows:

1. Select the entry "Internal" from the "Source" list.

Control deviation

Set a deadband range under the following requirement:

- The process value signal is noisy.
- The controller gain is high.
- The derivative action is activated.

The noise component of the process value causes strong deviations of the manipulated variable in this case. The deadband suppresses the noise component in the steady controller state. The deadband range specifies the size of the deadband. With a deadband range of 0.0, the deadband is turned off.

See also

Mode of operation TCONT_CP (Page 456)

7.3.2.2 Controlling algorithm

General

1. Enter the "Sampling time PID algorithm".
   A controller sampling time should not exceed 10 % of the determined integratl action time of the controller (TI).
2. If the controller structure contains a proportional action, enter the "proportional gain".
   A negative proportional gain inverts the rule meaning.

Proportional action

For changes of the setpoint, it may lead to overshooting of the proportional action. Through the weighting of the proportional action, you can select how strongly the proportional action should react when setpoint changes are made. The weakening of the proportional action is reached through a compensation of the integral action.

1. To weaken the proportional action for setpoint changes, enter a "Proportional action weighting".
   - 1.0: Proportional action for setpoint change is fully effective
   - 0.0: Proportional action for setpoint change is not effective

Integral action

With a limitation of the manipulated value, the integral action is stopped. With a control deviation that moves the integral action in the direction of an internal setting range, the integral action is released again.

1. If the controller structure contains an integral action, enter the "integral action time".
   With an integral action time of 0.0, the integral action is switched off.
2. To give the integral action an initialization value, select the "Initialize integral action" check box and enter the "Initialization value".
   Upon restart or COM_RST = TRUE, the integral action is set to this value.

Derivative action

1. If the controller structure contains a derivative action, enter the derivative action time (TD) and the coefficients DT1 (D_F).
   With switched derivative action, the following equation should be maintained:
   TD = 0.5 × CYCLE× D_F.
   The delay time is calculated from this according to the formula:
   delay time = TD/D_F

Set PD-controller with operating point

1. Enter the integral action time 0.0.
2. Activate the "Initialize integral action" check box.
3. Enter the operating point as the initialization value.

Set P-controller with operating point

1. Set a PD-controller with an operating point.
2. Enter the derivative action time 0.0.
   The derivative action is disabled.

Control zone

The control zone limits the value range of the control deviation. If the control deviation is outside of this value range, the manipulated value limits are used.

With an occurrence in the control zone, the derivative action leads to a very quick reduction of the manipulated variable. Thus, the control zone only makes sense for switched on derivative actions. Without control zone, only the reducing proportional action would reduce the manipulated value. The control zone leads to a quick oscillation without over/under shooting if the emitted minimum or maximum manipulated values are removed from the manipulated value required for the new operating point.

1. Activate the "Activate" check box in the "control zone" group.
2. Enter a setpoint value in the "Width" input field from which the process value may deviate above or below.

See also

Mode of operation TCONT_CP (Page 456)

7.3.2.3 Manipulated value continual controller

Manipulated value limits

The manipulated value is limited at the top and bottom so that it can only accept valid values. You cannot turn off the limitation. Exceeding the limits is displayed through the output parameters QLMN_HLM and QLMN_LLM.

1. Enter a value for the high and low manipulated value limits.

Scaling

The manipulated value can be scaled for output as a floating point and periphery value through a factor and an offset according to the following formula.

Scaled manipulated value = manipulated value x factor + offset

Default is a factor of 1.0 and an offset of 0.0.

1. Enter a value for the factor and offset.

Pulse generator

The pulse generator must be turned on for a continual controller.

1. Disable the "Activate" option check box in the "Pulse generator" group.

See also

Mode of operation TCONT_CP (Page 456)

7.3.2.4 Manipulated value pulse controller

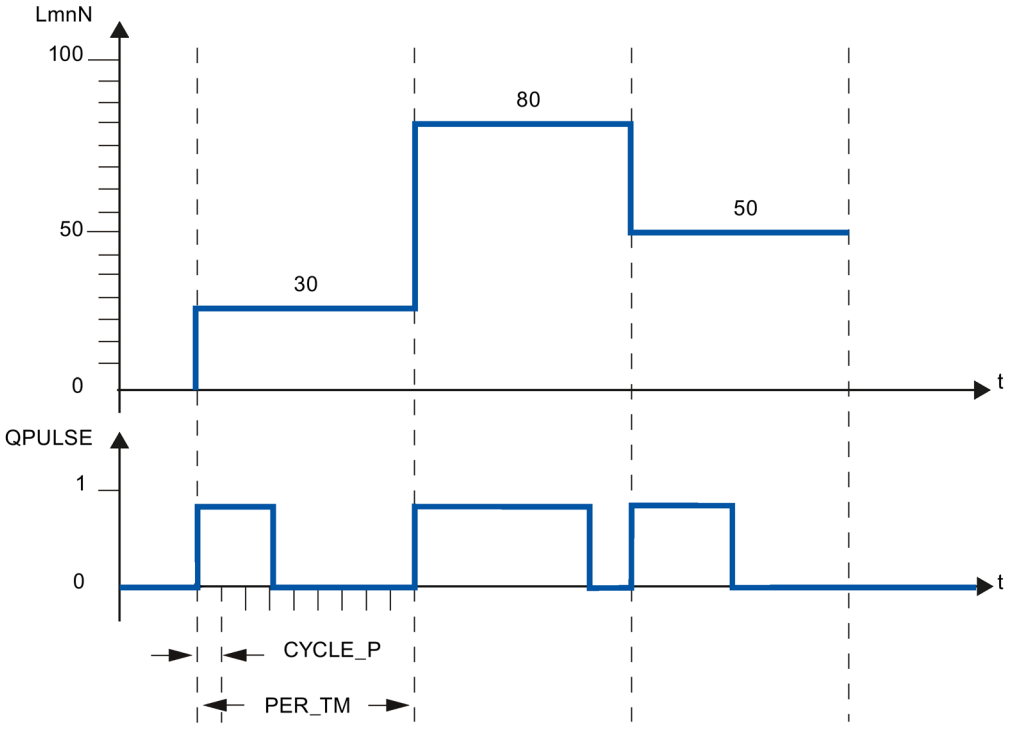
Pulse generator

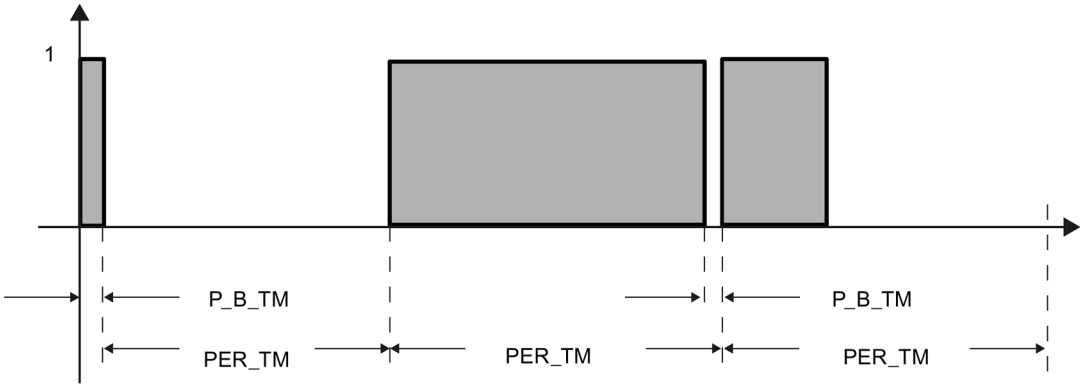
The analog manipulated value (LmnN) can be emitted through pulse-duration modulation on the output parameter QPULSE as an impulse sequence.

To use the pulse generator, proceed as follows:

1. Activate the "Activate" option check box in the "pulse generator" group.
2. Enter the "sampling time pulse generator", the "minimum impulse/break duration" and the "period duration".

The following graphics clarify the connection between the "sampling pulse generator" (CYCLE_P), the "minimum impulse/break duration" (P_B_TM) and the "period duration" (PER_TM):





Sampling time pulse generator

The sampling time pulse generator must agree with the time tact of the cyclic interrupt OB being called. The duration of the created impulse is always a whole number factor of this value. For an adequately precise manipulated value resolution, the following relationship should apply:
CYCLE_P ≤ PER_TM/50

Minimum impulse/break duration

Through the minimum impulse/break duration, short on or off times on the actuator are avoided. An impulse smaller than P_B_TM is suppressed.

Recommended are values P_B_TM ≤ 0.1 × PER_TM.

Period duration

The period duration should not exceed 20% of the determined integration time of the controller (TI):
PER_TM ≤ TI/5

Example for the effect of the parameter CYCLE_P, CYCLE and PER_TM:

Period duration PER_TM = 10 s

Sampling time PID-algorithm CYCLE = 1 s

Sampling time pulse generator CYCLE_P = 100 ms.

Every second, a new manipulated value, every 100 ms the comparison of the manipulated value occurs with the previously emitted impulse length and break length.

- If an impulse is emitted, there are 2 possibilities:
  - The calculated manipulated value is larger than the previous impulse length/PER_TM. Then the impulse is extended.
  - The calculated manipulated value is less than or equal to the previous impulse length/PER_TM. Then no impulse signal will be emitted.
- If no impulse is emitted, there are also 2 possibilities:
  - The value (100 % - calculated manipulated value) is greater than the previous break length / PER_TM. Then the break is extended.
  - The value (100 % - calculated manipulated value) is less than or equal to the previous break length / PER_TM. Then an impulse signal will be emitted.

See also

Mode of operation TCONT_CP (Page 456)

Operating principle of the pulse generator (Page 465)

7.3.3 Commissioning TCONT_CP

7.3.3.1 Optimization of TCONT_CP

Application possibilities

The controller optimization for heating or cooling processes from process type I is applicable. But you can use the block for processes with higher levels like process type II or III.

The PI/PID parameters are automatically determined and set. The controller draft is designed for an optimal disruption behavior The "precise" parameters resulting from this lead to overshooting of 10% to 40% of the jump height for setpoint jump heights.

Phases of controller optimization

For the controller optimization, individual phases are run through, which you can read on the parameter PHASE .

PHASE = 0

No tuning is running. TCONT_CP works in automatic or manual mode.

During PHASE = 0, you can make sure that the controlled system fulfills the requirements for an optimization.

At the end of the optimization, TCONT_CP changes back into PHASE = 0.

PHASE = 1

TCONT_CP is prepared for optimization. PHASE = 1 may only be started if the requirements for an optimization are fulfilled.

During PHASE = 1, the following values are determined:

- Process value noise NOISE_PV
- Initial slope PVDT0
- Average of the manipulated variable
- Sampling time PID algorithm CYCLE
- Sampling time pulse generator CYCLE_P

PHASE = 2

In phase 2, the process value attempts to detect the point of inflection with a constant manipulated variable. This method prevents the point of inflection from being found too early as a result of process variable noise.

With the pulse controller, the process variable is averaged over N pulse cycles and then made available to the controller stage. There is a further averaging of the process variable in the controller stage: Initially, this averaging is inactive; in other words, averaging always takes place over 1 cycle. As long as the noise exceeds a certain level, the number of cycles is doubled.

The period and amplitude of the noise are calculated. The search for the point of inflection is canceled and phase 2 is exited only when the gradient is always smaller than the maximum rise during the estimated period. TU and T_P_INF are, however, calculated at the actual point of inflection.

Tuning, however, is only ended when the following two conditions are met:

1. The process value is more than 2*NOISE_PV away from the point of inflection.
2. The process value has exceeded the point of inflection by 20%.

Note

When exciting the process using a setpoint step change, tuning is ended at the latest when the process value exceeds 75% of the setpoint step change (SP_INT-PV0) (see below).

PHASE = 3, 4, 5

The phases 3, 4 and 5 last 1 cycle each.

In Phase 3, the valid PI/PID parameters are saved before the optimization and the process parameter is calculated.

In Phase 4, the new PI/PID parameters are calculated.

In Phase 5, the new manipulated variable is calculated and the controlled system is given.

PHASE = 7

The process type is inspected in Phase 7, because TCONT_CP always changes to automatic mode after optimization. The automatic mode starts with LMN = LMN0 + 0.75*TUN_DLMN as a manipulated variable. The testing of the process type occurs **in the automatic mode** with the recently recalculated controller parameters and ends at the latest 0.35*TA (equilibrium time) after the point of inflection. If the process order deviates strongly from the estimated value, the controller parameters are newly calculated and STATUS_D is counted up by 1, otherwise, the controller parameters remain unchanged.

Then the optimization mode is complete and TCONT_CP is back in PHASE = 0. At the STATUS_H parameter, you can identify whether the tuning was successfully completed.

Premature cancellation of the optimization

In Phase 1, 2 or 3, you can cancel the optimization by resetting TUN_ON = FALSE without calculating new parameters. The controller starts in the automatic mode with LMN = LMN0 + TUN_DLMN. If the controller was in manual mode before the tuning, the old manual manipulated variable is output.

If the tuning is canceled in Phase 4, 5 or 7 with TUN_ON = FALSE, the determined controlled parameters are contained until then.

7.3.3.2 Requirements for an optimization

Transient response

The process must have a stable, asymptotic transient response with time lag.

The process value must settle to steady state after a step change of the manipulated variable. This therefore excludes processes that already show an oscillating response without control, as well as processes with no recovery (integrator in the control system).

⚠ WARNING

This may result in death, severe injury or considerable property damage.

During an tuning, the parameter MAN_ON is ineffective. Through this, the output value or process value may take on undesired - even extreme - values.

The output value is defined through the tuning. To cancel the tuning, you first have to set TUN_ON = FALSE. This makes MAN_ON effective again.

Guaranteeing a stationary initial state (phase 0)

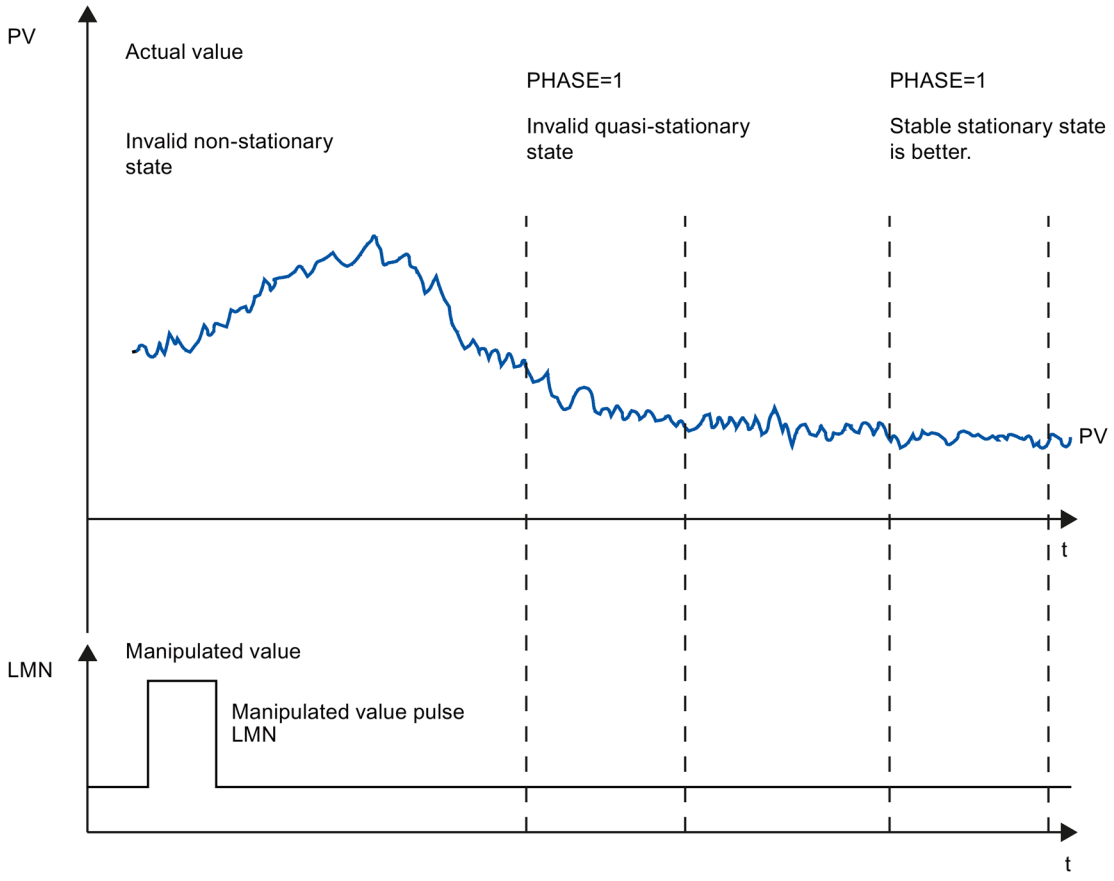
With lower-frequency oscillations of the process value, for example, due to incorrect controller parameters, the controller must be put in manual mode before the tuning is started and wait for the oscillation to stop. Alternatively, you could switch to a "soft" set PI controller (small loop gain large integration time).

Now you have to wait until the stationary state is reached, this means, until the process value and output value have a steady state. It is also permissible to have an asymptotic transient oscillation or slow drifting of the process value (stationary state, see the following image). The output value must be constant or fluctuate by a constant average.

Note

Avoid changing the manipulated variable shortly before starting the tuning. A change of the manipulated variable can occur in an unintended manner through the establishment of the test conditions (for example, closing an oven door)! If this does happen, you have to at least wait until the process value has an asymptotic transient oscillation in a stationary state again. Better controller parameters can be reached if you wait until the transient effect has completely subsided.

In the following image, the transient oscillation is illustrated in the stationary state:



Linearity and operating range

The process response must be linear across the operating range. Non-linear response occurs, for example, when an aggregation state changes. Tuning must take place in a linear part of the operating range.

This means, during tuning and normal control operation non-linear effects within the operating range must be insignificant. It is, however possible to retune the process when the operating point changes, providing tuning is repeated in the close vicinity of the new operating point and non-linearity does not occur during tuning.

If a specific static non-linearity (e.g., valve characteristics) is known, it is always advisable to compensate this with a polyline to linearize the process response.

Disturbance in temperature processes

Disturbances such as the transfer of heat to neighboring zones must not affect the overall temperature process too much. For example, when optimizing the zones of an extruder, all zones must be heated simultaneously.

7.3.3.3 Possibilities for optimization

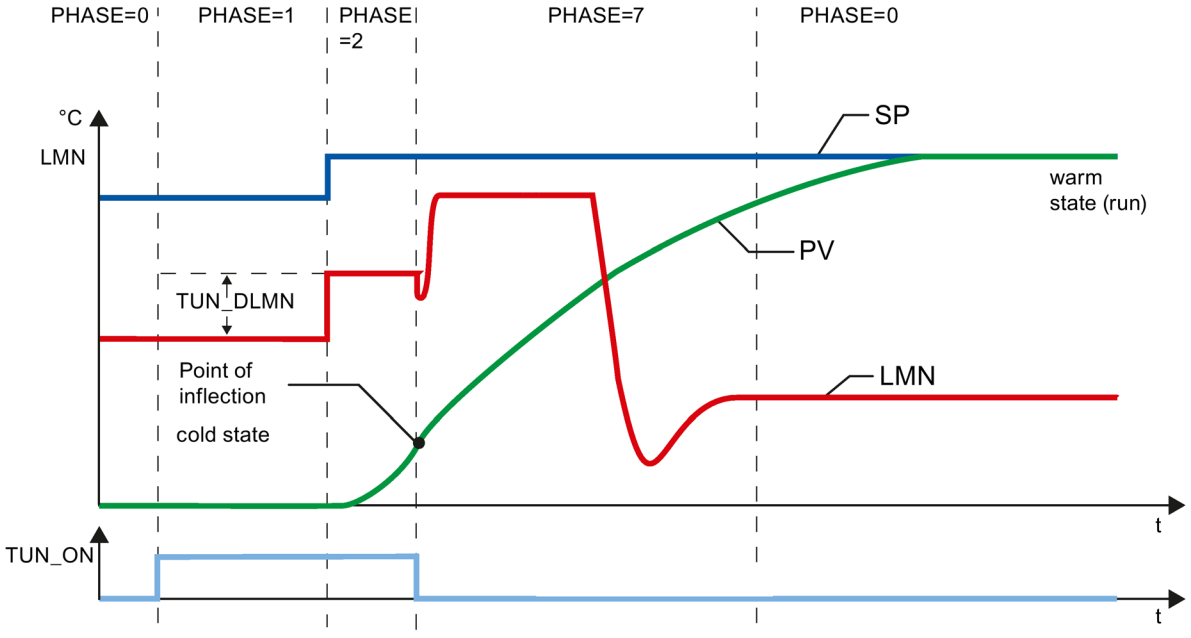
The following possibilities for tuning exist:

- Pretuning
- Fine tuning
- Manual fine-tuning in control mode

Pretuning

During this tuning, the working point is approached from the cold state through a setpoint jump.

With TUN_ON = TRUE, you can establish the tuning readiness. The controller switches from PHASE = 0 to PHASE = 1.



The tuning manipulated variable (LMN0 + TUN_DLMN) is activated by a setpoint change (transition phase 1 -> 2). The setpoint is not effective until the inflection point has been reached (automatic mode is not enabled until this point is reached).

The user is responsible for defining the output excitation delta (TUN_DLMN) according to the permitted process value change. The sign of TUN_DLMN must be set depending on the intended process value change (take into account the direction in which the control is operating).

The setpoint step change and TUN_DLMN must be suitably matched. If the value of TUN_DLMN is too high, there is a risk that the point of inflection will not be found before 75% of the setpoint step change is reached.

TUN_DLMN must nonetheless be high enough to ensure that the process value reaches at least 22 % of the setpoint step change. Otherwise, the process will remain in tuning mode (phase 2).

Remedy: Reduce the setpoint value during the inflection point search.

Note

If processes are extremely sluggish, it is advisable during tuning to specify a target setpoint that is somewhat lower than the desired operating point and to monitor the status bits and PV closely (risk of overshooting).

Tuning only in the linear range:

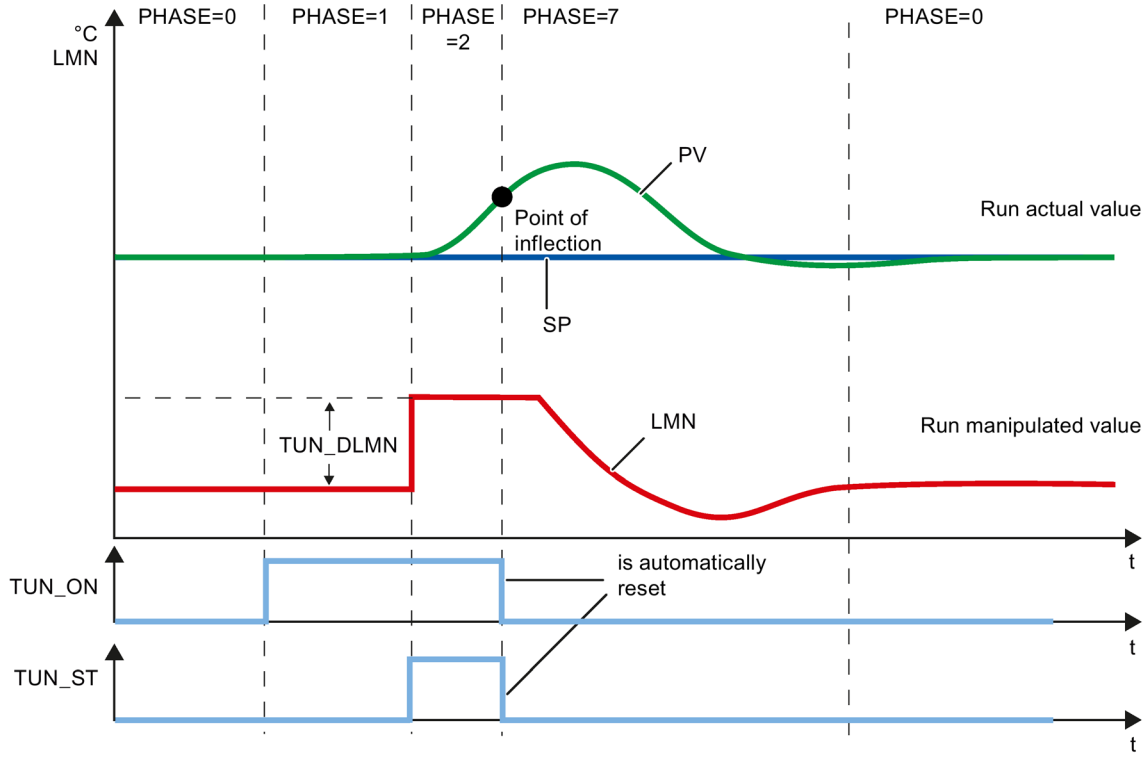
The signals of certain processes (e.g., zinc or magnesium smelters) will pass a non-linear area at the approach of the operating range (change in the state of aggregation).

By selecting a suitable setpoint step change, tuning can be limited to the linear range. When the process value has passed 75% of the setpoint step change (SP_INT-PV0), tuning is ended.

At the same time, TUN_DLMN should be reduced to the extent that the point of inflection is guaranteed to be found before 75% of the setpoint step change is reached.

Fine tuning

During this tuning, the process with a constant setpoint is activated through a output value jump.



The tuning manipulated variable (LMN0 + TUN_DLMN) is activated by setting the start bit TUN_ST (transition from phase 1 -> 2). When you modify the setpoint value, the new value will not take effect until the point of inflection has been reached (automatic mode will not be enabled until this point has been reached).

The user is responsible for defining the output excitation delta (TUN_DLMN) according to the permitted process value change. The sign of TUN_DLMN must be set depending on the intended process value change (take into account the direction in which the control is operating).

NOTICE
Safety off at 75% is not available when you excite the process via TUN_ST. Tuning is ended when the point of inflection is reached. However, in noisy processes the point of inflection may be significantly exceeded.

Manual fine-tuning in control mode

The following measures can be employed to achieve an overshoot-free setpoint response:

- Adapting the control zone
- Optimize command action
- Attenuation of control parameters
- Modifying control parameters

7.3.3.4 Tuning result

The left cipher of STATUS_H displays the tuning status

STATUS_H	Result
0	Default, i.e., new controller parameters have not (yet) been found.
10000	Suitable control parameters found.
2xxxx	Control parameters have been found via estimated values; check the control response or check the STATUS_H diagnostic message and repeat controller tuning.
3xxxx	An operator error has occurred; check the STATUS_H diagnostic message and repeat controller tuning.

The CYCLE and CYCLE_P sampling times were already checked in phase 1.

The following controller parameters are updated on TCONT_CP:

- P (proportional GAIN)
- I (integration time TI)
- D (derivative time TD)
- Weighting of the proportional action PFAC_SP
- Coefficient DT1 (D_F)
- Control zone on/off CONZ_ON
- Control zone width CON_ZONE

The control zone is only activated if the process type is suitable (process type I and II) and a PID controller is used (CONZ_ON = TRUE).

Depending on PID_ON, control is implemented either with a PI or a PID controller. The old controller parameters are saved and can be retrieved with UNDO_PAR. A PI parameter record and a PID parameter record are saved additionally in the PI_CON and PID_CON structures. Using LOAD_PID and making a suitable setting for PID_ON, it is also possible to switch later between the tuned PI or PID parameters.

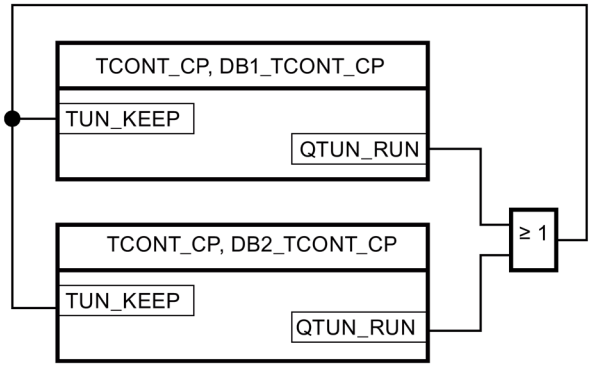
7.3.3.5 Parallel tuning of controller channels

Adjacent zones (strong heat coupling)

If two or more controllers are controlling the temperature, on a plate, for example (in other words, there are two heaters and two measured process values with strong heat coupling), proceed as follows:

1. OR the two outputs QTUN_RUN.
2. Interconnect each TUN_KEEP input with the output of the OR element.
3. Start both controllers by specifying a setpoint step change at the same time or by setting TUN_ST at the same time.

The following schematic illustrates the parallel tuning of controller channels.



Advantage:

Both controllers output LMN0 + TUN_DLMN until both controllers have left phase 2. This prevents the controller that completes tuning first from falsifying the tuning result of the other controller due to the change in its manipulated variable.

NOTICE
Reaching 75% of the setpoint step change causes an exiting of phase 2 and resetting of output QTUN_RUN. However, automatic mode does not start until TUN_KEEP is also 0.

Adjacent zones (weak heat coupling)

In general terms, tuning should be carried out to reflect the way in which the controller will operate subsequently. If zones are operated together during production such that the temperature differences between the zones remain the same, the temperature of the adjacent zones ought to be increased accordingly during tuning.

Differences in temperature at the beginning of the tuning are irrelevant since they will be compensated by the initial heating (-> initial rise = 0).

7.3.3.6 Fault descriptions and corrective measures

Compensating operator errors

Operator error	STATUS and action	Comment
TUN_ON and setpoint step change or TUN_ST are set simultaneously	Transition to phase 1; however, tuning is not started. • SP_INT = SP_{old} or • TUN_ST = FALSE	The setpoint change is canceled. This prevents the controller from settling to the new setpoint value and from leaving the stationary operating point unnecessarily.
Effective TUN_DLMN < 5% (end of phase 1)	STATUS_H = 30002 • Transition to phase 0 • TUN_ON = FALSE • SP = SP_{old}	Tuning is canceled. The setpoint change is canceled. This prevents the controller from settling to the new setpoint value and from leaving the stationary operating point unnecessarily.

Point of inflection not reached (only if excited by setpoint step change)

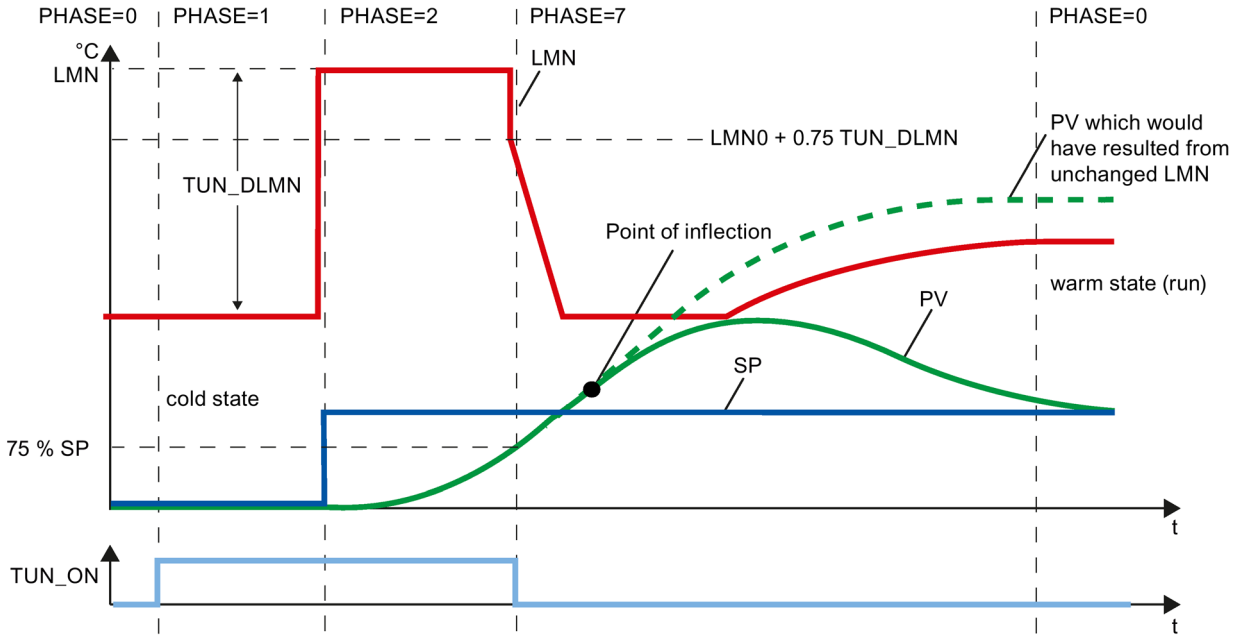
At the latest, tuning is ended when the process value has passed 75% of the setpoint step change (SP_INT-PV0). This is signaled by "inflection point not reached" in STATUS_H (2xx2x).

The currently valid setpoint always applies. By reducing the setpoint, it is possible to achieve an earlier end of the tuning function.

In typical temperature processes, cancelation of tuning at 75% of the setpoint step change is normally adequate to prevent overshoot. However, **caution** is advised, particularly in processes with a greater delay (TU/TA > 0.1, process type III). If manipulated variable excitation is too strong compared to the setpoint step change, the process value can overshoot heavily (up to a factor of 3).

In higher-order processes, if the point of inflection is still a long way off after reaching 75% of the setpoint step change, there will be significant overshoot. In addition, the controller parameters are too stringent. In this case, you should reduce the controller parameters or repeat the attempt.

The following schematic illustrates the overshoot of the process variable when the excitation is too strong (process type III):



In typical temperature processes, cancelation shortly before reaching the point of inflection is not critical in terms of the controller parameters.

If you repeat the attempt, reduce TUN_DLMN or increase the setpoint step change.

Principle: The value of the manipulated variable used for tuning must be suitable for the setpoint step change.

Error estimating the delay time or order

The delay time (STATUS_H = 2x1xx or 2x3xx) or order (STATUS_H = 21xxx or 22xxx) were not acquired correctly. Operation continues with an estimate that can lead to non-optimum controller parameters.

Repeat the tuning procedure and ensure that disturbances do not occur at the process value.

Note

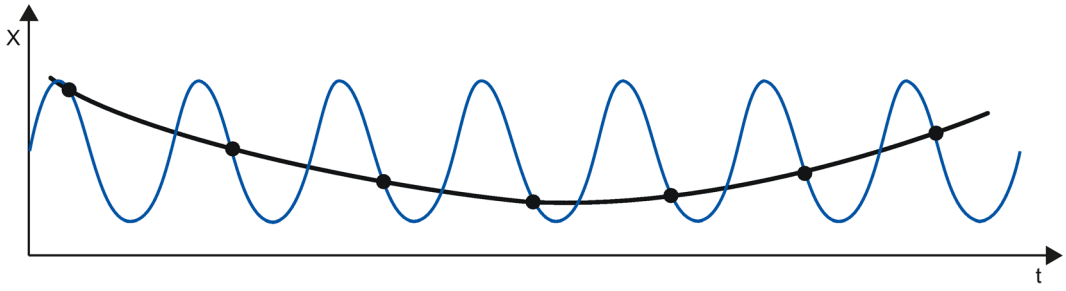
The special case of a PT1-only process is also indicated by STATUS_H = 2x1xx (TU <= 3*CYCLE). In this case, it is not necessary to repeat the attempt. Reduce the controller parameters if the control oscillates.

Quality of measuring signals (measurement noise, low-frequency interference)

The results of tuning can be distorted by measurement noise or by low-frequency interference. Note the following:

- If you encounter measurement noise, set the sampling frequency higher rather than lower. During one noise period, the process value should be sampled at least twice. In pulse mode, integrated mean value filtering can be helpful. This assumes, however, that the process variable PV is transferred to the instruction in the fast pulse cycle. The degree of noise should not exceed 5% of the useful signal change.
- High-frequency interference cannot be filtered out by TCONT_CP. This should be filtered earlier in the measuring sensor to prevent the aliasing effect.

  The following schematic illustrates the aliasing effect when the sampling time is too long:



- With low-frequency interference, it is relatively easy to ensure an adequately high sampling rate. However, the TCONT_CP must then generate a uniform measuring signal by having a large interval in the mean value filtering. Mean value filtering must extend over at least two noise periods. Internally in the block, this soon results in higher sampling times such that the accuracy of the tuning is adversely affected. Adequate accuracy is guaranteed with at least 40 noise periods up to the point of inflection.

  Possible remedy when repeating the attempt:

  Increase TUN_DLMN.

Overshoot

Overshoot can occur in the following situations:

Situation	Cause	Remedy
End of tuning	• Excitation by a too high manipulated value change compared with the set-point step change (see above). • PI controller activated by PID_ON = FALSE.	• Increase the setpoint step change or reduce the manipulated value step change. • If the process permits a PID controller, start tuning with PID_ON = TRUE.
Tuning in phase 7	Initially, less aggressive controller parameters were determined (process type III); these can lead to an overshoot in phase 7.	-
Control mode	PI controller with PFAC_SP = 1.0 for process type I.	If the process permits a PID controller, start tuning with PID_ON = TRUE.

7.3.3.7 Performing pretuning

Requirements

- The instruction and the technology object are loaded on the CPU.

Procedure

To manually determine the optimum PID parameters for initial commissioning, follow these steps:

1. Click the "Start" icon.

   If there is no online connection, this will be established. The current values for the setpoint, process value and output value are recorded.

2. Select "Pretuning" from the "Mode" drop-down list.

   TCONT_CP is ready for tuning.

3. In the "Output value jump" field, specify how much the output value should be increased.
4. Enter a setpoint in the "Setpoint" field. The output value jump only takes effect when another setpoint is entered.
5. Click the "Start tuning" icon.

   The pretuning starts. The status of the tuning is displayed.

7.3.3.8 Performing fine tuning

Requirements

- The instruction and the technology object are loaded on the CPU.

Procedure

To determine the optimal PID parameters at the operating point, follow these steps:

1. Click the "Start" icon.

   If there is no online connection, this will be established. The current values for the setpoint, process value and output value are recorded.

2. Select "Fine tuning" from the "Mode" drop-down list.

   TCONT_CP is ready for tuning.

3. In the "Output value jump" field, specify how much the output value should be increased.

4. Click the "Start tuning" icon.

   Fine tuning starts. The status of the tuning is displayed.

7.3.3.9 Cancelling pretuning or fine tuning

To cancel pretuning or fine tuning, click on the icon, "Stop tuning".

If the PID parameters have not yet been calculated and stored, TCONT_CP starts in automatic mode LMN = LMN0 + TUN_DLMN. If the controller was in manual mode before the tuning, the old manual manipulated variable is output.

If the calculated PID parameters have already been saved, TCONT_CP starts in automatic mode and works with the previously determined PID parameters.

7.3.3.10 Manual fine-tuning in control mode

The following measures can be employed to achieve an overshoot-free setpoint response:

Adapting the control zone

During tuning, "TCONT_CP" determines a control zone CON_ZONE and activated if the process type is suitable (process type I and II) and a PID controller is used (CONZ_ON = TRUE). In control mode, you can modify the control zone or switch it off completely (with CONZ_ON = FALSE).

Note

Activating the control zone with higher-order processes (process type III) does not normally provide any benefit since the control zone is then larger than the control range that can be achieved with a 100% manipulated variable. There is also no advantage in activating the control zone for PI controllers.

Before you switch on the control zone manually, make sure that the control zone is not too narrow. If the control zone is set too narrow, oscillations occur in the manipulated variable and the process value.

Continuous attenuation of the control response with PFAC_SP

The control response can be attenuated with the PFAC_SP parameter. This parameter specifies the percentage of proportional component that is effective for setpoint step changes.

Regardless of the process type, PFAC_SP is set to a default value of 0.8 by the tuning function; you can later modify this value if required. To limit overshoot during setpoint step changes (with otherwise correct controller parameters) to approximately 2%, the following values are adequate for PFAC_SP:

	Process type I	Process type II	Process type III
	Typical temperature process	Intermediate range	Higher-order temperature process
PI	0.8	0.82	0.8
PID	0.6	0.75	0.96

Adjust the default factor (0.8) in the following situations, in particular:

- Process type I with PID (0.8 →0.6): Setpoint step changes within the control zone still lead to approximately 18% overshoot with PFAC_SP = 0.8.
- Process type III with PID (0.8 →0.96): Setpoint step changes with PFAC_SP = 0.8 are attenuated too strongly. This leads to a significantly slower response time.

Attenuation of control parameters

When a closed-loop control circuit oscillates or if overshoot occurs after setpoint step changes, you can reduce the controller GAIN (e.g., to 80% of the original value) and increase integral time TI (e.g., to 150% of the original value). If the analog output value of the continuous controller is converted to binary actuating signals by a pulse shaper, quantization noise may cause minor permanent oscillation. You can eliminate this by increasing the controller deadband DEADB_W.

Modifying control parameters

Proceed as follows to modify control parameters:

1. Save the current parameters with SAVE_PAR.
2. Modify the parameters.
3. Test the control response.

If the new parameter settings are worse than the old ones, retrieve the old parameters with UNDO_PAR.

7.3.3.11 Performing fine tuning manually

Requirements

- The instruction and the technology object have been loaded to the CPU.

Procedure

To manually determine the optimal PID parameters, proceed as follows:

1. Click the "Start" icon.

   If there is no online connection, this will be established. The current values for the setpoint, process value and output value are recorded.
2. Select "Manual" from the "Mode" drop-down list.
3. Enter the new PID parameters.
4. Click on the icon "Send parameter to CPU" in the "Tuning" group.
5. Select the "Change setpoint" check box in the "Current values" group.
6. Enter a new setpoint and click in the "Current Values" group on the icon .
7. Clear the "Manual mode" check box.

   The controller works with the new PID parameters and controls the new setpoint.
8. Check the quality of the PID parameter to check the curve points.
9. Repeat steps 3 to 8 until you are satisfied with the controller results.

7.4 TCONT_S

7.4.1 Technology object TCONT_S

The technology object TCONT_S provides a step controller for actuators with integrating behavior and is used to control technical temperature processes with binary output value output signals. The technology object corresponds to the instance data block of the TCONT_S instruction. The operating principle is based on the PI control algorithm of the sampling controller. The step controller operates without a position feedback signal. Both manual and automatic mode are possible.

S7-1500
All parameters and tags of the technology object are retentive and can only be changed during download to the device if you completely download TCONT_S.

See also

Overview of software controller (Page 39)

Add technology objects (Page 42)

Configure technology objects (Page 43)

TCONT_S (Page 480)

Downloading technology objects to device (Page 46)

7.4.2 Configure controller difference TCONT_S

Use process value periphery

To use the input parameter PV_PER, proceed as follows:

1. Select the entry "Periphery" from the "Source" list.
2. Select the "sensor type".
   Depending on the sensor type, the process value is scaled according to different formulas.
   - Standard
     Thermoelements; PT100/NI100

     PV = 0.1 × PV_PER × PV_FAC + PV_OFFS
   - Cooling;
     PT100/NI100

     PV = 0.01 × PV_PER × PV_FAC + PV_OFFS
   - Current/voltage

     PV = 100/27648 × PV_PER × PV_FAC + PV_OFFS
3. Enter the factor and offset for the scaling of the process value periphery.

Use internal process values

To use the input parameter PV_IN, proceed as follows:

1. Select the entry "Internal" from the "Source" list.

Control deviation

Set a dead zone range under the following requirement:

- The process value signal is noisy.
- The controller gain is high.
- The derivative action is activated.

The noise component of the process value causes strong deviations of the output value in this case. The dead zone suppresses the noise component in the steady controller state. The dead zone range specifies the size of the dead zone. With a dead zone range of 0.0, the dead zone is turned off.

See also

Mode of operation TCONT_S (Page 481)

7.4.3 Configure controller algorithm TCONT_S

General

1. Enter the "Sampling time PID algorithm".
   A controller sampling time should not exceed 10 % of the determined integral action time of the controller (TI).
2. If the controller structure contains a proportional action, enter the "proportional gain".
   A negative proportional gain inverts the rule meaning.

Proportional action

For changes of the setpoint, it may lead to overshooting of the proportional action. Through the weighting of the proportional action, you can select how strongly the proportional action should react when setpoint changes are made. The weakening of the proportional action is reached through a compensation of the integral action.

1. To weaken the proportional action for setpoint changes, enter a "Proportional action weighting".
   - 1.0: Proportional action for setpoint change is fully effective
   - 0.0: Proportional action for setpoint change is not effective

Integral action

1. If the controller structure contains an integral action, enter the "integral action time".
   With an integral action time of 0.0, the integral action is switched off.

See also

Mode of operation TCONT_S (Page 481)

7.4.4 Configure manipulated value TCONT_S

Pulse generator

1. Enter the minimum impulse duration and minimum pause duration.
   The values must be greater than or equal to the cycle time for the input parameter CYCLE. The frequency of operation is reduced through this.
2. Enter the motor setting time.
   The value must be greater than or equal to the cycle time of the input parameter CYCLE.

See also

Mode of operation TCONT_S (Page 481)

7.4.5 Commissioning TCONT_S

Requirements

- The instruction and the technology object have been loaded to the CPU.

Procedure

To manually determine the optimal PID parameters, proceed as follows:

1. Click the "Start" icon.

   If there is no online connection, this will be established. The current values for the setpoint, process value and output value are recorded.
2. Enter new PID parameters in the "P", "I" and weighting proportional action fields.
3. Click on the icon "Send parameter to CPU" in the "Tuning" group.
4. Select the "Change setpoint" check box in the "Current values" group.
5. Enter a new setpoint and click in the "Current Values" group on the icon .
6. Clear the "Manual mode" check box.

   The controller works with the new parameters and controls the new setpoint.
7. Check the quality of the PID parameter to check the curve points.
8. Repeat steps 2 to 6 until you are satisfied with the controller results.

Instructions

8

8.1 PID_Compact

8.1.1 New features of PID_Compact

PID_Compact V2.2

- **Use with S7-1200**

  As of PID_Compact V2.2, the instruction with V2 functionality can also be used on S7-1200 with firmware version 4.0 or higher.

PID_Compact V2.0

- **Reaction to error**

  The reaction to error has been completely overhauled. PID_Compact now reacts in a more fault-tolerant manner in the default setting. This reaction is set when copying PID_Compact V1.X from an S7-1200 CPU to an S7-1500 CPU.

NOTICE
Your system may be damaged. If you use the default setting, PID_Compact remains in automatic mode when the process value limits are exceeded. This may damage your system. It is essential to configure how your controlled system reacts in the event of an error to protect your system from damage.

  The Error parameter indicates if an error is pending. When the error is no longer pending, Error = FALSE. The ErrorBits parameter shows which errors have occurred. Use ErrorAck to acknowledge the errors and warnings without restarting the controller or clearing the integral action. Switching operating modes no longer clears errors that are no longer pending.

  You can configure the reaction to error with SetSubstituteOutput and ActivateRecoverMode.

- **Substitute output value**

  You can configure a substitute output value that is to be output if an error occurs.

- **Switching the operating mode**

  You specify the operating mode at the Mode in/out parameter and use a rising edge at ModeActivate to start the operating mode. The sRet.i_Mode tag has been omitted.

- **Multi-instance capability**

  You can call up PID_Compact as multi-instance DB. No technology object is created in this case and no parameter assignment interface or commissioning interface is available. You must assign parameters for PID_Compact directly in the multi-instance DB and commission it via a watch table.

- **Startup characteristics**

  The operating mode specified at the Mode parameter is also started on a falling edge at Reset and during a CPU cold restart, if RunModeByStartup = TRUE.

- **ENO characteristics**

  ENO is set depending on the operating mode.

  If State = 0, then ENO = FALSE.

  If State ≠ 0, then ENO = TRUE.

- **Setpoint value specification during tuning**

  You configure the permitted fluctuation of the setpoint during tuning at the CancelTuningLevel tag.

- **Value range for output value limits**

  The value 0.0 no longer has to fall within the output value limits.

- **Pre-assigning the integral action**

  Using the tags IntegralResetMode and OverwriteInitialOutputValue, you can determine the pre-assignment of the integral action when switching from "Inactive" operating mode to "Automatic mode".

- **Switching a disturbance variable on**

  You can switch a disturbance variable on at the Disturbance parameter.

- **Default value of PID parameters**

  The following default settings have been changed:

  – Proportional action weighting (PWeighting) from 0.0 to 1.0

  – Derivative action weighting (DWeighting) from 0.0 to 1.0

  – Coefficient for derivative delay (TdFiltRatio) from 0.0 to 0.2

- **Renaming tags**

  The static tags have been given new names that are compatible with PID_3Step.

PID_Compact V1.2

- **Manual mode on CPU startup**

  If ManualEnable = TRUE when the CPU starts, PID_Compact starts in manual mode. A rising edge at ManualEnable is not necessary.

- **Pretuning**

  If the CPU is switched off during pretuning, pretuning starts again when the CPU is switched back on.

PID_Compact V1.1

- **Manual mode on CPU startup**

  When the CPU starts up, PID_Compact only switches to manual mode with a rising edge at ManualEnable. Without rising edge, PID_Compact starts in the last operating mode in which ManualEnable was FALSE.

- **Reaction to reset**

  A rising edge at Reset resets the errors and warnings and clears the integral action. A falling edge at Reset triggers a switchover to the most recently active operating mode.

- **Default of process value high limit**

  The default value of r_Pv_Hlm has been changed to 120.0.

- **Monitoring the sampling time**

  – An error is no longer output when the current sampling time is >= 1.5 x current mean value or when the current sampling time is <= 0.5 x current mean value. The sampling time may deviate much more in automatic mode.

  – PID_Compact is compatible with FW, V2.0 or higher.

- **Access to tags**

  The following tags can now be used in the user program.

  – i_Event_SUT

  – i_Event_TIR

  – r_Ctrl_Ioutv

- **Troubleshooting**

  PID_Compact now outputs the correct pulses when the shortest ON time is not equal to the shortest OFF time.

8.1.2 Compatibility with CPU and FW

The following table shows which version of PID_Compact can be used on which CPU.

CPU	FW	PID_Compact
S7-1200	≥ V4.x	V2.2 V1.2
S7-1200	≥ V3.X	V1.2 V1.1
S7-1200	≥ V2.X	V1.2 V1.1
S7-1200	≥ V1.X	V1.0
S7-1500	≥ V1.5	V2.2 V2.1 V2.0
S7-1500	≥ V1.1	V2.1 V2.0
S7-1500	≥ V1.0	V2.0

8.1.3 CPU processing time and memory requirement PID_Compact V2.x

CPU processing time

Typical CPU processing times of the PID_Compact technology object as of Version V2.0, depending on CPU type.

CPU	Typ. CPU processing time PID_Compact V2.x
CPU 1211C ≥ V4.0	300 µs
CPU 1215C ≥ V4.0	300 µs
CPU 1217C ≥ V4.0	300 µs
CPU 1505S ≥ V1.0	45 µs
CPU 1510SP-1 PN ≥ V1.6	85 µs
CPU 1511-1 PN ≥ V1.5	85 µs
CPU 1512SP-1 PN ≥ V1.6	85 µs
CPU 1516-3 PN/DP ≥ V1.5	50 µs
CPU 1518-4 PN/DP ≥ V1.5	4 µs

Memory requirement

Memory requirement of an instance DB of the PID_Compact technology object as of Version V2.0.

	Memory requirement of the instance DB of PID_Compact V2.x
Load memory requirement	Approx. 12000 bytes
Total work memory requirement	788 bytes
Retentive work memory requirement	44 bytes

8.1.4 PID_Compact V2

8.1.4.1 Description of PID_Compact V2

Description

The PID_Compact instruction provides a PID controller with integrated tuning for actuators with proportional action.

The following operating modes are possible:

- Inactive
- Pretuning
- Fine tuning
- Automatic mode
- Manual mode
- Substitute output value with error monitoring

For a more detailed description of the operating modes, see the State parameter.

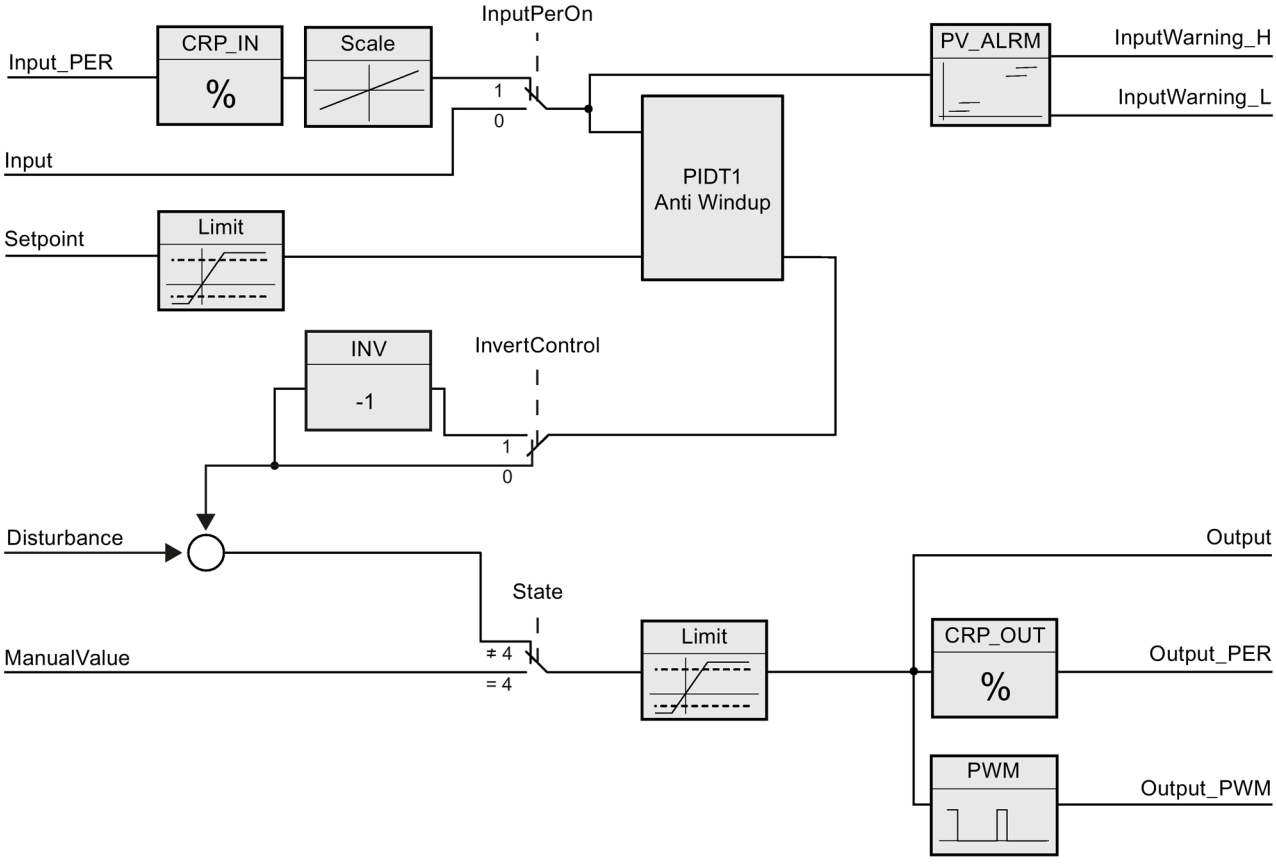
PID algorithm

PID_Compact is a PIDT1 controller with anti-windup and weighting of the proportional and derivative actions. The PID algorithm operates according to the following equation:

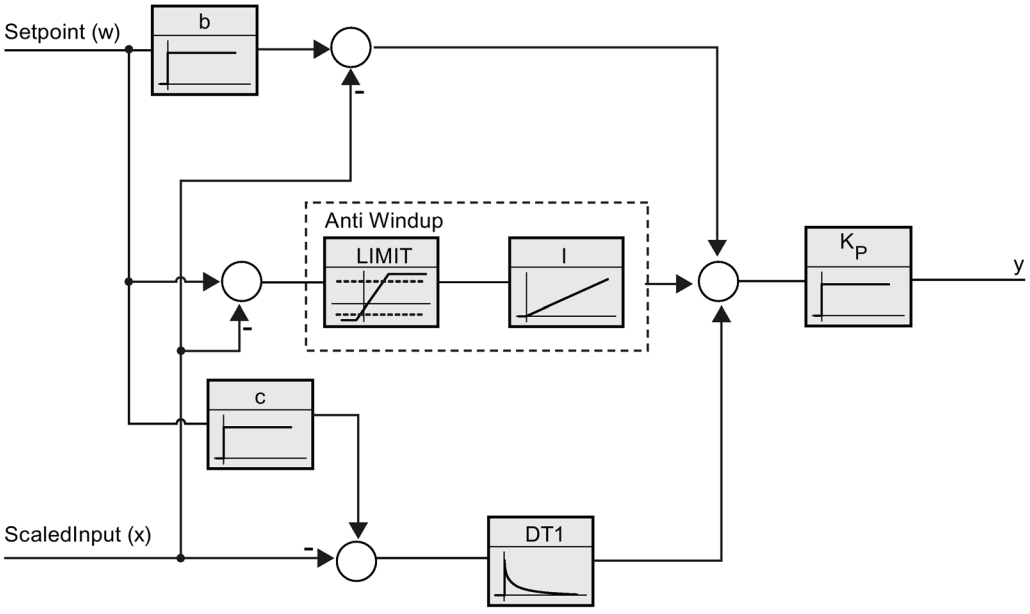
$$y = K_p \left[(b \cdot w - x) + \frac{1}{T_I \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c \cdot w - x) \right]$$

Symbol	Description
y	Output value of the PID algorithm
K_p	Proportional gain
s	Laplace operator
b	Proportional action weighting
w	Setpoint
x	Process value
T_I	Integral action time
T_D	Derivative action time
a	Derivative delay coefficient (derivative delay T1 = a × T_D)
c	Derivative action weighting

Block diagram of PID_Compact



Block diagram of PIDT1 with anti-windup



Call

PID_Compact is called in the constant time scale of a cycle interrupt OB.

If you call PID_Compact as a multi-instance DB, no technology object is created. No parameter assignment interface or commissioning interface is available. You must assign parameters for PID_Compact directly in the multi-instance DB and commission it via a watch table.

Download to device

The actual values of retentive variables are only updated when you download PID_Compact completely.

Downloading technology objects to device (Page 46)

Startup

When the CPU starts up, PID_Compact starts in the operating mode that is saved in the Mode in/out parameter. To switch to "Inactive" operating mode during startup, set RunModeByStartup = FALSE.

Reaction to error

In automatic mode and during commissioning, the reaction to error depends on the SetSubstituteOutput and ActivateRecoverMode variables. In manual mode, the reaction is independent of SetSubstituteOutput and ActivateRecoverMode. If ActivateRecoverMode = TRUE, the reaction additionally depends on the error that occurred.

SetSubstitute-Output	Acti-vateRecov-erMode	Configuration editor > output value > Set Output to	Reaction
Not relevant	FALSE	Zero (inactive)	Switch to "Inactive" mode (State = 0) The value 0.0 0 is transferred to the actuator.
FALSE	TRUE	Current output value while error is pending	Switch to "Substitute output value with error monitoring" mode (State = 5) The current output value is transferred to the actuator while the error is pending.
TRUE	TRUE	Substitute output value while error is pending	Switch to "Substitute output value with error monitoring" mode (State = 5) The value at SubstituteOutput is transferred to the actuator while the error is pending.

In manual mode, PID_Compact uses ManualValue as output value, unless ManualValue is invalid. If ManualValue is invalid, SubstituteOutput is used. If ManualValue and SubstituteOutput are invalid, Config.OutputLowerLimit is used.

The Error parameter indicates if an error is pending. When the error is no longer pending, Error = FALSE. The ErrorBits parameter shows which errors have occurred. ErrorBits is reset by a rising edge at Reset or ErrorAck.

8.1.4.2 PID_Compact V2 mode of operation

Monitoring process value limits

You specify the high limit and low limit of the process value in the Config.InputUpperLimit and Config.InputLowerLimit tags. If the process value is outside these limits, an error occurs (ErrorBits = 0001h).

You specify a high and low warning limit of the process value in the Config.InputUpperWarning and Config.InputLowerWarning tags. If the process value is outside these warning limits, a warning occurs (Warning = 0040h), and the InputWarning_H or InputWarning_L output parameter changes to TRUE.

Limiting the setpoint

You specify a high limit and low limit of the setpoint in the Config.SetpointUpperLimit and Config.SetpointLowerLimit tags. PID_Compact automatically limits the setpoint to the process value limits. You can limit the setpoint to a smaller range. PID_Compact checks whether this range falls within the process value limits. If the setpoint is outside these limits, the high or low limit is used as the setpoint, and output parameter SetpointLimit_H or SetpointLimit_L is set to TRUE.

The setpoint is limited in all operating modes.

Limiting the output value

You specify a high limit and low limit of the output value in the Config.OutputUpperLimit and Config.OutputLowerLimit tags. Output, ManualValue, and SubstituteOutput are limited to these values. The output value limits must match the control logic.

The valid output value limit values depend on the Output used.

Output	-100.0 to 100.0%
Output_PER	-100.0 to 100.0%
Output_PWM	0.0 to 100.0%

Rule:

OutputUpperLimit > OutputLowerLimit

Substitute output value

In the event of an error, PID_Compact can output a substitute output value that you define at the tag SubstituteOutput. The substitute output value must be within the output value limits.

Monitoring signal validity

The values of the following parameters are monitored for validity when used:

- Setpoint
- Input
- Input_PER
- Disturbance
- ManualValue
- SubstituteOutput
- Output
- Output_PER
- Output_PWM

Monitoring of the sampling time PID_Compact

Ideally, the sampling time is equivalent to the cycle time of the calling OB. The PID_Compact instruction measures the time interval between two calls. This is the current sampling time. On every switchover of operating mode and during the initial startup, the mean value is formed from the first 10 sampling times. Too great a difference between the current sampling time and this mean value triggers an error (Error = 0800h).

The error occurs during tuning if:

- New mean value >= 1.1 x old mean value
- New mean value <= 0.9 x old mean value

The error occurs in automatic mode if:

- New mean value >= 1.5 x old mean value
- New mean value <= 0.5 x old mean value

If you deactivate the sampling time monitoring (CycleTime.EnMonitoring = FALSE), you can also call PID_Compact in OB1. You must then accept a lower control quality due to the deviating sampling time.

Sampling time of the PID algorithm

The controlled system needs a certain amount of time to respond to changes in the output value. It is therefore not advisable to calculate the output value in every cycle. The sampling time of the PID algorithm represents the time between two calculations of the output value. It is calculated during tuning and rounded to a multiple of the cycle time. All other functions of PID_Compact are executed at every call.

If you use Output_PWM, the accuracy of the output signal is determined by the ratio of the PID algorithm sampling time to the cycle time of the OB. The cycle time should be at least 10 times the PID algorithm sampling time.

Control logic

An increase of the output value is generally intended to cause an increase in the process value. This is referred to as a normal control logic. For cooling and discharge control systems, it may be necessary to invert the control logic. PID_Compact does not work with negative proportional gain. If InvertControl = TRUE, an increasing control deviation causes a reduction in the output value. The control logic is also taken into account during pretuning and fine tuning.

8.1.4.3 Input parameters of PID_Compact V2

Parameter	Data type	Default	Description
Setpoint	REAL	0.0	Setpoint of the PID controller in automatic mode
Input	REAL	0.0	A tag of the user program is used as the source of the process value. If you are using the Input parameter, then Config.InputPerOn = FALSE must be set.
Input_PER	INT	0	An analog input is used as the source of the process value. If you are using the Input_PER parameter, then Config.InputPerOn = TRUE must be set.
Disturbance	REAL	0.0	Disturbance variable or precontrol value
ManualEnable	BOOL	FALSE	• A FALSE -> TRUE edge activates "manual mode", while State = 4, Mode remain unchanged. As long as ManualEnable = TRUE, you cannot change the operating mode via a rising edge at ModeActivate or use the commissioning dialog. • A TRUE -> FALSE edge activates the operating mode that is specified by Mode. We recommend that you change the operating mode using ModeActivate only.
ManualValue	REAL	0.0	Manual value This value is used as the output value in manual mode. Values from Config.OutputLowerLimit to Config.OutputUpperLimit are permitted.
ErrorAck	BOOL	FALSE	• FALSE -> TRUE edge ErrorBits and Warning are reset.
Reset	BOOL	FALSE	Restarts the controller. • FALSE -> TRUE edge – Switch to "Inactive" mode – ErrorBits and Warnings are reset. – Integral action is cleared (PID parameters are retained) • As long as Reset = TRUE, PID_Compact remains in "Inactive" mode (State = 0). • TRUE -> FALSE edge PID_Compact switches to the operating mode that is saved in the Mode parameter.
ModeActivate	BOOL	FALSE	• FALSE -> TRUE edge PID_Compact switches to the operating mode that is saved in the Mode parameter.

8.1.4.4 Output parameters of PID_Compact V2

Parameter	Data type	Default	Description
ScaledInput	REAL	0.0	Scaled process value
The "Output", "Output_PER", and "Output_PWM" outputs can be used concurrently.			
Output	REAL	0.0	Output value in REAL format
Output_PER	INT	0	Analog output value
Output_PWM	BOOL	FALSE	Pulse-width-modulated output value The output value is formed by by variable On and Off times.
SetpointLimit_H	BOOL	FALSE	If SetpointLimit_H = TRUE, the absolute setpoint high limit is reached (Setpoint ≥ Config.SetpointUpperLimit). The setpoint is limited to Config.SetpointUpperLimit .
SetpointLimit_L	BOOL	FALSE	If SetpointLimit_L = TRUE, the absolute setpoint low limit has been reached (Setpoint ≤ Config.SetpointLowerLimit). The setpoint is limited to Config.SetpointLowerLimit .
InputWarning_H	BOOL	FALSE	If InputWarning_H = TRUE, the process value has reached or exceeded the warning high limit.
InputWarning_L	BOOL	FALSE	If InputWarning_L = TRUE, the process value has reached or fallen below the warning low limit.
State	INT	0	The State parameter (Page 267) shows the current operating mode of the PID controller. You can change the operating mode using the input parameter Mode and a rising edge at ModeActivate. • State = 0: Inactive • State = 1: Pretuning • State = 2: Fine tuning • State = 3: Automatic mode • State = 4: Manual mode • State = 5: Substitute output value with error monitoring
Error	BOOL	FALSE	If Error = TRUE, at least one error message is pending in this cycle.
ErrorBits	DWORD	DW#16#0	The ErrorBits parameter (Page 271) shows which error messages are pending. ErrorBits is retentive and is reset upon a rising edge at Reset or ErrorAck.

8.1.4.5 In/out parameters of PID_Compact V2

Parameter	Data type	Default	Description
Mode	INT	4	At Mode, specify the operating mode to which PID_Compact is to switch. Options are: • Mode = 0: Inactive • Mode = 1: Pretuning • Mode = 2: Fine tuning • Mode = 3: Automatic mode • Mode = 4: Manual mode The operating mode is activated by: • Rising edge at ModeActivate • Falling edge at Reset • Falling edge at ManualEnable • Cold restart of CPU if RunModeBy-Startup = TRUE Mode is retentive. A detailed description of the operating modes can be found in Parameters State and Mode V2 (Page 267).

See also

Parameters State and Mode V2 (Page 267)

8.1.4.6 Static tags of PID_Compact V2

You must not change variables that are not listed. These are used for internal purposes only.

Tag	Data type	Default	Description
IntegralResetMode	INT	1	The tag IntegralResetMode determines how PIDCtrl.IntegralSum is pre-assigned when switching from "Inactive" operating mode to "Automatic mode". This setting only works for one cycle. Options are: • IntegralResetMode = 0: Smoothing The value of IntegralSum is pre-assigned so that the switchover is bumpless. • IntegralResetMode = 1: Deleting The value of IntegralSum is deleted. Any control deviation will cause a jump change of the output value. • IntegralResetMode = 2: Holding The value of IntegralSum is not changed. You can define a new value using the user program. • IntegralResetMode = 3: Pre-assigning The value of IntegralSum is automatically pre-assigned so that Output is calculated with reference to the value OverwriteInitialOutputValue. This setting is useful, for example, for an override controller.
OverwriteInitialOutputValue	REAL	0.0	If IntegralResetMode = 3, the value of IntegralSum is automatically pre-assigned so that Output = OverwriteInitialOutputValue in the next cycle.
RunModeByStartup	BOOL	TRUE	Activate operating mode at Mode parameter after CPU restart If RunModeByStartup = TRUE, PID_Compact starts in the operating mode saved in the Mode parameter after CPU startup. If RunModeByStartup = FALSE, PID_Compact remains in "Inactive" mode after CPU startup.
LoadBackUp	BOOL	FALSE	If LoadBackUp = TRUE, the last set of PID parameters is reloaded. The set was saved prior to the last tuning. LoadBackUp is automatically set back to FALSE.
PhysicalUnit	INT	0	Unit of measurement of the process value and setpoint, e.g., ºC, or ºF.
PhysicalQuantity	INT	0	Physical quantity of the process value and setpoint, e.g., temperature.
ActivateRecoverMode	BOOL	TRUE	The Tag ActivateRecoverMode V2 (Page 273) determines the reaction to error.

Tag	Data type	Default	Description
Warning	DWORD	0	Tag Warning V2 (Page 275) shows the warnings since Reset = TRUE or ErrorAck =TRUE. Warning is retentive.
Progress	REAL	0.0	Progress of tuning as a percentage (0.0 - 100.0)
CurrentSetpoint	REAL	0.0	CurrentSetpoint always displays the current setpoint. This value is frozen during tuning.
CancelTuningLevel	REAL	10.0	Permissible fluctuation of setpoint during tuning. Tuning is not canceled until: • Setpoint > CurrentSetpoint + CancelTuningLevel or • Setpoint < CurrentSetpoint - CancelTuningLevel
SubstituteOutput	REAL	0.0	Substitute output value When the following conditions are met, the substitute output value is used: • An error has occurred in automatic mode. • SetSubstituteOutput = TRUE • ActivateRecoverMode = TRUE
SetSubstituteOutput	BOOL	TRUE	If SetSubstituteOutput = TRUE and ActivateRecoverMode = TRUE, the substitute output value configured is output as long as an error is pending. If SetSubstituteOutput = FALSE and ActivateRecoverMode = TRUE, the actuator remains at the current output value as long as an error is pending. If ActivateRecoverMode = FALSE, SetSubstituteOutput is not effective. If SubstituteOutput is invalid (ErrorBits = 20000h), the substitute output value cannot be output.
Config.InputPerOn	BOOL	TRUE	If InputPerOn = TRUE, the Input_PER parameter is used. If InputPerOn = FALSE, the Input parameter is used.
Config.InvertControl	BOOL	FALSE	Invert control logic If InvertControl = TRUE, an increasing control deviation causes a reduction in the output value.
Config.InputUpperLimit	REAL	120.0	High limit of the process value Input and Input_PER are monitored to ensure adherence to this limit. At the I/O input, the process value can be a maximum of 18% higher than the standard range (overrange). This pre-assignment ensures that an error is no longer signaled due to a violation of the "Process value high limit". Only a wire-break and a short-circuit are recognized and PID_Compact reacts according to the configured reaction to error. InputUpperLimit > InputLowerLimit

Tag	Data type	Default	Description
Config.InputLowerLimit	REAL	0.0	Low limit of the process value Input and Input_PER are monitored to ensure adherence to this limit. InputLowerLimit < InputUpperLimit
Config.InputUpperWarning	REAL	3.402822e+38	Warning high limit of the process value If you set InputUpperWarning outside the process value limits, the configured absolute process value high limit is used as the warning high limit. If you configure InputUpperWarning within the process value limits, this value is used as the warning high limit. InputUpperWarning > InputLowerWarning InputUpperWarning ≤ InputUpperLimit
Config.InputLowerWarning	REAL	-3.402822e+38	Warning low limit of the process value If you set InputLowerWarning outside the process value limits, the configured absolute process value low limit is used as the warning low limit. If you configure InputLowerWarning within the process value limits, this value is used as the warning low limit. InputLowerWarning < InputUpperWarning InputLowerWarning ≥ InputLowerLimit
Config.OutputUpperLimit	REAL	100.0	High limit of output value For details, see OutputLowerLimit OutputUpperLimit > OutputLowerLimit
Config.OutputLowerLimit	REAL	0.0	Low limit of output value For Output and Output_PER, the range of values from -100.0 to +100.0, including zero, is valid. At -100.0, Output_PER = -27648; at +100.0, Output_PER = 27648. For Output_PWM, the value range 0.0 to +100.0 applies. The output value limits must match the control logic. OutputLowerLimit < OutputUpperLimit
Config.SetpointUpperLimit	REAL	3.402822e+38	High limit of setpoint If you configure SetpointUpperLimit outside the process value limits, the configured absolute process value high limit is used as the setpoint high limit. If you configure SetpointUpperLimit within the process value limits, this value is used as the setpoint high limit.
Config.SetpointLowerLimit	REAL	-3.402822e+38	Low limit of the setpoint If you set SetpointLowerLimit outside the process value limits, the configured process value absolute low limit is used as the setpoint low limit. If you set SetpointLowerLimit within the process value limits, this value is used as the setpoint low limit.

Tag	Data type	Default	Description
Config.MinimumOnTime	REAL	0.0	The minimum ON time of the pulse width modulation in seconds is rounded to MinimumOnTime = n×CycleTime.Value
Config.MinimumOffTime	REAL	0.0	The minimum OFF time of the pulse width modulation in seconds is rounded to MinimumOffTime = n×CycleTime.Value
Config.InputScaling.UpperPointIn	REAL	27648.0	Scaling Input_PER high Input_PER is converted to percent based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn.
Config.InputScaling.LowerPointIn	REAL	0.0	Scaling Input_PER low Input_PER is converted to percent based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn.
Config.InputScaling.UpperPointOut	REAL	100.0	Scaled high process value Input_PER is converted to percent based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn.
Config.InputScaling.LowerPointOut	REAL	0.0	Scaled low process value Input_PER is converted to percent based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn.
CycleTime.StartEstimation	BOOL	TRUE	If CycleTime.StartEstimation = TRUE, the automatic determination of the cycle time is started. CycleTime.StartEstimation = FALSE once measurement is complete.
CycleTime.EnEstimation	BOOL	TRUE	If CycleTime.EnEstimation = TRUE, the PID_Compact sampling time is calculated. If CycleTime.EnEstimation = FALSE, the PID_Compact sampling time is not calculated and you need to correct the configuration of CycleTime.Value manually.
CycleTime.EnMonitoring	BOOL	TRUE	If CycleTime.EnMonitoring = FALSE, the PID_Compact sampling time is not monitored. If it is not possible to execute PID_Compact within the sampling time, no error (ErrorBits=0800h) is output and PID_Compact does not switch to "Inactive" mode.
CycleTime.Value	REAL	0.1	PID_Compact sampling time in seconds CycleTime.Value is determined automatically and is usually equivalent to the cycle time of the calling OB.
CtrlParamsBackUp.Gain	REAL	1.0	Saved proportional gain You can reload values from the CtrlParamsBackUp structure with LoadBackUp = TRUE.
CtrlParamsBackUp.Ti	REAL	20.0	Saved integral action time [s]
CtrlParamsBackUp.Td	REAL	0.0	Saved derivative action time [s]
CtrlParamsBackUp.TdFiltRatio	REAL	0.2	Saved derivative delay coefficient
CtrlParamsBackUp.PWeighting	REAL	1.0	Saved proportional action weighting factor
CtrlParamsBackUp.DWeighting	REAL	1.0	Saved derivative action weighting factor

Tag	Data type	Default	Description
CtrlParamsBackUp.Cycle	REAL	1.0	Saved sampling time of PID algorithm
PIDSelfTune.SUT.CalculateParams	BOOL	FALSE	The properties of the controlled system are saved during tuning. If SUT.CalculateParams = TRUE, the parameters for pretuning are recalculated according to these properties. This enables you to change the parameter calculation method without having to repeat controller tuning. SUT.CalculateParams is set to FALSE after the calculation.
PIDSelfTune.SUT.TuneRule	INT	0	Methods used to calculate parameters during pretuning: • SUT.TuneRule = 0: PID according to Chien, Hrones and Reswick • SUT.TuneRule = 1: PI according to Chien, Hrones and Reswick
PIDSelfTune.SUT.State	INT	0	The SUT.State tag indicates the current phase of pretuning: • State = 0: Initialize pretuning • State = 100: Calculate standard deviation • State = 200: Determine point of inflection • State = 9900: Pretuning successful • State = 1: Pretuning not successful
PIDSelfTune.TIR.RunIn	BOOL	FALSE	With the RunIn tag, you can specify that fine tuning can also be performed without pretuning. • RunIn = FALSE Pretuning is started when fine tuning is started from inactive or manual mode. If the requirements for pretuning are not met, PID_Compact reacts as when RunIn = TRUE. If fine tuning is started from automatic mode, the system uses the existing PID parameters to control to the setpoint. Only then will fine tuning start. If pretuning is not possible, PID_Compact switches to the mode from which tuning was started. • RunIn = TRUE The pretuning is skipped. PID_Compact tries to reach the setpoint with minimum or maximum output value. This can produce increased overshoot. Fine tuning then starts automatically. RunIn is set to FALSE after fine tuning.

Tag	Data type	Default	Description
PIDSelfTune.TIR.CalculateParams	BOOL	FALSE	The properties of the controlled system are saved during tuning. If TIR.CalculateParams = TRUE, the parameters for fine tuning are recalculated according to these properties. This enables you to change the parameter calculation method without having to repeat controller tuning. TIR.CalculateParams is set to FALSE after the calculation.
PIDSelfTune.TIR.TuneRule	INT	0	Methods used to calculate parameters during fine tuning: • TIR.TuneRule = 0: PID automatic • TIR.TuneRule = 1: PID rapid • TIR.TuneRule = 2: PID slow • TIR.TuneRule = 3: Ziegler-Nichols PID • TIR.TuneRule = 4: Ziegler-Nichols PI • TIR.TuneRule = 5: Ziegler-Nichols P
PIDSelfTune.TIR.State	INT	0	The TIR.State tag indicates the current phase of fine tuning: • State = -100 Fine tuning is not possible. Pretuning will be performed first. • State = 0: Initialize fine tuning • State = 200: Calculate standard deviation • State = 300: Attempt to reach the setpoint • State = 400: Attempt to reach the setpoint with existing PID parameters (if pretuning was successful) • State = 500: Determine oscillation and calculate parameters • State = 9900: Fine tuning successful • State = 1: Fine tuning not successful
PIDCtrl.IntegralSum	REAL	0.0	Current integral action
Retain.CtrlParams.Gain	REAL	1.0	Active proportional gain To invert the control logic, use the Config.InvertControl tag. Negative values at Gain also invert the control logic. We recommend you use only InvertControl to set the control logic. The control logic is also inverted if InvertControl = TRUE and Gain < 0.0. Gain is retentive.
Retain.CtrlParams.Ti	REAL	20.0	• CtrlParams.Ti > 0.0: Active integral action time • CtrlParams.Ti = 0.0: Integral action is deactivated Ti is retentive.
Retain.CtrlParams.Td	REAL	0.0	• CtrlParams.Td > 0.0: Active derivative action time • CtrlParams.Td = 0.0: Derivative action is deactivated Td is retentive.

Tag	Data type	Default	Description
Retain.CtrlParams.TdFiltRatio	REAL	0.2	Active derivative delay coefficient The derivative delay coefficient delays the effect of the derivative action. Derivative delay = derivative action time × derivative delay coefficient • 0.0: Derivative action is effective for one cycle only and therefore almost not effective. • 0.5: This value has proved useful in practice for controlled systems with **one** dominant time constant. • > 1.0: The greater the coefficient, the longer the effect of the derivative action is delayed. TdFiltRatio is retentive.
Retain.CtrlParams.PWeighting	REAL	1.0	Active proportional action weighting The proportional action may weaken with changes to the setpoint. Values from 0.0 to 1.0 are applicable. • 1.0: Proportional action for setpoint change is fully effective • 0.0: Proportional action for setpoint change is not effective The proportional action is always fully effective when the process value is changed. PWeighting is retentive.
Retain.CtrlParams.DWeighting	REAL	1.0	Active derivative action weighting The derivative action may weaken with changes to the setpoint. Values from 0.0 to 1.0 are applicable. • 1.0: Derivative action is fully effective upon setpoint change • 0.0: Derivative action is not effective upon setpoint change The derivative action is always fully effective when the process value is changed. DWeighting is retentive.
Retain.CtrlParams.Cycle	REAL	1.0	Active sampling time of the PID algorithm CtrlParams.Cycle is calculated during tuning and rounded to an integer multiple of CycleTime.Value. Cycle is retentive.

Note

Change the tags listed in this table in "Inactive" mode to prevent malfunction of the PID controller.

See also

Tag ActivateRecoverMode V2 (Page 273)

Tag Warning V2 (Page 275)

Downloading technology objects to device (Page 46)

8.1.4.7 Changing the PID_Compact V2 interface

The following table shows what has changed in the PID_Compact instruction interface.

PID_Compact V1	PID_Compact V2	Change
Input_PER	Input_PER	Data type from Word to Int
	Disturbance	New
	ErrorAck	New
	ModeActivate	New
Output_PER	Output_PER	Data type from Word to Int
Error	ErrorBits	Renamed
	Error	New
	Mode	New
sb_RunModeByStartup	RunModeByStartup	Function
	IntegralResetMode	
	OverwriteInitialOutputValue	New
	SetSubstituteOutput	New
	CancelTuningLevel	New
	SubstituteOutput	New

The following table shows which variables have been renamed.

PID_Compact V1.x	PID_Compact V2
sb_GetCycleTime	CycleTime.StartEstimation
sb_EnCyclEstimation	CycleTime.EnEstimation
sb_EnCyclMonitoring	CycleTime.EnMonitoring
sb_RunModeByStartup	RunModeByStartup
si_Unit	PhysicalUnit
si_Type	PhysicalQuantity
sd_Warning	Warning
sBackUp.r_Gain	CtrlParamsBackUp.Gain
sBackUp.r_Ti	CtrlParamsBackUp.Ti
sBackUp.r_Td	CtrlParamsBackUp.Td
sBackUp.r_A	CtrlParamsBackUp.TdFiltRatio
sBackUp.r_B	CtrlParamsBackUp.PWeighting
sBackUp.r_C	CtrlParamsBackUp.DWeighting
sBackUp.r_Cycle	CtrlParamsBackUp.Cycle
sPid_Calc.r_Cycle	CycleTime.Value
sPid_Calc.b_RunIn	PIDSelfTune.TIR.RunIn
sPid_Calc.b_CalcParamSUT	PIDSelfTune.SUT.CalculateParams
sPid_Calc.b_CalcParamTIR	PIDSelfTune.TIR.CalculateParams
sPid_Calc.i_CtrlTypeSUT	PIDSelfTune.SUT.TuneRule
sPid_Calc.i_CtrlTypeTIR	PIDSelfTune.TIR.TuneRule

PID_Compact V1.x	PID_Compact V2
sPid_Calc.r_Progress	Progress
sPid_Cmpt.r_Sp_Hlm	Config.SetpointUpperLimit
sPid_Cmpt.r_Sp_Llm	Config.SetpointLowerLimit
sPid_Cmpt.r_Pv_Norm_IN_1	Config.InputScaling.LowerPointIn
sPid_Cmpt.r_Pv_Norm_IN_2	Config.InputScaling.UpperPointIn
sPid_Cmpt.r_Pv_Norm_OUT_1	Config.InputScaling.LowerPointOut
sPid_Cmpt.r_Pv_Norm_OUT_2	Config.InputScaling.UpperPointOut
sPid_Cmpt.r_Lmn_Hlm	Config.OutputUpperLimit
sPid_Cmpt.r_Lmn_Llm	Config.OutputLowerLimit
sPid_Cmpt.b_Input_PER_On	Config.InputPerOn
sPid_Cmpt.b_LoadBackUp	LoadBackUp
sPid_Cmpt.b_InvCtrl	Config.InvertControl
sPid_Cmpt.r_Lmn_Pwm_PPTm	Config.MinimumOnTime
sPid_Cmpt.r_Lmn_Pwm_PBTm	Config.MinimumOffTime
sPid_Cmpt.r_Pv_Hlm	Config.InputUpperLimit
sPid_Cmpt.r_Pv_Llm	Config.InputLowerLimit
sPid_Cmpt.r_Pv_HWrn	Config.InputUpperWarning
sPid_Cmpt.r_Pv_LWrn	Config.InputLowerWarning
sParamCalc.i_Event_SUT	PIDSelfTune.SUT.State
sParamCalc.i_Event_TIR	PIDSelfTune.TIR.State
sRet.i_Mode	sRet.i_Mode has been omitted. The operating mode is changed using Mode and ModeActivate.
sRet.r_Ctrl_Gain	Retain.CtrlParams.Gain
sRet.r_Ctrl_Ti	Retain.CtrlParams.Ti
sRet.r_Ctrl_Td	Retain.CtrlParams.Td
sRet.r_Ctrl_A	Retain.CtrlParams.TdFiltRatio
sRet.r_Ctrl_B	Retain.CtrlParams.PWeighting
sRet.r_Ctrl_C	Retain.CtrlParams.DWeighting
sRet.r_Ctrl_Cycle	Retain.CtrlParams.Cycle

8.1.4.8 Parameters State and Mode V2

Correlation of the parameters

The State parameter shows the current operating mode of the PID controller. You cannot change the State parameter.

With a rising edge at ModeActivate, PID_Compact switches to the operating mode saved in the Mode in-out parameter.

When the CPU is switched on or switches from Stop to RUN mode, PID_Compact starts in the operating mode that is saved in the Mode parameter. To leave PID_Compact in "Inactive" mode, set RunModeByStartup = FALSE.

Meaning of values

State / Mode	Description of operating mode
0	Inactive In "Inactive" operating mode, the output value 0.0 is always output, regardless of Config.OutputUpperLimit and Config.OutputLowerLimit. Pulse width modulation is off.
1	Pretuning The pretuning determines the process response to a jump change of the output value and searches for the point of inflection. The PID parameters are calculated from the maximum rate of rise and dead time of the controlled system. You obtain the best PID parameters when you perform pretuning and fine tuning. Pretuning requirements: • Inactive (State = 0), manual mode (State = 4), or automatic mode (State = 3) • ManualEnable = FALSE • Reset = FALSE • The process value must not be too close to the setpoint. |Setpoint - Input| > 0.3 * | Config.InputUpperLimit - Config.InputLowerLimit| and |Setpoint - Input| > 0.5 * |Setpoint| • The setpoint and the process value lie within the configured limits. The more stable the process value is, the easier it is to calculate the PID parameters and the more precise the result will be. Noise on the process value can be tolerated as long as the rate of rise of the process value is significantly higher compared to the noise. The setpoint is frozen in the CurrentSetpoint tag. Tuning is canceled when: • Setpoint > CurrentSetpoint + CancelTuningLevel or • Setpoint < CurrentSetpoint - CancelTuningLevel Before the PID parameters are recalculated, they are backed up and can be reactivated with LoadBackUp. The controller switches to automatic mode following successful pretuning. If pretuning is unsuccessful, the switchover of the operating mode is dependent on ActivateRecoverMode. The phase of pretuning is indicated with PIDSelfTune.SUT.State.

State / Mode	Description of operating mode
2	Fine tuning Fine tuning generates a constant, limited oscillation of the process value. The PID parameters are recalculated based on the amplitude and frequency of this oscillation. PID parameters from fine tuning usually have better master control and disturbance characteristics than PID parameters from pretuning. You obtain the best PID parameters when you perform pretuning and fine tuning. PID_Compact automatically attempts to generate an oscillation greater than the noise of the process value. Fine tuning is only minimally influenced by the stability of the process value. The setpoint is frozen in the CurrentSetpoint tag. Tuning is canceled when: • Setpoint > CurrentSetpoint + CancelTuningLevel or • Setpoint < CurrentSetpoint - CancelTuningLevel Before the PID parameters are recalculated, they are backed up and can be reactivated with LoadBackUp. Requirements for fine tuning: • No disturbances are expected. • The setpoint and the process value lie within the configured limits. • ManualEnable = FALSE • Reset = FALSE • Automatic (State = 3), inactive (State = 0) or manual (State = 4) mode Fine tuning proceeds as follows when started from: • Automatic mode (State = 3) Start fine tuning from automatic mode if you wish to improve the existing PID parameters through tuning. PID_Compact controls the system using the existing PID parameters until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start. • Inactive (State = 0) or manual mode (State = 4) If the requirements for pretuning are met, pretuning is started. The determined PID parameters will be used for control until the control loop has stabilized and the requirements for fine tuning have been met. If the process value for pretuning is already too near the setpoint or PIDSelfTune.TIR.RunIn = TRUE, an attempt is made to reach the setpoint with the minimum or maximum output value. This can produce increased overshoot. Only then will fine tuning start. The controller switches to automatic mode following successful fine tuning. If fine tuning is unsuccessful, the switchover of the operating mode is dependent on ActivateRecoverMode. The "Fine tuning" phase is indicated with PIDSelfTune.TIR.State.
3	Automatic mode In automatic mode, PID_Compact corrects the controlled system in accordance with the parameters specified. The controller switches to automatic mode if one the following requirements is fulfilled: • Pretuning successfully completed • Fine tuning successfully completed • Changing of the Mode in-out parameter to the value 3 and a rising edge at ModeActivate. The switchover from automatic mode to manual mode is only bumpless if carried out in the commissioning editor. The ActivateRecoverMode tag is taken into consideration in automatic mode.

State / Mode	Description of operating mode
4	Manual mode In manual mode, you specify a manual output value in the ManualValue parameter. You can also activate this operating mode using ManualEnable = TRUE. We recommend that you change the operating mode using Mode and ModeActivate only. The switchover from manual mode to automatic mode is bumpless. Manual mode is also possible when an error is pending.
5	Substitute output value with error monitoring The control algorithm is deactivated. The SetSubstituteOutput tag determines which output value is output in this operating mode. • SetSubstituteOutput = FALSE: Last valid output value • SetSubstituteOutput = TRUE: Substitute output value You cannot activate this operating mode using Mode = 5. In the event of an error, it is activated instead of "Inactive" operating mode if all the following conditions are met: • Automatic mode (Mode = 3) • ActivateRecoverMode = TRUE • One or more errors have occurred in which ActivateRecoverMode is effective. As soon as the errors are no longer pending, PID_Compact switches back to automatic mode.

ENO characteristics

If State = 0, then ENO = FALSE.

If State ≠ 0, then ENO = TRUE.

Automatic switchover of operating mode during commissioning

Automatic mode is activated following successful pretuning or fine tuning. The following table shows how Mode and State change during successful pretuning.

Cycle no.	Mode	State	Action
0	4	4	Set Mode = 1
1	1	4	Set ModeActivate = TRUE
1	4	1	Value of State is saved in Mode parameter Pretuning is started
n	4	1	Pretuning successfully completed
n	3	3	Automatic mode is started

PID_Compact automatically switches the operating mode in the event of an error. The following table shows how Mode and State change during pretuning with errors.

Cycle no.	Mode	State	Action
0	4	4	Set Mode = 1
1	1	4	Set ModeActivate = TRUE
1	4	1	Value of State is saved in Mode parameter Pretuning is started
n	4	1	Pretuning canceled
n	4	4	Manual mode is started

If ActivateRecoverMode = TRUE, the operating mode that is saved in the Mode parameter is activated. At the start of pretuning or fine tuning, PID_Compact has saved the value of State in the Mode in/out parameter. PID_Compact therefore switches to the operating mode from which tuning was started.

If ActivateRecoverMode = FALSE, the system switches to "Inactive" operating mode.

See also

Output parameters of PID_Compact V2 (Page 255)

8.1.4.9 Parameter ErrorBits V2

If several errors are pending simultaneously, the values of the ErrorBits are displayed with binary addition. The display of ErrorBits = 0003h, for example, indicates that the errors 0001h and 0002h are pending simultaneously.

In manual mode, PID_Compact uses ManualValue as output value. The exception is Errorbits = 10000h.

ErrorBits (DW#16#...)	Description
0000	There is no error.
0001	The "Input" parameter is outside the process value limits. • Input > Config.InputUpperLimit or • Input < Config.InputLowerLimit If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact remains in automatic mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact switches to the operating mode that is saved in the Mode parameter.
0002	Invalid value at "Input_PER" parameter. Check whether an error is pending at the analog input. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact outputs the configured substitute output value. As soon as the error is no longer pending, PID_Compact switches back to automatic mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact switches to the operating mode that is saved in the Mode parameter.
0004	Error during fine tuning. Oscillation of the process value could not be maintained. If ActivateRecoverMode = TRUE before the error occurred, PID_Compact cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0008	Error at start of pretuning. The process value is too close to the setpoint. Start fine tuning. If ActivateRecoverMode = TRUE before the error occurred, PID_Compact cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0010	The setpoint was changed during tuning. You can set the permitted fluctuation of the setpoint at the CancelTuningLevel tag. If ActivateRecoverMode = TRUE before the error occurred, PID_Compact cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0020	Pretuning is not permitted during fine tuning. If ActivateRecoverMode = TRUE before the error occurred, PID_Compact remains in fine tuning mode.
0080	Error during pretuning. Incorrect configuration of output value limits. Check whether the limits of the output value are configured correctly and match the control logic. If ActivateRecoverMode = TRUE before the error occurred, PID_Compact cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0100	Error during fine tuning resulted in invalid parameters. If ActivateRecoverMode = TRUE before the error occurred, PID_Compact cancels the tuning and switches to the operating mode that is saved in the Mode parameter.

ErrorBits (DW#16#...)	Description
0200	Invalid value at "Input" parameter: Value has an invalid number format. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact outputs the configured substitute output value. As soon as the error is no longer pending, PID_Compact switches back to automatic mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact switches to the operating mode that is saved in the Mode parameter.
0400	Calculation of output value failed. Check the PID parameters. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact outputs the configured substitute output value. As soon as the error is no longer pending, PID_Compact switches back to automatic mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact switches to the operating mode that is saved in the Mode parameter.
0800	Sampling time error: PID_Compact is not called within the sampling time of the cyclic interrupt OB. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact remains in automatic mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact switches to the operating mode that is saved in the Mode parameter.
1000	Invalid value at "Setpoint" parameter: Value has an invalid number format. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact outputs the configured substitute output value. As soon as the error is no longer pending, PID_Compact switches back to automatic mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Compact switches to the operating mode that is saved in the Mode parameter.
10000	Invalid value at ManualValue parameter. Value has an invalid number format. If ActivateRecoverMode = TRUE before an error occurred, PID_Compact uses SubstituteOutput as the output value. As soon as you specify a valid value in ManualValue, PID_Compact uses it as the output value.
20000	Invalid value at SubstituteOutput tag. Value has an invalid number format. PID_Compact uses the output value low limit as the output value. If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_Compact switches back to automatic mode.
40000	Invalid value at Disturbance parameter. Value has an invalid number format. If automatic mode was active and ActivateRecoverMode = TRUE before the error occurred, Disturbance is set to zero. PID_Compact remains in automatic mode. If pretuning or fine tuning mode was active and ActivateRecoverMode = TRUE before the error occurred, PID_Compact switches to the operating mode saved in the Mode parameter. If Disturbance in the current phase has no effect on the output value, tuning is not be canceled.

8.1.4.10 Tag ActivateRecoverMode V2

The ActivateRecoverMode tag determines the reaction to error. The Error parameter indicates if an error is pending. When the error is no longer pending, Error = FALSE. The ErrorBits parameter shows which errors have occurred.

Automatic mode

NOTICE
Your system may be damaged. If ActivateRecoverMode = TRUE, PID_Compact remains in automatic mode even if there is an error and the process limit values are exceeded. This may damage your system. It is essential to configure how your controlled system reacts in the event of an error to protect your system from damage.

ActivateRecoverMode	Description
FALSE	PID_Compact automatically switches to "Inactive" mode in the event of an error. The controller is only activated by a falling edge at Reset or a rising edge at ModeActivate.
TRUE	If errors occur frequently in automatic mode, this setting has a negative effect on the control response, because PID_Compact switches between the calculated output value and the substitute output value at each error. In this case, check the ErrorBits parameter and eliminate the cause of the error. If one or more of the following errors occur, PID_Compact stays in automatic mode: • 0001h: The "Input" parameter is outside the process value limits. • 0800h: Sampling time error • 40000h: Invalid value at parameter Disturbance. If one or more of the following errors occur, PID_Compact switches to "Substitute output value with error monitoring" mode: • 0002h: Invalid value at Input_PER parameter. • 0200h: Invalid value at Input parameter. • 0400h: Calculation of output value failed. • 1000h: Invalid value at Setpoint parameter. If the following error occurs, PID_Compact switches to "Substitute output value with error monitoring" mode and moves the actuator to Config.OutputLowerLimit: • 20000h: Invalid value at SubstituteOutput tag. Value has an invalid number format. This characteristics are independent of SetSubstituteOutput. As soon as the errors are no longer pending, PID_Compact switches back to automatic mode.

Pretuning and fine tuning

ActivateRecov-erMode	Description
FALSE	PID_Compact automatically switches to "Inactive" mode in the event of an error. The controller is only activated by a falling edge at Reset or a rising edge at ModeActivate.
TRUE	If the following error occurs, PID_Compact remains in the active mode: • 0020h: Pretuning is not permitted during fine tuning. The following errors are ignored: • 10000h: Invalid value at ManualValue parameter. • 20000h: Invalid value at SubstituteOutput tag. When any other error occurs, PID_Compact cancels the tuning and switches to the mode from which tuning was started.

Manual mode

ActivateRecoverMode is not effective in manual mode.

8.1.4.11 Tag Warning V2

If several warnings are pending simultaneously, the values of the Warning tag are displayed with binary addition. The display of warning 0003h, for example, indicates that the warnings 0001h and 0002h are pending simultaneously.

Warning (DW#16#....)	Description
0000	No warning pending.
0001	The point of inflection was not found during pretuning.
0004	The setpoint was limited to the configured limits.
0008	Not all the necessary controlled system properties were defined for the selected method of calculation. Instead, the PID parameters were calculated using the TIR.TuneRule = 3 method.
0010	The operating mode could not be changed because Reset = TRUE or ManualEnable = TRUE.
0020	The cycle time of the calling OB limits the sampling time of the PID algorithm. Improve results by using shorter OB cycle times.
0040	The process value exceeded one of its warning limits.
0080	Invalid value at Mode. The operating mode is not switched.
0100	The manual value was limited to the limits of the controller output.
0200	The specified rule for tuning is not supported. No PID parameters are calculated.
1000	The substitute output value cannot be reached because it is outside the output value limits.

The following warnings are deleted as soon as the cause is eliminated:

- 0001h
- 0004h
- 0008h
- 0040h
- 0100h

All other warnings are cleared with a rising edge at Reset or ErrorAck.

8.1.5 PID_Compact V1

8.1.5.1 Description of PID_Compact V1

Description

The PID_Compact instruction provides a PID controller with integrated tuning for automatic and manual mode.

Call

PID_Compact is called in the constant interval of the cycle time of the calling OB (preferably in a cyclic interrupt OB).

Download to device

The actual values of retentive tags are only updated when you download PID_Compact completely.

Downloading technology objects to device (Page 46)

Startup

At the startup of the CPU, PID_Compact starts in the operating mode that was last active. To retain PID_ Compact in "Inactive" mode, set sb_RunModeByStartup = FALSE.

Monitoring of the sampling time PID_Compact

Ideally, the sampling time is equivalent to the cycle time of the calling OB. The PID_Compact instruction measures the time interval between two calls. This is the current sampling time. On every switchover of operating mode and during the initial startup, the mean value is formed from the first 10 sampling times. If the current sampling time deviates too much from this mean value, Error = 0800 hex occurs and PID_Compact switches to "Inactive" mode.

PID_Compact, Version 1.1 or higher is set to "Inactive" mode during controller tuning under the following conditions:

- New mean value >= 1.1 x old mean value
- New mean value <= 0.9 x old mean value

In automatic mode, PID_Compact, Version 1.1 or higher, is set to "Inactive" mode under the following conditions:

- New mean value >= 1.5 x old mean value
- New mean value <= 0.5 x old mean value

During controller tuning and in automatic mode, PID_Compact 1.0 is set to "Inactive" operating mode under the following conditions:

- New mean value >= 1.1 x old mean value
- New mean value <= 0.9 x old mean value
- Current sampling time >= 1.5 x current mean value
- Current sampling time <= 0.5 x current mean value

Sampling time of the PID algorithm

The controlled system needs a certain amount of time to respond to changes in the output value. It is therefore not advisable to calculate the output value in every cycle. The sampling time of the PID algorithm represents the time between two calculations of the output value. It is calculated during tuning and rounded to a multiple of the cycle time. All other functions of PID_Compact are executed at every call.

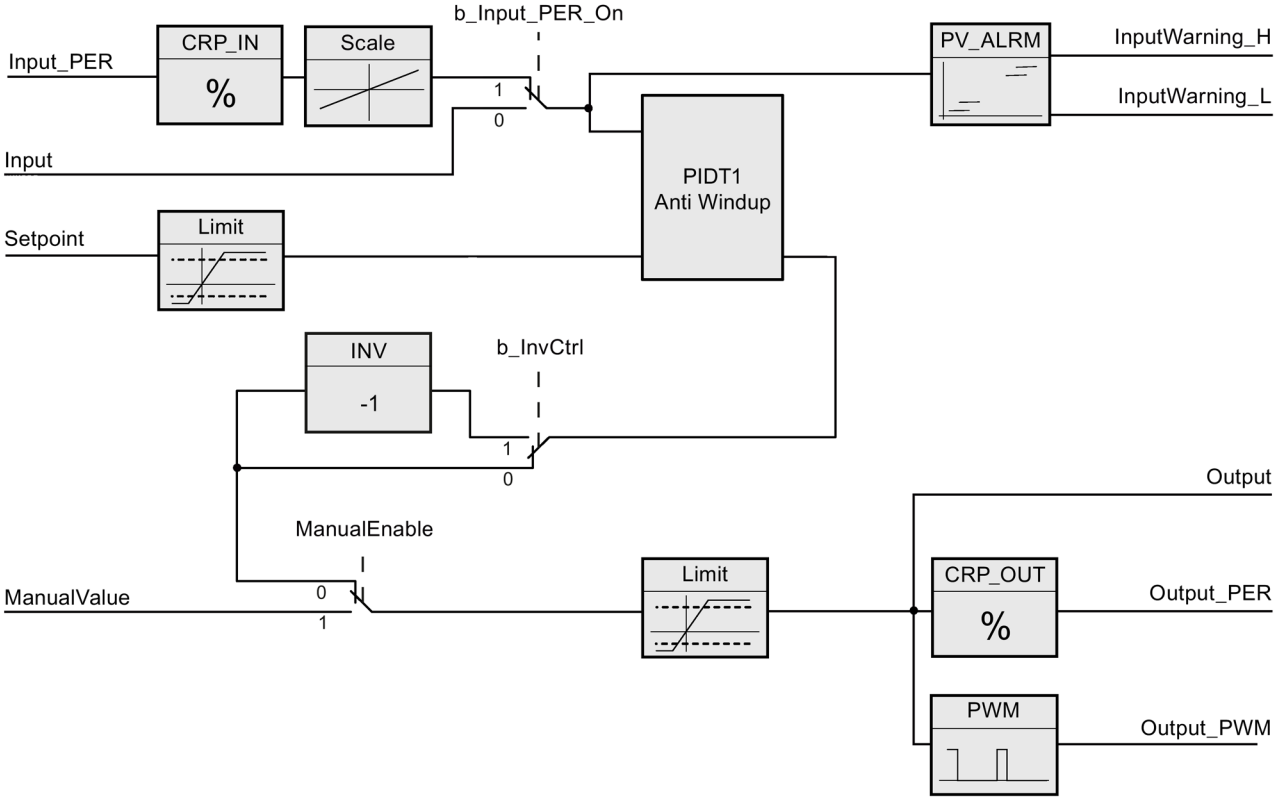
PID algorithm

PID_Compact is a PIDT1 controller with anti-windup and weighting of the proportional and derivative actions. The following equation is used to calculate the output value.

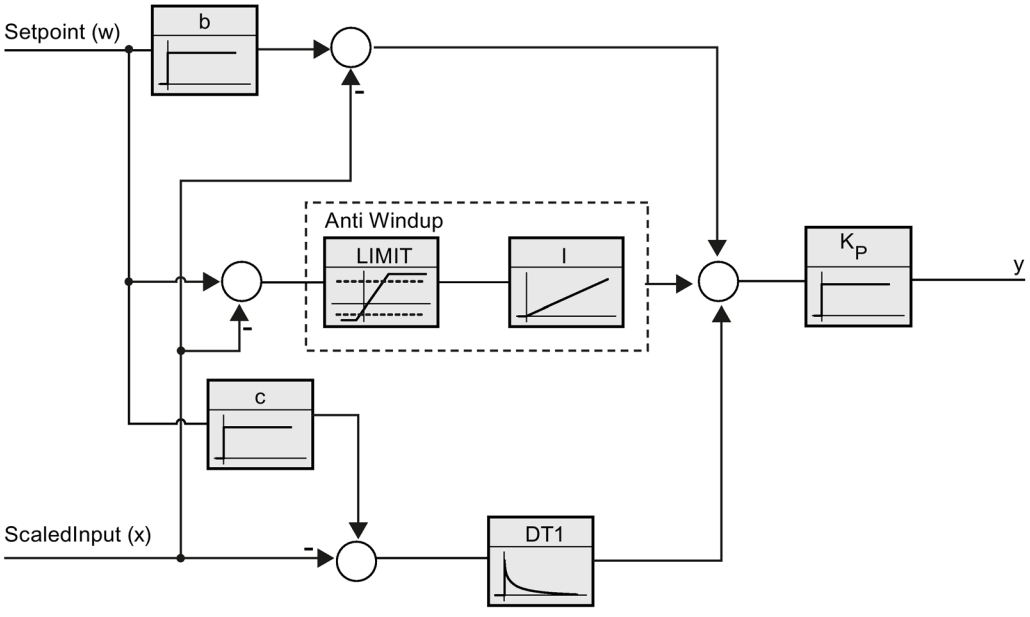
$$y = K_p \left[(b \cdot w - x) + \frac{1}{T_I \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c \cdot w - x) \right]$$

Symbol	Description
y	Output value
K_p	Proportional gain
s	Laplace operator
b	Proportional action weighting
w	Setpoint
x	Process value
T_I	Integral action time
a	Derivative delay coefficient (T1 = a × T_D)
	Derivative action time
c	Derivative action weighting

Block diagram of PID_Compact



Block diagram of PIDT1 with anti-windup



Reaction to error

If errors occur, they are output in parameter Error, and PID_Compact changes to "Inactive" mode. Reset the errors using the Reset parameter.

Control logic

An increase of the output value is generally intended to cause an increase in the process value. This is referred to as a normal control logic. For cooling and discharge control systems, it may be necessary to invert the control logic. PID_Compact does not work with negative proportional gain. If InvertControl = TRUE, an increasing control deviation causes a reduction in the output value. The control logic is also taken into account during pretuning and fine tuning.

See also

Controller type (Page 99)

8.1.5.2 Input parameters of PID_Compact V1

Parameter	Data type	Default	Description
Setpoint	REAL	0.0	Setpoint of the PID controller in automatic mode
Input	REAL	0.0	A variable of the user program is used as source for the process value. If you are using parameter Input, then sPid_Cmpt.b_Input_PER_On = FALSE must be set.
Input_PER	WORD	W#16#0	Analog input as the source of the process value If you are using parameter Input_PER, then sPid_Cmpt.b_Input_PER_On = TRUE must be set.
ManualEnable	BOOL	FALSE	• A FALSE -> TRUE edge selects "Manual mode", while State = 4, sRet.i_Mode remains unchanged. • A TRUE -> FALSE edge selects the most recently active operating mode, State =sRet.i_Mode A change of sRet.i_Mode will not take effect during ManualEnable = TRUE. The change of sRet.i_Mode will only be considered upon a TRUE -> FALSE edge at ManualEnable . **PID_Compact V1.2 und PID_Compact V1.0** If at start of the CPU ManualEnable = TRUE, PID_Compact starts in manual mode. A rising edge (FALSE > TRUE) at ManualEnable is not necessary. **PID_Compact V1.1** At the start of the CPU, PID_Compact only switches to manual mode with a rising edge (FALSE->TRUE) at ManualEnable . Without rising edge, PID_Compact starts in the last operating mode in which ManualEnable was FALSE.
ManualValue	REAL	0.0	Manual value This value is used as the output value in manual mode.
Reset	BOOL	FALSE	The Reset parameter (Page 292) restarts the controller.

8.1.5.3 Output parameters of PID_Compact V1

Parameter	Data type	Default	Description
ScaledInput	REAL	0.0	Output of the scaled process value
Outputs "Output", "Output_PER", and "Output_PWM" can be used concurrently.			
Output	REAL	0.0	Output value in REAL format
Output_PER	WORD	W#16#0	Analog output value
Output_PWM	BOOL	FALSE	Pulse-width-modulated output value The output value is formed by minimum On and Off times.
SetpointLimit_H	BOOL	FALSE	If SetpointLimit_H = TRUE, the setpoint absolute high limit is reached. The setpoint in the CPU is limited to the configured setpoint absolute high limit. The configured process value absolute high limit is the default for the setpoint high limit. If you set sPid_Cmpt.r_Sp_Hlm to a value within the process value limits, this value is used as the setpoint high limit.
SetpointLimit_L	BOOL	FALSE	If SetpointLimit_L = TRUE, the setpoint absolute low limit has been reached. In the CPU, the setpoint is limited to the configured setpoint absolute low limit. The configured process value absolute low limit is the default setting for the setpoint low limit. If you set sPid_Cmpt.r_Sp_Llm to a value within the process value limits, this value is used as the setpoint low limit.
InputWarning_H	BOOL	FALSE	If InputWarning_H = TRUE, the process value has reached or exceeded the warning high limit.
InputWarning_L	BOOL	FALSE	If InputWarning_L = TRUE, the process value has reached or fallen below the warning low limit.
State	INT	0	The State parameter (Page 287) shows the current operating mode of the PID controller. To change the operating mode, use variable sRet.i_Mode. • State = 0: Inactive • State = 1: pretuning • State = 2: fine tuning • State = 3: Automatic mode • State = 4: Manual mode
Error	DWORD	W#16#0	The Error parameter (Page 291) indicates the error messages. Error = 0000: No error pending.

8.1.5.4 Static tags of PID_Compact V1

You must not change tags that are not listed. These are used for internal purposes only.

Tag	Data type	Default	Description
sb_GetCycleTime	BOOL	TRUE	If sb_GetCycleTime = TRUE, the automatic determination of the cycle time is started. CycleTime.StartEstimation = FALSE once measurement is complete.
sb_EnCyclEstimation	BOOL	TRUE	If sb_EnCyclEstimation = TRUE, the sampling time PID_Compact is calculated.
sb_EnCyclMonitoring	BOOL	TRUE	If sb_EnCyclMonitoring = FALSE, the sampling time PID_Compact is not monitored. If it is not possible to execute PID_Compact within the sampling time, an 0800 error is not output and PID_Compact does not change to "Inactive" mode.
sb_RunModeByStartup	BOOL	TRUE	Activate Mode after CPU restart If sb_RunModeByStartup = FALSE, the controller will remain inactive after a CPU startup. After a CPU startup and if sb_RunModeByStartup = TRUE, the controller will return to the most recently active operating mode.
si_Unit	INT	0	Unit of measurement of the process value and setpoint, e.g., ºC, or ºF.
si_Type	INT	0	Physical quantity of the process value and setpoint, e.g., temperature.
sd_Warning	DWORD	DW#16#0	Variable sd_warning (Page 294) displays the warnings generated since the reset, or since the last change of the operating mode.
sBackUp.r_Gain	REAL	1.0	Saved proportional gain You can reload values from the sBackUp structure with sPid_Cmpt.b_LoadBackUp = TRUE.
sBackUp.r_Ti	REAL	20.0	Saved integral action time [s]
sBackUp.r_Td	REAL	0.0	Saved derivative action time [s]
sBackUp.r_A	REAL	0.0	Saved derivative delay coefficient
sBackUp.r_B	REAL	0.0	Saved proportional action weighting factor
sBackUp.r_C	REAL	0.0	Saved derivative action weighting factor
sBackUp.r_Cycle	REAL	1.0	Saved sampling time of PID algorithm
sPid_Calc.r_Cycle	REAL	0.1	Sampling time of the PID_Compact instruction r_Cycle is determined automatically and usually equivalent to the cycle time of the calling OB.

Tag	Data type	Default	Description
sPid_Calc.b_RunIn	BOOL	FALSE	• b_RunIn = FALSE Pretuning is started when fine tuning is started from inactive or manual mode. If the requirements for pretuning are not met, PID_Compact reacts like b_RunIn = TRUE. If fine tuning is started from automatic mode, the system uses the existing PID parameters to control to the setpoint. Only then will fine tuning start. If pretuning is not possible, PID_Compact will change to "Inactive" mode. • b_RunIn = TRUE The pretuning is skipped. PID_3Compact tries to reach the setpoint with minimum or maximum output value. This can produce increased overshoot. Fine tuning then starts automatically. b_RunIn is set to FALSE after fine tuning.
sPid_Calc.b_CalcParamSUT	BOOL	FALSE	The parameters for pretuning will be recalculated if b_CalcParamSUT = TRUE. This enables you to change the parameter calculation method without having to repeat controller tuning. b_CalcParamSUT will be set to FALSE after calculation.
sPid_Calc.b_CalcParamTIR	BOOL	FALSE	The parameters for fine tuning will be recalculated if b_CalcParamTIR = TRUE. This enables you to change the parameter calculation method without having to repeat controller tuning. b_CalcParamTIR will be set to FALSE after calculation.
sPid_Calc.i_CtrlTypeSUT	INT	0	Methods used to calculate parameters during pretuning: • i_CtrlTypeSUT = 0: PID according to Chien, Hrones and Reswick • i_CtrlTypeSUT = 1: PI according to Chien, Hrones and Reswick
sPid_Calc.i_CtrlTypeTIR	INT	0	Methods used to calculate parameters during fine tuning: • i_CtrlTypeTIR = 0: PID automatic • i_CtrlTypeTIR = 1: PID rapid • i_CtrlTypeTIR = 2: PID slow • i_CtrlTypeTIR = 3: Ziegler-Nichols PID • i_CtrlTypeTIR = 4: Ziegler-Nichols PI • i_CtrlTypeTIR = 5: Ziegler-Nichols P
sPid_Calc.r_Progress	REAL	0.0	Progress of tuning as a percentage (0.0 - 100.0)

Tag	Data type	Default	Description
sPid_Cmpt.r_Sp_Hlm	REAL	+3.402822e+38	High limit of setpoint If you set sPid_Cmpt.r_Sp_Hlm outside the process value limits, the configured process value absolute high limit is used as the setpoint high limit. If you set sPid_Cmpt.r_Sp_Hlm within the process value limits, this value is used as the setpoint high limit.
sPid_Cmpt.r_Sp_Llm	REAL	-3.402822e+38	Low limit of the setpoint If you set sPid_Cmpt.r_Sp_Llm outside the process value limits, the configured process value absolute low limit is used as the setpoint low limit. If you set sPid_Cmpt.r_Sp_Llm within the process value limits, this value is used as the setpoint low limit.
sPid_Cmpt.r_Pv_Norm_IN_1	REAL	0.0	Scaling Input_PER low Input_PER is converted to percent based on the two value pairs r_Pv_Norm_OUT_1, r_Pv_Norm_IN_1 and r_Pv_Norm_OUT_2, r_Pv_Norm_IN_2 from the sPid_Cmpt structure.
sPid_Cmpt.r_Pv_Norm_IN_2	REAL	27648.0	Scaling Input_PER high Input_PER is converted to percent based on the two value pairs r_Pv_Norm_OUT_1, r_Pv_Norm_IN_1 and r_Pv_Norm_OUT_2, r_Pv_Norm_IN_2 from the sPid_Cmpt structure.
sPid_Cmpt.r_Pv_Norm_OUT_1	REAL	0.0	Scaled low process value Input_PER is converted to percent based on the two value pairs r_Pv_Norm_OUT_1, r_Pv_Norm_IN_1 and r_Pv_Norm_OUT_2, r_Pv_Norm_IN_2 from the sPid_Cmpt structure.
sPid_Cmpt.r_Pv_Norm_OUT_2	REAL	100.0	Scaled high process value Input_PER is converted to percent based on the two value pairs r_Pv_Norm_OUT_1, r_Pv_Norm_IN_1 and r_Pv_Norm_OUT_2, r_Pv_Norm_IN_2 from the sPid_Cmpt structure.
sPid_Cmpt.r_Lmn_Hlm	REAL	100.0	Output value high limit for output parameter "Output"
sPid_Cmpt.r_Lmn_Llm	REAL	0.0	Low output value limit for output parameter "Output"
sPid_Cmpt.b_Input_PER_On	BOOL	TRUE	If b_Input_PER_On = TRUE, then parameter Input_PER is used. If b_Input_PER_On = FALSE, then parameter Input is used.
sPid_Cmpt.b_LoadBackUp	BOOL	FALSE	Activate the back-up parameter set. If an optimization has failed, you can reactivate the previous PID parameters by setting this bit.
sPid_Cmpt.b_InvCtrl	BOOL	FALSE	Invert control logic With b_InvCtrl = TRUE, a rising control deviation reduces the output value.

Tag	Data type	Default	Description
sPid_Cmpt.r_Lmn_Pwm_PPTm	REAL	0.0	The minimum ON time of the pulse width modulation in seconds is rounded to r_Lmn_Pwm_PPTm = r_Cycle or r_Lmn_Pwm_PPTm = n*r_Cycle
sPid_Cmpt.r_Lmn_Pwm_PBTm	REAL	0.0	The minimum OFF time of the pulse width modulation in seconds is rounded to r_Lmn_Pwm_PBTm = r_Cycle or r_Lmn_Pwm_PBTm = n*r_Cycle
sPid_Cmpt.r_Pv_Hlm	REAL	120.0	High limit of the process value At the I/O input, the process value can be a maximum of 18% higher than the standard range (overrange). An error is no longer reported for a violation of the "Process value high limit". Only a wire-break and a short-circuit are recognized and the PID_Compact switches to "Inactive" mode. r_Pv_Hlm > r_Pv_Llm
sPid_Cmpt.r_Pv_Llm	REAL	0.0	Low limit of the process value r_Pv_Llm < r_Pv_Hlm
sPid_Cmpt.r_Pv_HWrn	REAL	+3.402822e+38	Warning high limit of the process value If you set r_Pv_HWrn outside the process value limits, the configured process value absolute high limit is used as the warning high limit. If you set r_Pv_HWrn within the process value limits, this value is used as the warning high limit. r_Pv_HWrn > r_Pv_LWrn r_Pv_HWrn ≤ r_Pv_Hlm
sPid_Cmpt.r_Pv_LWrn	REAL	-3.402822e+38	Warning low limit of the process value If you set r_Pv_LWrn outside the process value limits, the configured process value absolute low limit is used as the warning low limit. If you set r_Pv_LWrn within the process value limits, this value is used as the warning low limit. r_Pv_LWrn < r_Pv_HWrn r_Pv_LWrn ≥ r_Pv_LWrn
sParamCalc.i_Event_SUT	INT	0	Variable i_Event_SUT (Page 294) indicates the current phase of "pretuning":
sParamCalc.i_Event_TIR	INT	0	Variable i_Event_TIR (Page 295) indicates the current phase of "fine tuning":
sRet.i_Mode	INT	0	The operating mode is changed edge-triggered. The following operating mode is enabled on a change to • i_Mode = 0: "Inactive" (controller stop) • i_Mode = 1: "Pretuning" mode • i_Mode = 2: "Fine tuning" mode • i_Mode = 3: "Automatic mode" • i_Mode = 4: "Manual mode" i_Mode is retentive.

Tag	Data type	Default	Description
sRet.r_Ctrl_Gain	REAL	1.0	Active proportional gain Gain is retentive.
sRet.r_Ctrl_Ti	REAL	20.0	• r_Ctrl_Ti > 0.0: active integral action time • r_Ctrl_Ti = 0.0: Integral action is disabled r_Ctrl_Ti is retentive.
sRet.r_Ctrl_Td	REAL	0.0	• r_Ctrl_Td > 0.0: Active derivative action time • r_Ctrl_Td = 0.0: Derivative action is disabled r_Ctrl_Td is retentive.
sRet.r_Ctrl_A	REAL	0.0	Active derivative delay coefficient r_Ctrl_A is retentive.
sRet.r_Ctrl_B	REAL	0.0	Active proportional action weighting r_Ctrl_B is retentive.
sRet.r_Ctrl_C	REAL	0.0	Active derivative action weighting r_Ctrl_C is retentive.
sRet.r_Ctrl_Cycle	REAL	1.0	Active sampling time of the PID algorithm r_Ctrl_Cycle is calculated during controller tuning and rounded to an integer multiple of r_Cycle. r_Ctrl_Cycle is retentive.

Note

Change the tags listed in this table in "Inactive" mode to prevent malfunction of the PID controller. The "Inactive" mode is forced by setting variable "sRet.i_Mode" to "0".

See also

Downloading technology objects to device (Page 46)

8.1.5.5 Parameters State and sRet.i_Mode V1

Correlation of the parameters

The State parameter indicates the current operating mode of the PID controller. You cannot modify the State parameter.

You need to modify the sRet.i_Mode tag to change the operating mode. This also applies when the value for the new operating mode is already in sRet.i_Mode. First set sRet.i_Mode = 0 and then sRet.i_Mode = 3. Provided the current operating mode of the controller supports this change, State is set to the value of sRet.i_Mode.

When PID_Compact automatically switches the operating mode, the following applies: State != sRet.i_Mode.

Examples:

- Successful pretuning
  State = 3 and sRet.i_Mode = 1
- Error
  State = 0 and sRet.i_Mode remains at the same value, e.g sRet.i_Mode = 3
- ManualEnalbe = TRUE
  State = 4 and sRet.i_Mode remain at the previous value, for example, sRet.i_Mode = 3

Note

You wish to repeat successful fine tuning without exiting automatic mode with i_Mode = 0.

Setting sRet.i_Mode to an invalid value such as 9999 for one cycle has no effect on State. Set Mode = 2 in the next cycle. You can generate a change to sRet.i_Mode without first switching to "inactive" mode.

Meaning of values

State / sRet.i_Mode	Description of the operating mode
0	Inactive The controller is switched off. The controller was in "inactive" mode before pretuning was performed. The PID controller will change to "inactive" mode when running if an error occurs or if the "Deactivate controller" icon is clicked in the commissioning window.
1	Pretuning The pretuning determines the process response to a jump of the output value and searches for the point of inflection. The optimized PID parameters are calculated as a function of the maximum rate of rise and dead time of the controlled system. Pretuning requirements: • The controller is in inactive mode or manual mode • ManualEnable = FALSE • The process value must not be too close to the setpoint. |Setpoint - Input| > 0.3 * |sPid_Cmpt.r_Pv_Hlm - sPid_Cmpt.r_Pv_Llm| and |Setpoint - Input| > 0.5 * |Setpoint| • The setpoint may not be changed during pretuning. The higher the stability of the process value, the easier it is to calculate the PID parameters and increase precision of the result. Noise on the process value can be tolerated as long as the rate of rise of the process value is significantly higher compared to the noise. PID parameters are backed up before they are recalculated and can be reactivated with sPid_Cmpt.b_LoadBackUp. There is a change to automatic mode following successful pretuning and to "inactive" mode following unsuccessful pretuning. The phase of pretuning is indicated with Tag i_Event_SUT V1 (Page 294).

State / sRet.i_Mode	Description of the operating mode
2	Fine tuning Fine tuning generates a constant, limited oscillation of the process value. The PID parameters are optimized based on the amplitude and frequency of this oscillation. The differences between the process response during pretuning and fine tuning are analyzed. All PID parameters are recalculated on the basis of the findings. PID parameters from fine tuning usually have better master control and disturbance behavior than PID parameters from pretuning. PID_Compact automatically attempts to generate an oscillation greater than the noise of the process value. Fine tuning is only minimally influenced by the stability of the process value. PID parameters are backed up before they are recalculated and can be reactivated with sPid_Cmpt.b_LoadBackUp. Requirements for fine tuning: • No disturbances are expected. • The setpoint and the process value lie within the configured limits. • The setpoint may not be changed during fine tuning. • ManualEnable = FALSE • Automatic (State = 3), inactive (State = 0) or manual (State = 4) mode Fine tuning proceeds as follows when started in: • Automatic mode (State = 3) Start fine tuning in automatic mode if you wish to improve the existing PID parameters using controller tuning. PID_Comact will regulate using the existing PID parameters until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start. • Inactive (State = 0) or manual (State = 4) mode If the requirements for pretuning are met, pretuning is started. The PID parameters established will be used for adjustment until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start. If pretuning is not possible, PID_Compact will change to "Inactive" mode. An attempt is made to reach the setpoint with a minimum or maximum output value if the process value for pretuning is already too near the setpoint or sPid_Calc.b_RunIn = TRUE. This can produce increased overshoot. The controller will change to "automatic mode" after successfully completed "fine tuning" and to "inactive" mode if "fine tuning" has not been successfully completed. The "Fine tuning" phase is indicated with Tag i_Event_TIR V1 (Page 295).

State / sRet.i_Mode	Description of the operating mode
3	Automatic mode In automatic mode, PID_Compact corrects the controlled system in accordance with the parameters specified. The controller changes to automatic mode if one the following conditions is fulfilled: • Pretuning successfully completed • Fine tuning successfully completed • Change of variable sRet.i_Mode to the value 3. After CPU startup or change from Stop to RUN mode, PID_Compact will start in the most recently active operating mode. To retain PID_Compact in "Inactive" mode, set sb_RunModeByStartup = FALSE.
4	Manual mode In manual mode, you specify a manual output value in the ManualValue parameter. This operating mode is enabled if sRet.i_Mode = 4, or at the rising edge on ManualEnable. If ManualEnable changes to TRUE, only State will change. sRet.i_Mode will retain its current value. PID_Compact will return to the previous operating mode upon a falling edge at ManualEnable. The change to automatic mode is bumpless.

See also

Output parameters of PID_Compact V1 (Page 281)

Pretuning (Page 111)

Fine tuning (Page 113)

"Manual" mode (Page 115)

Tag i_Event_SUT V1 (Page 294)

Tag i_Event_TIR V1 (Page 295)

8.1.5.6 Parameter Error V1

If several errors are pending simultaneously, the values of the error codes are displayed with binary addition. The display of error code 0003, for example, indicates that the errors 0001 and 0002 are pending simultaneously.

Error (DW#16#...)	Description
0000	There is no error.
0001	The "Input" parameter is outside the process value limits. • Input > sPid_Cmpt.r_Pv_Hlm or • Input < sPid_Cmpt.r_Pv_Llm You cannot move the actuator again until you eliminate the error.
0002	Invalid value at "Input_PER" parameter. Check whether an error is pending at the analog input.
0004	Error during fine tuning. Oscillation of the process value could not be maintained.
0008	Error at start of pretuning. The process value is too close to the setpoint. Start fine tuning.
0010	The setpoint was changed during tuning.
0020	Pretuning is not permitted in automatic mode or during fine tuning.
0080	Incorrect configuration of output value limits. Check whether the limits of the output value are configured correctly and match the control logic.
0100	Error during tuning resulted in invalid parameters.
0200	Invalid value at "Input" parameter: Value has an invalid number format.
0400	Calculation of output value failed. Check the PID parameters.
0800	Sampling time error: PID_Compact is not called within the sampling time of the cyclic interrupt OB.
1000	Invalid value at "Setpoint" parameter: Value has an invalid number format.

See also

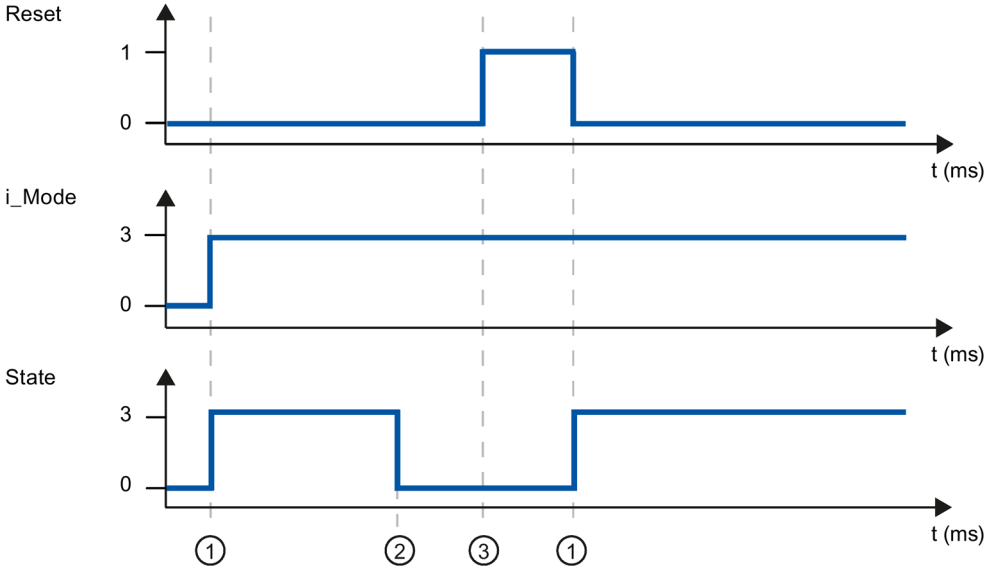
Output parameters of PID_Compact V1 (Page 281)

8.1.5.7 Parameter Reset V1

The response to Reset = TRUE depends on the version of the PID_Compact instruction.

Reset response PID_Compact V.1.1 or higher

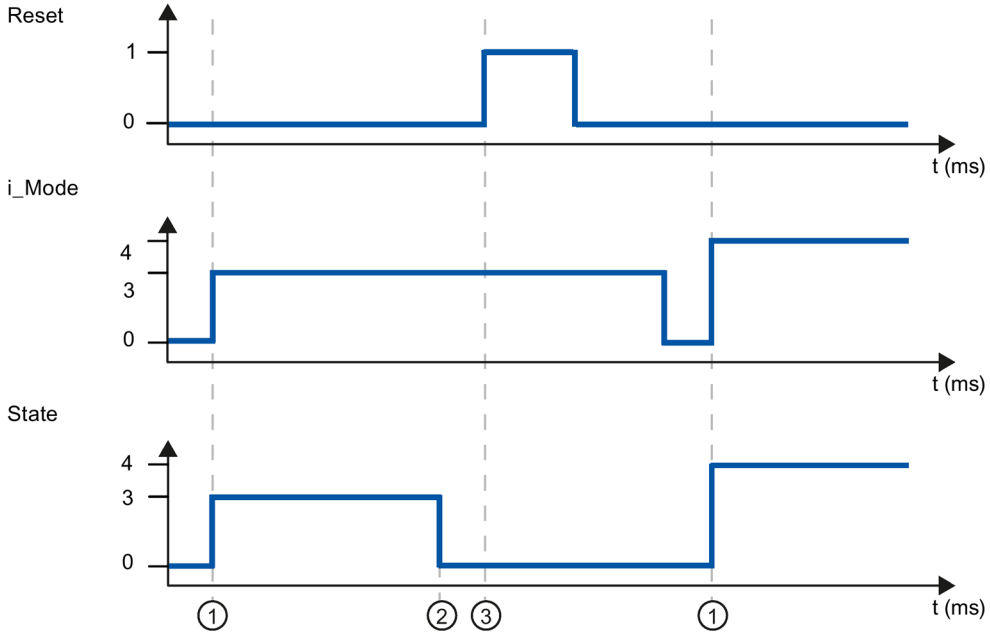
A rising edge at Reset resets the errors and warnings and clears the integral action. A falling edge at Reset triggers a change to the most recently active operating mode.



① Activation
② Error
③ Reset

Reset response PID_Compact V.1.0

A rising edge at Reset resets the errors and warnings and clears the integral action. The controller is not reactivated until the next edge at i_Mode.



① Activation
② Error
③ Reset

8.1.5.8 Tag sd_warning V1

If several warnings are pending, the values of variable sd_warning are displayed by means of binary addition. The display of warning 0003, for example, indicates that the warnings 0001 and 0002 are also pending.

sd_warning (DW#16#....)	Description
0000	No warning pending.
0001	The point of inflection was not found during pretuning.
0002	Oscillation increased during fine tuning.
0004	The setpoint was outside the set limits.
0008	Not all the necessary controlled system properties were defined for the selected method of calculation. The PID parameters were instead calculated using the "i_CtrlTypeTIR = 3" method.
0010	The operating mode could not be changed because ManualEnable = TRUE.
0020	The cycle time of the calling OB limits the sampling time of the PID algorithm. Improve results by using shorter OB cycle times.
0040	The process value exceeded one of its warning limits.

The following warnings are deleted as soon as the cause is dealt with:

- 0004
- 0020
- 0040

All other warnings are cleared with a rising edge at Reset.

8.1.5.9 Tag i_Event_SUT V1

i_Event_SUT	Name	Description
0	SUT_INIT	Initialize pretuning
100	SUT_STDABW	Calculate the standard deviation
200	SUT_GET_POI	Find the point of inflection
9900	SUT_IO	Pretuning successful
1	SUT_NIO	Pretuning not successful

See also

Static tags of PID_Compact V1 (Page 282)

Parameters State and sRet.i_Mode V1 (Page 287)

8.1.5.10 Tag i_Event_TIR V1

i_Event_TIR	Name	Description
-100	TIR_FIRST_SUT	Fine tuning is not possible. Pretuning will be executed first.
0	TIR_INIT	Initialize fine tuning
200	TIR_STDABW	Calculate the standard deviation
300	TIR_RUN_IN	Attempt to reach the setpoint
400	TIR_CTRLN	Attempt to reach the setpoint with the existing PID parameters (if pretuning has been successful)
500	TIR_OSZIL	Determine oscillation and calculate parameters
9900	TIR_IO	Fine tuning successful
1	TIR_NIO	Fine tuning not successful

See also

Static tags of PID_Compact V1 (Page 282)
Parameters State and sRet.i_Mode V1 (Page 287)

8.2 PID_3Step

8.2.1 New features of PID_3Step

PID_3Step V2.2

- **Use with S7-1200**

  As of PID_3Step V2.2, the instruction with V2 functionality can also be used on S7-1200 with firmware version 4.0 or higher.

PID_3Step V2.0

- **Reaction to error**

  The reaction to ActivateRecoverMode = TRUE has been completely overhauled. PID_3Step reacts in a more fault tolerant manner in the default setting.

NOTICE
Your system may be damaged. If you use the default setting, PID_3Step remains in automatic mode even if the process value limits are exceeded. This may damage your system. It is essential to configure how your controlled system reacts in the event of an error to protect your system from damage.

  You use the ErrorAck input parameter to acknowledge the errors and warnings without restarting the controller or clearing the integral action.

  Switching operating modes does not acknowledge errors that are no longer pending.

- **Switching the operating mode**

  You specify the operating mode at the Mode in/out parameter and use a rising edge at ModeActivate to start the operating mode. The Retain.Mode tag has been omitted.

  The transition time measurement can no longer be started with GetTransitTime.Start, but only with Mode = 6 and a rising edge at ModeActivate.

- **Multi-instance capability**

  You can call up PID_3Step as multi-instance DB. No technology object is created in this case and no parameter assignment interface or commissioning interface is available. You must assign parameters for PID_3Step directly in the multi-instance DB and commission it via a watch table.

- **Startup characteristics**

  The operating mode specified at the Mode parameter is also started on a falling edge at Reset and during a CPU cold restart, if RunModeByStartup = TRUE.

- **ENO characteristics**

  ENO is set depending on the operating mode.

  If State = 0, then ENO = FALSE.

  If State ≠ 0, then ENO = TRUE.

- **Manual mode**

  The Manual_UP and Manual_DN input parameters no longer function as edge-triggered parameters. Edge-triggered manual mode continues to be possible using the ManualUpInternal and ManualDnInternal tags.

  In "Manual mode without endstop signals" (Mode = 10), the endstop signals Actuator_H and Actuator_L are ignored even though they are activated.

- **Default value of PID parameters**

  The following default settings have been changed:

  – Proportional action weighting (PWeighting) from 0.0 to 1.0

  – Derivative action weighting (DWeighting) from 0.0 to 1.0

  – Coefficient for derivative delay (TdFiltRatio) from 0.0 to 0.2

- **Limiting of motor transition time**

  You configure the maximum percentage of the motor transition time that the actuator will travel in one direction in the Config.VirtualActuatorLimit tag.

- **Setpoint value specification during tuning**

  You configure the permitted fluctuation of the setpoint during tuning at the CancelTuningLevel tag.

- **Switching a disturbance variable on**

  You can switch a disturbance variable on at the Disturbance parameter.

- **Troubleshooting**

  If the endstop signals are not activated (ActuatorEndStopOn = FALSE), ScaledFeedback is determined without Actuator_H or Actuator_L.

PID_3Step V1.1

- **Manual mode on CPU startup**

  If ManualEnable = TRUE when the CPU starts, PID_3Step starts in manual mode. A rising edge at ManualEnable is not necessary.

- **Reaction to error**

  The ActivateRecoverMode tag is no longer effective in manual mode.

- **Troubleshooting**

  The Progress tag is reset following successful tuning or transition time measurement.

8.2.2 Compatibility with CPU and FW

The following table shows which version of PID_3Step can be used on which CPU.

CPU	FW	PID_3Step
S7-1200	≥ V4.X	V2.2 V1.1
S7-1200	≥ V3.X	V1.1 V1.0
S7-1200	≥ V2.X	V1.1 V1.0
S7-1200	≥ V1.X	-
S7-1500	≥ V1.5	V2.2 V2.1 V2.0
S7-1500	≥ V1.1	V2.1 V2.0
S7-1500	≥ V1.0	V2.0

8.2.3 CPU processing time and memory requirement PID_3Step V2.x

CPU processing time

Typical CPU processing times of the PID_3Step technology object as of Version V2.0, depending on CPU type.

CPU	Typ. CPU processing time PID_3Step V2.x
CPU 1211C ≥ V4.0	410 µs
CPU 1215C ≥ V4.0	410 µs
CPU 1217C ≥ V4.0	410 µs
CPU 1505S ≥ V1.0	50 µs
CPU 1510SP-1 PN ≥ V1.6	120 µs
CPU 1511-1 PN ≥ V1.5	120 µs
CPU 1512SP-1 PN ≥ V1.6	120 µs
CPU 1516-3 PN/DP ≥ V1.5	65 µs
CPU 1518-4 PN/DP ≥ V1.5	5 µs

Memory requirement

Memory requirement of an instance DB of the PID_3Step technology object as of Version V2.0.

	Memory requirement of the instance DB of PID_3Step V2.x
Load memory requirement	Approx. 15000 bytes
Total work memory requirement	1040 bytes
Retentive work memory requirement	60 bytes

8.2.4 PID_3Step V2

8.2.4.1 Description of PID_3Step V2

Description

You use the PID_3Step instruction to configure a PID controller with self tuning for valves or actuators with integrating behavior.

The following operating modes are possible:

- Inactive
- Pretuning
- Fine tuning
- Automatic mode
- Manual mode
- Approach substitute output value
- Transition time measurement
- Error monitoring
- Approach substitute output value with error monitoring
- Manual mode without endstop signals

For a more detailed description of the operating modes, see the State parameter.

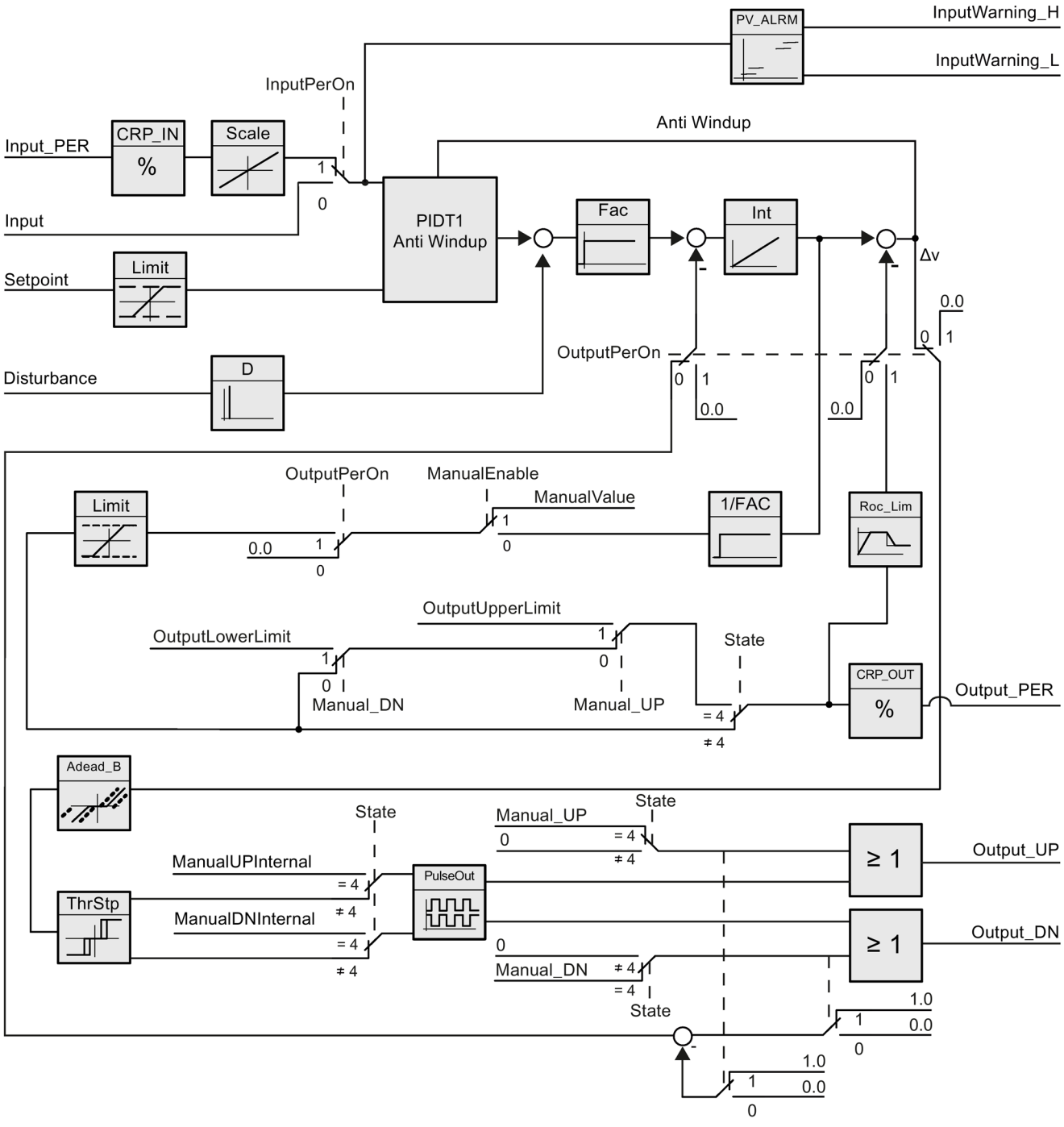
PID algorithm

PID_3Step is a PIDT1 controller with anti-windup and weighting of the proportional and derivative actions. The PID algorithm operates according to the following equation:

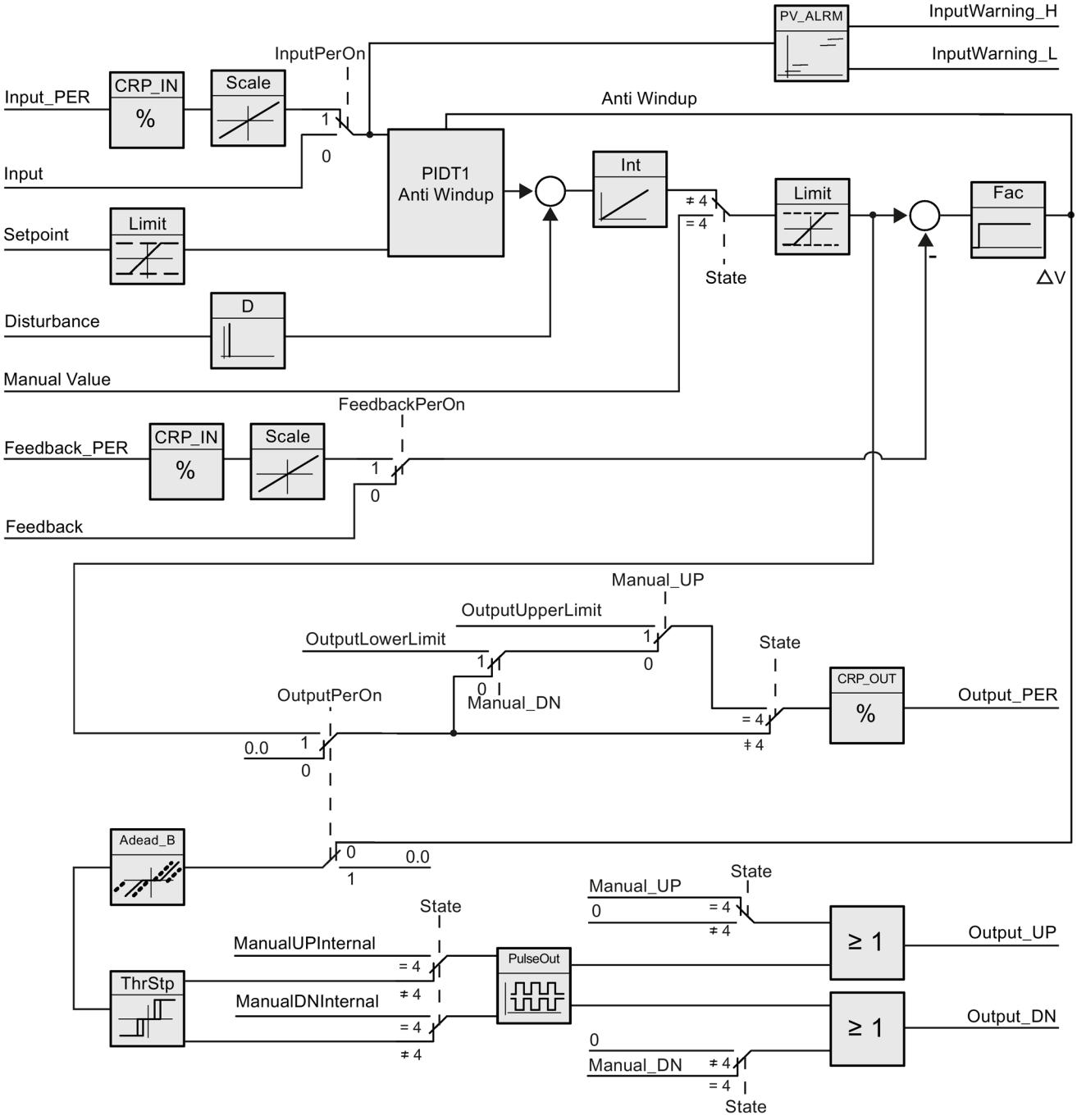
$$\Delta y = K_p \cdot s \cdot \left[(b \cdot w - x) + \frac{1}{T_I \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c \cdot w - x) \right]$$

Symbol	Description
Δy	Output value of the PID algorithm
K_p	Proportional gain
s	Laplace operator
b	Proportional action weighting
w	Setpoint
x	Process value
T_I	Integral action time
T_D	Derivative action time
a	Derivative delay coefficient (derivative delay T1 = a × T_D)
c	Derivative action weighting

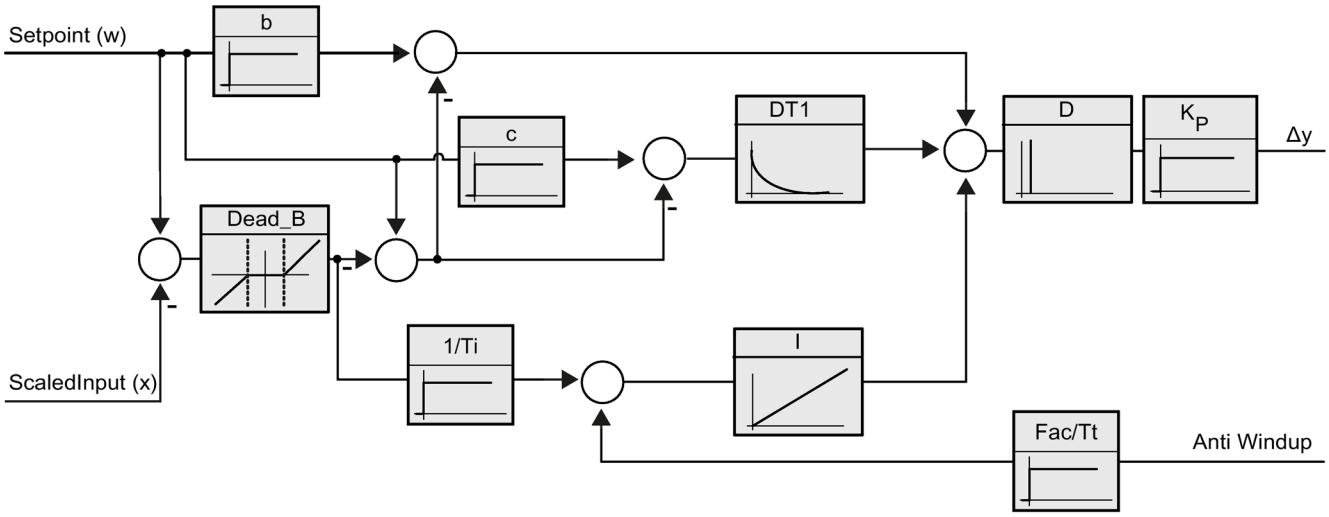
Block diagram without position feedback



Block diagram with position feedback



Block diagram of PIDT1 with anti-windup



Call

PID_3Step is called in the constant time scale of a cycle interrupt OB.

If you call PID_3Step as a multi-instance DB, no technology object is created. No parameter assignment interface or commissioning interface is available. You must assign parameters for PID_3Step directly in the multi-instance DB and commission it via a watch table.

Download to device

The actual values of retentive tags are only updated when you download PID_3Step completely.

Downloading technology objects to device (Page 46)

Startup

When the CPU starts up, PID_3Step starts in the operating mode that is saved in the Mode in/out parameter. To leave PID_3Step in "Inactive" mode, set RunModeByStartup = FALSE.

Reaction to error

In automatic mode and during commissioning, the reaction to error depends on the ErrorBehaviour and ActivateRecoverMode tags. In manual mode, the reaction is independent of ErrorBehaviour and ActivateRecoverMode. If ActivateRecoverMode = TRUE, the reaction additionally depends on the error that occurred.

ErrorBehaviour	ActivateRecoverMode	Configuration editor > actuator setting > Set Output to	Reaction
FALSE	FALSE	Current output value	Switch to "Inactive" mode (State = 0) The actuator remains in the current position.
FALSE	TRUE	Current output value while error is pending	Switch to "Error monitoring" mode (State = 7) The actuator remains in the current position while the error is pending.
TRUE	FALSE	Substitute output value	Switch to "Approach substitute output value" mode (State = 5) The actuator moves to the configured substitute output value. Switch to "Inactive" mode (State = 0) The actuator remains in the current position.
TRUE	TRUE	Substitute output value while error is pending	Switch to "Approach substitute output value with error monitoring" mode (State = 8) The actuator moves to the configured substitute output value. Switch to "Error monitoring" mode (State = 7)

In manual mode, PID_3Step uses ManualValue as output value, unless the following errors occur:

- 2000h: Invalid value at Feedback_PER parameter.
- 4000h: Invalid value at Feedback parameter.
- 8000h: Error during digital position feedback.

You can only change the position of the actuator with Manual_UP and Manual_DN, not with ManualValue.

The Error parameter indicates whether an error has occurred in this cycle. The ErrorBits parameter shows which errors have occurred. ErrorBits is reset by a rising edge at Reset or ErrorAck.

See also

Parameters State and Mode V2 (Page 324)

Parameter ErrorBits V2 (Page 329)

Configuring PID_3Step V2 (Page 118)

8.2.4.2 Mode of operation of PID_3Step V2

Monitoring process value limits

You specify the high limit and low limit of the process value in the Config.InputUpperLimit and Config.InputLowerLimit variables. If the process value is outside these limits, an error occurs (ErrorBits = 0001h).

You specify a high and low warning limit of the process value in the Config.InputUpperWarning and Config.InputLowerWarning variables. If the process value is outside these warning limits, a warning occurs (Warning = 0040h), and the InputWarning_H or InputWarning_L output parameter changes to TRUE.

Limiting the setpoint

You specify a high limit and low limit of the setpoint in the Config.SetpointUpperLimit and Config.SetpointLowerLimit variables. PID_3Step automatically limits the setpoint to the process value limits. You can limit the setpoint to a smaller range. PID_3Step checks whether this range falls within the process value limits. If the setpoint is outside these limits, the high or low limit is used as the setpoint, and output parameter SetpointLimit_H or SetpointLimit_L is set to TRUE.

The setpoint is limited in all operating modes.

Limiting the output value

You specify a high limit and low limit of the output value in the Config.OutputUpperLimit and Config.OutputLowerLimit variables. The output value limits must be within "Low endstop" and "High endstop".

- High endstop: Config.FeedbackScaling.UpperPointOut
- Low endstop: Config.FeedbackScaling.LowerPointOut

Rule:

UpperPointOut ≥ OutputUpperLimit > OutputLowerLimit ≥ LowerPointOut

The valid values for "High endstop" and "Low endstop" depend upon:

- FeedbackOn
- FeedbackPerOn
- OutputPerOn

OutputPerOn	FeedbackOn	FeedbackPerOn	LowerPointOut	UpperPointOut
FALSE	FALSE	FALSE	Cannot be set (0.0%)	Cannot be set (100.0%)
FALSE	TRUE	FALSE	-100.0% or 0.0%	0.0% or +100.0%
FALSE	TRUE	TRUE	-100.0% or 0.0%	0.0% or +100.0%
TRUE	FALSE	FALSE	Cannot be set (0.0%)	Cannot be set (100.0%)
TRUE	TRUE	FALSE	-100.0% or 0.0%	0.0% or +100.0%
TRUE	TRUE	TRUE	-100.0% or 0.0%	0.0% or +100.0%

If OutputPerOn = FALSE and FeedbackOn = FALSE, you cannot limit the output value. Output_UP and Output_DN are then reset at Actuator_H = TRUE or Actuator_L = TRUE. If endstop signals are also not present, Output_UP and Output_DN are reset after a travel time of Config.VirtualActuatorLimit × Retain.TransitTime/100.

The output value is 27648 at 100% and -27648 at -100%. PID_3Step must be able to close the valve completely.

Substitute output value

If an error has occurred, PID_3Step can output a substitute output value and move the actuator to a safe position that is specified in the SavePosition tag. The substitute output value must be within the output value limits.

Monitoring signal validity

The values of the following parameters are monitored for validity when used:

- Setpoint
- Input
- Input_PER
- Input_PER
- Feedback
- Feedback_PER
- Disturbance
- ManualValue
- SavePosition
- Output_PER

Monitoring the PID_3Step sampling time

Ideally, the sampling time is equivalent to the cycle time of the calling OB. The PID_3Step instruction measures the time interval between two calls. This is the current sampling time. On every switchover of operating mode and during the initial startup, the mean value is formed from the first 10 sampling times. Too great a difference between the current sampling time and this mean value triggers an error (ErrorBits = 0800h).

The error occurs during tuning if:

- New mean value >= 1.1 x old mean value
- New mean value <= 0.9 x old mean value

The error occurs in automatic mode if:

- New mean value >= 1.5 x old mean value
- New mean value <= 0.5 x old mean value

If you deactivate the sampling time monitoring (CycleTime.EnMonitoring = FALSE), you can also call PID_3Step in OB1. You must then accept a lower control quality due to the deviating sampling time.

Sampling time of the PID algorithm

The controlled system needs a certain amount of time to respond to changes in the output value. It is therefore not advisable to calculate the output value in every cycle. The sampling time of the PID algorithm represents the time between two calculations of the output value. It is calculated during tuning and rounded to a multiple of the cycle time. All other functions of PID_3Step are executed at every call.

Measuring the motor transition time

The motor transition time is the time in seconds the motor requires to move the actuator from the closed to the opened state. The actuator is moved in one direction for a maximum time of Config.VirtualActuatorLimit × Retain.TransitTime/100. PID_3Step requires the motor transition time to be as accurate as possible for good controller results. The data in the actuator documentation contains average values for this type of actuator. The value for the specific actuator used may differ. You can measure the motor transition time during commissioning. The output value limits are not taken into consideration during the motor transition time measurement. The actuator can travel to the high or the low endstop.

Control logic

An increase of the output value is generally intended to cause an increase in the process value. This is referred to as a normal control logic. For cooling and discharge control systems, it may be necessary to invert the control logic. PID_3Step does not work with negative proportional gain. If InvertControl = TRUE, an increasing control deviation causes a reduction in the output value. The control logic is also taken into account during pretuning and fine tuning.

See also

Configuring PID_3Step V1 (Page 139)

8.2.4.3 Changing the PID_3Step V2 interface

The following table shows what has changed in the PID_3Step instruction interface.

PID_3Step V1	PID_3Step V2	Change
Input_PER	Input_PER	Data type from Word to Int
Feedback_PER	Feedback_PER	Data type from Word to Int
	Disturbance	New
Manual_UP	Manual_UP	Function
Manual_DN	Manual_DN	Function
	ErrorAck	New
	ModeActivate	New
Output_PER	Output_PER	Data type from Word to Int
	ManualUPInternal	New
	ManualDNInternal	New
	CancelTuningLevel	New
	VirtualActuatorLImit	New
Config.Loadbackup	Loadbackup	Renamed
Config.TransitTime	Retain.TransitTime	Renamed and retentivity added
GetTransitTime.Start		Replaced by Mode and ModeActivate
SUT.CalculateSUTParams	SUT.CalculateParams	Renamed
SUT.TuneRuleSUT	SUT.TuneRule	Renamed
TIR.CalculateTIRParams	TIR.CalculateParams	Renamed
TIR.TuneRuleTIR	TIR.TuneRule	Renamed
Retain.Mode	Mode	Function Declaration of static for in-out parameters

8.2.4.4 Input parameters of PID_3Step V2

Parameter	Data type	Default	Description
Setpoint	REAL	0.0	Setpoint of the PID controller in automatic mode
Input	REAL	0.0	A tag of the user program is used as the source of the process value. If you are using the Input parameter, then Config.InputPerOn = FALSE must be set.
Input_PER	INT	0	An analog input is used as the source of the process value. If you are using the Input_PER parameter, then Config.InputPerOn = TRUE must be set.
Actuator_H	BOOL	FALSE	Digital position feedback of the valve for the high endstop If Actuator_H = TRUE, the valve is at the high endstop and is no longer moved towards this direction.
Actuator_L	BOOL	FALSE	Digital position feedback of the valve for the low endstop If Actuator_L = TRUE, the valve is at the low endstop and is no longer moved towards this direction.
Feedback	REAL	0.0	Position feedback of the valve If you are using the Feedback parameter, then Config.FeedbackPerOn = FALSE must be set.
Feedback_PER	INT	0	Analog position feedback of a valve If you are using the Feedback_PER parameter, then Config.FeedbackPerOn = TRUE must be set. Feedback_PER is scaled based on the tags: • Config.FeedbackScaling.LowerPointIn • Config.FeedbackScaling.UpperPointIn • Config.FeedbackScaling.LowerPointOut • Config.FeedbackScaling.UpperPointOut
Disturbance	REAL	0.0	Disturbance tag or precontrol value
ManualEnable	BOOL	FALSE	• A FALSE -> TRUE edge activates "manual mode", while State = 4, Mode remain unchanged. As long as ManualEnable = TRUE, you cannot change the operating mode via a rising edge at ModeActivate or use the commissioning dialog. • A TRUE -> FALSE edge activates the operating mode that is specified by Mode. We recommend that you change the operating mode using ModeActivate only.
ManualValue	REAL	0.0	In manual mode, the absolute position of the valve is specified. ManualValue is only evaluated if you are using Output_PER, **or** if position feedback is available.

Parameter	Data type	Default	Description
Manual_UP	BOOL	FALSE	• Manual_UP = TRUE The valve is opened even if you are using Output_PER or a position feedback. The valve is no longer moved if the high endstop has been reached. See also Config.VirtualActuatorLimit • Manual_UP = FALSE If you are using Output_PER or a position feedback, the valve is moved to ManualValue. Otherwise, the valve is no longer moved. If Manual_UP and Manual_DN are set to TRUE simultaneously, the valve is not moved.
Manual_DN	BOOL	FALSE	• Manual_DN = TRUE The valve is closed even if you are using Output_PER or a position feedback. The valve is no longer moved if the low endstop has been reached. See also Config.VirtualActuatorLimit • Manual_DN = FALSE If you are using Output_PER or a position feedback, the valve is moved to ManualValue. Otherwise, the valve is no longer moved.
ErrorAck	BOOL	FALSE	• FALSE -> TRUE edge ErrorBits and Warning are reset.
Reset	BOOL	FALSE	Restarts the controller. • FALSE -> TRUE edge – Switch to "Inactive" mode – ErrorBits and Warning are reset. – Integral action is cleared (PID parameters are retained) • As long as Reset = TRUE, PID_3Step remains in "Inactive" mode (State = 0). • TRUE -> FALSE edge PID_3Step switches to the operating mode that is saved in the Mode parameter.
ModeActivate	BOOL	FALSE	• FALSE -> TRUE edge PID_3Step switches to the operating mode that is saved in the Mode parameter.

8.2.4.5 Output parameters of PID_3Step V2

Parameter	Data type	Default	Description
ScaledInput	REAL	0.0	Scaled process value
ScaledFeedback	REAL	0.0	Scaled position feedback For an actuator without position feedback, the position of the actuator indicated by ScaledFeedback is very imprecise. ScaledFeedback may only be used for rough estimation of the current position in this case.
Output_UP	BOOL	FALSE	Digital output value for opening the valve If Config.OutputPerOn = FALSE, the Output_UP parameter is used.
Output_DN	BOOL	FALSE	Digital output value for closing the valve If Config.OutputPerOn = FALSE, the Output_DN parameter is used.
Output_PER	INT	0	Analog output value If Config.OutputPerOn = TRUE, Output_PER is used.
SetpointLimit_H	BOOL	FALSE	If SetpointLimit_H = TRUE, the absolute setpoint high limit is reached (Setpoint ≥ Config.SetpointUpperLimit). The setpoint is limited to Config.SetpointUpperLimit .
SetpointLimit_L	BOOL	FALSE	If SetpointLimit_L = TRUE, the absolute setpoint low limit has been reached (Setpoint ≤ Config.SetpointLowerLimit). The setpoint is limited to Config.SetpointLowerLimit .
InputWarning_H	BOOL	FALSE	If InputWarning_H = TRUE, the process value has reached or exceeded the warning high limit.
InputWarning_L	BOOL	FALSE	If InputWarning_L = TRUE, the process value has reached or fallen below the warning low limit.
State	INT	0	The State parameter (Page 324) shows the current operating mode of the PID controller. You can change the operating mode using the input parameter Mode and a rising edge at ModeActivate. • State = 0: Inactive • State = 1: Pretuning • State = 2: Fine tuning • State = 3: Automatic mode • State = 4: Manual mode • State = 5: Approach substitute output value • State = 6: Transition time measurement • State = 7: Error monitoring • State = 8: Approach substitute output value with error monitoring • State = 10: Manual mode without end stop signals

Parameter	Data type	Default	Description
Error	BOOL	FALSE	If Error = TRUE, at least one error message is pending in this cycle.
ErrorBits	DWORD	DW#16#0	The ErrorBits parameter (Page 329) shows which error messages are pending. ErrorBits is retentive and is reset upon a rising edge at Reset or ErrorAck.

See also

Parameters State and Mode V2 (Page 324)

Parameter ErrorBits V2 (Page 329)

8.2.4.6 In-out parameters of PID_3Step V2

Parameter	Data type	Default	Description
Mode	INT	4	At the Mode parameter, you specify the operating mode to which PID_3Step is to switch. Options are: • Mode = 0: Inactive • Mode = 1: Pretuning • Mode = 2: Fine tuning • Mode = 3: Automatic mode • Mode = 4: Manual mode • Mode = 6: Transition time measurement • Mode = 10: Manual mode without endstop signals The operating mode is activated by: • Rising edge at ModeActivate • Falling edge at Reset • Falling edge at ManualEnable • Cold restart of CPU if RunModeByStartup = TRUE Mode is retentive. A detailed description of the operating modes can be found in Parameters State and Mode V2 (Page 324).

8.2.4.7 Static tags of PID_3Step V2

You must not change tags that are not listed. These are used for internal purposes only.

Tag	Data type	Default	Description
ManualUpInternal	BOOL	FALSE	In manual mode, each rising edge opens the valve by 5% of the total control range or for the duration of the minimum motor transition time. ManualUpInternal is only evaluated if you are not using Output_PER or a position feedback. This tag is used in the commissioning dialog.
ManualDnInternal	BOOL	FALSE	In manual mode, every rising edge closes the valve by 5% of the total control range or for the duration of the minimum motor transition time. ManualDnInternal is only evaluated if you are not using Output_PER or position feedback. This tag is used in the commissioning dialog.
ActivateRecoverMode	BOOL	TRUE	The ActivateRecoverMode V2 (Page 332) tag determines the reaction to error.
RunModeByStartup	BOOL	TRUE	Activate operating mode at Mode parameter after CPU restart If RunModeByStartup = TRUE, PID_3Step starts in the operating mode saved in the Mode parameter after CPU startup. If RunModeByStartup = FALSE, PID_3Step remains in "Inactive" mode after CPU startup.
LoadBackUp	BOOL	FALSE	If LoadBackUp = TRUE, the last set of PID parameters is reloaded. The set was saved prior to the last tuning. LoadBackUp is automatically set back to FALSE.
PhysicalUnit	INT	0	Unit of measurement of the process value and setpoint, e.g., ºC, or ºF.
PhysicalQuantity	INT	0	Physical quantity of the process value and setpoint, e.g., temperature
ErrorBehaviour	BOOL	FALSE	If ErrorBehaviour = FALSE and an error has occurred, the valve stays at its current position and the controller switches directly to "Inactive" or "Error monitoring" mode. If ErrorBehaviour = TRUE and an error occurs, the actuator moves to the substitute output value and only then switches to "Inactive" or "Error monitoring" mode. If the following errors occur, you can no longer move the valve to a configured substitute output value. • 2000h: Invalid value at Feedback_PER parameter. • 4000h: Invalid value at Feedback parameter. • 8000h: Error during digital position feedback. • 20000h: Invalid value at SavePosition tag.
Warning	DWORD	DW#16#0	The Warning tag (Page 324) shows the warnings since Reset = TRUE or ErrorAck =TRUE. Warning is retentive. Cyclic warnings (for example, process value warning) are shown until the cause of the warning is removed. They are automatically deleted once their cause has gone. Non-cyclic warnings (for example, point of inflection not found) remain and are deleted like errors.

Tag	Data type	Default	Description
SavePosition	REAL	0.0	Substitute output value If ErrorBehaviour = TRUE, the actuator is moved to a position that is safe for the plant when an error occurs. As soon as the substitute output value has been reached, PID_3Step switches the operating mode according to ActivateRecoverMode.
CurrentSetpoint	REAL	0.0	Currently active setpoint. This value is frozen at the start of tuning.
CancelTuningLevel	REAL	10.0	Permissible fluctuation of setpoint during tuning. Tuning is not canceled until: • Setpoint > CurrentSetpoint + CancelTuningLevel or • Setpoint < CurrentSetpoint - CancelTuningLevel
Progress	REAL	0.0	Progress of tuning as a percentage (0.0 - 100.0)
Config.InputPerOn	BOOL	TRUE	If InputPerOn = TRUE, the Input_PER parameter is used. If InputPerOn = FALSE, the Input parameter is used.
Config.OutputPerOn	BOOL	FALSE	If OutputPerOn = TRUE, the Output_PER parameter is used. If OutputPerOn = FALSE, the Ouput_UP and Output_DN parameters are used.
Config.InvertControl	BOOL	FALSE	Invert control logic If InvertControl = TRUE, an increasing control deviation causes a reduction in the output value.
Config.FeedbackOn	BOOL	FALSE	If FeedbackOn = FALSE, a position feedback is simulated. Position feedback is generally activated when FeedbackOn = TRUE.
Config.FeedbackPerOn	BOOL	FALSE	FeedbackPerOn is only effective when FeedbackOn = TRUE. If FeedbackPerOn = TRUE, the analog input is used for the position feedback (Feedback_PER parameter). If FeedbackPerOn = FALSE, the Feedback parameter is used for the position feedback.
Config.ActuatorEndStopOn	BOOL	FALSE	If ActuatorEndStopOn = TRUE, the digital position feedback Actuator_L and Actuator_H are taken into consideration.
Config.InputUpperLimit	REAL	120.0	High limit of the process value Input and Input_PER are monitored to ensure adherence to this limit. At the I/O input, the process value can be a maximum of 18% higher than the standard range (overrange). An error is no longer signaled due to a violation of the "Process value high limit". Only a wire-break and a short-circuit are recognized and PID_3Step reacts according to the configured reaction to error. InputUpperLimit > InputLowerLimit
Config.InputLowerLimit	REAL	0.0	Low limit of the process value InputLowerLimit < InputUpperLimit

Tag	Data type	Default	Description
Config.InputUpperWarning	REAL	+3.402822e+38	Warning high limit of the process value If you set InputUpperWarning outside the process value limits, the configured absolute process value high limit is used as the warning high limit. If you configure InputUpperWarning within the process value limits, this value is used as the warning high limit. InputUpperWarning > InputLowerWarning InputUpperWarning ≤ InputUpperLimit
Config.InputLowerWarning	REAL	-3.402822e+38	Warning low limit of the process value If you set InputLowerWarning outside the process value limits, the configured absolute process value low limit is used as the warning low limit. If you configure InputLowerWarning within the process value limits, this value is used as the warning low limit. InputLowerWarning < InputUpperWarning InputLowerWarning ≥ InputLowerLimit
Config.OutputUpperLimit	REAL	100.0	High limit of output value For details, see OutputLowerLimit
Config.OutputLowerLimit	REAL	0.0	Low limit of output value If OutputPerOn = TRUE or FeedbackOn = TRUE, the range of values from -100% to +100%, including zero, is valid. At -100%, Output = -27648; at +100% Output = 27648 If OutputPerOn = FALSE, the range of values from 0% to 100% is valid. The valve is completely closed at 0% and completely opened at 100%.
Config.SetpointUpperLimit	REAL	+3.402822e+38	High limit of setpoint If you set SetpointUpperLimit outside the process value limits, the configured absolute process value high limit is preassigned as the setpoint high limit. If you configure SetpointUpperLimit within the process value limits, this value is used as the setpoint high limit.
Config.SetpointLowerLimit	REAL	- 3.402822e+38	Low limit of the setpoint If you set SetpointLowerLimit outside the process value limits, the configured absolute process value low limit is preassigned as the setpoint low limit. If you set SetpointLowerLimit within the process value limits, this value is used as the setpoint low limit.
Config.MinimumOnTime	REAL	0.0	Minimum ON time Minimum time in seconds for which the servo drive must be switched on.
Config.MinimumOffTime	REAL	0.0	Minimum OFF time Minimum time in seconds for which the servo drive must be switched off.

Tag	Data type	Default	Description
Config.VirtualActuatorLimit	REAL	150.0	If all the following conditions have been satisfied, the actuator is moved in one direction for the maximum period of VirtualActuatorLimit × Retain.TransitTime/100 and the warning 2000h is output: • Config.OutputPerOn = FALSE • Config.ActuatorEndStopOn = FALSE • Config.FeedbackOn = FALSE If Config.OutputPerOn = FALSE and Config.ActuatorEndStopOn = TRUE or Config.FeedbackOn = TRUE, only the warning 2000h is output. If Config.OutputPerOn = TRUE, VirtualActuatorLimit is not taken into consideration.
Config.InputScaling.UpperPointIn	REAL	27648.0	Scaling Input_PER high Input_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the InputScaling structure.
Config.InputScaling.LowerPointIn	REAL	0.0	Scaling Input_PER low Input_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the InputScaling structure.
Config.InputScaling.UpperPointOut	REAL	100.0	Scaled high process value Input_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the InputScaling structure.
Config.InputScaling.LowerPointOut	REAL	0.0	Scaled low process value Input_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the InputScaling structure.
Config.FeedbackScaling.UpperPointIn	REAL	27648.0	Scaling Feedback_PER high Feedback_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the FeedbackScaling structure.
Config.FeedbackScaling.LowerPointIn	REAL	0.0	Scaling Feedback_PER low Feedback_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the FeedbackScaling structure.
Config.FeedbackScaling.UpperPointOut	REAL	100.0	High endstop Feedback_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the FeedbackScaling structure.
Config.FeedbackScaling.LowerPointOut	REAL	0.0	Low endstop Feedback_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the FeedbackScaling structure.

Tag	Data type	Default	Description
GetTransitTime.InvertDirection	BOOL	FALSE	If InvertDirection = FALSE, the valve is fully opened, closed, and then reopened in order to determine the valve transition time. If InvertDirection = TRUE, the valve is fully closed, opened, and then closed again.
GetTransit-Time.SelectFeedback	BOOL	FALSE	If SelectFeedback = TRUE, then Feedback_PER, or Feedback is taken into consideration in the transition time measurement. If SelectFeedback = FALSE, then Actuator_H and Actuator_L are taken into consideration in the transition time measurement.
GetTransitTime.State	INT	0	Current phase of the transition time measurement • State = 0: Inactive • State = 1: Open valve completely • State = 2: Close valve completely • State = 3: Move valve to target position (NewOutput) • State = 4: Transition time measurement successfully completed • State = 5: Transition time measurement canceled
GetTransitTime.NewOutput	REAL	0.0	Target position for transition time measurement with position feedback The target position must be between "High endstop" and "Low endstop". The difference between NewOutput and ScaledFeedback must be at least 50% of the permissible control range.
CycleTime.StartEstimation	BOOL	TRUE	If StartEstimation = TRUE, the measurement of the PID_3Step sampling time is started. CycleTime.StartEstimation = FALSE once measurement is complete.
CycleTime.EnEstimation	BOOL	TRUE	If EnEstimation = TRUE, the PID_3Step sampling time is calculated. If CycleTime.EnEstimation = FALSE, the PID_3Step sampling time is not calculated and you need to correct the configuration of CycleTime.Value manually.
CycleTime.EnMonitoring	BOOL	TRUE	If EnMonitoring = TRUE, the PID_3Step sampling time is monitored. If it is not possible to execute PID_3Step within the sampling time, the error 0800h is output and the operating mode is switched. ActivateRecoverMode and ErrorBehaviour determine which operating mode is switched to. If EnMonitoring = FALSE, the PID_3Step sampling time is not monitored, the error 0800h is not output, and the operating mode is not switched.
CycleTime.Value	REAL	0.1	PID_3Step sampling time in seconds CycleTime.Value is determined automatically and is usually equivalent to the cycle time of the calling OB.

Tag	Data type	Default	Description
CtrlParamsBackUp.SetByUser	BOOL	FALSE	Saved value of Retain.CtrlParams.SetByUser You can reload values from the CtrlParamsBackUp structure with LoadBackUp = TRUE.
CtrlParamsBackUp.Gain	REAL	1.0	Saved proportional gain
CtrlParamsBackUp.Ti	REAL	20.0	Saved integral action time in seconds
CtrlParamsBackUp.Td	REAL	0.0	Saved derivative action time in seconds
CtrlParamsBackUp.TdFiltRatio	REAL	0.2	Saved derivative delay coefficient
CtrlParamsBack-Up.PWeighting	REAL	1.0	Saved proportional action weighting
CtrlParamsBack-Up.DWeighting	REAL	1.0	Saved derivative action weighting
CtrlParamsBackUp.Cycle	REAL	1.0	Saved sampling time of PID algorithm in seconds
CtrlParamsBack-Up.InputDeadBand	REAL	0.0	Saved deadband width of the control deviation
PIDSelf-Tune.SUT.CalculateParams	BOOL	FALSE	The properties of the controlled system are saved during tuning. If CalculateParams = TRUE, the PID parameters are recalculated on the basis of these properties. The PID parameters are calculated using the method set in TuneRule. CalculateParams is set to FALSE following calculation.
PIDSelfTune.SUT.TuneRule	INT	1	Methods used to calculate parameters during pretuning: • SUT.TuneRule = 0: PID rapid I • SUT.TuneRule = 1: PID slow I • SUT.TuneRule = 2: Chien, Hrones and Reswick PID • SUT.TuneRule = 3: Chien, Hrones, Reswick PI • SUT.TuneRule = 4: PID rapid II • SUT.TuneRule = 5: PID slow II
PIDSelfTune.SUT.State	INT	0	The SUT.State tag indicates the current phase of pretuning: • State = 0: Initialize pretuning • State = 50: Determine start position without position feedback • State = 100: Calculate standard deviation • State = 200: Determine point of inflection • State = 300: Determine rise time • State = 9900: Pretuning successful • State = 1: Pretuning not successful

Tag	Data type	Default	Description
PIDSelfTune.TIR.RunIn	BOOL	FALSE	With the RunIn tag, you can specify that fine tuning can also be performed without pretuning. • RunIn = FALSE Pretuning is started when fine tuning is started from inactive or manual mode. If fine tuning is started from automatic mode, the system uses the existing PID parameters to control to the setpoint. Only then will fine tuning start. If pretuning is not possible, PID_3Step switches to the mode from which tuning was started. • RunIn = TRUE The pretuning is skipped. PID_3Step attempts to reach the setpoint with the minimum or maximum output value. This can produce increased overshoot. Only then will fine tuning start. RunIn is set to FALSE after fine tuning.
PIDSelf-Tune.TIR.CalculateParams	BOOL	FALSE	The properties of the controlled system are saved during tuning. If CalculateParams = TRUE, the PID parameters are recalculated on the basis of these properties. The PID parameters are calculated using the method set in TuneRule. CalculateParams is set to FALSE following calculation.
PIDSelfTune.TIR.TuneRule	INT	0	Methods used to calculate parameters during fine tuning: • TIR.TuneRule = 0: PID automatic • TIR.TuneRule = 1: PID rapid • TIR.TuneRule = 2: PID slow • TIR.TuneRule = 3: Ziegler-Nichols PID • TIR.TuneRule = 4: Ziegler-Nichols PI • TIR.TuneRule = 5: Ziegler-Nichols P

Tag	Data type	Default	Description
PIDSelfTune.TIR.State	INT	0	The TIR.State tag indicates the current phase of fine tuning: • State = -100 Fine tuning is not possible. Pretuning will be performed first. • State = 0: Initialize fine tuning • State = 200: Calculate standard deviation • State = 300: Attempt to reach the setpoint with the maximum or minimum output value • State = 400: Attempt to reach the setpoint with existing PID parameters (if pretuning was successful) • State = 500: Determine oscillation and calculate parameters • State = 9900: Fine tuning successful • State = 1: Fine tuning not successful
Retain.TransitTime	REAL	30.0	Motor transition time in seconds Time in seconds the actuating drive requires to move the valve from the closed to the opened state. TransitTime is retentive.
Retain.CtrlParams.SetByUser	BOOL	FALSE	If SetByUser = FALSE, the PID parameters are determined automatically and PID_3Step operates with a deadband at the output value. The deadband width is calculated during tuning on the basis of the standard deviation of the output value and saved in Retain.CtrlParams.OutputDeadBand. If SetByUser = TRUE, the PID parameters are entered manually and PID_3 Step operates without a deadband at the output value. Retain.CtrlParams.OutputDeadBand = 0.0 SetByUser is retentive.
Retain.CtrlParams.Gain	REAL	1.0	Active proportional gain To invert the control logic, use the Config.InvertControl tag. Negative values at Gain also invert the control logic. We recommend you use only InvertControl to set the control logic. The control logic is also inverted if InvertControl = TRUE and Gain < 0.0. Gain is retentive.
Retain.CtrlParams.Ti	REAL	20.0	• Ti > 0.0: Active integral action time in seconds • Ti = 0.0: Integral action is deactivated Ti is retentive.
Retain.CtrlParams.Td	REAL	0.0	• Td > 0.0: Active derivative action time in seconds • Td = 0.0: Derivative action is deactivated Td is retentive.

Tag	Data type	Default	Description
Retain.CtrlParams.TdFiltRatio	REAL	0.2	Active derivative delay coefficient The derivative delay coefficient delays the effect of the derivative action. Derivative delay = derivative action time × derivative delay coefficient • 0.0: Derivative action is effective for one cycle only and therefore almost not effective. • 0.5: This value has proved useful in practice for controlled systems with **one** dominant time constant. • > 1.0: The greater the coefficient, the longer the effect of the derivative action is delayed. TdFiltRatio is retentive.
Retain.CtrlParams.PWeighting	REAL	1.0	Active proportional action weighting The proportional action may weaken with changes to the setpoint. Values from 0.0 to 1.0 are applicable. • 1.0: Proportional action for setpoint change is fully effective • 0.0: Proportional action for setpoint change is not effective The proportional action is always fully effective when the process value is changed. PWeighting is retentive.
Retain.CtrlParams.DWeighting	REAL	1.0	Active derivative action weighting The derivative action may weaken with changes to the setpoint. Values from 0.0 to 1.0 are applicable. • 1.0: Derivative action is fully effective upon setpoint change • 0.0: Derivative action is not effective upon setpoint change The derivative action is always fully effective when the process value is changed. DWeighting is retentive.
Retain.CtrlParams.Cycle	REAL	1.0	Active sampling time of PID algorithm in seconds, rounded to an integer multiple of the cycle time of the calling OB. Cycle is retentive.
Retain.CtrlParams.InputDeadBand	REAL	0.0	Deadband width of the control deviation InputDeadBand is retentive.

Note

Change the tags listed in this table in "Inactive" mode to prevent malfunction of the PID controller.

See also

Parameters State and Mode V2 (Page 324)

Tag ActivateRecoverMode V2 (Page 332)

Downloading technology objects to device (Page 46)

8.2.4.8 Parameters State and Mode V2

Correlation of the parameters

The State parameter shows the current operating mode of the PID controller. You cannot change the State parameter.

With a rising edge at ModeActivate, PID_3Step switches to the operating mode saved in the Mode in-out parameter.

When the CPU is switched on or switches from Stop to RUN mode, PID_3Step starts in the operating mode that is saved in the Mode parameter. To leave PID_3Step in "Inactive" mode, set RunModeByStartup = FALSE.

Meaning of values

State	Description of operating mode
0	Inactive The controller is switched off and no longer changes the valve position.
1	Pretuning The pretuning determines the process response to a pulse of the output value and searches for the point of inflection. The PID parameters are calculated from the maximum rate of rise and dead time of the controlled system. You obtain the best PID parameters when you perform pretuning and fine tuning. Pretuning requirements: • The motor transition time has been configured or measured. • Inactive (State = 0), manual mode (State = 4), or automatic mode (State = 3) • ManualEnable = FALSE • Reset = FALSE • The setpoint and the process value lie within the configured limits. The more stable the process value is, the easier it is to calculate the PID parameters and the more precise the result will be. Noise on the process value can be tolerated as long as the rate of rise of the process value is significantly higher as compared to the noise. This is most likely the case in operating modes "Inactive" and "manual mode". The setpoint is frozen in the CurrentSetpoint tag. Tuning is canceled when: • Setpoint > CurrentSetpoint + CancelTuningLevel or • Setpoint < CurrentSetpoint - CancelTuningLevel Before the PID parameters are recalculated, they are backed up and can be reactivated with LoadBackUp. The controller switches to automatic mode following successful pretuning. If pretuning is unsuccessful, the switchover of operating mode is dependent on ActivateRecoverMode and ErrorBehaviour. The pretuning phase is indicated with the SUT.State tag.

State	Description of operating mode
2	Fine tuning Fine tuning generates a constant, limited oscillation of the process value. The PID parameters are recalculated based on the amplitude and frequency of this oscillation. PID parameters from fine tuning usually have better master control and disturbance characteristics than PID parameters from pretuning. You obtain the best PID parameters when you perform pretuning and fine tuning. PID_3Step automatically attempts to generate an oscillation greater than the noise of the process value. Fine tuning is only minimally influenced by the stability of the process value. The setpoint is frozen in the CurrentSetpoint tag. Tuning is canceled when: • Setpoint > CurrentSetpoint + CancelTuningLevel or • Setpoint < CurrentSetpoint - CancelTuningLevel The PID parameters are backed up before fine tuning. They can be reactivated with LoadBackUp. Requirements for fine tuning: • The motor transition time has been configured or measured. • The setpoint and the process value lie within the configured limits. • ManualEnable = FALSE • Reset = FALSE • Automatic (State = 3), inactive (State = 0) or manual (State = 4) mode Fine tuning proceeds as follows when started from: • Automatic mode (State = 3) Start fine tuning from automatic mode if you wish to improve the existing PID parameters through tuning. PID_3Step controls the system using the existing PID parameters until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start. • Inactive (State = 0) or manual mode (State = 4) If the requirements for pretuning are met, pretuning is started. The determined PID parameters will be used for control until the control loop has stabilized and the requirements for fine tuning have been met. If PIDSelfTune.TIR.RunIn = TRUE, pretuning is skipped and an attempt is made to reach the setpoint with the minimum or maximum output value. This can produce increased overshoot. Fine tuning then starts automatically. The controller switches to automatic mode following successful fine tuning. If fine tuning is unsuccessful, the switchover of operating mode is dependent on ActivateRecoverMode and ErrorBehaviour. The fine tuning phase is indicated with the TIR.State tag.
3	Automatic mode In automatic mode, PID_3Step controls the controlled system in accordance with the parameters specified. The controller switches to automatic mode if one the following requirements is fulfilled: • Pretuning successfully completed • Fine tuning successfully completed • Changing of the Mode in-out parameter to the value 3 and a rising edge at ModeActivate. The switchover from automatic mode to manual mode is only bumpless if carried out in the commissioning editor. The ActivateRecoverMode tag is taken into consideration in automatic mode.

State	Description of operating mode
4	Manual mode In manual mode, you specify manual output values in the Manual_UP and Manual_DN parameters or ManualValue parameter. Whether or not the actuator can be moved to the output value in the event of an error is described in the ErrorBits parameter. You can also activate this operating mode using ManualEnable = TRUE. We recommend that you change the operating mode using Mode and ModeActivate only. The switchover from manual mode to automatic mode is bumpless. Manual mode is also possible when an error is pending.
5	Approach substitute output value This operating mode is activated in the event of an error, if Errorbehaviour = TRUE and ActivateRecoverMode = FALSE.. PID_3Step moves the actuator to the substitute output value and then switches to "Inactive" mode.
6	Transition time measurement The time that the motor needs to completely open the valve from the closed condition is determined. This operating mode is activated when Mode = 6 and ModeActivate = TRUE is set. If endstop signals are used to measure the transition time, the valve will be opened completely from its current position, closed completely, and opened completely again. If GetTransitTime.InvertDirection = TRUE, this behavior is inverted. If position feedback is used to measure the transition time, the actuator will be moved from its current position to a target position. The output value limits are not taken into consideration during the transition time measurement. The actuator can travel to the high or the low endstop.
7	Error monitoring The control algorithm is switched off and no longer changes the valve position. This operating mode is activated instead of "Inactive" mode in the event of an error. All the following conditions must be met: • Automatic mode (Mode = 3) • Errorbehaviour = FALSE • ActivateRecoverMode = TRUE • One or more errors have occurred in which ActivateRecoverMode (Page 332) is effective. As soon as the errors are no longer pending, PID_3Step switches back to automatic mode.
8	Approach substitute output value with error monitoring This operating mode is activated instead of "approach substitute output value" mode when an error occurs. PID_3Step moves the actuator to the substitute output value and then switches to "error monitoring" mode. All the following conditions must be met: • Automatic mode (Mode = 3) • Errorbehaviour = TRUE • ActivateRecoverMode = TRUE • One or more errors have occurred in which ActivateRecoverMode (Page 332) is effective. As soon as the errors are no longer pending, PID_3Step switches back to automatic mode.
10	Manual mode without endstop signals The endstop signals are **not** taken into consideration, even though Config.ActuatorEndStopOn = TRUE. The output value limits are not taken into consideration. Otherwise, PID_3Step behaves the same as in manual mode.

ENO characteristics

If State = 0, then ENO = FALSE.

If State ≠ 0, then ENO = TRUE.

Automatic switchover of operating mode during commissioning

Automatic mode is activated following successful pretuning or fine tuning. The following table shows how Mode and State change during successful pretuning.

Cycle no.	Mode	State	Action
0	4	4	Set Mode = 1
1	1	4	Set ModeActivate = TRUE
1	4	1	Value of State is saved in Mode parameter Pretuning is started
n	4	1	Pretuning successfully completed
n	3	3	Automatic mode is started

PID_3Step automatically switches the operating mode in the event of an error. The following table shows how Mode and State change during pretuning with errors.

Cycle no.	Mode	State	Action
0	4	4	Set Mode = 1
1	1	4	Set ModeActivate = TRUE
1	4	1	Value of State is saved in Mode parameter Pretuning is started
n	4	1	Pretuning canceled
n	4	4	Manual mode is started

If ActivateRecoverMode = TRUE, the operating mode that is saved in the Mode parameter is activated. At the start of transition time measurement, pretuning, or fine tuning, PID_3Step saved the value of State in the Mode in/out parameter. PID_3Step therefore switches to the operating mode from which transition time measurement or tuning was started.

If ActivateRecoverMode = FALSE, "Inactive" or "Approach substitute output value" mode is activated.

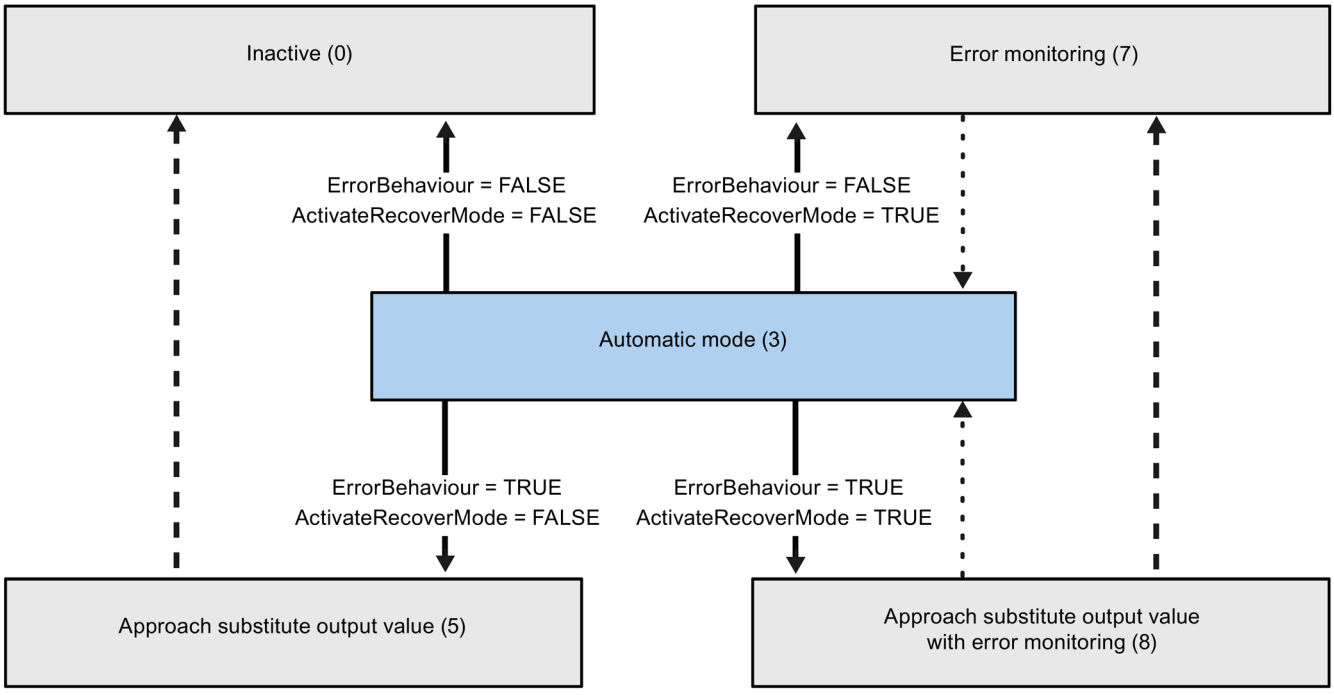
Automatic switchover of operating mode after transition time measurement

If ActivateRecoverMode = TRUE, the operating mode that is saved in the Mode parameter is activated after successful transition time measurement.

If ActivateRecoverMode = FALSE, the system switches to "Inactive" operating mode after successful transition time measurement.

Automatic switchover of operating mode in automatic mode

PID_3Step automatically switches the operating mode in the event of an error. The following diagram illustrates the influence of ErrorBehaviour and ActivateRecoverMode on this switchover of operating mode.



Automatic switchover of operating mode in the event of an error

Automatic switchover of operating mode once the current operation has been completed.

Automatic switchover of operating mode when error is no longer pending.

See also

Tag ActivateRecoverMode V2 (Page 332)

Parameter ErrorBits V2 (Page 329)

8.2.4.9 Parameter ErrorBits V2

If several errors are pending simultaneously, the values of the ErrorBits are displayed with binary addition. The display of ErrorBits = 0003h, for example, indicates that the errors 0001h and 0002h are pending simultaneously.

If there is a position feedback, PID_3Step uses ManualValue as output value in manual mode. The exception is Errorbits = 10000h.

ErrorBits (DW#16#...)	Description
0000	There is no error.
0001	The "Input" parameter is outside the process value limits. • Input > Config.InputUpperLimit or • Input < Config.InputLowerLimit If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_3Step remains in automatic mode. If pretuning, fine tuning, or transition time measurement mode and ActivateRecoverMode = TRUE were active before the error occurred, PID_3Step switches to the operating mode that is saved in the Mode parameter.
0002	Invalid value at "Input_PER" parameter. Check whether an error is pending at the analog input. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_3Step switches to "Approach substitute output value with error monitoring" or "Error monitoring" mode. As soon as the error is no longer pending, PID_3Step switches back to automatic mode. If pretuning, fine tuning, or transition time measurement mode and ActivateRecoverMode = TRUE were active before the error occurred, PID_3Step switches to the operating mode that is saved in the Mode parameter.
0004	Error during fine tuning. Oscillation of the process value could not be maintained. If ActivateRecoverMode = TRUE before the error occurred, PID_3Step cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0010	The setpoint was changed during tuning. You can set the permitted fluctuation of the setpoint at the CancelTuningLevel tag. If ActivateRecoverMode = TRUE before the error occurred, PID_3Step cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0020	Pretuning is not permitted during fine tuning. If ActivateRecoverMode = TRUE before the error occurred, PID_3Step remains in fine tuning mode.
0080	Error during pretuning. Incorrect configuration of output value limits. Check whether the limits of the output value are configured correctly and match the control logic. If ActivateRecoverMode = TRUE before the error occurred, PID_3Step cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0100	Error during fine tuning resulted in invalid parameters. If ActivateRecoverMode = TRUE before the error occurred, PID_3Step cancels the tuning and switches to the operating mode that is saved in the Mode parameter.

ErrorBits (DW#16#...)	Description
0200	Invalid value at "Input" parameter: Value has an invalid number format. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_3Step switches to "Approach substitute output value with error monitoring" or "Error monitoring" mode. As soon as the error is no longer pending, PID_3Step switches back to automatic mode. If pretuning, fine tuning, or transition time measurement mode and ActivateRecoverMode = TRUE were active before the error occurred, PID_3Step switches to the operating mode that is saved in the Mode parameter.
0400	Calculation of output value failed. Check the PID parameters. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_3Step switches to "Approach substitute output value with error monitoring" or "Error monitoring" mode. As soon as the error is no longer pending, PID_3Step switches back to automatic mode. If pretuning, fine tuning, or transition time measurement mode and ActivateRecoverMode = TRUE were active before the error occurred, PID_3Step switches to the operating mode that is saved in the Mode parameter.
0800	Sampling time error: PID_3Step is not called within the sampling time of the cyclic interrupt OB. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_3Step remains in automatic mode. If pretuning, fine tuning, or transition time measurement mode and ActivateRecoverMode = TRUE were active before the error occurred, PID_3Step switches to the operating mode that is saved in the Mode parameter.
1000	Invalid value at "Setpoint" parameter: Value has an invalid number format. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_3Step switches to "Approach substitute output value with error monitoring" or "Error monitoring" mode. As soon as the error is no longer pending, PID_3Step switches back to automatic mode. If pretuning, fine tuning, or transition time measurement mode and ActivateRecoverMode = TRUE were active before the error occurred, PID_3Step switches to the operating mode that is saved in the Mode parameter.
2000	Invalid value at Feedback_PER parameter. Check whether an error is pending at the analog input. The actuator cannot be moved to the substitute output value and remains in its current position. In manual mode, you can change the position of the actuator only with Manual_UP and Manual_DN, and not with ManualValue. If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_3Step switches back to automatic mode. If pretuning, fine tuning, or transition time measurement mode and ActivateRecoverMode = TRUE were active before the error occurred, PID_3Step switches to the operating mode that is saved in the Mode parameter.
4000	Invalid value at Feedback parameter. Value has an invalid number format. The actuator cannot be moved to the substitute output value and remains in its current position. In manual mode, you can change the position of the actuator only with Manual_UP and Manual_DN, and not with ManualValue. If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_3Step switches back to automatic mode. If pretuning, fine tuning, or transition time measurement mode and ActivateRecoverMode = TRUE were active before the error occurred, PID_3Step switches to the operating mode that is saved in the Mode parameter.

ErrorBits (DW#16#...)	Description
8000	Error during digital position feedback. Actuator_H = TRUE and Actuator_L = TRUE. The actuator cannot be moved to the substitute output value and remains in its current position. Manual mode is not possible in this state. In order to move the actuator from this state, you must deactivate the "Actuator endstop" (Config.ActuatorEndStopOn = FALSE) or switch to manual mode without endstop signals (Mode = 10). If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_3Step switches back to automatic mode. If pretuning, fine tuning, or transition time measurement mode and ActivateRecoverMode = TRUE were active before the error occurred, PID_3Step switches to the operating mode that is saved in the Mode parameter.
10000	Invalid value at ManualValue parameter. Value has an invalid number format. The actuator cannot be moved to the manual value and remains in its current position. Specify a valid value in ManualValue or move the actuator in manual mode with Manual_UP and Manual_DN.
20000	Invalid value at SavePosition tag. Value has an invalid number format. The actuator cannot be moved to the substitute output value and remains in its current position.
40000	Invalid value at Disturbance parameter. Value has an invalid number format. If automatic mode was active and ActivateRecoverMode = TRUE before the error occurred, Disturbance is set to zero. PID_3Step remains in automatic mode. If pretuning or fine tuning mode was active and ActivateRecoverMode = TRUE before the error occurred, PID_3Step switches to the operating mode saved in the Mode parameter. If Disturbance in the current phase has no effect on the output value, tuning is not be canceled. The error has no effect during transition time measurement.

8.2.4.10 Tag ActivateRecoverMode V2

The ActivateRecoverMode tag determines the reaction to error. The Error parameter indicates if an error is pending. When the error is no longer pending, Error = FALSE. The ErrorBits parameter shows which errors have occurred.

NOTICE
Your system may be damaged. If ActivateRecoverMode = TRUE, PID_3Step remains in automatic mode even if the process limit values are exceeded. This may damage your system. It is essential to configure how your controlled system reacts in the event of an error to protect your system from damage.

Automatic mode

ActivateRecov-erMode	Description
FALSE	In the event of an error, PID_3Step switches to "Inactive" or "Approach substitute output value" mode. The controller is only activated by a falling edge at Reset or a rising edge at ModeActivate.
TRUE	If errors occur frequently in automatic mode, this setting has a negative effect on the control response, because PID_3Step switches between the calculated output value and the substitute output value at each error. In this case, check the ErrorBits parameter and eliminate the cause of the error. If one or more of the following errors occur, PID_3Step stays in automatic mode: • 0001h: The "Input" parameter is outside the process value limits. • 0800h: Sampling time error • 40000h: Invalid value at Disturbance parameter. If one or more of the following errors occur, PID_3Step switches to "Approach substitute output value with error monitoring" or "Error monitoring" mode: • 0002h: Invalid value at Input_PER parameter. • 0200h: Invalid value at Input parameter. • 0400h: Calculation of output value failed. • 1000h: Invalid value at Setpoint parameter. If one or more of the following errors occur, PID_3Step can no longer move the actuator: • 2000h: Invalid value at Feedback_PER parameter. • 4000h: Invalid value at Feedback parameter. • 8000h: Error during digital position feedback. • 20000h: Invalid value at SavePosition tag. Value has an invalid number format. The characteristics are independent of ErrorBehaviour. As soon as the errors are no longer pending, PID_3Step switches back to automatic mode.

Pretuning, fine tuning, and transition time measurement

ActivateRecoverMode	Description
FALSE	In the event of an error, PID_3Step switches to "Inactive" or "Approach substitute output value" mode. The controller is only activated by a falling edge at Reset or a rising edge at ModeActivate. The controller changes to "Inactive" mode after successful transition time measurement.
TRUE	If the following error occurs, PID_3Step remains in the active mode: • 0020h: Pretuning is not permitted during fine tuning. The following errors are ignored: • 10000h: Invalid value at ManualValue parameter. • 20000h: Invalid value at SavePosition tag. When any other error occurs, PID_3Step cancels the tuning and switches to the mode from which tuning was started.

Manual mode

ActivateRecoverMode is not effective in manual mode.

See also

Static tags of PID_3Step V2 (Page 314)

Parameters State and Mode V2 (Page 324)

8.2.4.11 Tag Warning V2

If several warnings are pending simultaneously, their values are displayed with binary addition. The display of warning 0005h, for example, indicates that the warnings 0001h and 0004h are pending simultaneously.

Warning (DW#16#...)	Description
0000	No warning pending.
0001	The point of inflection was not found during pretuning.
0004	The setpoint was limited to the configured limits.
0008	Not all the necessary controlled system properties were defined for the selected method of calculation. Instead, the PID parameters were calculated using the TIR.TuneRule = 3 method.
0010	The operating mode could not be changed because Reset = TRUE or ManualEnable = TRUE.
0020	The cycle time of the calling OB limits the sampling time of the PID algorithm. Improve results by using shorter OB cycle times.
0040	The process value exceeded one of its warning limits.
0080	Invalid value at Mode. The operating mode is not switched.
0100	The manual value was limited to the limits of the controller output.
0200	The specified rule for tuning is not supported. No PID parameters are calculated.
0400	The transition time cannot be measured because the actuator settings do not match the selected measuring method.
0800	The difference between the current position and the new output value is too small for transition time measurement. This can produce incorrect results. The difference between the current output value and new output value must be at least 50% of the entire control range.
1000	The substitute output value cannot be reached because it is outside the output value limits.
2000	The actuator was moved in one direction for longer than Config.VirtualActuatorLimit × Retain.TransitTime. Check whether the actuator has reached an endstop signal.

The following warnings are deleted as soon as the cause is eliminated:

- 0001h
- 0004h
- 0008h
- 0040h
- 0100h
- 2000h

All other warnings are cleared with a rising edge at Reset or ErrorAck.

8.2.5 PID_3Step V1

8.2.5.1 Description PID_3Step V1

Description

You use the PID_3Step instruction to configure a PID controller with self tuning for valves or actuators with integrating behavior.

The following operating modes are possible:

- Inactive
- Pretuning
- Fine tuning
- Automatic mode
- Manual mode
- Approach substitute output value
- Transition time measurement
- Approach substitute output value with error monitoring
- Error monitoring

For a more detailed description of the operating modes, see the State parameter.

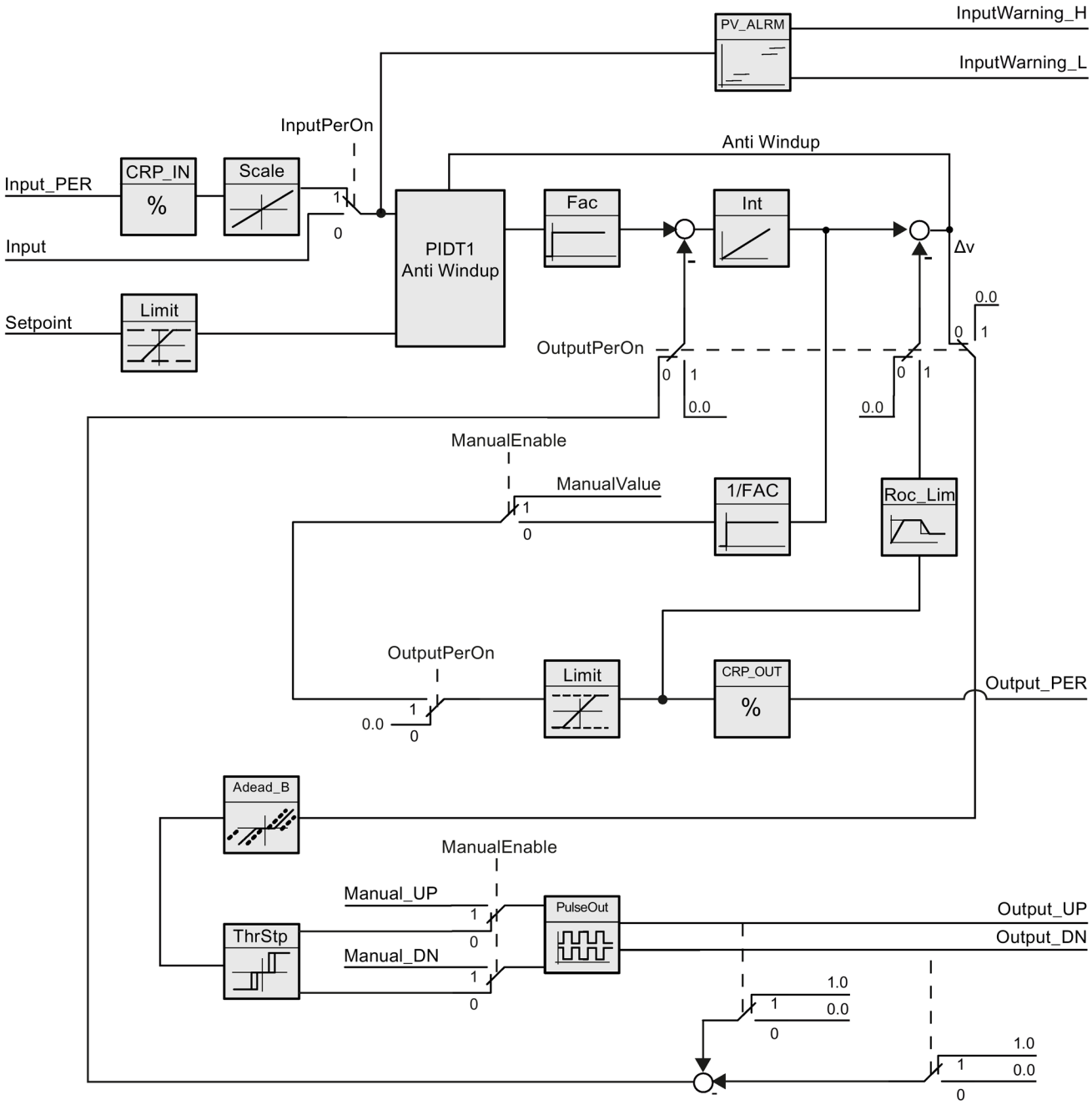
PID algorithm

PID_3Step is a PIDT1 controller with anti-windup and weighting of the proportional and derivative actions. The following equation is used to calculate the output value.

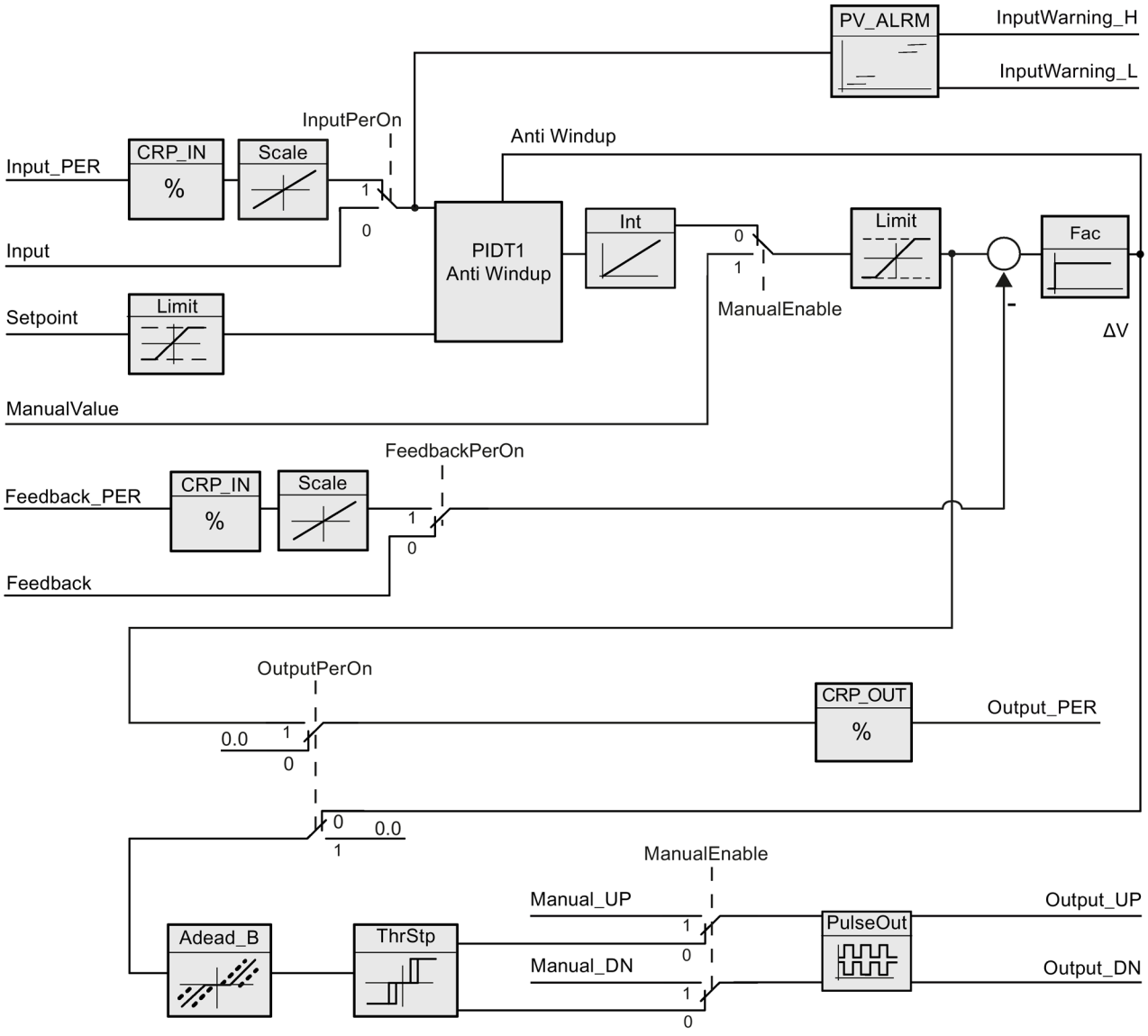
$$\Delta y = K_p \cdot s \cdot \left[(b \cdot w - x) + \frac{1}{T_I \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c \cdot w - x) \right]$$

Symbol	Description
y	Output value
K_p	Proportional gain
s	Laplace operator
b	Proportional action weighting
w	Setpoint
x	Process value
T_I	Integral action time
a	Derivative delay coefficient (T1 = a × T_D)
T_D	Derivative action time
c	Derivative action weighting

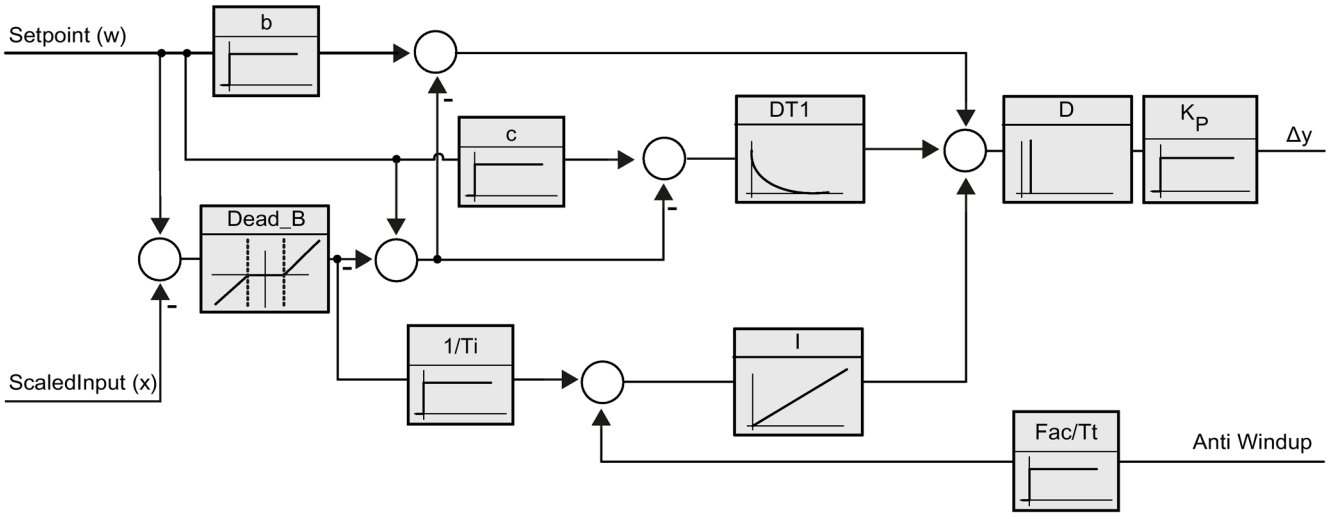
Block diagram without position feedback



Block diagram with position feedback



Block diagram of PIDT1 with anti-windup



Call

PID_3Step is called in a constant time interval of the cycle time of the calling OB (preferably in a cyclic interrupt OB).

Download to device

The actual values of retentive tags are only updated when you download PID_3Step completely.

Downloading technology objects to device (Page 46)

Startup

At the startup of the CPU, PID_3Step starts in the operating mode that was last active. To leave PID_3Step in "Inactive" mode, set RunModeByStartup = FALSE.

Reaction to error

If errors occur, these are output in the Error parameter. You configure the reaction of PID_3Step using the ErrorBehaviour and ActivateRecoverMode tags.

ErrorBehaviour	ActivateRecoverMode	Actuator setting configuration Set Output to	Reaction
0	FALSE	Current output value	Switch to "Inactive" mode (Mode = 0)
0	TRUE	Current output value while error is pending	Switch to "Error monitoring" mode (Mode = 7)
1	FALSE	Substitute output value	Switch to "Approach substitute output value" mode (Mode = 5) Switch to "Inactive" mode (Mode = 0)
1	TRUE	Substitute output value while error is pending	Switch to "Approach substitute output value with error monitoring" mode (Mode = 8) Switch to "Error monitoring" mode (Mode = 7)

The ErrorBits parameter shows which errors have occurred.

See also

Parameter State and Retain.Mode V1 (Page 356)

Parameter ErrorBits V1 (Page 364)

Configuring PID_3Step V1 (Page 139)

8.2.5.2 Operating principle PID_3Step V1

Monitoring process value limits

You specify the high limit and low limit of the process value in the Config.InputUpperLimit and Config.InputLowerLimit tags. If the process value is outside these limits, an error occurs (ErrorBits = 0001hex).

You specify a high and low warning limit of the process value in the Config.InputUpperWarning and Config.InputLowerWarning tags. If the process value is outside these warning limits, a warning occurs (Warnings = 0040hex), and the InputWarning_H or InputWarning_L output parameter changes to TRUE.

Limiting the setpoint

You specify a high limit and low limit of the setpoint in the Config.SetpointUpperLimit and Config.SetpointLowerLimit tags. PID_3Step automatically limits the setpoint to the process value limits. You can limit the setpoint to a smaller range. PID_3Step checks whether this range falls within the process value limits. If the setpoint is outside these limits, the high or low limit is used as the setpoint, and output parameter SetpointLimit_H or SetpointLimit_L is set to TRUE.

The setpoint is limited in all operating modes.

Limiting the output value

You specify a high limit and low limit of the output value in the Config.OutputUpperLimit and Config.OutputLowerLimit tags. The output value limits must be within "Low endstop" and "High endstop".

- High endstop: Config.FeedbackScaling.UpperPointOut
- Low endstop: Config.FeedbackScaling.LowerPointOut

Rule:

UpperPointOut ≥ OutputUpperLimit > OutputLowerLimit ≥ LowerPointOut

The valid values for "High endstop" and "Low endstop" depend upon:

- FeedbackOn
- FeedbackPerOn
- OutputPerOn

OutputPerOn	FeedbackOn	FeedbackPerOn	LowerPointOut	UpperPointOut
FALSE	FALSE	FALSE	Cannot be set (0.0%)	Cannot be set (100.0%)
FALSE	TRUE	FALSE	-100.0% or 0.0%	0.0% or +100.0%
FALSE	TRUE	TRUE	-100.0% or 0.0%	0.0% or +100.0%
TRUE	FALSE	FALSE	Cannot be set (100.0%)	Cannot be set (100.0%)
TRUE	TRUE	FALSE	-100.0% or 0.0%	0.0% or +100.0%
TRUE	TRUE	TRUE	-100.0% or 0.0%	0.0% or +100.0%

If OutputPerOn = FALSE and FeedbackOn = FALSE, you cannot limit the output value. The digital outputs are reset with Actuator_H = TRUE or Actuator_L = TRUE, or after a travel time amounting to 110% of the motor transition time.

The output value is 27648 at 100% and -27648 at -100%. PID_3Step must be able to close the valve completely. Therefore, zero must be included in the output value limits.

Substitute output value

If an error has occurred, PID_3Step can output a substitute output value and move the actuator to a safe position that is specified in the SavePosition tag. The substitute output value must be within the output value limits.

Monitoring signal validity

The values of the following parameters are monitored for validity:

- Setpoint
- Input
- Input_PER
- Feedback
- Feedback_PER
- Output

Monitoring the PID_3Step sampling time

Ideally, the sampling time is equivalent to the cycle time of the calling OB. The PID_3Step instruction measures the time interval between two calls. This is the current sampling time. On every switchover of operating mode and during the initial startup, the mean value is formed from the first 10 sampling times. Too great a difference between the current sampling time and this mean value triggers an error (ErrorBits = 0800 hex).

PID_3Step is set to "Inactive" mode during tuning under the following conditions:

- New mean value >= 1.1 x old mean value
- New mean value <= 0.9 x old mean value

In automatic mode, PID_3Step is set to "Inactive" mode under the following conditions:

- New mean value >= 1.5 x old mean value
- New mean value <= 0.5 x old mean value

Sampling time of the PID algorithm

The controlled system needs a certain amount of time to respond to changes in the output value. It is therefore not advisable to calculate the output value in every cycle. The sampling time of the PID algorithm represents the time between two calculations of the output value. It is calculated during tuning and rounded to a multiple of the cycle time. All other functions of PID_3Step are executed at every call.

Measuring the motor transition time

The motor transition time is the time in seconds the motor requires to move the actuator from the closed to the opened state. The maximum time that the actuator is moved in one direction is 110% of the motor transition time. PID_3Step requires the motor transition time to be as accurate as possible for good controller results. The data in the actuator documentation contains average values for this type of actuator. The value for the specific actuator used may differ. You can measure the motor transition time during commissioning. The output value limits are not taken into consideration during the motor transition time measurement. The actuator can travel to the high or the low endstop.

Control logic

An increase of the output value is generally intended to cause an increase in the process value. This is referred to as a normal control logic. For cooling and discharge control systems, it may be necessary to invert the control logic. PID_3Step does not work with negative proportional gain. If InvertControl = TRUE, an increasing control deviation causes a reduction in the output value. The control logic is also taken into account during pretuning and fine tuning.

See also

Configuring PID_3Step V1 (Page 139)

8.2.5.3 PID_3Step V1 input parameters

Parameters	Data type	Default	Description
Setpoint	REAL	0.0	Setpoint of the PID controller in automatic mode
Input	REAL	0.0	A variable of the user program is used as source for the process value. If you are using parameter Input, then Config.InputPerOn = FALSE must be set.
Input_PER	WORD	W#16#0	An analog input is used as source for the process value. If you are using parameter Input_PER, then Config.InputPerOn = TRUE must be set.
Actuator_H	BOOL	FALSE	Digital position feedback of the valve for the high endstop If Actuator_H = TRUE, the valve is at the high endstop and is no longer moved towards this direction.
Actuator_L	BOOL	FALSE	Digital position feedback of the valve for the low endstop If Actuator_L = TRUE, the valve is at the low endstop and is no longer moved towards this direction.
Feedback	REAL	0.0	Position feedback of the valve If you are using parameter Feedback, then Config.FeedbackPerOn = FALSE must be set.
Feedback_PER	WORD	W#16#0	Analog feedback of the valve position If you are using parameter Feedback_PER, then Config.FeedbackPerOn = TRUE must be set. Feedback_PER is scaled based on the variables: • Config.FeedbackScaling.LowerPointIn • Config.FeedbackScaling.UpperPointIn • Config.FeedbackScaling.LowerPointOut • Config.FeedbackScaling.UpperPointOut
ManualEnable	BOOL	FALSE	• A FALSE -> TRUE edge selects "Manual mode", while State = 4, Retain.Mode remains unchanged. • A TRUE -> FALSE edge selects the most recently active operating mode A change of Retain.Mode will not take effect during ManualEnable = TRUE. The change of Retain.Mode will only be considered upon a TRUE -> FALSE edge at ManualEnable . **PID_3Step V1.1**If at start of the CPU ManualEnable = TRUE, PID_3Step starts in manual mode. A rising edge (FALSE > TRUE) at ManualEnable is not necessary. **PID_3Step V1.0** At the start of the CPU, PID_3Step only switches to manual mode with a rising edge (FALSE->TRUE) at ManualEnable . Without rising edge, PID_3Step starts in the last operating mode in which ManualEnable was FALSE.
ManualValue	REAL	0.0	In manual mode, you specify the absolute position of the valve. ManualValue will only be evaluated if you are using OutputPer, **or** if position feedback is available.

Parameters	Data type	Default	Description
Manual_UP	BOOL	FALSE	In manual mode, every rising edge opens the valve by 5% of the total control range, or for the duration of the minimum motor transition time. Manual_UP is evaluated only if you are not using Output_PER and there is no position feedback available.
Manual_DN	BOOL	FALSE	In manual mode, every rising edge closes the valve by 5% of the total control range, or for the duration of the minimum motor transition time. Manual_DN is evaluated only if you are not using Output_PER and there is no position feedback available.
Reset	BOOL	FALSE	Restarts the controller. • FALSE -> TRUE edge – Change to "Inactive" mode – Intermediate controller values are reset (PID parameters are retained) • TRUE -> FALSE edge Change in most recent active mode

8.2.5.4 PID_3Step V1 output parameters

Parameter	Data type	Default	Description
ScaledInput	REAL	0.0	Scaled process value
ScaledFeedback	REAL	0.0	Scaled position feedback For an actuator without position feedback, the position of the actuator indicated by ScaledFeedback is very imprecise. ScaledFeedback may only be used for rough estimation of the current position in this case.
Output_UP	BOOL	FALSE	Digital output value for opening the valve If Config.OutputPerOn = FALSE, the Output_UP parameter is used.
Output_DN	BOOL	FALSE	Digital output value for closing the valve If Config.OutputPerOn = FALSE, the Output_DN parameter is used.
Output_PER	WORD	W#16#0	Analog output value If Config.OutputPerOn = TRUE, Output_PER is used.
SetpointLimit_H	BOOL	FALSE	If SetpointLimit_H = TRUE, the absolute setpoint high limit is reached. In the CPU, the setpoint is limited to the configured absolute setpoint high limit. The configured absolute process value high limit is the default for the setpoint high limit. If you configure Config.SetpointUpperLimit to a value within the process value limits, this value is used as the setpoint high limit.
SetpointLimit_L	BOOL	FALSE	If SetpointLimit_L = TRUE, the absolute setpoint low limit has been reached. In the CPU, the setpoint is limited to the configured absolute setpoint low limit. The configured absolute process value low limit is the default setting for the setpoint low limit. If you configure Config.SetpointLowerLimit to a value within the process value limits, this value is used as the setpoint low limit.
InputWarning_H	BOOL	FALSE	If InputWarning_H = TRUE, the process value has reached or exceeded the warning high limit.
InputWarning_L	BOOL	FALSE	If InputWarning_L = TRUE, the process value has reached or fallen below the warning low limit.

Parameter	Data type	Default	Description
State	INT	0	The State parameter (Page 356) shows the current operating mode of the PID controller. You change the operating mode with the Retain.Mode tag. • State = 0: Inactive • State = 1: Pretuning • State = 2: Fine tuning • State = 3: Automatic mode • State = 4: Manual mode • State = 5: Approach substitute output value • State = 6: Transition time measurement • State = 7: Error monitoring • State = 8: Approach substitute output value with error monitoring
Error	BOOL	FALSE	If Error = TRUE, at least one error message is pending.
ErrorBits	DWORD	DW#16#0	The ErrorBits parameter (Page 364) indicates the error messages.

See also

Parameter State and Retain.Mode V1 (Page 356)

Parameter ErrorBits V1 (Page 364)

8.2.5.5 PID_3Step V1 static tags

You must not change tags that are not listed. These are used for internal purposes only.

Tag	Data type	Default	Description
ActivateRecoverMode	BOOL	TRUE	The ActivateRecoverMode tag (Page 366) determines the reaction to error.
RunModeByStartup	BOOL	TRUE	Activate Mode after CPU restart If RunModeByStartup = TRUE, the controller returns to the last active operating mode after a CPU restart. If RunModeByStartup = FALSE, the controller remains inactive after a CPU restart.
PhysicalUnit	INT	0	Unit of measurement of the process value and setpoint, e.g., ºC, or ºF.
PhysicalQuantity	INT	0	Physical quantity of the process value and setpoint, e.g., temperature.
ErrorBehaviour	INT	0	If ErrorBehaviour = 0 and an error has occurred, the valve stays at its current position and the controller switches directly to "Inactive" or "Error monitoring" mode. If ErrorBehaviour = 1 and an error occurs, the actuator moves to the substitute output value and only then switches to "Inactive" or "Error monitoring" mode. If the following errors occur, you can no longer move the valve to a configured substitute output value. • 2000h: Invalid value at Feedback_PER parameter. • 4000h: Invalid value at Feedback parameter. • 8000h: Error during digital position feedback.
Warning	DWORD	DW#16#0	The Warning tag (Page 356) displays the warnings generated since a Reset or since the last switchover of operating mode. Cyclic warnings (for example, process value warning) are shown until the cause of the warning is removed. They are automatically deleted once their cause has gone. Non-cyclic warnings (for example, point of inflection not found) remain and are deleted like errors.
SavePosition	REAL	0.0	Substitute output value If ErrorBehaviour = 1 and an error occurs, the actuator moves to a safe position for the plant and only then switches to "Inactive" mode.
CurrentSetpoint	REAL	0.0	Currently active setpoint. This value is frozen at the start of tuning.
Progress	REAL	0.0	Progress of tuning as a percentage (0.0 - 100.0)
Config.InputPerOn	BOOL	TRUE	If InputPerOn = TRUE, the Input_PER parameter is used. If InputPerOn = FALSE, the Input parameter is used.
Config.OutputPerOn	BOOL	FALSE	If OutputPerOn = TRUE, the Output_PER parameter is used. If OutputPerOn = FALSE, the Ouput_UP and Output_DN parameters are used.

Tag	Data type	Default	Description
Config.LoadBackUp	BOOL	FALSE	If LoadBackUp = TRUE, the last set of PID parameters is reloaded. This set was saved prior to the last tuning operation. LoadBackUp is automatically reset to FALSE.
Config.InvertControl	BOOL	FALSE	Invert control logic If InvertControl = TRUE, an increasing control deviation causes a reduction in the output value.
Config.FeedbackOn	BOOL	FALSE	If FeedbackOn = FALSE, a position feedback is simulated. Position feedback is generally activated when FeedbackOn = TRUE.
Config.FeedbackPerOn	BOOL	FALSE	FeedbackPerOn is only effective when FeedbackOn = TRUE. If FeedbackPerOn = TRUE, the analog input is used for the position feedback (Feedback_PER parameter). If FeedbackPerOn = FALSE, the Feedback parameter is used for the position feedback.
Config.ActuatorEndStopOn	BOOL	FALSE	If ActuatorEndStopOn = TRUE, the digital position feedback Actuator_L and Actuator_H are taken into consideration.
Config.InputUpperLimit	REAL	120.0	High limit of the process value At the I/O input, the process value can be a maximum of 18% higher than the standard range (overrange). An error is no longer signaled due to a violation of the "Process value high limit". Only a wire-break and a short-circuit are recognized and PID_3Step reacts according to the configured reaction to error. InputUpperLimit > InputLowerLimit
Config.InputLowerLimit	REAL	0.0	Low limit of the process value InputLowerLimit < InputUpperLimit
Config.InputUpperWarning	REAL	+3.402822e+38	Warning high limit of the process value If you set InputUpperWarning outside the process value limits, the configured absolute process value high limit is used as the warning high limit. If you configure InputUpperWarning within the process value limits, this value is used as the warning high limit. InputUpperWarning > InputLowerWarning InputUpperWarning ≤ InputUpperLimit
Config.InputLowerWarning	REAL	-3.402822e+38	Warning low limit of the process value If you set InputLowerWarning outside the process value limits, the configured absolute process value low limit is used as the warning low limit. If you configure InputLowerWarning within the process value limits, this value is used as the warning low limit. InputLowerWarning < InputUpperWarning InputLowerWarning ≥ InputLowerLimit
Config.OutputUpperLimit	REAL	100.0	High limit of output value For details, see OutputLowerLimit

Tag	Data type	Default	Description
Config.OutputLowerLimit	REAL	0.0	Low limit of output value If OutputPerOn = TRUE or FeedbackOn = TRUE, the range of values from -100% to +100%, including zero, is valid. At -100%, Output = -27648; at +100%, Output = 27648 If OutputPerOn = FALSE, the range of values from 0% to 100% is valid. The valve is completely closed at 0% and completely opened at 100%.
Config.SetpointUpperLimit	REAL	+3.402822e+38	High limit of setpoint If you set SetpointUpperLimit outside the process value limits, the configured absolute process value high limit is preassigned as the setpoint high limit. If you configure SetpointUpperLimit within the process value limits, this value is used as the setpoint high limit.
Config.SetpointLowerLimit	REAL	- 3.402822e+38	Low limit of the setpoint If you set SetpointLowerLimit outside the process value limits, the configured absolute process value low limit is preassigned as the setpoint low limit. If you set SetpointLowerLimit within the process value limits, this value is used as the setpoint low limit.
Config.MinimumOnTime	REAL	0.0	Minimum ON time Minimum time in seconds for which the servo drive must be switched on.
Config.MinimumOffTime	REAL	0.0	Minimum OFF time Minimum time in seconds for which the servo drive must be switched off.
Config.TransitTime	REAL	30.0	Motor transition time Time in seconds the actuating drive requires to move the valve from the closed to the opened state.
Config.InputScaling.UpperPointIn	REAL	27648.0	Scaling Input_PER high Input_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the InputScaling structure.
Config.InputScaling.LowerPointIn	REAL	0.0	Scaling Input_PER low Input_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the InputScaling structure.
Config.InputScaling.UpperPointOut	REAL	100.0	Scaled high process value Input_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the InputScaling structure.
Config.InputScaling.LowerPointOut	REAL	0.0	Scaled low process value Input_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the InputScaling structure.
Config.FeedbackScaling.UpperPointIn	REAL	27648.0	Scaling Feedback_PER high Feedback_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the FeedbackScaling structure.

Tag	Data type	Default	Description
Config.FeedbackScaling.LowerPointIn	REAL	0.0	Scaling Feedback_PER low Feedback_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the FeedbackScaling structure.
Config.FeedbackScaling.UpperPointOut	REAL	100.0	High endstop Feedback_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the FeedbackScaling structure.
Config.FeedbackScaling.LowerPointOut	REAL	0.0	Low endstop Feedback_PER is converted to a percentage based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn of the FeedbackScaling structure.
GetTransitTime.InvertDirection	BOOL	FALSE	If InvertDirection = FALSE, the valve is fully opened, closed, and then reopened in order to determine the valve transition time. If InvertDirection = TRUE, the valve is fully closed, opened, and then closed again.
GetTransitTime.SelectFeedback	BOOL	FALSE	If SelectFeedback = TRUE, then Feedback_PER, or Feedback is taken into consideration in the transition time measurement. If SelectFeedback = FALSE, then Actuator_H and Actuator_L are taken into consideration in the transition time measurement.
GetTransitTime.Start	BOOL	FALSE	If Start = TRUE, the transition time measurement is started.
GetTransitTime.State	INT	0	Current phase of the transition time measurement • State = 0: Inactive • State = 1: Open valve completely • State = 2: Close valve completely • State = 3: Move valve to target position (NewOutput) • State = 4: Transition time measurement successfully completed • State = 5: Transition time measurement canceled
GetTransitTime.NewOutput	REAL	0.0	Target position for transition time measurement with position feedback The target position must be between "High endstop" and "Low endstop". The difference between NewOutput and ScaledFeedback must be at least 50% of the permissible control range.
CycleTime.StartEstimation	BOOL	TRUE	If StartEstimation = TRUE, the measurement of the PID_3Step sampling time is started. CycleTime.StartEstimation = FALSE once measurement is complete.
CycleTime.EnEstimation	BOOL	TRUE	If EnEstimation = TRUE, the PID_3Step sampling time is calculated.

Tag	Data type	Default	Description
CycleTime.EnMonitoring	BOOL	TRUE	If EnMonitoring = TRUE, the PID_3Step sampling time is monitored. If it is not possible to execute PID_3Step within the sampling time, the error 0800h is output and the operating mode is switched. ActivateRecoverMode and ErrorBehaviour determine which operating mode is switched to. If EnMonitoring = FALSE, the PID_3Step sampling time is not monitored, the error 0800h is not output, and the operating mode is not switched.
CycleTime.Value	REAL	0.1	PID_3Step sampling time in seconds CycleTime.Value is determined automatically and is usually equivalent to the cycle time of the calling OB.
CtrlParamsBackUp.SetByUser	BOOL	FALSE	Saved value of Retain.CtrlParams.SetByUser. You can reload values from the CtrlParamsBackUp structure with Config.LoadBackUp = TRUE.
CtrlParamsBackUp.Gain	REAL	1.0	Saved proportional gain
CtrlParamsBackUp.Ti	REAL	20.0	Saved integral action time
CtrlParamsBackUp.Td	REAL	0.0	Saved derivative action time
CtrlParamsBackUp.TdFiltRatio	REAL	0.0	Saved derivative delay coefficient
CtrlParamsBack-Up.PWeighting	REAL	0.0	Saved proportional action weighting
CtrlParamsBack-Up.DWeighting	REAL	0.0	Saved derivative action weighting
CtrlParamsBackUp.Cycle	REAL	1.0	Saved sampling time of PID algorithm
CtrlParamsBack-Up.InputDeadBand	REAL	0.0	Saved dead band width of the control deviation
PIDSelf-Tune.SUT.CalculateSUTParams	BOOL	FALSE	The properties of the controlled system are saved during tuning. If CalculateSUTParams = TRUE, the PID parameters are recalculated on the basis of these properties. The PID parameters are calculated using the method set in TuneRuleSUT. CalculateSUTParams is set to FALSE following calculation.
PIDSelf-Tune.SUT.TuneRuleSUT	INT	1	Methods used to calculate parameters during pretuning: • TuneRuleSUT = 0: PID rapid I • TuneRuleSUT = 1: PID slow I • TuneRuleSUT = 2: Chien, Hrones and Reswick PID • TuneRuleSUT = 3TuneRuleSUT = 3: Chien, Hrones, Reswick PI • TuneRuleSUT = 4: PID rapid II • TuneRuleSUT = 5: PID slow II
PIDSelfTune.SUT.State	INT	0	The SUT.State tag indicates the current phase of pretuning:

Tag	Data type	Default	Description
PIDSelfTune.TIR.RunIn	BOOL	FALSE	• RunIn = FALSE Pretuning is started when fine tuning is started from inactive or manual mode. If fine tuning is started from automatic mode, the system uses the existing PID parameters to control to the setpoint. Only then will fine tuning start. If pretuning is not possible, PID_3Step switches to "Inactive" mode. • RunIn = TRUE The pretuning is skipped. PID_3Step attempts to reach the setpoint with the minimum or maximum output value. This can produce increased overshoot. Only then will fine tuning start. RunIn is set to FALSE after fine tuning.
PIDSelf-Tune.TIR.CalculateTIRParams	BOOL	FALSE	The properties of the controlled system are saved during tuning. If CalculateTIRParams = TRUE, the PID parameters are recalculated on the basis of these properties. The PID parameters are calculated using the method set in TuneRuleTIR. CalculateTIRParams is set to FALSE following calculation.
PIDSelf-Tune.TIR.TuneRuleTIR	INT	0	Methods used to calculate parameters during fine tuning: • TuneRuleTIR = 0: PID automatic • TuneRuleTIR = 1: PID rapid • TuneRuleTIR = 2: PID slow • TuneRuleTIR = 3: Ziegler-Nichols PID • TuneRuleTIR = 4: Ziegler-Nichols PI • TuneRuleTIR = 5: Ziegler-Nichols P
PIDSelfTune.TIR.State	INT	0	The TIR.State tag indicates the current phase of "fine tuning":

Tag	Data type	Default	Description
Retain.Mode	INT	0	A change to the value of Retain.Mode initiates a switch to another operating mode. The following operating mode is enabled upon a change of Mode to: • Mode = 0: Inactive • Mode = 1: Pretuning • Mode = 2: Fine tuning • Mode = 3: Automatic mode • Mode = 4: Manual mode • Mode = 5: Approach substitute output value • Mode = 6: Transition time measurement • Mode = 7Mode = 7: Error monitoring • Mode = 8: Approach substitute output value with error monitoring Mode is retentive.
Retain.CtrlParams.SetByUser	BOOL	FALSE	If SetByUser = FALSE, the PID parameters are determined automatically and PID_3Step operates with a dead band at the output value. The dead band width is calculated during tuning on the basis of the standard deviation of the output value and saved in Retain.CtrlParams.OutputDeadBand. If SetByUser = TRUE, the PID parameters are entered manually and PID_3 Step operates without a dead band at the output value. Retain.CtrlParams.OutputDeadBand = 0.0 SetByUser is retentive.
Retain.CtrlParams.Gain	REAL	1.0	Active proportional gain Gain is retentive.
Retain.CtrlParams.Ti	REAL	20.0	• Ti > 0.0: Active integral action time • Ti = 0.0: Integral action is deactivated Ti is retentive.
Retain.CtrlParams.Td	REAL	0.0	• Td > 0.0: Active derivative action time • Td = 0.0: Derivative action is deactivated Td is retentive.
Retain.CtrlParams.TdFiltRatio	REAL	0.0	Active derivative delay coefficient TdFiltRatio is retentive.
Retain.CtrlParams.PWeighting	REAL	0.0	Active proportional action weighting PWeighting is retentive.
Retain.CtrlParams.DWeighting	REAL	0.0	Active derivative action weighting DWeighting is retentive.
Retain.CtrlParams.Cycle	REAL	1.0	Active sampling time of PID algorithm in seconds, rounded to an integer multiple of the cycle time of the calling OB. Cycle is retentive.
Retain.CtrlParams.InputDeadBand	REAL	0.0	Dead band width of the control deviation InputDeadBand is retentive.

Note

Change the tags listed in this table in "Inactive" mode to prevent malfunction of the PID controller. "Inactive" mode is forced by setting the "Retain.Mode" tag to "0".

See also

Parameter State and Retain.Mode V1 (Page 356)

Tag ActivateRecoverMode V1 (Page 366)

Downloading technology objects to device (Page 46)

8.2.5.6 Parameter State and Retain.Mode V1

Correlation of the parameters

The State parameter shows the current operating mode of the PID controller. You cannot change the State parameter.

To switch from one operating mode to another, you must change the Retain.Mode tag. This also applies when the value for the new operating mode is already in Retain.Mode. For example, set Retain.Mode = 0 first and then Retain.Mode = 3. Provided the current operating mode of the controller permits this switchover, State will be set to the value of Retain.Mode.

When PID_3Step automatically switches from one operating mode to another, the following applies: State != Retain.Mode.

Examples:

- After successful pretuning
  State = 3 and Retain.Mode = 1
- In the event of an error
  State = 0 and Retain.Mode remain at the previous value, for example, Retain.Mode = 3
- ManualEnalbe = TRUE
  State = 4 and Retain.Mode remain at the previous value, e.g., Retain.Mode = 3

Note

You want, for example, to repeat successful fine tuning without exiting automatic mode with Mode = 0.

Setting Retain.Mode to an invalid value such as 9999 for one cycle has no effect on State. Set Mode = 2 in the next cycle. In this way, you can generate a change to Retain.Mode without first switching to "Inactive" mode.

Meaning of values

State / Retain.Mode	Description
0	Inactive The controller is switched off and no longer changes the valve position.
1	Pretuning The pretuning determines the process response to a pulse of the output value and searches for the point of inflection. The optimized PID parameters are calculated as a function of the maximum rate of rise and dead time of the controlled system. Pretuning requirements: • State = 0 or State = 4 • ManualEnable = FALSE • The motor transition time has been configured or measured. • The setpoint and the process value lie within the configured limits. The more stable the process value is, the easier it is to calculate the PID parameters and the more precise the result will be. Noise on the process value can be tolerated as long as the rate of rise of the process value is significantly higher as compared to the noise. Before the PID parameters are recalculated, they are backed up and can be reactivated with Config.LoadBackUp. The setpoint is frozen in the CurrentSetpoint tag. The controller switches to automatic mode following successful pretuning and to "Inactive" mode following unsuccessful pretuning. The pretuning phase is indicated with the SUT.State tag.

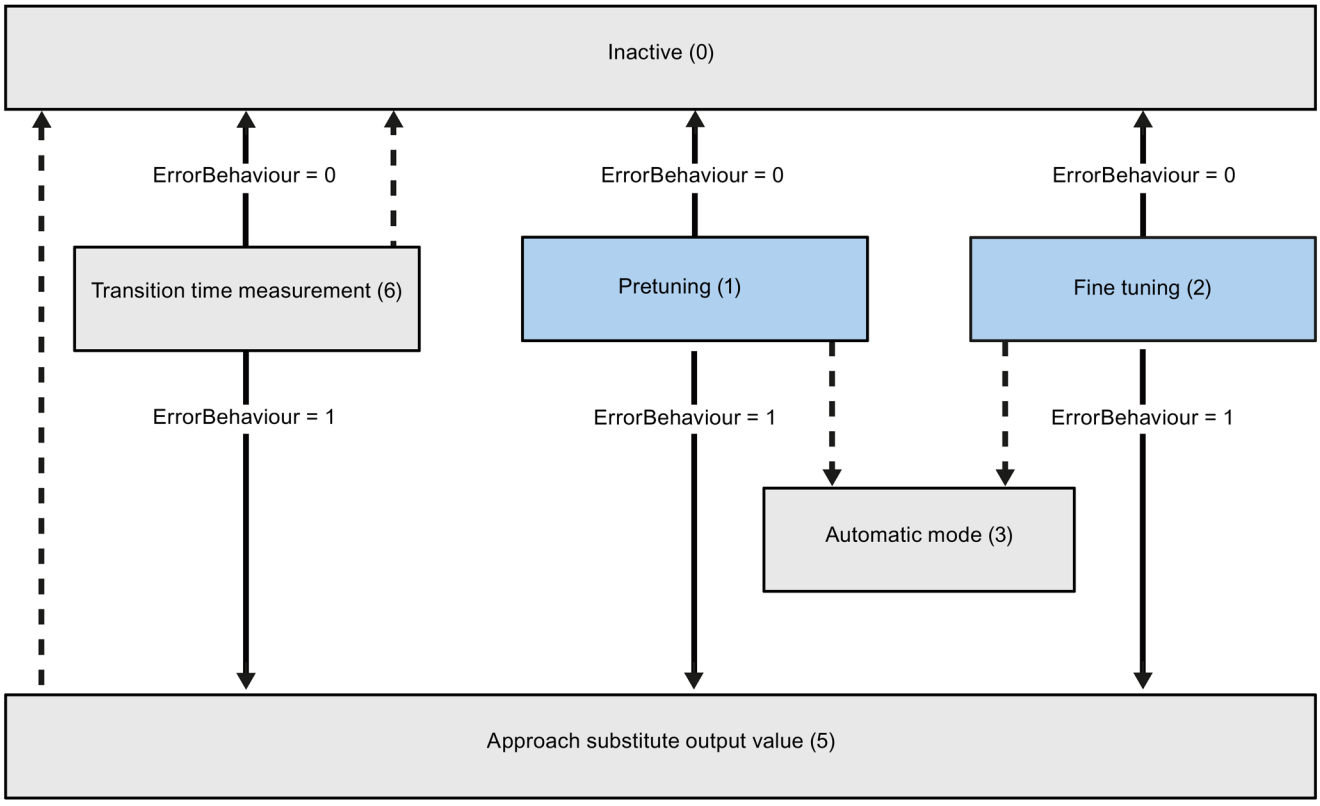
State / Retain.Mode	Description
2	Fine tuning Fine tuning generates a constant, limited oscillation of the process value. The PID parameters are tuned based on the amplitude and frequency of this oscillation. The differences between the process response during pretuning and fine tuning are analyzed. All PID parameters are recalculated from the results. PID parameters from fine tuning usually have better master control and disturbance characteristics than PID parameters from pretuning. PID_3Step automatically attempts to generate an oscillation greater than the noise of the process value. Fine tuning is only minimally influenced by the stability of the process value. The PID parameters are backed up before fine tuning. They can be reactivated with Config.LoadBackUp. The setpoint is frozen in the CurrentSetpoint tag. Requirements for fine tuning: • The motor transition time has been configured or measured. • The setpoint and the process value lie within the configured limits. • ManualEnable = FALSE • Automatic (State = 3), inactive (State = 0) or manual (State = 4) mode Fine tuning proceeds as follows when started from: • Automatic mode (State = 3) Start fine tuning from automatic mode if you wish to improve the existing PID parameters through tuning. PID_3Step controls the system using the existing PID parameters until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start. • Inactive (State = 0) or manual mode (State = 4) Pretuning is always started first. The determined PID parameters will be used for control until the control loop has stabilized and the requirements for fine tuning have been met. If PIDSelfTune.TIR.RunIn = TRUE, pretuning is skipped and an attempt is made to reach the setpoint with the minimum or maximum output value. This can produce increased overshoot. Fine tuning then starts automatically. The controller switches to automatic mode following successful fine tuning. If fine tuning was not successful, the controller switches to "Inactive" mode. The fine tuning phase is indicated with the TIR.State tag.
3	Automatic mode In automatic mode, PID_3Step controls the controlled system in accordance with the parameters specified. The controller switches to automatic mode if one the following requirements is fulfilled: • Pretuning successfully completed • Fine tuning successfully completed • Changing the Retain.Mode tag to the value 3. When the CPU is switched on or switches from Stop to RUN mode, PID_3Step starts in the most recently active operating mode. To leave PID_3Step in "Inactive" mode, set RunModeByStartup = FALSE. The ActivateRecoverMode tag is taken into consideration in automatic mode.

State / Retain.Mode	Description
4	Manual mode In manual mode, you specify manual output values in the Manual_UP and Manual_DN parameters or ManualValue parameter. Whether or not the actuator can be moved to the output value in the event of an error is described in the ErrorBits parameter. This operating mode is enabled if Retain.Mode = 4, or on a rising edge at ManualEnable. If ManualEnable changes to TRUE, only State changes. Retain.Mode retains its current value. On a falling edge at ManualEnable, PID_3Step returns to the previous operating mode. The switchover to automatic mode is bumpless. **PID_3Step V1.1** Manual mode is always possible in the event of an error. **PID_3Step V1.0** Manual mode is dependent on the ActivateRecoverMode tag in the event of an error.
5	Approach substitute output value This operating mode is activated in the event of an error or when Reset = TRUE if Errorbehaviour = 1 and ActivateRecoverMode = FALSE.. PID_3Step moves the actuator to the substitute output value and then switches to "Inactive" mode.
6	Transition time measurement The time that the motor needs to completely open the valve from the closed condition is determined. This operating mode is activated when GetTransitTime.Start = TRUE is set. If endstop signals are used to measure the transition time, the valve will be opened completely from its current position, closed completely, and opened completely again. If GetTransit-Time.InvertDirection = TRUE, this behavior is inverted. If position feedback is used to measure the transition time, the actuator will be moved from its current position to a target position. The output value limits are not taken into consideration during the transition time measurement. The actuator can travel to the high or the low endstop.

State / Retain.Mode	Description
7	Error monitoring The control algorithm is switched off and no longer changes the valve position. This operating mode is activated instead of "Inactive" mode in the event of an error. All the following conditions must be met: • Mode = 3 (automatic mode) • Errorbehaviour = 0 • ActivateRecoverMode = TRUE • One or more errors have occurred in which ActivateRecoverMode (Page 366) is effective. As soon as the errors are no longer pending, PID_3Step switches back to automatic mode.
8	Approach substitute output value with error monitoring This operating mode is activated instead of "Approach substitute output value" mode in the event of an error. PID_3Step moves the actuator to the substitute output value and then switches to "Error monitoring" mode. All the following conditions must be met: • Mode = 3 (automatic mode) • Errorbehaviour = 1 • ActivateRecoverMode = TRUE • One or more errors have occurred in which ActivateRecoverMode (Page 366) is effective. As soon as the errors are no longer pending, PID_3Step switches back to automatic mode.

Automatic switchover of operating mode during commissioning

PID_3Step automatically switches the operating mode in the event of an error. The following diagram illustrates the influence of ErrorBehaviour on the switchover of operating mode from transition time measurement, pretuning, and fine tuning modes.

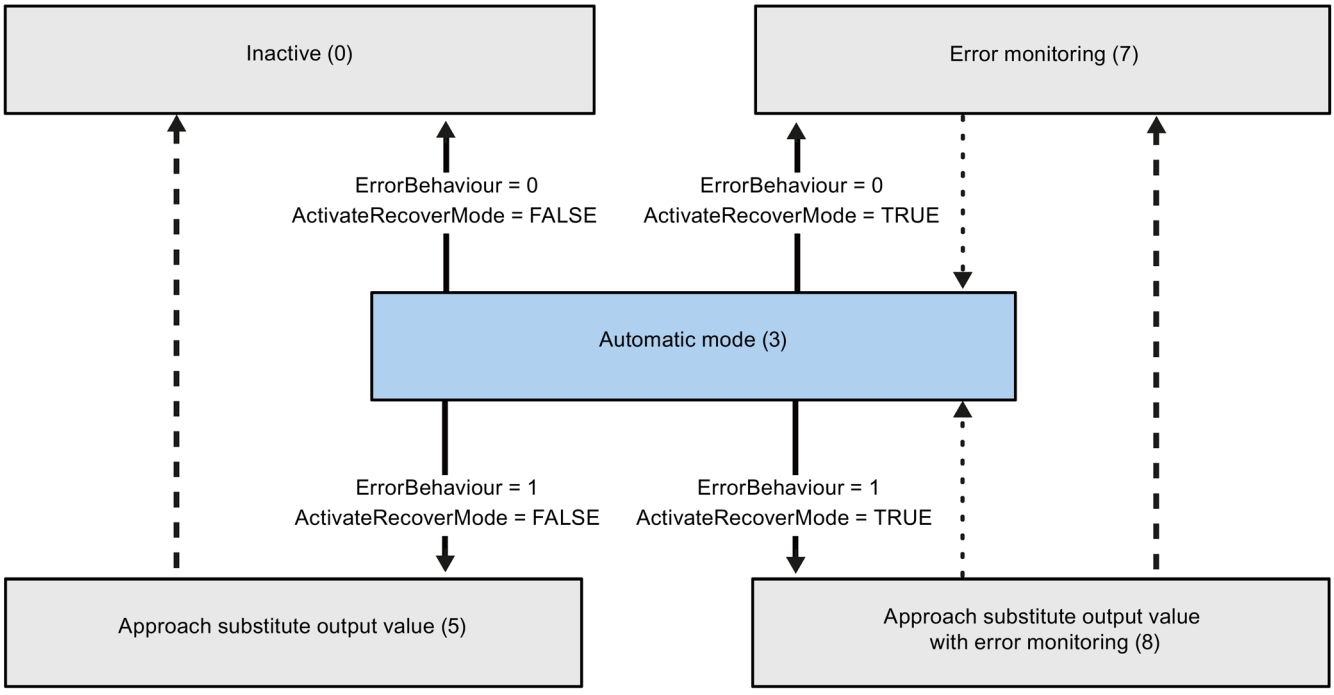


Automatic switchover of operating mode in the event of an error

Automatic switchover of operating mode once the current operation has been completed.

Automatic switchover of operating mode in automatic mode (PID_3Step V1.1)

PID_3Step automatically switches the operating mode in the event of an error. The following diagram illustrates the influence of ErrorBehaviour and ActivateRecoverMode on this switchover of operating mode.

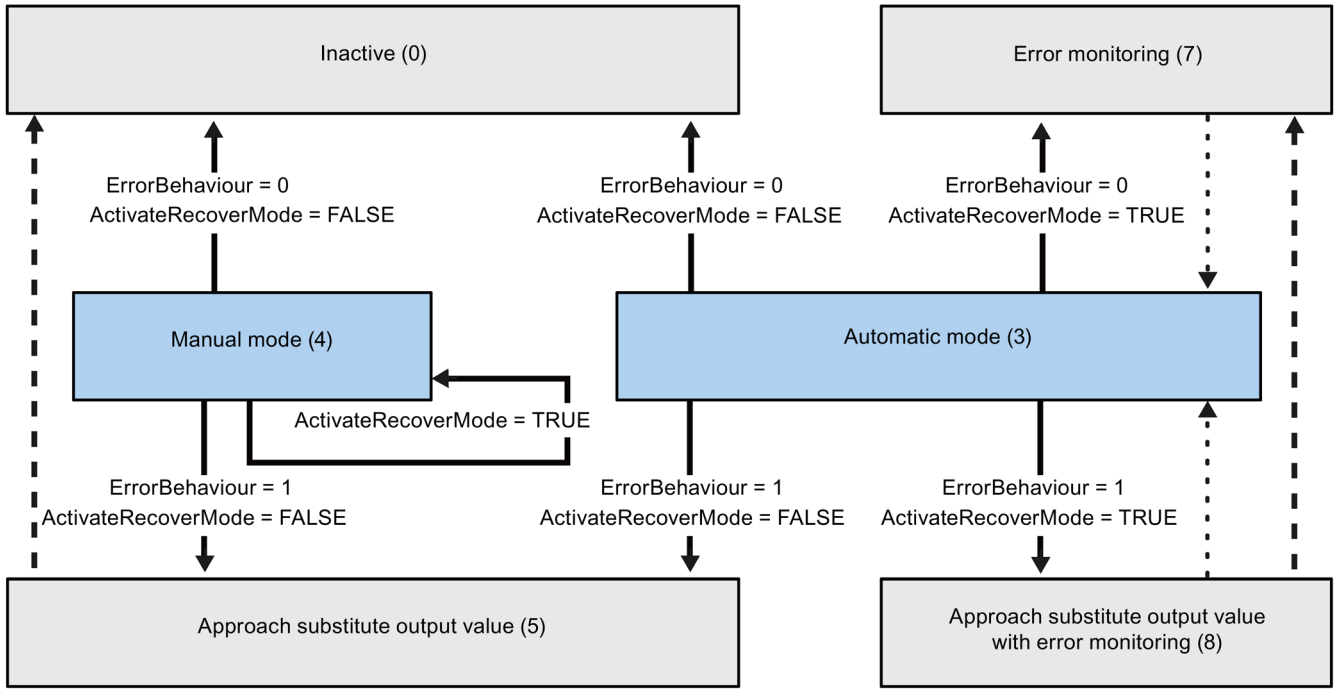


Automatic switchover of operating mode in the event of an error

Automatic switchover of operating mode once the current operation has been completed.

Automatic switchover of operating mode in automatic and manual modes (PID_3Step V1.0)

PID_3Step automatically switches the operating mode in the event of an error. The following diagram illustrates the influence of ErrorBehaviour and ActivateRecoverMode on this switchover of operating mode.



Automatic switchover of operating mode in the event of an error

Automatic switchover of operating mode once the current operation has been completed.

Automatic switchover of operating mode when error is no longer pending.

See also

Tag ActivateRecoverMode V1 (Page 366)

Parameter ErrorBits V1 (Page 364)

8.2.5.7 Parameter ErrorBits V1

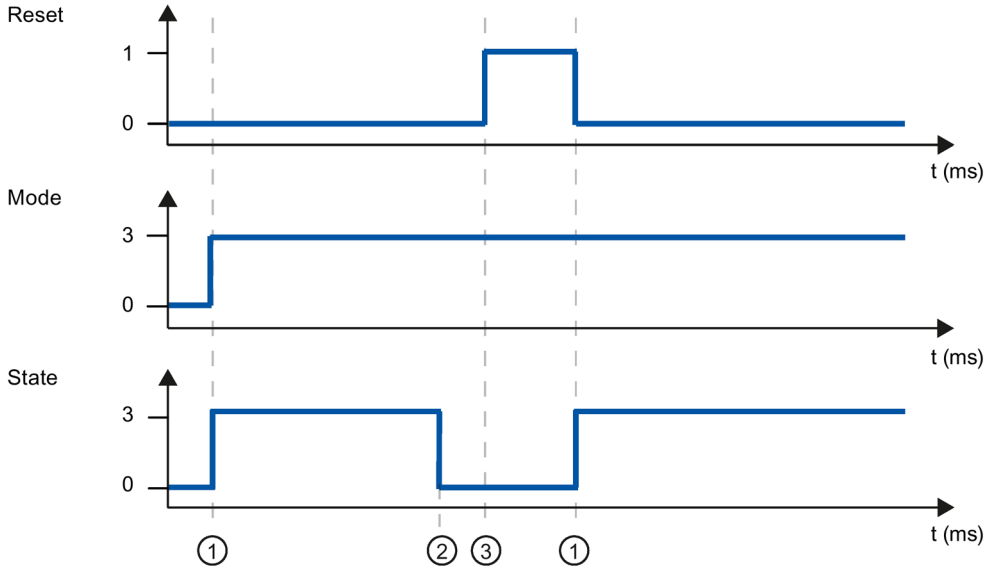
If several errors are pending simultaneously, the values of the error codes are displayed with binary addition. The display of error code 0003, for example, indicates that the errors 0001 and 0002 are pending simultaneously.

ErrorBits (DW#16#...)	Description
0000	There is no error.
0001	The "Input" parameter is outside the process value limits. • Input > Config.InputUpperLimit or • Input < Config.InputLowerLimit If ActivateRecoverMode = TRUE and ErrorBehaviour = 1, the actuator moves to the substitute output value. If ActivateRecoverMode = TRUE and ErrorBehaviour = 0, the actuator stops in its current position. If ActivateRecoverMode = FALSE, the actuator stops in its current position. PID_3Step V1.1 You can move the actuator in manual mode. PID_3Step V1.0 Manual mode is not possible in this state. You cannot move the actuator again until you eliminate the error.
0002	Invalid value at "Input_PER" parameter. Check whether an error is pending at the analog input. If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_3Step switches back to automatic mode.
0004	Error during fine tuning. Oscillation of the process value could not be maintained.
0020	Pretuning is not permitted in automatic mode or during fine tuning.
0080	Error during pretuning. Incorrect configuration of output value limits. Check whether the limits of the output value are configured correctly and match the control logic.
0100	Error during fine tuning resulted in invalid parameters.
0200	Invalid value at "Input" parameter: Value has an invalid number format. If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_3Step switches back to automatic mode.
0400	Calculation of output value failed. Check the PID parameters.
0800	Sampling time error: PID_3Step is not called within the sampling time of the cyclic interrupt OB. If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_3Step switches back to automatic mode.
1000	Invalid value at "Setpoint" parameter: Value has an invalid number format. If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_3Step switches back to automatic mode.
2000	Invalid value at Feedback_PER parameter. Check whether an error is pending at the analog input. The actuator cannot be moved to the substitute output value and remains in its current position. Manual mode is not possible in this state. You must deactivate position feedback (Config. FeedbackOn = FALSE) to move the actuator from this state. If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_3Step switches back to automatic mode.

ErrorBits (DW#16#...)	Description
4000	Invalid value at Feedback parameter. Value has an invalid number format. The actuator cannot be moved to the substitute output value and remains in its current position. Manual mode is not possible in this state. You must deactivate position feedback (Config. FeedbackOn = FALSE) to move the actuator from this state. If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_3Step switches back to automatic mode.
8000	Error during digital position feedback. Actuator_H = TRUE and Actuator_L = TRUE. The actuator cannot be moved to the substitute output value and remains in its current position. Manual mode is not possible in this state. In order to move the actuator from this state, you must deactivate the "Actuator endstop" (Config.ActuatorEndStopOn = FALSE). If automatic mode was active before the error occurred, ActivateRecoverMode = TRUE, and the error is no longer pending, PID_3Step switches back to automatic mode.

8.2.5.8 Parameter Reset V1

A rising edge at Reset resets the errors and warnings and clears the integral action. A falling edge at Reset triggers a change to the most recently active operating mode.



① Activation
② Error
③ Reset

8.2.5.9 Tag ActivateRecoverMode V1

The effect of the ActivateRecoverMode variable depends on the version of the PID_3Step.

Behavior in version 1.1

The ActivateRecoverMode variable determines the behavior in the event of an error in automatic mode. ActivateRecoverMode is not effective during pretuning, fine tuning and transition time measurement.

ActivateRecoverMode	Description
FALSE	In the event of an error, PID_3Step switches to "Inactive" or "Approach substitute output value" operating mode. The controller is activated by a reset or a change in Retain.Mode.
TRUE	If errors occur frequently in automatic mode, this setting has a negative effect on the control response. In this case, check the ErrorBits parameter and eliminate the cause of the error. If one or more errors occur, PID_3Step switches to "Approach substitute output value with error monitoring" or "Error monitoring" mode: • 0002h: Invalid value at parameter Input_PER. • 0200h: Invalid value at parameter Input. • 0800h: Sampling time error • 1000h: Invalid value at parameter Setpoint. • 2000h: Invalid value at parameter Feedback_PER. • 4000h: Invalid value at parameter Feedback. • 8000h: Error in digital position feedback. With errors 2000h, 4000h and 8000h, PID_3Step **cannot** approach the configured substitute output value. As soon as the errors are no longer pending, PID_3Step switches back to automatic mode.

Behavior in version 1.0

The ActivateRecoverMode variable determines the behavior in the event of an error in automatic and manual mode. ActivateRecoverMode is not effective during pretuning, fine tuning and transition time measurement.

ActivateRecoverMode	Description
FALSE	In the event of an error, PID_3Step switches to "Inactive" or "Approach substitute output value" operating mode. The controller is activated by a reset or a change in Retain.Mode.
TRUE	**Errors in automatic mode** If errors occur frequently in automatic mode, this setting has a negative effect on the control response. In this case, check the ErrorBits parameter and eliminate the cause of the error. If one or more errors occur, PID_3Step switches to "Approach substitute output value with error monitoring" or "Error monitoring" mode: • 0002h: Invalid value at parameter Input_PER. • 0200h: Invalid value at parameter Input. • 0800h: Sampling time error • 1000h: Invalid value at parameter Setpoint. • 2000h: Invalid value at parameter Feedback_PER. • 4000h: Invalid value at parameter Feedback. • 8000h: Error in digital position feedback. With errors 2000h, 4000h and 8000h, PID_3Step **cannot** approach the configured substitute output value. As soon as the errors are no longer pending, PID_3Step switches back to automatic mode. **Errors in manual mode** If one or more of the following errors occur, PID_3Step stays in manual mode: • 0002h: Invalid value at parameter Input_PER. • 0200h: Invalid value at parameter Input. • 0800h: Sampling time error • 1000h: Invalid value at parameter Setpoint. • 2000h: Invalid value at parameter Feedback_PER. • 4000h: Invalid value at parameter Feedback. • 8000h: Error in digital position feedback. With errors 2000h, 4000h and 8000h, you **cannot** move the valve to a suitable position.

See also

PID_3Step V1 static tags (Page 348)

Parameter State and Retain.Mode V1 (Page 356)

8.2.5.10 Tag Warning V1

If several warnings are pending simultaneously, their values are displayed with binary addition. The display of warning 0003, for example, indicates that the warnings 0001 and 0002 are pending simultaneously.

Warning (DW#16#...)	Description
0000	No warning pending.
0001	The point of inflection was not found during pretuning.
0002	Oscillation increased during fine tuning.
0004	The setpoint was limited to the configured limits.
0008	Not all the necessary controlled system properties were defined for the selected method of calculation. The PID parameters were instead calculated using the TuneRuleTIR = 3 method.
0010	The operating mode could not be changed because ManualEnable = TRUE.
0020	The cycle time of the calling OB limits the sampling time of the PID algorithm. Improve results by using shorter OB cycle times.
0040	The process value exceeded one of its warning limits.
0080	Invalid value at Retain.Mode. The operating mode is not switched.
0100	The manual value was limited to the limits of the controller output.
0200	The rule used for tuning produces an incorrect result, or is not supported.
0400	Method selected for transition time measurement not suitable for actuator. The transition time cannot be measured because the actuator settings do not match the selected measuring method.
0800	The difference between the current position and the new output value is too small for transition time measurement. This can produce incorrect results. The difference between the current output value and new output value must be at least 50% of the entire control range.
1000	The substitute output value cannot be reached because it is outside the output value limits.

The following warnings are deleted as soon as the cause is eliminated:

- 0004
- 0020
- 0040
- 0100

All other warnings are cleared with a rising edge at Reset.

8.2.5.11 Tag SUT.State V1

SUT.State	Name	Description
0	SUT_INIT	Initialize pretuning
50	SUT_TPDN	Determine start position without position feedback
100	SUT_STDABW	Calculate the standard deviation
200	SUT_GET_POI	Find the point of inflection
300	SUT_GET_RISETM	Determine the rise time
9900	SUT_IO	Pretuning successful
1	SUT_NIO	Pretuning not successful

8.2.5.12 Tag TIR.State V1

TIR.State	Name	Description
-100	TIR_FIRST_SUT	Fine tuning is not possible. Pretuning will be executed first.
0	TIR_INIT	Initialize fine tuning
200	TIR_STDABW	Calculate the standard deviation
300	TIR_RUN_IN	Attempt to reach the setpoint with the maximum or minimum output value
400	TIR_CTRLN	Attempt to reach the setpoint with the existing PID parameters (if pretuning has been successful)
500	TIR_OSZIL	Determine oscillation and calculate parameters
9900	TIR_IO	Fine tuning successful
1	TIR_NIO	Fine tuning not successful

8.3 PID_Temp

8.3.1 Compatibility with CPU and FW

The following table shows which version of PID_Temp can be used on which CPU.

CPU	FW	PID_Temp
S7-1200	≥ V4.1	V1.0
S7-1500	≥ V1.7	V1.0

8.3.2 CPU processing time and memory requirement PID_Temp V1

CPU processing time

Typical CPU processing times of the PID_Temp technology object as of Version 1.0, depending on CPU type.

CPU	Typ. CPU processing time PID_Temp V1
CPU 1211C ≥ V4.1	580 µs
CPU 1215C ≥ V4.1	580 µs
CPU 1217C ≥ V4.1	580 µs
CPU 1505S ≥ V1.0	50 µs
CPU 1510SP-1 PN ≥ V1.7	130 µs
CPU 1511-1 PN ≥ V1.7	130 µs
CPU 1512SP-1 PN ≥ V1.7	130 µs
CPU 1516-3 PN/DP ≥ V1.7	75 µs
CPU 1518-4 PN/DP ≥ V1.7	6 µs

Memory requirement

Memory requirement of an instance DB of the PID_Temp technology object as of Version V1.0.

	Memory requirement of the instance DB of PID_Temp V1
Load memory requirement	Approx. 17000 bytes
Total work memory requirement	1280 bytes
Retentive work memory requirement	100 bytes

8.3.3 PID_Temp

8.3.3.1 Description of PID_Temp

Description

The PID_Temp instruction provides a PID controller with integrated tuning for temperature processes. PID_Temp can be used for pure heating or heating/cooling applications.

The following operating modes are possible:

- Inactive
- Pretuning
- Fine tuning
- Automatic mode
- Manual mode
- Substitute output value with error monitoring

For a more detailed description of the operating modes, see the State parameter.

PID algorithm

PID_Temp is a PIDT1 controller with anti-windup and weighting of the proportional and derivative actions. The PID algorithm operates according to the following equation (control zone and deadband deactivated):

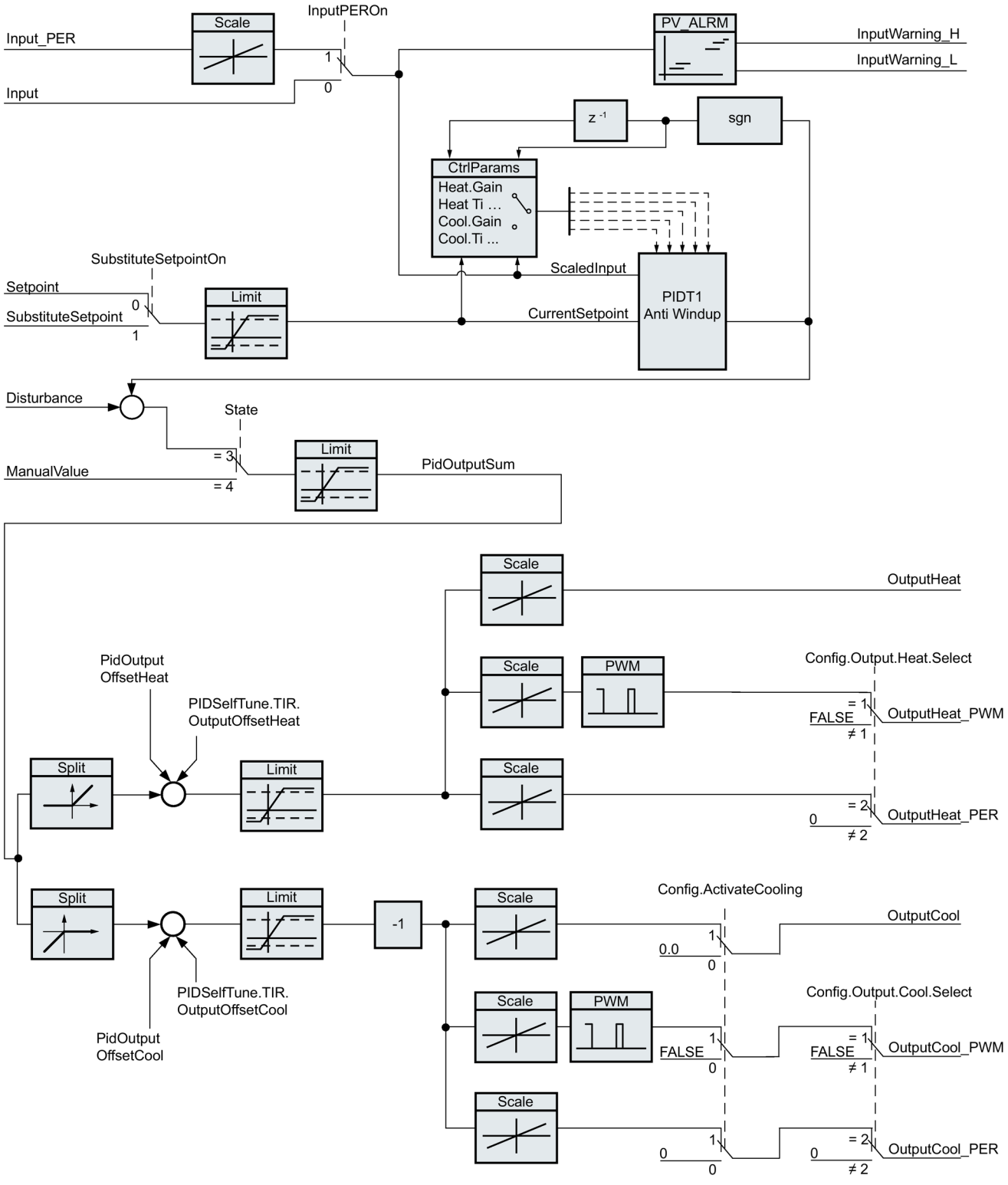
$$y = K_p \left[(b \cdot w - x) + \frac{1}{T_I \cdot s} (w - x) + \frac{T_D \cdot s}{a \cdot T_D \cdot s + 1} (c \cdot w - x) \right]$$

The table below shows the meaning of the icons used in the equation and in the subsequent figures.

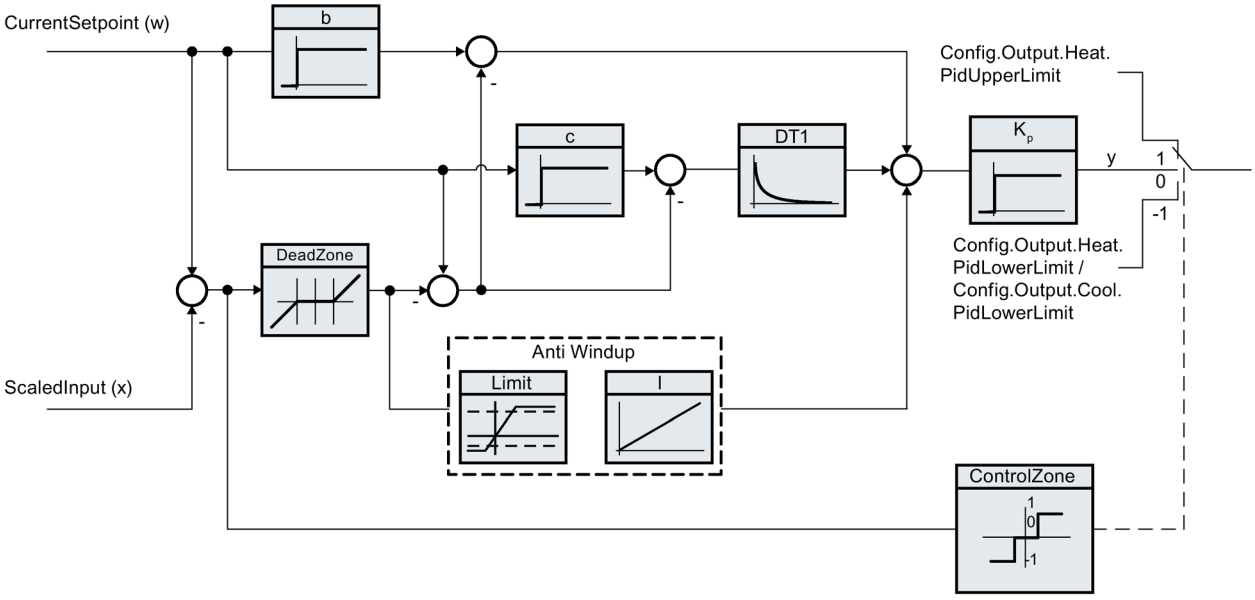
Icon	Description	Associated parameters of the PID_Temp instruction
y	Output value of the PID algorithm	-
K_p	Proportional gain	Retain.CtrlParams.Heat.Gain Retain.CtrlParams.Cool.Gain CoolFactor
s	Laplace operator	-
b	Proportional action weighting	Retain.CtrlParams.Heat.PWeighting Retain.CtrlParams.Cool.PWeighting
w	Setpoint	CurrentSetpoint
x	Process value	ScaledInput
T_I	Integral action time	Retain.CtrlParams.Heat.Ti Retain.CtrlParams.Cool.Ti

Icon	Description	Associated parameters of the PID_Temp instruction
T_D	Derivative action time	Retain.CtrlParams.Heat.Td Retain.CtrlParams.Cool.Td
a	Derivative delay coefficient (derivative delay T1 = a × T_D)	Retain.CtrlParams.Heat.TdFiltRatio Retain.CtrlParams.Cool.TdFiltRatio
c	Derivative action weighting	Retain.CtrlParams.Heat.DWeighting Retain.CtrlParams.Cool.DWeighting
DeadZone	Deadband width	Retain.CtrlParams.Heat.DeadZone Retain.CtrlParams.Cool.DeadZone
ControlZone	Control zone width	Retain.CtrlParams.Heat.ControlZone Retain.CtrlParams.Cool.ControlZone

PID_Temp block diagram



Block diagram of PIDT1 with anti-windup



Call

PID_Temp is called in the constant time scale of a cyclic interrupt OB.

If you call PID_Temp as a multi-instance DB, no technology object is created. No parameter assignment interface or commissioning interface is available. You must assign parameters for PID_Temp directly in the multi-instance DB and commission it via a watch table.

Download to device

The process values of retentive variables are only updated when you download PID_Temp completely.

Download technology object to device (Page 46)

Startup

When the CPU starts up, PID_Temp starts in the operating mode that is saved in the Mode in/out parameter. To switch to "Inactive" operating mode during startup, set RunModeByStartup = FALSE.

Reaction to error

The behavior in the case of an error is determined by the tags SetSubstituteOutput and ActivateRecoverMode. If ActivateRecoverMode = TRUE, the behavior also depends on the error that occurred.

SetSubstitute-Output	Acti-vateRecov-erMode	Configuration editor > Basic settings of output > Set PidOutputSum to	Reaction
Not relevant	FALSE	Zero (Inactive)	Switch to "Inactive" (State = 0) mode The output value of the PID algorithm and all outputs for heating and cooling are set to 0. The scaling of the outputs for heating and cooling is not active.
FALSE	TRUE	Current value for error while error is pending	Switch to "Substitute output value with error monitoring" mode (State = 5) The current output value is transferred to the actuator while the error is pending.
TRUE	TRUE	Substitute output value while error is pending	Switch to "Substitute output value with error monitoring" mode (State = 5) The value at SubstituteOutput is transferred to the actuator while the error is pending.

In manual mode, PID_Temp uses ManualValue as output value, unless ManualValue is invalid.

- If ManualValue is invalid, SubstituteOutput is used.
- If ManualValue and SubstituteOutput are invalid, Config.Output.Heat.PidLowerLimit is used.

The Error parameter indicates if an error is pending. When the error is no longer pending, Error = FALSE. The ErrorBits parameter shows which errors have occurred. ErrorBits is reset by a rising edge at Reset or ErrorAck.

8.3.3.2 Functional description of PID_Temp

Monitoring process value limits

You specify the high limit and low limit of the process value in the Config.InputUpperLimit and Config.InputLowerLimit tags. If the process value is outside these limits, an error occurs (ErrorBits = 0000001h).

You specify a high and low warning limit of the process value in the Config.InputUpperWarning and Config.InputLowerWarning tags. If the process value is outside these warning limits, a warning occurs (Warning = 0000040h), and the InputWarning_H or InputWarning_L output parameter changes to TRUE.

Limiting the setpoint

You specify a high limit and low limit of the setpoint in the Config.SetpointUpperLimit and Config.SetpointLowerLimit tags. PID_Temp automatically limits the setpoint to the process value limits. You can limit the setpoint to a smaller area. PID_Temp checks whether this area is within the process value limits. If the setpoint is outside these limits, the high or low limit is used as the setpoint, and output parameter SetpointLimit_H or SetpointLimit_L is set to TRUE.

The setpoint is limited in all operating modes.

Substitute setpoint

You can specify a substitute setpoint at the SubstituteSetpoint tag and activate it with SubstituteSetpointOn = TRUE. In this way, you can temporarily specify the setpoint directly, for example for a slave controller in a cascade, without having to change the user program. The limits set for the setpoint also apply to the substitute setpoint.

Heating and cooling

With the default setting, PID_Temp only uses the outputs for heating (OutputHeat, OutputHeat_PWM, OutputHeat_PER). The output value of the PID algorithm (PidOutputSum) is scaled and output at the outputs for heating. You specify with Config.Output.Heat.Select if OutputHeat_PWM or OutputHeat_PER is calculated. OutputHeat is always calculated.

With Config.ActivateCooling = TRUE, you can also activate the outputs for cooling (OutputCool, OutputCool_PWM, OutputCool_PER). Positive output values of the PID algorithm (PidOutputSum) are scaled and output at the outputs for heating. Negative output values of the PID algorithm are scaled and output at the outputs for cooling. You specify with Config.Output.Cool.Select if OutputCool_PWM or OutputCool_PER is calculated. OutputCool is always calculated.

Two methods are available to calculate the PID output value with activated cooling:

- Cooling factor (Config.AdvancedCooling = FALSE):

  The output value calculation for cooling takes place with the PID parameters for heating, taking into consideration the configurable cooling factor Config.CoolFactor. This method is suitable if the heating and cooling actuator have similar time responses but different gains. When you select this method, pretuning and fine tuning for cooling as well as the PID parameter set for cooling are not available. You can only execute the tuning for heating.

- PID parameter switching (Config.AdvancedCooling = TRUE):

  The output value calculation for cooling takes place by means of a separate PID parameter set. Based on the calculated output value and the control deviation, the PID algorithm decides whether the PID parameter for heating or cooling is used. This method is suitable if the heating and cooling actuator have different time responses and different gains. Pretuning and fine tuning for cooling are only available when you select this method.

Output value limits and scaling

Depending on the operating mode, the PID output value (PidOutputSum) is calculated automatically by the PID algorithm or defined by the manual value (ManualValue) or the configured substitute output value (SubstituteOutput).

The PID output value is limited according to the configuration:

- If cooling is deactivated (Config.ActivateCooling = FALSE), Config.Output.Heat.PidUpperLimit is the high limit and Config.Output.Heat.PidLowerLimit the low limit.
- If cooling is activated (Config.ActivateCooling = TRUE), Config.Output.Heat.PidUpperLimit is the high limit and Config.Output.Cool.PidLowerLimit the low limit.

The PID output value is scaled and output at the outputs for heating and cooling. Scaling can be defined separately for each output and is specified in the structures Config.Output.Heat or Config.Output.Cool with 2 value pairs each:

Output	Value pair	Parameter
OutputHeat	Value pair 1	High limit PID output value (heating) Config.Output.Heat.PidUpperLimit, Scaled high output value (heating) Con-fig.Output.Heat.UpperScaling
	Value pair 2	Low limit PID output value (heating) Config.Output.Heat.PidLowerLimit, Scaled low output value (heating) Con-fig.Output.Heat.LowerScaling
OutputHeat_PWM	Value pair 1	High limit PID output value (heating) Config.Output.Heat.PidUpperLimit, Scaled high PWM output value (heating) Config.Output.Heat.PwmUpperScaling

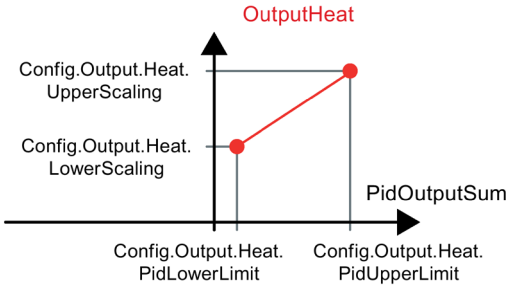
Output	Value pair	Parameter
	Value pair 2	Low limit PID output value (heating) Config.Output.Heat.PidLowerLimit, Scaled low PWM output value (heating) Config.Output.Heat.PwmLowerScaling
OutputHeat_PER	Value pair 1	High limit PID output value (heating) Config.Output.Heat.PidUpperLimit, Scaled high analog output value (heating) Config.Output.Heat.PerUpperScaling
	Value pair 2	Low limit PID output value (heating) Config.Output.Heat.PidLowerLimit, Scaled low analog output value (heating) Config.Output.Heat.PerLowerScaling
OutputCool	Value pair 1	Low limit PID output value (cooling) Config.Output.Cool.PidLowerLimit, Scaled high output value (cooling) Config.Output.Cool.UpperScaling
	Value pair 2	High limit PID output value (cooling) Config.Output.Cool.PidUpperLimit, Scaled low output value (cooling) Config.Output.Cool.LowerScaling
OutputCool_PWM	Value pair 1	Low limit PID output value (cooling) Config.Output.Cool.PidLowerLimit, Scaled high PWM output value (cooling) Config.Output.Cool.PwmUpperScaling
	Value pair 2	High limit PID output value (cooling) Config.Output.Cool.PidUpperLimit, Scaled low PWM output value (cooling) Config.Output.Cool.PwmLowerScaling
OutputCool_PER	Value pair 1	Low limit PID output value (cooling) Config.Output.Cool.PidLowerLimit, Scaled high analog output value (cooling) Config.Output.Cool.PerUpperScaling
	Value pair 2	High limit PID output value (cooling) Config.Output.Cool.PidUpperLimit, Scaled low analog output value (cooling) Config.Output.Cool.PerLowerScaling

If cooling is activated (Config.ActivateCooling = TRUE), Config.Output.Heat.PidLowerLimit must have the value 0.0.

Config.Output.Cool.PidUpperLimit must always have the value 0.0.

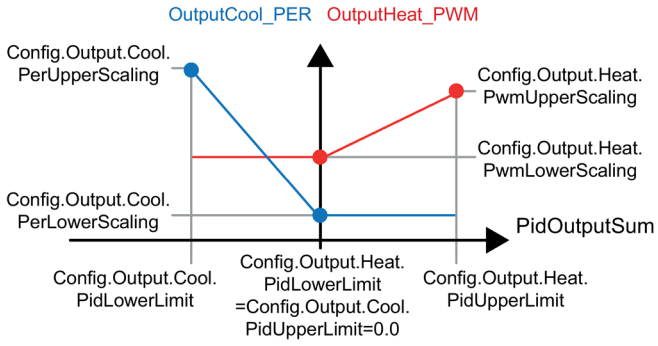
Example:

Output scaling when using output OutputHeat (cooling deactivated; Config.Output.Heat.PidLowerLimit may be unequal to 0.0):



Example:

Output scaling when using output OutputHeat_PWM and OutputCool_PER (cooling activated; Config.Output.Heat.PidLowerLimit must be 0.0):



With the exception of the "Inactive" operating mode, the value at an output is always located between its scaled high output value and scaled low output value, for example, for OutputHeat always between Config.Output.Heat.UpperScaling and Config.Output.Heat.LowerScaling.

If you want to limit the value at the associated output, you must also adjust these scaling values.

Cascading

PID_Temp supports you when you use cascade control (see: Program creation (Page 196)).

Substitute output value

In the event of an error, PID_Temp can output a substitute output value that you define at the SubstituteOutput tag. The substitute output value must be within the limits for the PID output value. The values at the outputs for heating and cooling resulting from the substitute output value are the result of the configured output scaling.

Monitoring signal validity

The values of the following parameters are monitored for validity when used:

- Setpoint
- SubstituteSetpoint
- Input
- Input_PER
- Disturbance
- ManualValue
- SubstituteOutput
- PID parameters in the structures Retain.CtrlParams.Heat and Retain.CtrlParams.Cool.

Monitoring the sampling time PID_Temp

Ideally, the sampling time is equivalent to the cycle time of the cyclic interrupt OB. The PID_Temp instruction measures the time interval between two calls. This is the current sampling time. On every switchover of operating mode and during the initial startup, the mean value is formed from the first 10 sampling times. Too great a difference between the current sampling time and this mean value triggers an error (Error = 0000800h).

The error occurs during tuning if:

- New mean value >= 1.1 x old mean value
- New mean value <= 0.9 x old mean value

The error occurs in automatic mode if:

- New mean value >= 1.5 x old mean value
- New mean value <= 0.5 x old mean value

If you deactivate the sampling time monitoring (CycleTime.EnMonitoring = FALSE), you can also call PID_Temp in OB1. You must then accept a lower control quality due to the deviating sampling time.

Sampling time of the PID algorithm

The controlled system needs a certain amount of time to respond to changes in the output value. It is therefore not advisable to calculate the output value in every cycle. The sampling time of the PID algorithm represents the time between two calculations of the output value. It is calculated during tuning and rounded to a multiple of the cycle time of the cyclic interrupt OB (sampling time PID_Temp). All other functions of the PID_Temp are executed at every call.

If cooling and PID parameter switching are activated, PID_Temp uses a separate sampling time of the PID algorithm for heating and cooling. In all other configurations, only the sampling time of the PID algorithm for heating is used.

If you use OutputHeat_PWM or OutputCool_PWM, the sampling time of the PID algorithm is used as time period of the pulse width modulation. The accuracy of the output signal is determined by the ratio of the PID algorithm sampling time to the cycle time of the OB. The cycle time should be no more than a tenth of the PID algorithm sampling time.

If the PID algorithm sampling time and thus the time period of the pulse width modulation is very high when you use OutputHeat_PWM or OutputCool_PWM, you can define a deviating shorter time period at the Config.Output.Heat.PwmPeriode or Config.Output.Cool.PwmPeriode parameters to improve the smoothness of the process value.

Control logic

PID_Temp can be used for heating or heating/cooling applications and always works with normal control logic.

An increase of the PID output value (PidOutputSum) is intended to increase the process value. The values at the outputs for heating and cooling resulting from the PID output value are the result of the configured output scaling.

An inverted control logic or negative proportional gain are not supported.

If you only need an output value for your application in which an increase is to reduce the process value (for example, discharge control), you can use PID_Compact with inverted control logic.

8.3.3.3 Input parameters of PID_Temp

Parameter	Data type	Default	Description
Setpoint	REAL	0.0	Setpoint of the PID controller in automatic mode Valid range of values: Config.SetpointUpperLimit ≥ Setpoint ≥ Config.SetpointLowerLimit Config.InputUpperLimit ≥ Setpoint ≥ Config.InputLowerLimit
Input	REAL	0.0	A tag of the user program is used as the source of the process value. If you are using the Input parameter, Config.InputPerOn = FALSE must be set.
Input_PER	INT	0	An analog input is used as the source of the process value. If you are using the Input_PER parameter, Config.InputPerOn = TRUE must be set.
Disturbance	REAL	0.0	Disturbance variable or precontrol value
ManualEnable	BOOL	FALSE	• A FALSE -> TRUE edge activates "Manual mode", State = 4, Mode remains unchanged. As long as ManualEnable = TRUE, you cannot change the operating mode via a rising edge at ModeActivate or use the commissioning dialog. • A TRUE -> FALSE edge activates the operating mode that is specified by Mode. We recommend that you change the operating mode using Mode and ModeActivate only.
ManualValue	REAL	0.0	Manual value This value is used in manual mode as PID output value (PidOutputSum). The values at the outputs for heating and cooling resulting from this manual value are the result of the configured output scaling (structures Config.Output.Heat and Config.Output.Cool). For controllers with activated cooling output (Config.ActivateCooling = TRUE), define: • a positive manual value to output the value at the outputs for heating • a negative manual value to output the value at the outputs for cooling The permitted value range is determined by the configuration. • Cooling output deactivated (Config.ActivateCooling = FALSE): Config.Output.Heat.PidUpperLimit ≥ ManualValue ≥ Config.Output.Heat.PidLowerLimit • Cooling output activated (Config.ActivateCooling = TRUE): Config.Output.Heat.PidUpperLimit ≥ ManualValue ≥ Config.Output.Cool.PidLowerLimit
ErrorAck	BOOL	FALSE	• FALSE -> TRUE edge ErrorBits and Warning are reset.

Parameter	Data type	Default	Description
Reset	BOOL	FALSE	Restarts the controller. • FALSE -> TRUE edge – Switch to "Inactive" mode – ErrorBits and Warning are reset. – Integral action is cleared (PID parameters are retained) • As long as Reset = TRUE, – PID_Tempremains in "Inactive" mode (State = 0). – you cannot change the operating mode with Mode and ModeActivate or ManualEnable – you cannot use the commissioning dialog. • TRUE -> FALSE edge PID_Temp switches to the operating mode that is saved in the Mode parameter.
ModeActivate	BOOL	FALSE	• FALSE -> TRUE edge PID_Temp switches to the operating mode that is saved at the Mode input.

8.3.3.4 Output parameters of PID_Temp

Parameter	Data type	Default	Description
ScaledInput	REAL	0.0	Scaled process value
OutputHeat	REAL	0.0	Output value (heating) in REAL format The PID output value (PidOutputSum) is scaled with the two value pairs Config.Output.Heat.PidUpperLimit, Config.Output.Heat.UpperScaling and Config.Output.Heat.PidLowerLimit, Config.Output.Heat.LowerScaling and output in REAL format at OutputHeat. OutputHeat is always calculated.
OutputCool	REAL	0.0	Output value (cooling) in REAL format The PID output value (PidOutputSum) is scaled with the two value pairs Config.Output.Cool.PidUpperLimit, Config.Output.Cool.LowerScaling and Config.Output.Cool.PidLowerLimit, Config.Output.Cool.UpperScaling and output in REAL format at OutputCool. OutputCool is only calculated if the cooling output is activated (Config.ActivateCooling = TRUE).
OutputHeat_PER	INT	0	Analog output value (heating) The PID output value (PidOutputSum) is scaled with the two value pairs Config.Output.Heat.PidUpperLimit, Config.Output.Heat.PerUpperScaling and Config.Output.Heat.PidLowerLimit, Config.Output.Heat.PerLowerScaling and output as analog value at OutputHeat_PER. OutputHeat_PER is only calculated if Config.Output.Heat.Select = 2.
OutputCool_PER	INT	0	Analog output value (cooling) The PID output value (PidOutputSum) is scaled with the two value pairs Config.Output.Cool.PidUpperLimit, Config.Output.Cool.PerLowerScaling and Config.Output.Cool.PidLowerLimit, Config.Output.Cool.PerUpperScaling and output as analog value at OutputCool_PER. OutputCool_PER is only calculated if the cooling output is activated (Config.ActivateCooling = TRUE) and Config.Output.Cool.Select = 2.
OutputHeat_PWM	BOOL	FALSE	Pulse-width modulated output value (heating) The PID output value (PidOutputSum) is scaled with the two value pairs Config.Output.Heat.PidUpperLimit, Config.Output.Heat.PwmUpperScaling and Config.Output.Heat.PidLowerLimit, Config.Output.Heat.PwmLowerScaling and output as pulse-width modulated value (variable switch on and switch off times) at OutputHeat_PWM. OutputHeat_PWM is only calculated if Config.Output.Heat.Select = 1.
OutputCool_PWM	BOOL	FALSE	Pulse-width modulated output value (cooling) The PID output value (PidOutputSum) is scaled with the two value pairs Config.Output.Cool.PidUpperLimit, Config.Output.Cool.PwmLowerScaling and Config.Output.Cool.PidLowerLimit, Config.Output.Cool.PwmUpperScaling and output as pulse-width modulated value (variable switch on and switch off times) at OutputCool_PWM. OutputCool_PWM is only calculated if the cooling output is activated (Config.ActivateCooling = TRUE) and Config.Output.Cool.Select = 1.
SetpointLimit_H	BOOL	FALSE	If SetpointLimit_H = TRUE, the absolute setpoint high limit is reached (Setpoint ≥ Config.SetpointUpperLimit) or Setpoint ≥ Config.InputUpperLimit. The setpoint high limit is the minimum of Config.SetpointUpperLimit and Config.InputUpperLimit.

Parameter	Data type	Default	Description
SetpointLimit_L	BOOL	FALSE	If SetpointLimit_L = TRUE, the absolute setpoint low limit is reached (Setpoint ≤ Config.SetpointLowerLimit) or Setpoint ≤ Config.InputLowerLimit. The setpoint low limit is the maximum of Config.SetpointLowerLimit and Config.InputLowerLimit.
InputWarning_H	BOOL	FALSE	If InputWarning_H = TRUE, the process value has reached or exceeded the warning high limit (ScaledInput ≥ Config.InputUpperWarning).
InputWarning_L	BOOL	FALSE	If InputWarning_L = TRUE, the process value has reached or fallen below the warning low limit (ScaledInput ≤ Config.InputLowerWarning).
State	INT	0	The PID_Temp state and mode parameters (Page 416) shows the current operating mode of the PID controller. You can change the operating mode using the input parameter Mode and a rising edge at ModeActivate. For pretuning and fine tuning, you specify with Heat.EnableTuning and Cool.EnableTuning whether tuning takes place for heating or cooling. • State = 0: Inactive • State = 1: Pretuning • State = 2: Fine tuning • State = 3: Automatic mode • State = 4: Manual mode • State = 5: Substitute output value with error monitoring
Error	BOOL	FALSE	If Error = TRUE, at least one error message is pending in this cycle.
ErrorBits	DWORD	DW#16#0	The PID_Temp ErrorBits parameter (Page 424) shows the pending error messages. ErrorBits is retentive and is reset with a rising edge at Reset or ErrorAck.

8.3.3.5 PID_Temp in/out parameters

Parameter	Data type	Default	Description
Mode	INT	4	At Mode, specify the operating mode to which PID_Temp is to switch. Options are: • Mode = 0: Inactive • Mode = 1: Pretuning • Mode = 2: Fine tuning • Mode = 3: Automatic mode • Mode = 4: Manual mode The operating mode is activated by: • Rising edge at ModeActivate • Falling edge at Reset • Falling edge at ManualEnable • Cold restart of CPU if RunModeByStartup = TRUE For pretuning and fine tuning, you specify with Heat.EnableTuning and Cool.EnableTuning whether tuning takes place for heating or cooling. Mode is retentive. A detailed description of the operating modes can be found in State and Mode parameters (Page 416).

Parameter	Data type	Default	Description
Master	DWORD	DW#16#0	Interface for cascade control If this PID_Temp instance is used as slave controller in a cascade (Config.Cascade.IsSlave = TRUE), assign the Master parameter at the instruction call with the Slave parameter of the master controller. Example: Call of a slave controller "PID_Temp_2" with master controller "PID_Temp_1" in SCL: `"PID_Temp_2"(Master := "PID_Temp_1".Slave, Setpoint := "PID_Temp_1".OutputHeat);` You use this interface to exchange slave controller information about operating mode, limit and substitute setpoint with your master controller. Keep in mind that the call of the master controller has to take place before the call of the slave controller in the same cyclic interrupt OB. Assignment: • Bits 0 to 15: Unassigned • Bits 16 to 23 – Limit counter: A slave controller whose output value is limited increments this counter. Depending on the configured number of slaves (Config.Cascade.CountSlaves) and of the anti-windup mode (Config.Cascade.AntiWindUpMode), the master controller reacts accordingly. • Bit 24 – Automatic mode of the slave controllers: TRUE, if all slave controllers are in automatic mode • Bit 25 – Substitute setpoint of the slave controllers: TRUE, if a slave controller has activated the substitute setpoint (SubstituteSetpointOn = TRUE)
Slave	DWORD	DW#16#0	Interface for cascade control You use this interface to exchange slave controller information about operating mode, limit and substitute setpoint with your master controller. See description of Master parameter

See also

PID_Temp state and mode parameters (Page 416)

Program creation (Page 196)

Cascade control with PID_Temp (Page 194)

8.3.3.6 PID_Temp static tags

You must not change tags that are not listed. These are used for internal purposes only.

Tag	Data type	Default	Description
IntegralResetMode	Int	1	The IntegralResetMode tag determines the default setting of the integral action PIDCtrl.IOutputOld when you change the operating mode from "Inactive" to "Automatic mode". This setting only works for one cycle. • IntegralResetMode = 0: Smoothing The value is assigned in such a way that the switchover is bumpless. • IntegralResetMode = 1: Deleting The value is cleared. Any control deviation will cause a jump change of the output value. • IntegralResetMode = 2: Holding The value is not changed. You can define a new value using the user program. • IntegralResetMode = 3: Pre-assigning The value is automatically pre-assigned as if PidOutputSum = OverwriteInitialOutputValue in the last cycle. This setting is useful, for example, for an override controller.
OverwriteInitialOutputValue	REAL	0.0	If IntegralResetMode = 3, the value of PIDCtrl.IOutputOld is pre-assigned as if "PidOutputSum" = "OverwriteInitialOutputValue" in the last cycle.
RunModeByStartup	BOOL	TRUE	Activate operating mode at Mode parameter after CPU restart • If RunModeByStartup = TRUE, PID_Temp starts in the operating mode saved in the Mode parameter after CPU startup. • If RunModeByStartup = FALSE, PID_Temp remains in "Inactive" mode after CPU startup.
LoadBackUp	BOOL	FALSE	If LoadBackUp = TRUE, the last set of PID parameters is reloaded from the CtrlParamsBackUp structure. The set was saved prior to the last tuning. LoadBackUp is automatically set back to FALSE. The acceptance is bumpless.
SetSubstituteOutput	BOOL	TRUE	Selection of the output value while an error is pending (State = 5): • If SetSubstituteOutput = TRUE and ActivateRecoverMode = TRUE, the configured substitute output value SubstituteOutput is output as PID output value as long as an error is pending. • If SetSubstituteOutput = FALSE and ActivateRecoverMode = TRUE, the actuator remains at the current PID output value as long as an error is pending. • If ActivateRecoverMode = FALSE, SetSubstituteOutput is not effective. • If SubstituteOutput is invalid (ErrorBits = 0020000h), the substitute output value cannot be output. In this case, the low limit of the PID output value for heating (Config.Output.Heat.PidLowerLimit) is used as PID output value.

Tag	Data type	Default	Description
PhysicalUnit	INT	0	Unit of measurement of the process value and setpoint, e.g., ºC, or ºF. This parameter is used for display in the editors and does not influence the control algorithm.
PhysicalQuantity	INT	0	Physical quantity of the process value and setpoint, e.g., temperature. This parameter is used for display in the editors and does not influence the control algorithm.
ActivateRecoverMode	BOOL	TRUE	The ActivateRecoverMode tag determines the reaction to error.
Warning	DWORD	0	The Warning tag shows the warnings since Reset = TRUE or ErrorAck =TRUE. Warning is retentive.
Progress	REAL	0.0	Progress of current tuning phase as a percentage (0.0 - 100.0)
CurrentSetpoint	REAL	0.0	CurrentSetpoint always displays the currently effective setpoint. This value is frozen during tuning.
CancelTuningLevel	REAL	10.0	Permissible fluctuation of setpoint during tuning. Tuning is not canceled until: • Setpoint > CurrentSetpoint + CancelTuningLevel or • Setpoint < CurrentSetpoint - CancelTuningLevel
SubstituteOutput	REAL	0.0	The substitute output value is used as PID output value as long as the following conditions are met: • One or more errors are pending in automatic mode for which ActivateRecoverMode is in effect • SetSubstituteOutput = TRUE • ActivateRecoverMode = TRUE The values at the outputs for heating and cooling resulting from the substitute output value are the result of the configured output scaling (structures Config.Output.Heat and Config.Output.Cool). For controllers with activated cooling output (Config.ActivateCooling = TRUE), define: • a positive substitute output value to output the value at the outputs for heating • a negative substitute output value to output the value at the outputs for cooling The permitted value range is determined by the configuration. • Cooling output deactivated (Config.ActivateCooling = FALSE): Config.Output.Heat.PidUpperLimit ≥ SubstituteOutput ≥ Config.Output.Heat.PidLowerLimit • Cooling output activated (Config.ActivateCooling = TRUE): Config.Output.Heat.PidUpperLimit ≥ SubstituteOutput ≥ Config.Output.Cool.PidLowerLimit

Tag	Data type	Default	Description
PidOutputSum	REAL	0.0	PID output value PidOutputSum displays the output value of the PID algorithm. Depending on the operating mode, it is either calculated automatically or defined by the manual value or the configured substitute output value. The values at the outputs for heating and cooling resulting from the PID output value are the result of the configured output scaling (structures Config.Output.Heat and Config.Output.Cool). The PidOutputSum is limited as defined in the configuration. • Cooling output deactivated (Config.ActivateCooling = FALSE): Config.Output.Heat.PidUpperLimit ≥ PidOutputSum ≥ Config.Output.Heat.PidLowerLimit • Cooling output activated (ConfigActivateCooling = TRUE): Config.Output.Heat.PidUpperLimit ≥ PidOutputSum ≥ Config.Output.Cool.PidLowerLimit
PidOutputOffsetHeat	REAL	0.0	Offset of the PID output value heating PidOutputOffsetHeat is added to the value that results from PidOutputSum for the heating branch. Enter a positive value for PidOutputOffsetHeat to receive a positive offset at the outputs for heating. The resulting values at the outputs for heating are the result of the configured output scaling (Config.Output.Heat structure). This offset can be used for actuators which need a fixed minimum value, for example, fans with minimum speed.
PidOutputOffsetCool	REAL	0.0	Offset of the PID output value cooling PidOutputOffsetCool is added to the value that results from PidOutputSum for the cooling branch. Enter a negative value for PidOutputOffsetCool to receive a positive offset at the outputs for cooling. The resulting values at the outputs for cooling are the result of the configured output scaling (Config.Output.Cool structure). This offset can be used for actuators which need a fixed minimum value, for example, fans with minimum speed.
SubstituteSetpointOn	BOOL	FALSE	Activates the substitute setpoint as controller setpoint. • FALSE = the Setpoint parameter is used. • TRUE = the SubstituteSetpoint parameter is used as setpoint SubstituteSetpointOn can be used to specify the setpoint of a slave controller in a cascade directly without having to change the user program.
SubstituteSetpoint	REAL	0.0	Substitute setpoint If SubstituteSetpointOn = TRUE, the SubstituteSetpoint parameter is used as setpoint. Valid range of values: Config.SetpointUpperLimit ≥ SubstituteSetpoint ≥ Config.SetpointLowerLimit, Config.InputUpperLimit ≥ SubstituteSetpoint ≥ Config.InputLowerLimit

Tag	Data type	Default	Description
Disable-Cooling	BOOL	FALSE	DisableCooling = TRUE deactivates the cooling branch for heating/cooling controllers (Config.ActivateCooling = TRUE) in Automatic mode by setting PidOutputSum to 0.0 as low limit. PidOutputOffsetCool and the output scaling for the cooling outputs remain active. DisableCooling can be used for tuning of multi-zone applications to temporarily deactivate the cooling branch as long as all controllers have not completed their tuning yet. This parameter is set/reset by the user manually and is not automatically reset by the PID_Temp instruction.
All-SlaveAuto-maticState	BOOL	FALSE	If this PID_Temp instance is used as master controller in a cascade (Config.Cascade.IsMaster = TRUE), AllSlaveAutomaticState = TRUE indicates that all slave controllers are in automatic mode. Tuning, manual mode or automatic mode of the master controller can only be executed accurately if all slave controllers are in automatic mode. AllSlaveAutomaticState is only determined if you interconnect the master controller and slave controller with the master and slave parameters. For details, see the Master parameter.
NoSlave-Substi-tuteSetpoint	BOOL	FALSE	If this PID_Temp instance is used as master controller in a cascade (Config.Cascade.IsMaster = TRUE), NoSlaveSubstituteSetpoint = TRUE indicates that no slave controller has activated its substitute setpoint. Tuning, manual mode or automatic mode of the master controller can only be executed accurately if no slave controller has activated its substitute setpoint. NoSlaveSubstituteSetpoint is only determined if you interconnect the master controller and slave controller with the master and slave parameters. For details, see the Master parameter.
Heat.Enable Tuning	BOOL	TRUE	Enabling of tuning for heating Heat.EnableTuning must be set for the following tunings (at the same time or prior to the start with Mode and ModeActivate): • Pretuning heating • Pretuning heating and cooling • Fine tuning heating This parameter is not automatically reset by the PID_Temp instruction.
Cool.Enable Tuning	BOOL	FALSE	Enabling of tuning for cooling Cool.EnableTuning must be set for the following tunings (simultaneously with or prior to the start with Mode and ModeActivate): • Pretuning cooling • Pretuning heating and cooling • Fine tuning cooling Only effective if the cooling output and PID parameter switching are activated ("Config.ActivateCooling" = TRUE and "Config.AdvancedCooling" = TRUE). This parameter is not automatically reset by the PID_Temp instruction.
Con-fig.InputPer On	BOOL	TRUE	If InputPerOn = TRUE, the Input_PER parameter is used for detecting the process value. If InputPerOn = FALSE, the Input parameter is used.

Tag	Data type	Default	Description
Config.InputUpperLimit	REAL	120.0	High limit of the process value Input and Input_PER are monitored to ensure adherence to this limit. If the limit is exceeded, an error is output and the reaction is determined by ActivateRecoverMode. At the I/O input, the process value can be a maximum of 18% higher than the nominal range (overrange). This means the limit cannot be exceeded when you use an I/O input with the pre-setting for high limit and process value scaling. When pretuning is started, the difference between high and low limit of the process value is checked to determine whether the distance between setpoint and process value meets the necessary requirements. InputUpperLimit > InputLowerLimit
Config.InputLowerLimit	REAL	0.0	Low limit of the process value Input and Input_PER are monitored to ensure adherence to this limit. If the limit is undershot, an error is output and the reaction is determined by ActivateRecoverMode. InputLowerLimit < InputUpperLimit
Config.InputUpperWarning	REAL	3.402822e+38	Warning high limit of the process value Input and Input_PER are monitored to ensure adherence to this limit. If the limit is exceeded, a warning is output at the Warning parameter. • If you set InputUpperWarning outside the process value limits, the configured absolute process value high limit is used as the warning high limit. • If you configure InputUpperWarning within the process value limits, this value is used as the warning high limit. InputUpperWarning > InputLowerWarning
Config.InputLowerWarning	REAL	-3.402822e+38	Warning low limit of the process value Input and Input_PER are monitored to ensure adherence to this limit. If the limit is undershot, a warning is output at the Warning parameter. • If you set InputLowerWarning outside the process value limits, the configured absolute process value low limit is used as the warning low limit. • If you configure InputLowerWarning within the process value limits, this value is used as the warning low limit. InputLowerWarning < InputUpperWarning
Config.SetpointUpperLimit	REAL	3.402822e+38	High limit of setpoint Setpoint and SubstituteSetpoint are monitored to ensure adherence to this limit. If the limit is exceeded, a warning is output at the Warning parameter. • If you configure SetpointUpperLimit outside the process value limits, the configured absolute process value high limit is used as the setpoint high limit. • If you configure SetpointUpperLimit within the process value limits, this value is used as the setpoint high limit. SetpointUpperLimit > SetpointLowerLimit

Tag	Data type	Default	Description
Config.SetpointLowerLimit	REAL	-3.402822e+38	Low limit of the setpoint Setpoint and SubstituteSetpoint are monitored to ensure adherence to this limit. If the limit is undershot, a warning is output at the Warning parameter. • If you set SetpointLowerLimit outside the process value limits, the configured process value absolute low limit is used as the setpoint low limit. • If you configure SetpointLowerLimit within the process value limits, this value is used as the setpoint low limit. SetpointLowerLimit < SetpointUpperLimit
Config.ActivateCooling	BOOL	FALSE	Activate cooling output • Config.ActivateCooling = FALSE Only the outputs for heating are used. • Config.ActivateCooling = TRUE The outputs for heating and cooling are used. If you are using the cooling output, the controller must not be configured as master controller (Config.Cascade.IsMaster must be FALSE) .
Config.AdvancedCooling	BOOL	TRUE	Method for heating/cooling • Cooling factor (Config.AdvancedCooling = FALSE) The output value calculation for cooling takes place with the PID parameters for heating (Retain.CtrlParams.Heat structure) taking into consideration the configurable cooling factor Config.CoolFactor. This method is suitable if the heating and cooling actuator have similar time responses but different gains. Pretuning and fine tuning for cooling are not available when you select this method. You can only execute the tuning for heating. • PID parameter switching (Config.AdvancedCooling = TRUE) The output value calculation for cooling takes place by means of a separate PID parameter set (Retain.CtrlParams.Cool structure). This method is suitable if the heating and cooling actuator have different time responses and different gains. Pretuning and fine tuning for cooling are only available when you select this method (Mode = 1 or 2, Cool.EnableTuning = TRUE). Config.AdvancedCooling is only calculated if the cooling output is activated (Config.ActivateCooling = TRUE).

Tag	Data type	Default	Description
Config.CoolFactor	REAL	1.0	Cooling factor If Config.AdvancedCooling = FALSE, Config.CoolFactor is considered as factor in the calculation of the output value for cooling. Different gains of the heating and cooling actuator can be considered in this way. Config.CoolFactor is not set automatically or adjusted during tuning. You must correctly configure Config.CoolFactor manually with the ratio "heating actuator gain/cooling actuator gain". Example: Config.CoolFactor = 2.0 means that the gain of the heating actuator is twice as high as the gain of the cooling actuator. Config.CoolFactor is only effective if the cooling output is activated (Config.ActivateCooling = TRUE) and cooling factor is selected as method for heating/cooling (Config.AdvancedCooling = FALSE). Config.CoolFactor > 0.0
Config.InputScaling.UpperPointIn	REAL	27648.0	Scaling Input_PER high Input_PER is scaled based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn. Only effective if Input_PER is used for process value detection (Config.InputPerOn = TRUE). UpperPointIn > LowerPointIn
Config.InputScaling.LowerPointIn	REAL	0.0	Scaling Input_PER low Input_PER is scaled based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn. Only effective if Input_PER is used for process value detection (Config.InputPerOn = TRUE). LowerPointIn < UpperPointIn
Config.InputScaling.UpperPointOut	REAL	100.0	Scaled high process value Input_PER is scaled based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn. Only effective if Input_PER is used for process value detection (Config.InputPerOn = TRUE). UpperPointOut > LowerPointOut
Config.InputScaling.LowerPointOut	REAL	0.0	Scaled low process value Input_PER is scaled based on the two value pairs UpperPointOut, UpperPointIn and LowerPointOut, LowerPointIn. Only effective if Input_PER is used for process value detection (Config.InputPerOn = TRUE). LowerPointOut < UpperPointOut
Config.Output.Heat.Select	INT	1	Selecting the output value for heating Config.Output.Heat.Select specifies which outputs are used for heating: • Heat.Select = 0 - OutputHeat is used • Heat.Select = 1 - OutputHeat and OutputHeat_PWM are used • Heat.Select = 2 -OutputHeat and OutputHeat_PER are used Outputs that are not used are not calculated and remain at their default value.

Tag	Data type	Default	Description
Config.Output.Heat.PwmPeriode	REAL	0.0	Time period of the pulse width modulation (PWM) for heating (OutputHeat_PWM output) in seconds: • Heat.PwmPeriode = 0.0 The sampling time of the PID algorithm for heating (Retain.CtrlParams.Heat.Cycle) is used as time period of the PWM. • Heat.PwmPeriode > 0.0 The value is rounded off to an integer multiple of the PID_Temp sampling time (CycleTime.Value) and used as time period of the PWM. This setting can be used to improve the smoothing of the process value with a long sampling time of the PID algorithm. The value must meet the following conditions: – Heat.PwmPeriode ≤ Retain.CtrlParams.Heat.Cycle, – Heat.PwmPeriode > Config.Output.Heat.MinimumOnTime – Heat.PwmPeriode > Config.Output.Heat.MinimumOffTime
Config.Output.Heat.PidUpperLimit	REAL	100.0	High limit of the PID output value for heating The PID output value (PidOutputSum) is limited to the high limit. Heat.PidUpperLimit forms a value pair together with the following parameters for scaling of the PID output value (PidOutputSum) to the outputs for heating: • Heat.UpperScaling for OutputHeat • Heat.PwmUpperScaling for OutputHeat_PWM • Heat.PerUpperScaling for OutputHeat_PER If you want to limit the value at the associated output, you must also adjust these scaling values. Heat.PidUpperLimit > Heat.PidLowerLimit
Config.Output.Heat.PidLowerLimit	REAL	0.0	Low limit of the PID output value for heating For controllers with **deactivated** cooling output (Config.ActivateCooling = FALSE), the PID output value (PidOutputSum) is limited to this low limit. For controllers with **activated** cooling output (Config.ActivateCooling = TRUE), the value must be 0.0. Heat.PidLowerLimit forms a value pair together with the following parameters for scaling of the PID output value (PidOutputSum) to the outputs for heating: • Heat.LowerScaling for OutputHeat • Heat.PwmLowerScaling for OutputHeat_PWM • Heat.PerLowerScaling for OutputHeat_PER If you want to limit the value at the associated output, you must also adjust these scaling values. The permitted value range is determined by the configuration. • Cooling output deactivated (Config.ActivateCooling = FALSE): Heat.PidLowerLimit < Heat.PidUpperLimit • Cooling output activated (Config.ActivateCooling = TRUE): Heat.PidLowerLimit = 0.0

Tag	Data type	Default	Description
Config.Output.Heat.UpperScaling	REAL	100.0	Scaled high output value for heating Heat.UpperScaling and Heat.PidUpperLimit form a value pair for scaling of the PID output value (PidOutputSum) to the output value for heating (OutputHeat). The OutputHeat value is always located between Heat.UpperScaling and Heat.LowerScaling. Heat.UpperScaling ≠ Heat.LowerScaling
Config.Output.Heat.LowerScaling	REAL	0.0	Scaled low output value for heating Heat.LowerScaling and Heat.PidLowerLimit form a value pair for scaling of the PID output value (PidOutputSum) to the output value for heating (OutputHeat). The OutputHeat value is always located between Heat.UpperScaling and Heat.LowerScaling. Heat.UpperScaling ≠ Heat.LowerScaling
Config.Output.Heat.PwmUpperScaling	REAL	100.0	Scaled high PWM output value for heating Heat.PwmUpperScaling and Heat.PidUpperLimit form a value pair for scaling of the PID output value (PidOutputSum) to the pulse-width modulated output value for heating (OutputHeat_PWM). The OutputHeat_PWM value is always located between Heat.PwmUpperScaling and Heat.PWMLowerScaling. Heat.PwmUpperScaling is only effective if OutputHeat_PWM is selected as output for heating (Heat.Select = 1) 100.0 ≥ Heat.PwmUpperScaling ≥ 0.0 Heat.PwmUpperScaling ≠ Heat.PwmLowerScaling
Config.Output.Heat.PwmLowerScaling	REAL	0.0	Scaled low PWM output value for heating Heat.PwmLowerScaling and Heat.PidLowerLimit form a value pair for scaling of the PID output value (PidOutputSum) to the pulse-width modulated output value for heating (OutputHeat_PWM). The OutputHeat_PWM value is always located between Heat.PwmUpperScaling and Heat.PwmLowerScaling. Heat.PwmLowerScaling is only effective if OutputHeat_PWM is selected as output for heating (Heat.Select = 1) 100.0 ≥ Heat.PwmLowerScaling ≥ 0.0 Heat.PwmUpperScaling ≠ Heat.PwmLowerScaling
Config.Output.Heat.PerUpperScaling	REAL	27648.0	Scaled high analog output value for heating Heat.PerUpperScaling and Heat.PidUpperLimit form a value pair for scaling of the PID output value (PidOutputSum) to the analog output value for heating (OutputHeat_PER). The OutputHeat_PER value is always located between Heat.PerUpperScaling and Heat.PerLowerScaling. Heat.PerUpperScaling is only effective if OutputHeat_PER is selected as output for heating (Heat.Select = 2) 32511.0 ≥ Heat.PerUpperScaling ≥ -32512.0 Heat.PerUpperScaling ≠ Heat.PerLowerScaling

Tag	Data type	Default	Description
Config.Output.Heat.PerLowerScaling	REAL	0.0	Scaled low analog output value for heating Heat.PerLowerScaling and Heat.PidLowerLimit form a value pair for scaling of the PID output value (PidOutputSum) to the analog output value for heating (OutputHeat_PER). The OutputHeat_PER value is always located between Heat.PerUpperScaling and Heat.PerLowerScaling. Heat.PerLowerScaling is only effective if OutputHeat_PER is selected as output for heating (Heat.Select = 2) 32511.0 ≥ Heat.PerLowerScaling ≥ -32512.0 Heat.PerUpperScaling ≠ Heat.PerLowerScaling
Config.Output.Heat.MinimumOnTime	REAL	0.0	Minimum on time of the pulse width modulation for heating (OutputHeat_PWM output) A PWM pulse is never shorter than this value. The value is rounded off to: Heat.MinimumOnTime = n × CycleTime.Value Heat.MinimumOnTime is only effective if the output for heating OutputHeat_PWM is selected (Heat.Select = 1)". 100000.0 ≥ Heat.MinimumOnTime ≥ 0.0
Config.Output.Heat.MinimumOffTime	REAL	0.0	Minimum off time of the pulse width modulation for heating (OutputHeat_PWM output) A PWM pause is never shorter than this value. The value is rounded off to: Heat.MinimumOffTime = n × CycleTime.Value Heat.MinimumOffTime is only effective if the output for heating OutputHeat_PWM is selected (Heat.Select = 1)". 100000.0 ≥ Heat.MinimumOffTime ≥ 0.0
Config.Output.Cool.Select	INT	1	Selecting the output value for cooling Config.Output.Cool.Select specifies which outputs are used for cooling: • Cool.Select = 0 - OutputCool is used • Cool.Select = 1 -OutputCool and OutputCool_PWM are used • Cool.Select = 2 - OutputCool and OutputCool_PER are used Outputs that are not used are not calculated and remain at their default value. Only effective if the cooling output is activated (Config.ActivateCooling = TRUE).

Tag	Data type	Default	Description
Config.Output.Cool.PwmPeriode	REAL	0.0	Time period of the pulse width modulation for cooling (OutputCool_PWM output) in seconds: • Cool.PwmPeriode = 0.0 and Config.AdvancedCooling = FALSE: sampling time of the PID algorithm for heating (Retain.CtrlParams.Heat.Cycle) is used as time period of the PWM. • Cool.PwmPeriode = 0.0 and Config.AdvancedCooling = TRUE: The sampling time of the PID algorithm for cooling (Retain.CtrlParams.Cool.Cycle) is used as time period of the PWM. • Cool.PwmPeriode > 0.0: The value is rounded off to an integer multiple of the PID_Temp sampling time (CycleTime.Value) and used as time period of the PWM. This setting can be used to improve the smoothing of the process value with a long sampling time of the PID algorithm. The value must meet the following conditions: – Cool.PwmPeriode ≤ Retain.CtrlParams.Cool.Cycle or Retain.CtrlParams.Heat.Cycle – Cool.PwmPeriode > Config.Output.Cool.MinimumOnTime – Cool.PwmPeriode > Config.Output.Cool.MinimumOffTime Only effective if the cooling output is activated (Config.ActivateCooling = TRUE).
Config.Output.Cool.PidUpperLimit	REAL	0.0	High limit of the PID output value for cooling The value must be 0.0. Cool.PidUpperLimit forms a value pair together with the following parameters for scaling of the PID output value (PidOutputSum) to the outputs for cooling: • Cool.LowerScaling for OutputCool • Cool.PwmLowerScaling for OutputCool_PWM • Cool.PerLowerScaling for OutputCool_PER If you want to limit the value at the associated output, you must also adjust these scaling values. Only effective if the cooling output is activated (Config.ActivateCooling = TRUE). Cool.PidUpperLimit = 0.0

Tag	Data type	Default	Description
Config.Output.Cool.PidLowerLimit	REAL	-100.0	Low limit of the PID output value for cooling For controllers with activated cooling output (Config.ActivateCooling = TRUE), the PID output value (PidOutputSum) is limited to this low limit. Cool.PidLowerLimit forms a value pair together with the following parameters for scaling of the PID output value (PidOutputSum) to the outputs for cooling: • Cool.UpperScaling for OutputCool • Cool.PwmUpperScaling for OutputCool_PWM • Cool.PerUpperScaling for OutputCool_PER If you want to limit the value at the associated output, you must also adjust these scaling values. Only effective if the cooling output is activated (Config.ActivateCooling = TRUE). Cool.PidLowerLimit < Cool.PidUpperLimit
Config.Output.Cool.UpperScaling	REAL	100.0	Scaled high output value for cooling Cool.UpperScaling and Cool.PidLowerLimit form a value pair for scaling of the PID output value (PidOutputSum) to the output value for cooling (OutputCool). The OutputCool value is always located between Cool.UpperScaling and Cool.LowerScaling. Only effective if the cooling output is activated (Config.ActivateCooling = TRUE). Cool.UpperScaling ≠ Cool.LowerScaling
Config.Output.Cool.LowerScaling	REAL	0.0	Scaled low output value for cooling Cool.LowerScaling and Cool.PidUpperLimit form a value pair for scaling of the PID output value (PidOutputSum) to the output value for cooling (OutputCool). The OutputCool value is always located between Cool.UpperScaling and Cool.LowerScaling. Only effective if the cooling output is activated (Config.ActivateCooling = TRUE). Cool.UpperScaling ≠ Cool.LowerScaling
Config.Output.Cool.PwmUpperScaling	REAL	100.0	Scaled high PWM output value for cooling Cool.PwmUpperScaling and Cool.PidLowerLimit form a value pair for scaling of the PID output value (PidOutputSum) to the pulse-width modulated output value for cooling (OutputCool_PWM). The OutputCool_PWM value is always located between Cool.PwmUpperScaling and Cool.PwmLowerScaling. Cool.PwmUpperScaling is only effective if the cooling output is activated (Config.ActivateCooling = TRUE) and OutputCool_PWM is selected as output for cooling (Cool.Select = 1). 100.0 ≥ Cool.PwmUpperScaling ≥ 0.0 Cool.PwmUpperScaling ≠ Cool.PwmLowerScaling

Tag	Data type	Default	Description
Config.Output.Cool.PwmLowerScaling	REAL	0.0	Scaled low PWM output value for cooling Cool.PwmLowerScaling and Cool.PidUpperLimit form a value pair for scaling of the PID output value (PidOutputSum) to the pulse-width modulated output value for cooling (OutputCool_PWM). The OutputCool_PWM value is always located between Cool.PwmUpperScaling and CoolPwm.LowerScaling. Cool.PwmLowerScaling is only effective if the cooling output is activated (Config.ActivateCooling = TRUE) and OutputCool_PWM is selected as output for cooling (Cool.Select = 1). 100.0 ≥ Cool.PwmLowerScaling ≥ 0.0 Cool.PwmUpperScaling ≠ Cool.PwmLowerScaling
Config.Output.Cool.PerUpperScaling	REAL	27648.0	Scaled high analog output value for cooling Cool.PerUpperScaling and Cool.PidLowerLimit form a value pair for scaling of the PID output value (PidOutputSum) to the analog output value for cooling (OutputCool_PER). The OutputCool_PER value is always located between Cool.PerUpperScaling and Cool.PerLowerScaling. Cool.PerUpperScaling is only effective if the cooling output is activated (Config.ActivateCooling = TRUE) and OutputCool_PER is selected as output for cooling (Cool.Select = 2). 32511.0 ≥ Cool.PerUpperScaling ≥ -32512.0 Cool.PerUpperScaling ≠ Cool.PerLowerScaling
Config.Output.Cool.PerLowerScaling	REAL	0.0	Scaled low analog output value for cooling Cool.PerLowerScaling and Cool.PidUpperLimit form a value pair for scaling of the PID output value (PidOutputSum) to the analog output value for cooling (OutputCool_PER). The OutputCool_PER value is always located between Cool.PerUpperScaling and Cool.PerLowerScaling. Cool.PerLowerScaling is only effective if the cooling output is activated (Config.ActivateCooling = TRUE) and OutputCool_PER is selected as output for cooling (Cool.Select = 2). 32511.0 ≥ Cool.PerLowerScaling ≥ -32512.0 Cool.PerUpperScaling ≠ Cool.PerLowerScaling
Config.Output.Cool.MinimumOnTime	REAL	0.0	Minimum on time of the pulse width modulation for cooling (OutputCool_PWM output) A PWM pulse is never shorter than this value. The value is rounded off to: Cool.MinimumOnTime = n × CycleTime.Value Cool.MinimumOnTime is only effective if the output for cooling OutputCool_PWM is selected (Cool.Select = 1). Only effective if the cooling output is activated (Config.ActivateCooling = TRUE). 100000.0 ≥ Cool.MinimumOnTime ≥ 0.0

Tag	Data type	Default	Description
Config.Output.Cool.MinimumOffTime	REAL	0.0	Minimum off time of the pulse width modulation for cooling (OutputCool_PWM output) A PWM pause is never shorter than this value. The value is rounded off to: Cool.MinimumOffTime = n × CycleTime.Value Cool.MinimumOffTime is only effective if the output for cooling OutputCool_PWM is selected (Cool.Select = 1). Only effective if the cooling output is activated (Config.ActivateCooling = TRUE). 100000.0 ≥ Cool.MinimumOffTime ≥ 0.0
If you are using PID_Temp in a cascade, the master controller and slave controller exchange information via the master and slave parameters. You need to make the interconnection. For details, see the Master parameter.			
Config.Cascade.IsMaster	BOOL	FALSE	The controller is master in a cascade and provides the slave setpoint. Set IsMaster = TRUE if you are using this PID_Temp instance as master controller in a cascade. A master controller defines the setpoint of a slave controller with its output. A PID_Temp instance can be master controller and slave controller at the same time. If the controller is used as master controller, the cooling output must be deactivated (Config.ActivateCooling = FALSE).
Config.Cascade.IsSlave	BOOL	FALSE	The controller is slave in a cascade and provides the master setpoint. Set IsSlave = TRUE if you are using this PID_Temp instance as slave controller in a cascade. A slave controller receives its setpoint (Setpoint parameter) from the output of its master controller (OutputHeat parameter). A PID_Temp instance can be master controller and slave controller at the same time.
Config.Cascade.AntiWindUpWindUpMode	INT	1	Anti-windup behavior in the cascade Options are: • Anti-windup = 0 The AntiWindUp functionality is deactivated. The master controller does not respond to the limit of its slave controllers. • Anti-windup = 1 The integral action of the master controller is reduced in the ratio "Slaves in limit" to "Number of slaves" ("CountSlaves" parameter). This means the effects of the limit are reduced to the control response. • Anti-windup = 2 The integral action of the master controller is held as soon as a slave controller is in the limit. Only effective if the controller is configured as master controller (Config.Cascade.IsMaster = TRUE).

Tag	Data type	Default	Description
Con-fig.Cascade.CountSlaves	INT	1	Number of subordinate slaves Here you enter the number of directly subordinate slave controllers which receive their setpoint from this master controller. Only effective if the controller is configured as master controller (Con-fig.Cascade.IsMaster = TRUE). 255 ≥ CountSlaves ≥ 1
Cy-cleTime.StartEstimation	BOOL	TRUE	If CycleTime.EnEstimation = TRUE, CycleTime.StartEstimation = TRUE starts automatic determination of the PID_Temp sampling time (cycle time of the calling OB). CycleTime.StartEstimation = FALSE is set once measurement is complete.
Cy-cleTime.EnEstimation	BOOL	TRUE	If CycleTime.EnEstimation = TRUE, the PID_Temp sampling time is deter-mined automatically. If CycleTime.EnEstimation = FALSE, the sampling time PID_Temp is not determined automatically and must be configured correctly manually with CycleTime.Value.
Cy-cleTime.EnMonitoring	BOOL	TRUE	If CycleTime.EnMonitoring = FALSE, the PID_Temp sampling time is not monitored. If PID_Temp cannot be executed within the sampling time, no error (ErrorBits=0000800h) is output and PID_Temp does not respond as configured with ActivateRecoverMode.
Cy-cleTime.Value	REAL	0.1	PID_Temp sampling time (cycle time of the calling OB) in seconds CycleTime.Value is determined automatically and is usually equivalent to the cycle time of the calling OB.
You can reload values from the CtrlParamsBackUp structure with LoadBackUp = TRUE.			
CtrlParams-Params-BackUp.SetByUser	BOOL	FALSE	Saved value of Retain.CtrlParams.SetByUser
CtrlParams-Params-BackUp.Heat.Gain	REAL	1.0	Saved proportional gain for heating
CtrlParams-Params-BackUp.Heat.Ti	REAL	20.0	Saved integral action time for heating in seconds
CtrlParams-Params-BackUp.Heat.Td	REAL	0.0	Saved derivative action time for heating in seconds
CtrlParams-Params-BackUp.Heat.TdFiltRatio	REAL	0.2	Saved derivative delay coefficient for heating
CtrlParams-Params-BackUp.Heat.PWeighting	REAL	1.0	Saved weighting of the proportional action for heating

Tag	Data type	Default	Description
CtrlParams-Params-BackUp.Heat.DWeighting	REAL	1.0	Saved weighting of the derivative action for heating
CtrlParams-Params-BackUp.Heat.Cycle	REAL	1.0	Saved sampling time of the PID algorithm for heating in seconds
CtrlParams-Params-BackUp.Heat.ControlZone	REAL	3.402822e+38	Saved control zone width for heating
CtrlParams-Params-BackUp.Heat.DeadZone	REAL	0.0	Saved deadband width for heating
CtrlParams-Params-BackUp.Cool.Gain	REAL	1.0	Saved proportional gain for cooling
CtrlParams-Params-BackUp.Cool.Ti	REAL	20.0	Saved integral action time for cooling in seconds
CtrlParams-Params-BackUp.Cool.Td	REAL	0.0	Saved derivative action time for cooling in seconds
CtrlParams-Params-BackUp.Cool.TdFiltRatio	REAL	0.2	Saved derivative delay coefficient for cooling
CtrlParams-Params-BackUp.Cool.PWeighting	REAL	1.0	Saved proportional action weighting factor for cooling
CtrlParams-Params-BackUp.Cool.DWeighting	REAL	1.0	Saved derivative action weighting factor for cooling
CtrlParams-Params-BackUp.Cool.Cycle	REAL	1.0	Saved sampling time of the PID algorithm for cooling in seconds

Tag	Data type	Default	Description
CtrlParams-Params-BackUp.Cool.ControlZone	REAL	3.402822e+38	Saved control zone width for cooling
CtrlParams-Params-BackUp.Cool.DeadZone	REAL	0.0	Saved deadband width for cooling
PIDSelf-Tune.SUT.Calculate-ParamsHeat	BOOL	FALSE	The properties of the heating branch of the controlled system are saved during pretuning for heating. If SUT.CalculateParamsHeat = TRUE, the PID parameters for heating are recalculated on the basis of these properties (Retain.CtrlParams.Heat structure). This enables you to change the parameter calculation method (PIDSelfTune.SUT.TuneRuleHeat parameter) without having to repeat the tuning. SUT.CalculateParamsHeat is set to FALSE after the calculation. Only possible if the pretuning was successful (SUT.ProcParHeatOk = TRUE).
PIDSelf-Tune.SUT.Calculate-ParamsCool	BOOL	FALSE	The properties of the cooling branch of the controlled system are saved during tuning for cooling. If SUT.CalculateParamsCool = TRUE, the PID parameters for cooling are recalculated on the basis of these properties (Retain.CtrlParams.Cool structure). This enables you to change the parameter calculation method (PIDSelfTune.SUT.TuneRuleCool parameter) without having to repeat the tuning. SUT.CalculateParamsCool is set to FALSE after the calculation. Only possible if the pretuning was successful (SUT.ProcParCoolOk = TRUE). Only effective if Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE.
PIDSelf-Tune.SUT.TuneRule-Heat	INT	2	Method for PID parameter calculation with pretuning for heating Options are: • SUT.TuneRuleHeat = 0: PID to CHR • SUT.TuneRuleHeat = 1: PI to CHR • SUT.TuneRuleHeat = 2: PID for temperature processes to CHR (results in a longer and rather asymptomatic control response with fewer overshoots than SUT.TuneRuleHeat = 0) (CHR = Chien, Hrones and Reswick) Only with SUT.TuneRuleHeat = 2 is the control zone Retain.CtrlParams.Heat.ControlZone automatically set during pretuning for heating.

Tag	Data type	Default	Description
PIDSelf-Tune.SUT.TuneRu-leCool	INT	2	Method for PID parameter calculation with pretuning for cooling Options are: • SUT.TuneRuleCool = 0: PID to CHR • SUT.TuneRuleCool = 1: PI to CHR • SUT.TuneRuleCool = 2: PID for temperature processes to CHR (results in a longer and rather asymptomatic control response with fewer overshoots than SUT.TuneRuleCool = 0) (CHR = Chien, Hrones and Reswick) Only with SUT.TuneRuleCool = 2 is the control zone Retain.CtrlParams.Cool.ControlZone automatically set during pretuning for cooling. SUT.TuneRuleCool is only effective if the cooling output and PID parameter switching are activated (Config.ActivateCooling = TRUE, Config.AdvancedCooling = TRUE).
PIDSelf-Tune.SUT.State	INT	0	The SUT.State tag indicates the current phase of pretuning: • State = 0: Initialize pretuning • State = 100: Calculate standard deviation for heating • State = 200: Calculate standard deviation for cooling • State = 300: Determine point of inflection for heating • State = 400: Determine point of inflection for cooling • State = 500: Set heating to setpoint after reaching point of inflection • State = 600: Set cooling to setpoint after reaching point of inflection • State = 700: Compare efficiency of the heating actuator and cooling actuator • State = 800: Heating and cooling activated • State = 900: Cooling activated • State = 1000: Determine delay time after switching off heating • State = 9900: Pretuning successful • State = 1: Pretuning not successful
PIDSelf-Tune.SUT.ProcParHeatOk	BOOL	FALSE	TRUE: The calculation of the process parameters for pretuning heating was successful. This tag is set during tuning. It must be TRUE for calculation of the PID parameters for heating.
PIDSelf-Tune.SUT.ProcParCoolOk	BOOL	FALSE	TRUE: The calculation of the process parameters for pretuning cooling was successful. This tag is set during tuning. It must be TRUE for calculation of the PID parameters for cooling.

Tag	Data type	Default	Description
PIDSelf-Tune.SUT.AdaptDelay-Time	INT	0	The AdaptDelayTime tag determines the adaptation of the delay time for heating at the operating point (for "Pretuning heating" and "Pretuning heating and cooling"). Options are: • SUT.AdaptDelayTime = 0: No adaptation of delay time. The SUT.State = 1000 phase is skipped. This option results in a shorter tuning time than with SUT.AdaptDelayTime = 1. • SUT.AdaptDelayTime = 1: Adaptation of the delay time to the setpoint in SUT.State = 1000 phase by switching off heating temporarily. This option results in a longer tuning time than with SUT.AdaptDelayTime = 0. It can improve the control response if the process behavior depends significantly on the operating point (non-linearity). This option should not be used for multi-zone applications with strong thermal connections.
PIDSelf-Tune.SUT.CoolingMode	INT	0	The CoolingMode tag determines the manipulated variable output to determine the cooling parameters (for pretuning heating and cooling). Options are: • SUT.CoolingMode = 0: Switch off heating and switch on cooling after reaching the setpoint. The SUT.State = 700 phase is skipped. Phase SUT.State = 500 is followed by phase SUT.State = 900. This option can improve the control response if the gain of the cooling actuator is low compared to the gain of the heating actuator. It results in a shorter tuning time than with SUT.CoolingMode = 1 or 2. • SUT.CoolingMode = 1: Switch on cooling in addition to heating after reaching the setpoint. The SUT.State = 700 phase is skipped. Phase SUT.State = 500 is followed by phase SUT.State = 800. This option can improve the control response if the gain of the cooling actuator is high compared to the gain of the heating actuator. • SUT.CoolingMode = 2: After heating up to the setpoint, a decision is automatically made in phase SUT.State = 700 as to whether heating is switched off. Phase SUT.State = 500 is followed by phase SUT.State = 700 and then SUT.State = 800 or SUT.State = 900. This option requires more time than options 0 and 1.

Tag	Data type	Default	Description
PIDSelf-Tune.TIR.RunIn	BOOL	FALSE	Use the RunIn tag to specify the sequence of fine tuning during start from automatic mode. • RunIn = FALSE If fine tuning is started from automatic mode, the system uses the existing PID parameters to control to the setpoint (TIR.State = 500 or 600). Only then will fine tuning start. • RunIn = TRUE PID_Temp tries to reach the setpoint with minimum or maximum output value (TIR.State = 300 or 400). This can produce increased overshoot. Fine tuning then starts automatically. RunIn is set to FALSE after fine tuning. During start of fine tuning from Inactive or Manual mode, PID_Temp reacts as described under RunIn = TRUE.
PIDSelf-Tune.TIR.CalculateParamsHeat	BOOL	FALSE	The properties of the heating branch of the controlled system are saved during fine tuning for heating. If TIR.CalculateParamsHeat= TRUE, the PID parameters for heating are recalculated on the basis of these properties (Retain.CtrlParams.Heat structure). This enables you to change the parameter calculation method (PIDSelfTune.TIR.TuneRuleHeat parameter) without having to repeat the tuning. TIR.CalculateParamsHeat is set to FALSE after the calculation. Only possible if fine tuning heating was successful beforehand (TIR.ProcParHeatOk = TRUE).
PIDSelf-Tune.TIR.CalculateParamsCool	BOOL	FALSE	The properties of the cooling branch of the controlled system are saved during fine tuning for cooling. If TIR.CalculateParamsCool= TRUE, the PID parameters for cooling are recalculated on the basis of these properties (Retain.CtrlParams.Cool structure). This enables you to change the parameter calculation method (PIDSelfTune.TIR.TuneRuleCool parameter) without having to repeat the tuning. TIR.CalculateParamsCool is set to FALSE after the calculation. Only possible if fine tuning cooling was successful beforehand (TIR.ProcParCoolOk = TRUE). Only effective if Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE

Tag	Data type	Default	Description
PIDSelf-Tune.TIR.TuneRule-Heat	INT	0	Method for parameter calculation during fine tuning for heating Options are: • TIR.TuneRuleHeat = 0: PID automatic • TIR.TuneRuleHeat = 1: PID fast (faster control response with higher amplitudes of the output value than with TIR.TuneRuleHeat = 2) • TIR.TuneRuleHeat = 2: PID slow (slower control response with lower amplitudes of the output value than with TIR.TuneRuleHeat = 1) • TIR.TuneRuleHeat = 3: ZN PID • TIR.TuneRuleHeat = 4: ZN PI • TIR.TuneRuleHeat = 5: ZN P (ZN=Ziegler-Nichols) To be able to repeat the calculation of the PID parameters for heating with TIR.CalculateParamsHeat and TIR.TuneRuleHeat = 0, 1 or 2, the previous fine tuning also has to have been executed with TIR.TuneRuleHeat = 0, 1 or 2. If this is not the case, TIR.TuneRuleHeat = 3 is used. The recalculation of the PID parameters for heating with TIR.CalculateParamsHeat and TIR.TuneRuleHeat = 3, 4 or 5 is always possible.
PIDSelf-Tune.TIR.TuneRu-leCool	INT	0	Method for parameter calculation during fine tuning for cooling Options are: • TIR.TuneRuleCool = 0: PID automatic • TIR.TuneRuleCool = 1: PID fast (faster control response with higher amplitudes of the output value than with TIR.TuneRuleCool = 2) • TIR.TuneRuleCool = 2: PID slow (slower control response with lower amplitudes of the output value than with TIR.TuneRuleCool = 1) • TIR.TuneRuleCool = 3: ZN PID • TIR.TuneRuleCool = 4: ZN PI • TIR.TuneRuleCool = 5: ZN P (ZN=Ziegler-Nichols) To be able to repeat the calculation of the PID parameters for cooling with TIR.CalculateParamsCool and TIR.TuneRuleCool = 0, 1 or 2, the previous fine tuning also has to have been executed with TIR.TuneRuleCool = 0, 1 or 2. If this is not the case, TIR.TuneRuleCool = 3 is used. The recalculation of the PID parameters for cooling with TIR.CalculateParamsCool and TIR.TuneRuleCool = 3, 4 or 5 is always possible. Only effective if the cooling output and PID parameter switching are activated (ConfigActivateCooling = TRUE and Config.AdvancedCooling = TRUE).

Tag	Data type	Default	Description
PIDSelf-Tune.TIR.State	INT	0	The TIR.State tag indicates the current phase of "fine tuning": • State = 0: Initialize fine tuning • State = 100: Calculate standard deviation for heating • State = 200: Calculate standard deviation for cooling • State = 300: Attempting to reach setpoint for heating with two-step control • State = 400: Attempting to reach setpoint for cooling with two-step control • State = 500: Attempting to reach setpoint for heating with PID control • State = 600: Attempting to reach setpoint for cooling with PID control • State = 700: Calculate standard deviation for heating • State = 800: Calculate standard deviation for cooling • State = 900: Determine oscillation and calculate parameters for heating • State = 1000: Determine oscillation and calculate parameters for cooling • State = 9900: Fine tuning successful • State = 1: Fine tuning not successful
PIDSelf-Tune.TIR.ProcParHeatOk	BOOL	FALSE	TRUE: The calculation of the process parameters for fine tuning heating was successful. This tag is set during tuning. It must be met for calculation of the PID parameters for heating.
PIDSelf-Tune.TIR.ProcParCoolOk	BOOL	FALSE	TRUE: The calculation of the process parameters for fine tuning cooling was successful. This tag is set during tuning. It must be met for calculation of the PID parameters for cooling.
PIDSelf-Tune.TIR.Output-OffsetHeat	REAL	0.0	Tuning offset heating of the PID output value TIR.OutputOffsetHeat is added to the value that results from PidOutputSum for the heating branch. To receive a positive offset at the outputs for heating, define a positive value for TIR.OutputOffsetHeat. The resulting values at the outputs for heating are the result of the configured output scaling (Struktur Config.Output.Heat). This tuning offset can be used in controllers with activated cooling output and PID parameter switching (Config.ActivateCooling = TRUE, Config.AdvancedCooling = TRUE) for fine tuning cooling. If the outputs for cooling are not active at the setpoint that is to be tuned (PidOutputSum > 0.0), fine tuning cooling is not possible. In this case, define a positive tuning offset heating which is greater than the PID output value (PidOutputSum) at the setpoint in the steady state before you start tuning. This step increases the values at the outputs for heating and activates the outputs for cooling (PidOutputSum < 0.0). Fine tuning cooling is now possible. When fine tuning is complete, TIR.OutputOffsetHeat is reset to 0.0. Major changes at TIR.OutputOffsetHeat in one step can result in temporary overshoots. Config.Output.Heat.PidUpperLimit ≥ PIDSelfTune.TIR.OutputOffsetHeat ≥ Config.Output.Heat.PidLowerLimit

Tag	Data type	Default	Description
PIDSelf-Tune.TIR.Output-OffsetCool	REAL	0.0	Tuning offset cooling of the PID output value TIR.OutputOffsetCool is added to the value that results from PidOutputSum for the cooling branch. To receive a positive offset at the outputs for cooling, define a negative value for TIR.OutputOffsetCool. The resulting values at the outputs for cooling are the result of the configured output scaling (Struktur Config.Output.Coool). This tuning offset can be used in controllers with activated cooling output (Config.ActivateCooling = TRUE) for fine tuning heating. If the outputs for heating are not active at the setpoint that is to be tuned (PidOutputSum < 0.0), fine tuning heating is not possible. In this case, define a negative tuning offset cooling which is less than the PID output value (PidOutputSum) at the setpoint in the steady state before you start tuning. This step increases the values at the outputs for cooling and activates the outputs for heating (PidOutputSum > 0.0). Fine tuning heating is now possible. When fine tuning is complete, TIR.OutputOffsetCool is reset to 0.0. Major changes at TIR.OutputOffsetCool in one step can result in temporary overshoots. Config.Output.Cool.PidUpperLimit ≥ PIDSelfTune.TIR.OutputOffsetCool ≥ Config.Output.Cool.PidLowerLimit
PIDSelf-Tune.TIR.WaitForControlIn	BOOL	FALSE	Waiting with fine tuning after reaching the setpoint If TIR.WaitForControlIn = TRUE, fine tuning waits in between reaching the setpoint (TIR.State = 500 or 600) and calculation of the standard deviation (TIR.State = 700 or 800) until a FALSE -> TRUE edge is given at TIR.FinishControlIn. TIR.WaitForControlIn can be used for simultaneous fine tuning of several controllers in multi-zone applications to synchronize tuning of the individual zones. It ensures that all zones have reached their setpoints before the actual tuning starts. The influence of thermal connections between the zones on tuning can be reduced in this way. TIR.WaitForControlIn is only effective if fine tuning is started from automatic mode with PIDSelfTune.TIR.RunIn = FALSE.
PIDSelf-Tune.TIR.ControlInReady	BOOL	FALSE	If TIR.WaitForControlIn = TRUE, PID_Temp sets TIR.ControlInReady = TRUE as soon as the setpoint has been reached and waits with additional tuning steps until a FALSE -> TRUE edge is given at TIR.FinishControlIn.
PIDSelf-Tune.TIR.FinishControlIn	BOOL	FALSE	If TIR.ControlInReady = TRUE, a FALSE -> TRUE edge at TIR.FinishControlIn stops the wait and fine tuning resumes.
PIDCtr.IOutputOld	REAL	0.0	Integral action in last cycle
Retain.CtrlParams.SetByUser	BOOL	FALSE	If the PID parameters are entered manually in the configuration editor, SetByUser = TRUE. This parameter is used for display in the editors and does not influence the control algorithm. SetByUser is retentive.

Tag	Data type	Default	Description
Re-tain.CtrlParams.Heat.Gain	REAL	1.0	Active proportional gain for heating Heat.Gain is retentive. Heat.Gain ≥ 0.0
Re-tain..CtrlParams.Heat.Ti	REAL	20.0	Active integral action time for heating in seconds The integral action for heating is switched off with Heat.CtrlParams.Ti = 0.0. Heat.Ti is retentive. 100000.0 ≥ Heat.Ti ≥ 0.0
Re-tain.CtrlParams.Heat.Td	REAL	0.0	Active derivative action time for heating in seconds The derivative action for heating is switched off with Heat.CtrlParams.Td = 0.0. Heat.Td is retentive. 100000.0 ≥ Heat.Td ≥ 0.0
Re-tain.CtrlParams.Heat.TdFiltRatio	REAL	0.2	Active derivative delay coefficient for heating The derivative delay coefficient delays the effect of the derivative action. Derivative delay = derivative action time × derivative delay coefficient • 0.0: Derivative action is effective for one cycle only and therefore almost not effective. • 0.5: This value has proved useful in practice for controlled systems with one dominant time constant. • > 1.0: The greater the coefficient, the longer the effect of the derivative action is delayed. Heat.TdFiltRatio is retentive. Heat.TdFiltRatio ≥ 0.0
Re-tain.CtrlParams.Heat.PWeighting	REAL	1.0	Active weighting of the proportional action for heating The proportional action may weaken with changes to the setpoint. Values from 0.0 to 1.0 are applicable. • 1.0: Proportional action for setpoint change is fully effective • 0.0: Proportional action for setpoint change is not effective The proportional action is always fully effective when the process value is changed. Heat.PWeighting is retentive. 1.0 ≥ Heat.PWeighting ≥ 0.0
Re-tain.CtrlParams.Heat.DWeighting	REAL	1.0	Active weighting of the derivative action for heating The derivative action may weaken with changes to the setpoint. Values from 0.0 to 1.0 are applicable. • 1.0: Derivative action is fully effective upon setpoint change • 0.0: Derivative action is not effective upon setpoint change The derivative action is always fully effective when the process value is changed. Heat.DWeighting is retentive. 1.0 ≥ Heat.DWeighting ≥ 0.0

Tag	Data type	Default	Description
Retain.CtrlParams.Heat.Cycle	REAL	1.0	Active sampling time of the PID algorithm for heating in seconds CtrlParams.Heat.Cycle is calculated during tuning and rounded to an integer multiple of CycleTime.Value. If Config.Output.Heat.PwmPeriode = 0.0, Heat.Cycle is used as time period of the pulse width modulation for heating. If Config.Output.Cool.PwmPeriode = 0.0 and Config.AdvancedCooling = FALSE, Heat.Cycle is used as time period of the pulse width modulation for cooling. Heat.Cycle is retentive. 100000.0 ≥ Heat.Cycle > 0.0
Retain.CtrlParams.Heat.ControlZone	REAL	3.402822e+38	Active control zone width for heating The control zone for heating is switched off with Heat.ControlZone = 3.402822e+38. Heat.ControlZone is only set automatically during pretuning heating or pretuning heating and cooling if PIDSelfTune.SUT.TuneRuleHeat = 2 is selected as method of the parameter calculation. For controllers with deactivated cooling output (Config.ActivateCooling = FALSE) or controllers with activated cooling output and cooling factor (Config.AdvancedCooling = FALSE), the control zone is symmetrically located between Setpoint – Heat.ControlZone and Setpoint + Heat.ControlZone. For controllers with activated cooling output and PID parameter switching (Config.ActivateCooling = TRUE, Config.AdvancedCooling = TRUE), the control zone is located between Setpoint – Heat.ControlZone and Setpoint + Cool.ControlZone. Heat.ControlZone is retentive. Heat.ControlZone > 0.0
Retain.CtrlParams.Heat.DeadZone	REAL	0.0	Active deadband width for heating (see PID parameters (Page 177)) The deadband for heating is switched off with Heat.DeadZone = 0.0. Heat.DeadZone is not set automatically or adjusted during tuning. You must correctly configure Heat.DeadZone manually. For controllers with deactivated cooling output (Config.ActivateCooling = FALSE) or controllers with activated cooling output and cooling factor (Config.AdvancedCooling = FALSE), the deadband is symmetrically located between Setpoint – Heat.DeadZone and Setpoint + Heat.DeadZone. For controllers with activated cooling output and PID parameter switching (Config.ActivateCooling = TRUE, Config.AdvancedCooling = TRUE), the deadband is located between Setpoint – Heat.DeadZone and Setpoint + Cool.DeadZone. Heat.DeadZone is retentive. Heat.DeadZone ≥ 0.0
Retain.CtrlParams.Cool.Gain	REAL	1.0	Active proportional gain for cooling Cool.Gain is retentive. Only effective if the cooling output and PID parameter switching are activated (Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE). Cool.Gain ≥ 0.0

Tag	Data type	Default	Description
Retain.CtrlParams.Cool.Ti	REAL	20.0	Active integral action time for cooling in seconds The integral action for cooling is switched off with Cool.CtrlParams.Ti = 0.0. Cool.Ti is retentive. Only effective if the cooling output and PID parameter switching are activated (Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE). 100000.0 ≥ Cool.Ti ≥ 0.0
Retain.CtrlParams.Cool.Td	REAL	0.0	Active derivative action time for cooling in seconds The derivative action for cooling is switched off with Cool.CtrlParams.Td = 0.0. Cool.Td is retentive. Only effective if the cooling output and PID parameter switching are activated (Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE). 100000.0 ≥ Cool.Td ≥ 0.0
Retain.CtrlParams.Cool.TdFiltRatio	REAL	0.2	Active derivative delay coefficient for cooling The derivative delay coefficient delays the effect of the derivative action. Derivative delay = derivative action time × derivative delay coefficient • 0.0: Derivative action is effective for one cycle only and therefore almost not effective. • 0.5: This value has proved useful in practice for controlled systems with one dominant time constant. • > 1.0: The greater the coefficient, the longer the effect of the derivative action is delayed. Cool.TdFiltRatio is retentive. Only effective if the cooling output and PID parameter switching are activated (Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE). Cool.TdFiltRatio ≥ 0.0
Retain.CtrlParams.Cool.PWeighting	REAL	1.0	Active weighting of the proportional action for cooling The proportional action may weaken with changes to the setpoint. Values from 0.0 to 1.0 are applicable. • 1.0: Proportional action for setpoint change is fully effective • 0.0: Proportional action for setpoint change is not effective The proportional action is always fully effective when the process value is changed. Cool.PWeighting is retentive. Only effective if the cooling output and PID parameter switching are activated (Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE). 1.0 ≥ Cool.PWeighting ≥ 0.0

Tag	Data type	Default	Description
Retain.CtrlParams.Cool.DWeighting	REAL	1.0	Active weighting of the derivative action for cooling The derivative action may weaken with changes to the setpoint. Values from 0.0 to 1.0 are applicable. • 1.0: Derivative action is fully effective upon setpoint change • 0.0: Derivative action is not effective upon setpoint change The derivative action is always fully effective when the process value is changed. Cool.DWeighting is retentive. Only effective if the cooling output and PID parameter switching are activated (Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE). 1.0 ≥ Cool.DWeighting ≥ 0.0
Retain.CtrlParams.Cool.Cycle	REAL	1.0	Active sampling time of the PID algorithm for cooling in seconds CtrlParams.Cool.Cycle is calculated during tuning and rounded off to an integer multiple of CycleTime.. If Config.Output.Cool.PwmPeriode = 0.0 and Config.AdvancedCooling = TRUE, Cool.Cycle is used as time period of the pulse width modulation for cooling. If Config.Output.Cool.PwmPeriode = 0.0 and Config.AdvancedCooling = FALSE, Heat.Cycle is used as time period of the pulse width modulation for cooling. Cool.Cycle is retentive. Only effective if the cooling output and PID parameter switching are activated (Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE). 100000.0 ≥ Cool.Cycle > 0.0
Retain.CtrlParams.Cool.ControlZone	REAL	3.402822e+38	Active control zone width for cooling The control zone for cooling is switched off with Cool.ControlZone = 3.402822e+38. Cool.ControlZone is only set automatically during pretuning cooling or pretuning heating and cooling if PIDSelfTune.SUT.TuneRuleCool = 2 is selected as method of the parameter calculation. Cool.ControlZone is retentive. Only effective if the cooling output and PID parameter switching are activated (Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE). Cool.ControlZone > 0.0
Retain.CtrlParams.Cool.DeadZone	REAL	0.0	Active deadband width for cooling (see PID parameters (Page 177)) The deadband for cooling is switched off with Cool.DeadZone = 0.0. Cool.DeadZone is not set automatically or adjusted during tuning. You must correctly configure Cool.DeadZone manually. Cool.DeadZone is retentive. Only effective if the cooling output and PID parameter switching are activated (Config.ActivateCooling = TRUE and Config.AdvancedCooling = TRUE). Cool.DeadZone ≥ 0.0

Note

Change the tags listed in this table in "Inactive" mode to prevent malfunction of the PID controller.

See also

PID_Temp ActivateRecoverMode tag (Page 427)

PID_Temp Warning tag (Page 430)

Multi-zone controlling with PID_Temp (Page 202)

8.3.3.7 PID_Temp state and mode parameters

Correlation of the parameters

The State parameter shows the current operating mode of the PID controller. You cannot change the State parameter.

With a rising edge at ModeActivate, PID_Temp switches to the operating mode saved in the Mode in-out parameter.

Heat.EnableTuning and Cool.EnableTuning specify for pretuning and fine tuning, if tuning takes place for heating or cooling.

If the CPU is switched on or switches from Stop to RUN mode, PID_Temp starts in the operating mode that is saved in the Mode parameter. To leave PID_Temp in "Inactive" mode, set RunModeByStartup = FALSE.

Meaning of values

State / Mode	Description of operating mode
0	**Inactive** The following output values are output in "Inactive" mode: • 0.0 as PID output value (PidOutputSum) • 0.0 as output value for heating (OutputHeat) and output value for cooling (OutputCool) • 0 as analog output value for heating (OutputHeat_PER) and analog output value for cooling (OutputCool_PER) • FALSE as PWM output value for heating (OutputHeat_PWM) and PWM output value for cooling (OutputCool_PWM) This does not depend on the configured output value limits and scaling in the structures Config.Output.Heat and Config.Output.Cool.

State / Mode	Description of operating mode
1	**Pretuning** The pretuning determines the process response to a jump change of the output value and searches for the point of inflection. The PID parameters are calculated from the maximum rate of rise and dead time of the controlled system. You obtain the best PID parameters when you perform pretuning and fine tuning. PID_Temp offers different pretuning types, depending on the configuration: • Pretuning heating: A jump change is output at the output value heating, the PID parameters for heating are calculated (Retain.CtrlParams.Heat structure), and control to the setpoint then takes place in automatic mode. If the process behavior strongly depends on the operating point, an adaptation of the delay time can be activated at the setpoint with PIDSelfTune.SUT.AdaptDelayTime. • Pretuning heating and cooling: A jump change is output at the output value heating. As soon as the process value is close to the setpoint, a jump change is output at the output value cooling. The PID parameters for heating (Retain.CtrlParams.Heat structure) and cooling (Retain.CtrlParams.Cool structure) are calculated. Then, control to the setpoint takes place in automatic mode. If the process behavior strongly depends on the operating point, an adaptation of the delay time can be activated at the setpoint with PIDSelfTune.SUT.AdaptDelayTime. Depending on the effect of the cooling actuator compared to the heating actuator, the quality of tuning can be influenced by whether or not the heating and cooling outputs are operated simultaneously during tuning. You can specify this with PIDSelfTune.SUT.CoolingMode. • Pretuning cooling: A jump change is output at the output value cooling and the PID parameters for cooling are calculated (Struktur Retain.CtrlParams.Cool). Then, control to the setpoint takes place in automatic mode. If you want to tune the PID parameters for heating and cooling, you can expect a better control response with "pretuning heating" followed by "pretuning cooling" rather than with "pretuning heating and cooling". However, pretuning in two steps takes longer. **General requirements for pretuning:** • The PID_Temp instruction is called in a cyclic interrupt OB. • Inactive (State = 0), manual mode (State = 4), or automatic mode (State = 3) • ManualEnable = FALSE • Reset = FALSE • The setpoint and the process value lie within the configured limits.

State / Mode	Description of operating mode
1	**Requirements for pretuning heating:** • Heat.EnableTuning = TRUE • Cool.EnableTuning = FALSE • The process value must not be too close to the setpoint. |Setpoint - Input| > 0.3 * |Config.InputUpperLimit - Config.InputLowerLimit| and |Setpoint - Input| > 0.5 * |Setpoint| • The setpoint is greater than the process value. Setpoint > Input **Requirements for pretuning heating and cooling:** • Heat.EnableTuning = TRUE· • Cool.EnableTuning = TRUE • The cooling output is activated (Config.ActivateCooling = TRUE). • The PID parameter switching is activated (Config.AdvancedCooling = TRUE). • The process value must not be too close to the setpoint. |Setpoint - Input| > 0.3 * |Config.InputUpperLimit - Config.InputLowerLimit| and |Setpoint - Input| > 0.5 * |Setpoint| • The setpoint is greater than the process value. Setpoint > Input **Requirements for pretuning cooling:** • Heat.EnableTuning = FALSE· • Cool.EnableTuning = TRUE· • The cooling output is activated (Config.ActivateCooling = TRUE). • The PID parameter switching is activated (Config.AdvancedCooling = TRUE). • A "pretuning heating" or "pretuning heating and cooling" has been successful (PIDSelf-Tune.SUT.ProcParHeatOk = TRUE), if possible at the same setpoint. • The process value must be close to the setpoint. |Setpoint - Input| < 0.05 * |Config.InputUpperLimit - Config.InputLowerLimit| The more stable the process value is, the easier it is to calculate the PID parameters and the more precise the result will be. Noise on the process value can be tolerated as long as the rate of rise of the process value is significantly higher compared to the noise. This is most likely the case in operating modes "Inactive" or "Manual mode".

State / Mode	Description of operating mode
1	The setpoint is frozen in the CurrentSetpoint tag. Tuning is canceled when: • Setpoint > CurrentSetpoint + CancelTuningLevel or • Setpoint < CurrentSetpoint - CancelTuningLevel The method for calculation of the PID parameters can be specified separately for heating and cooling with PIDSelfTune.SUT.TuneRuleHeat and PIDSelfTune.SUT.TuneRuleCool. Before the PID parameters are recalculated, they are backed up in the CtrlParamsBackUp structure and can be reactivated with LoadBackUp. After successful pretuning, the switch is made to automatic mode. After unsuccessful pretuning, the switch to the mode is determined by ActivateRecoverMode. The phase of pretuning is indicated with PIDSelfTune.SUT.State.
2	**Fine tuning** Fine tuning generates a constant, limited oscillation of the process value. The PID parameters are tuned for the operating point from the amplitude and frequency of this oscillation. PID parameters from fine tuning usually have better master control and disturbance characteristics than PID parameters from pretuning. You obtain the best PID parameters when you perform pretuning and fine tuning. PID_Temp automatically attempts to generate an oscillation greater than the noise of the process value. Fine tuning is only minimally influenced by the stability of the process value. PID_Temp offers different fine tuning types, depending on the configuration: • Fine tuning heating: PID_Temp generates an oscillation of the process value with periodic changes at the output value heating and calculates the PID parameters for heating (Struktur Retain.CtrlParams.Heat). • Fine tuning cooling: PID_Temp generates an oscillation of the process value with periodic changes at the output value cooling and calculates the PID parameters for cooling (Struktur Retain.CtrlParams.Cool). **Temporary tuning offset for heating/cooling controllers** If PID_Temp is used as heating/cooling controller (Config.ActivateCooling = TRUE), the PID output value (PidOutputSum) at the setpoint must meet the following requirements for a process value oscillation to be generated and fine tuning to be successful: • Positive PID output value for fine tuning heating • Negative PID output value for fine tuning cooling If this requirement is not met, you can define a temporary offset for fine tuning which is output at the output with the opposite effect: • Offset for cooling output (PIDSelfTune.TIR.OutputOffsetCool) with fine tuning heating. Define a negative tuning offset cooling which is less than the PID output value (PidOutputSum) at the setpoint in the steady state before you start tuning. • Offset for heating output (PIDSelfTune.TIR.OutputOffsetHeat) with fine tuning cooling. Define a positive tuning offset heating which is greater than the PID output value (PidOutputSum) at the setpoint in the steady state before you start tuning. The defined offset is balanced by the PID algorithm so that the process value remains at the setpoint. This means the size of the offset can be adapted accordingly with the PID output value so that it meets the requirements listed above.

State / Mode	Description of operating mode
2	To avoid larger overshoots of the process value when defining the offset, it can also be increased in several steps. If PID_Temp exits the fine tuning mode, the tuning offset is reset. Example for definition of an offset for fine tuning cooling: • Without offset: – Setpoint = Process value (ScaledInput) = 80°C – PID output value (PidOutputSum) = 30.0 – Output value heating (OutputHeat) = 30.0 – Output value cooling (OutputCool) = 0.0 An oscillation of the process value around the setpoint cannot be created with the cooling output alone. Fine tuning would fail here. • With definition of an offset for heating output (PIDSelfTune.TIR.OutputOffsetHeat) = 80.0 – Setpoint = process value (ScaledInput) = 80°C – PID output value (PidOutputSum) = -50.0 – Output value heating (OutputHeat) = 80.0 – Output value cooling (OutputCool) = -50.0 By defining an offset for the heating output, the cooling output can now create an oscillation of the process value around the setpoint. This means fine tuning can take place successfully. **General requirements for fine tuning:** • The PID_Temp instruction is called in a cyclic interrupt OB. • No disturbances are expected. • The setpoint and the process value lie within the configured limits. • The control loop has stabilized at the operating point. The operating point is reached when the process value corresponds to the setpoint. • ManualEnable = FALSE • Reset = FALSE • Automatic (State = 3), inactive (State = 0) or manual (State = 4) mode **Requirements for fine tuning heating:** • Heat.EnableTuning = TRUE • Cool.EnableTuning = FALSE • If PID_Temp is configured as heating/cooling controller (Config.ActivateCooling = TRUE), the heating output must be active at the operating point at which tuning is to take place (PidOutputSum > 0.0 (see tuning offset)).

State / Mode	Description of operating mode
2	**Requirements for fine tuning cooling:** • Heat.EnableTuning = FALSE • Cool.EnableTuning = TRUE • The cooling output is activated (Config.ActivateCooling = TRUE). • The PID parameter switching is activated (Config.AdvancedCooling = TRUE) • The cooling output must be active at the operating point at which tuning is to take place (PidOutputSum < 0.0 (see tuning offset)). **The course of fine tuning is determined by the mode from which it is started:** • Automatic mode (State = 3) with PIDSelfTune.TIR.RunIn = FALSE (default) Start fine tuning from automatic mode if you wish to improve the existing PID parameters through tuning. PID_Temp controls the system using the existing PID parameters until the control loop has stabilized and the requirements for fine tuning have been met. Only then will fine tuning start. • Inactive (State = 0), manual mode (State = 4), or automatic mode (State = 3) with PIDSelf-Tune.TIR.RunIn = TRUE Attempts are made to reach the setpoint with the minimum or maximum output value: – with minimum or maximum output value heating for fine tuning heating – with minimum or maximum output value cooling for fine tuning cooling. This can produce increased overshoot. Fine tuning starts when the setpoint is reached. If the setpoint cannot be reached, PID_Temp does not automatically abort tuning. The setpoint is frozen in the CurrentSetpoint tag. Tuning is canceled when: • Setpoint > CurrentSetpoint + CancelTuningLevel or • Setpoint < CurrentSetpoint - CancelTuningLevel The method for calculation of the PID parameters can be specified separately for heating and cooling with PIDSelfTune.TIR.TuneRuleHeat and PIDSelfTune.TIR.TuneRuleCool. Before the PID parameters are recalculated, they are backed up in the CtrlParamsBackUp structure and can be reactivated with LoadBackUp. The controller changes to automatic mode after successful fine tuning. After unsuccessful fine tuning, the switch to the mode is determined by ActivateRecoverMode. The "Fine tuning" phase is indicated with PIDSelfTune.TIR.State.
3	**Automatic mode** In automatic mode, PID_Temp corrects the controlled system in accordance with the parameters specified. The controller switches to automatic mode if one the following requirements is met: • Pretuning successfully completed • Fine tuning successfully completed • Changing of the Mode in-out parameter to the value 3 and a rising edge at ModeActivate. The switchover from automatic mode to manual mode is only bumpless if carried out in the commissioning editor. The ActivateRecoverMode tag is taken into consideration in automatic mode.

State / Mode	Description of operating mode
4	**Manual mode** In manual mode, you specify a manual PID output value in the ManualValue parameter. The values at the outputs for heating and cooling resulting from this manual value are the result of the configured output scaling. You can also activate this operating mode using ManualEnable = TRUE. We recommend that you change the operating mode using Mode and ModeActivate only. The switchover from manual mode to automatic mode is bumpless. The ActivateRecoverMode tag is taken into consideration in manual mode.
5	**Substitute output value with error monitoring** The control algorithm is deactivated. The SetSubstituteOutput tag determines which PID output value (PidOutputSum) is output in this operating mode. • SetSubstituteOutput = FALSE: Last valid PID output value • SetSubstituteOutput = TRUE: Substitute output value (SubstituteOutput) You cannot activate this operating mode using Mode = 5. In the event of an error, it is activated instead of "Inactive" operating mode if all the following conditions are met: • Automatic mode (State = 3) • ActivateRecoverMode = TRUE • One or more errors have occurred in which ActivateRecoverMode is effective. As soon as the errors are no longer pending, PID_Temp switches back to automatic mode.

ENO characteristics

If State = 0, then ENO = FALSE.

If State ≠ 0, then ENO = TRUE.

Automatic switchover of operating mode during commissioning

Automatic mode is activated following successful pretuning or fine tuning. The following table shows how Mode and State change during successful pretuning.

Cycle no.	Mode	State	Action
0	4	4	Set Mode = 1
1	1	4	Set ModeActivate = TRUE
1	4	1	Value of State is saved in Mode parameter Pretuning is started
n	4	1	Pretuning successfully completed
n	3	3	Automatic mode is started

PID_Temp automatically switches the operating mode in the event of an error.

The following table shows how Mode and State change during pretuning with errors.

Cycle no.	Mode	State	Action
0	4	4	Set Mode = 1
1	1	4	Set ModeActivate = TRUE
1	4	1	Value of State is saved in Mode parameter Pretuning is started
n	4	1	Pretuning canceled
n	4	4	Manual mode is started

If ActivateRecoverMode = TRUE, the operating mode that is saved in the Mode parameter is activated. When you start pretuning or fine tuning, PID_Temp has saved the value of State in the Mode in-out parameter. This means PID_Temp switches to the mode from which tuning was started.

If ActivateRecoverMode = FALSE, the system switches to "Inactive" operating mode.

See also

Output parameters of PID_Temp (Page 384)

PID_Temp in/out parameters (Page 386)

8.3.3.8 PID_Temp ErrorBits parameter

If several errors are pending simultaneously, the values of the ErrorBits are displayed with binary addition. The display of ErrorBits = 0000003h, for example, indicates that the errors 0000001h and 0000002h are pending simultaneously.

ErrorBits (DW#16#...)	Description
0000000	There is no error.
0000001	The "Input" parameter is outside the process value limits. • Input > Config.InputUpperLimit or • Input < Config.InputLowerLimit If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp remains in automatic mode. If manual mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp remains in manual mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp switches to the operating mode that is saved in the Mode parameter.
0000002	Invalid value at "Input_PER" parameter. Check whether an error is pending at the analog input. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp outputs the configured substitute output value. As soon as the error is no longer pending, PID_Temp switches back to automatic mode. If manual mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp remains in manual mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp switches to the operating mode that is saved in the Mode parameter.
0000004	Error during fine tuning. Oscillation of the process value could not be maintained. If PID_Temp is used as heating-cooling controller (Config.ActivateCooling = TRUE), the PID output value (PidOutputSum) at the setpoint must be positive for fine tuning heating and negative • for fine tuning cooling to be able • to generate actual value oscillation If this requirement is not met, use the tuning offsets (PIDSelfTune.TIR.OutputOffsetCool and PIDSelf-Tune.TIR.OutputOffsetHeat tags), see Fine tuning (Page 188). If ActivateRecoverMode was = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0000008	Error at start of pretuning. The process value is too close to the setpoint or greater than the setpoint. Start fine tuning. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0000010	The setpoint was changed during tuning. You can set the permitted fluctuation of the setpoint at the CancelTuningLevel tag. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0000020	Pretuning is not permitted during fine tuning. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp remains in fine tuning mode.
0000040	Error during pretuning. Cooling could not reduce the process value. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.

ErrorBits (DW#16#...)	Description
0000100	Error during fine tuning resulted in invalid parameters. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0000200	Invalid value at "Input" parameter: Value has an invalid number format. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp outputs the configured substitute output value. As soon as the error is no longer pending, PID_Temp switches back to automatic mode. If manual mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp remains in manual mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp switches to the operating mode that is saved in the Mode parameter.
0000400	Calculation of output value failed. Check the PID parameters. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp outputs the configured substitute output value. As soon as the error is no longer pending, PID_Temp switches back to automatic mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp switches to the operating mode that is saved in the Mode parameter.
0000800	Sampling time error: PID_Temp is not called within the sampling time of the cyclic interrupt OB. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp remains in automatic mode. If manual mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp remains in manual mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp switches to the operating mode that is saved in the Mode parameter.
0001000	Invalid value at "Setpoint" parameter or "SubstituteSetpoint": Value has an invalid number format. If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp outputs the configured substitute output value. As soon as the error is no longer pending, PID_Temp switches back to automatic mode. If manual mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp remains in manual mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp switches to the operating mode that is saved in the Mode parameter.
0010000	Invalid value at ManualValue parameter. Value has an invalid number format. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp remains in manual mode and uses SubstituteOutput as PID output value. As soon as you specify a valid value in ManualValue, PID_Temp uses it as the PID output value.
0020000	Invalid value at SubstituteOutput tag. Value has an invalid number format. PID_Temp remains in the "Substitute output value with error monitoring" mode or manual mode and uses the low limit of the PID output value for heating (Config.Output.Heat.PidLowerLimit) as PID output value. As soon as you specify a valid value in SubstituteOutput, PID_Temp uses it as the PID output value.
0040000	Invalid value at Disturbance parameter. Value has an invalid number format. If automatic mode was active and ActivateRecoverMode = TRUE before the error occurred, Disturbance is set to zero. PID_Temp remains in automatic mode. If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp switches to the operating mode that is saved in the Mode parameter. If Disturbance in the current phase has no effect on the output value, tuning is not be canceled.

ErrorBits (DW#16#...)	Description
0200000	Error in Master in the cascade: Slaves are not in automatic mode or have activated substitute setpoint and prevent tuning of the master. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0400000	Fine tuning heating is not permitted while cooling is active. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
0800000	The process value must be close to the setpoint to start pretuning cooling. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
1000000	Error at start of tuning: Heat.EnableTuning and Cool.EnableTuning are not set or do not match the configuration. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
2000000	Pretuning cooling requires successful pretuning heating. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
4000000	Error at start of fine tuning: Heat.EnableTuning and Cool.EnableTuning must not be set simultaneously. If ActivateRecoverMode = TRUE before the error occurred, PID_Temp cancels the tuning and switches to the operating mode that is saved in the Mode parameter.
8000000	Error during calculation of the PID parameters resulted in invalid parameters. The invalid parameters are discarded and the original PID parameters are retained unchanged. We can distinguish between the following cases: • If automatic mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp remains in automatic mode. • If manual mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp remains in manual mode. • If pretuning or fine tuning mode was active before the error occurred and ActivateRecoverMode = TRUE, PID_Temp switches to the operating mode that is saved in the Mode parameter.

8.3.3.9 PID_Temp ActivateRecoverMode tag

The ActivateRecoverMode tag determines the reaction to error. The Error parameter indicates if an error is pending. When the error is no longer pending, Error = FALSE. The ErrorBits parameter shows which errors have occurred.

Automatic mode and manual mode

NOTICE
Your system may be damaged. If ActivateRecoverMode = TRUE, PID_Temp remains in automatic mode or in manual mode even if there is an error and the process limit values are exceeded. This may damage your system. It is essential to configure how your controlled system reacts in the event of an error to protect your system from damage.

ActivateRecov-erMode	Description
FALSE	PID_Temp switches to "Inactive" mode in the event of an error. The controller is only activated by a falling edge at Reset or a rising edge at ModeActivate.
TRUE	**Automatic mode** If errors occur frequently in automatic mode, this setting has a negative effect on the control response, because PID_Temp switches between the calculated PID output value and the substitute output value at each error. In this case, check the ErrorBits parameter and eliminate the cause of the error. If one or several of the following errors occur and automatic mode was active before the error occurred, PID_Temp remains in automatic mode: • 0000001h: The "Input" parameter is outside the process value limits. • 0000800h: Sampling time error • 0040000h: Invalid value at Disturbance parameter. • 8000000h: Error during calculation of the PID parameters If one or several of the following errors occur and automatic mode was active before the error occurred, PID_Temp switches to "Substitute output value with error monitoring" mode: • 0000002h: Invalid value at Input_PER parameter. • 0000200h: Invalid value at Input parameter. • 0000400h: Calculation of output value failed. • 0001000h: Invalid value at Setpoint parameter or SubstituteSetpoint. As soon as the errors are no longer pending, PID_Temp switches back to automatic mode. If the following error occurs in "Substitute output value with error monitoring" mode, PID_Temp sets the PID output value to Config.Output.Heat.PidLowerLimit as long as this error is pending: • 0020000h: Invalid value at SubstituteOutput tag. Value has an invalid number format. This behavior is independent of SetSubstituteOutput.
	Manual mode If one or several errors occur and manual mode was active before the error occurred, PID_Temp remains in manual mode. If the following error occurs in manual mode, as long as this error is pending, PID_Temp sets the PID output value to SubstituteOutput: • 0010000h: Invalid value at ManualValue parameter. Value has an invalid number format. If the error 0010000h is pending in manual mode and the following error occurs, PID_Temp sets the PID output value to Config.Output.Heat.PidLowerLimit as long as this error is pending: • 0020000h: Invalid value at SubstituteOutput tag. Value has an invalid number format. This behavior is independent of SetSubstituteOutput.

Pretuning and fine tuning

ActivateRecov-erMode	Description
FALSE	PID_Temp switches to "Inactive" mode in the event of an error. The controller is only activated by a falling edge at Reset or a rising edge at ModeActivate.
TRUE	If the following error occurs, PID_Temp remains in the active mode: • 0000020h: Pretuning is not permitted during fine tuning. The following errors are ignored: • 0010000h: Invalid value at ManualValue parameter. • 0020000h: Invalid value at SubstituteOutput tag. When any other error occurs, PID_Temp cancels the tuning and switches to the mode from which tuning was started.

8.3.3.10 PID_Temp Warning tag

If several warnings are pending simultaneously, the values of the Warning tag are displayed with binary addition. If the warning 0000003h is displayed, for example, the warnings 0000001h and 0000002h are pending simultaneously.

Warning (DW#16#....)	Description
0000000	No warning pending.
0000001	The point of inflection was not found during pretuning.
0000004	The setpoint was limited to the configured limits.
0000008	Not all the necessary controlled system properties were defined for the selected method of calculation. Instead, the PID parameters were calculated using the TIR.TuneRuleHeat method or TIR.TuneRuleCool = 3.
0000010	The operating mode could not be changed because Reset = TRUE or ManualEnable = TRUE.
0000020	The cycle time of the calling OB limits the sampling time of the PID algorithm. Improve results by using shorter OB cycle times.
0000040	The process value exceeded one of its warning limits.
0000080	Invalid value at Mode. The operating mode is not switched.
0000100	The manual value was limited to the limits of the PID output value.
0000200	The specified rule for tuning is not supported. No PID parameters are calculated.
0001000	The substitute output value cannot be reached because it is outside the output value limits.
0004000	The specified number of the output value for heating and/or cooling is not supported. Only the output OutputHeat or OutputCool is used.
0008000	Invalid value at PIDSelfTune.SUT.AdaptDelayTime. The default value 0 is used.
0010000	Invalid value at PIDSelfTune.SUT.CoolingMode. The default value 0 is used.
0020000	The activation of cooling (Config.ActivateCooling tag) is not supported by the controller that is used as master (Config.Cascade.IsMaster tag). PID_Temp works as heating controller. Set the Config.ActivateCooling tag to FALSE.
0040000	Invalid value at Retain.CtrlParams.Heat.Gain, Retain.CtrlParams.Cool.Gain or Config.CoolFactor. PID_Temp supports only positive values for proportional gain (heating and cooling) and cooling factor. Automatic mode remains active with PID output value 0.0. The integral component is stopped.

The following warnings are deleted as soon as the cause has been remedied or you repeat the action with valid parameters:

- 0000001h
- 0000004h
- 0000008h
- 0000040h
- 0000100h

All other warnings are cleared with a rising edge at Reset or ErrorAck.

8.3.3.11 PwmPeriode tag

If the PID algorithm sampling time (Retain.CtrlParams.Heat.Cycle or Retain.CtrlParams.Heat.Cycle) and thus the time period of the pulse width modulation is very high when you use OutputHeat_PWM or OutputCool_PWM, you can define a deviating shorter time period at the Config.Output.Heat.PwmPeriode or Config.Output.Cool.PwmPeriode parameters to improve the smoothness of the process value.

Time period of the pulse width modulation at OutputHeat_PWM

Time period of the PWM at output OutputHeat_PWM depending on Config.Output.Heat.PwmPeriode:

- Heat.PwmPeriode = 0.0 (default)

  The sampling time of the PID algorithm for heating (Retain.CtrlParams.Heat.Cycle) is used as time period of the PWM.

- Heat.PwmPeriode > 0.0

  The value is rounded off to an integer multiple of the PID_Temp sampling time (CycleTime.Value) and used as time period of the PWM.

  The value must meet the following conditions:

  – Heat.PwmPeriode ≤ Retain.CtrlParams.Heat.Cycle

  – Heat.PwmPeriode > Config.Output.Heat.MinimumOnTime

  – Heat.PwmPeriode > Config.Output.Heat.MinimumOffTime

Time period of the pulse width modulation at OutputCool_PWM

Time period of the PWM at output OutputCool_PWM depending on Config.Output.Cool.PwmPeriode and the method for heating/cooling:

- Cool.PwmPeriode = 0.0 and cooling factor (Config.AdvancedCooling = FALSE):

  The sampling time of the PID algorithm for heating (Retain.CtrlParams.Heat.Cycle) is used as time period of the PWM.

- Cool.PwmPeriode = 0.0 and PID parameter switching (Config.AdvancedCooling = TRUE):

  The sampling time of the PID algorithm for cooling (Retain.CtrlParams.Cool.Cycle) is used as time period of the PWM.

- Cool.PwmPeriode > 0.0:

  The value is rounded off to an integer multiple of the PID_Temp sampling time (CycleTime.Value) and used as time period of the PWM.

  The value must meet the following conditions:

  – Cool.PwmPeriode ≤ Retain.CtrlParams.Cool.Cycle or Retain.CtrlParams.Heat.Cycle

  – Cool.PwmPeriode > Config.Output.Cool.MinimumOnTime

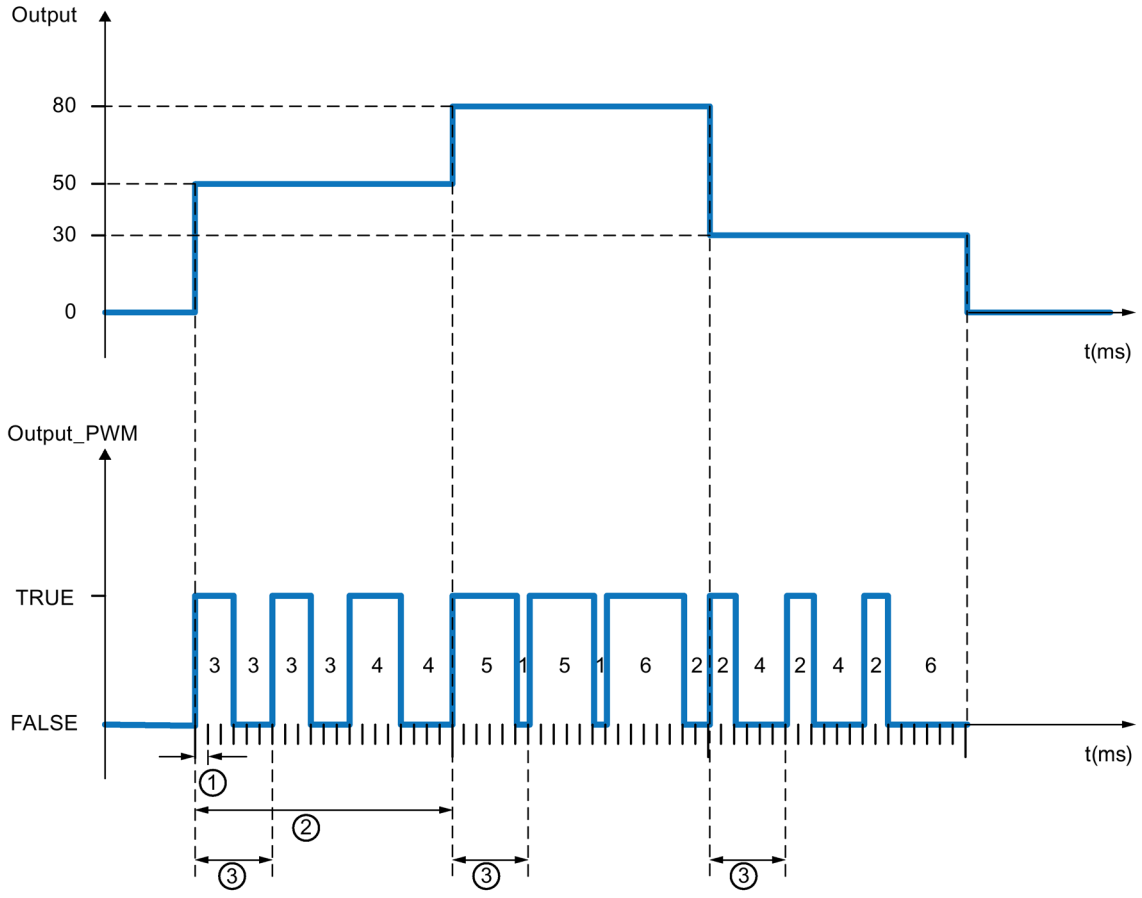
  – Cool.PwmPeriode > Config.Output.Cool.MinimumOffTime

Config.Output.Cool.PwmPeriode is only effective if the cooling output is activated (Config.ActivateCooling =TRUE).

When you use PwmPeriode, the accuracy of the PWM output signal is determined by the relationship of PwmPeriode to the PID_Temp sampling time (cycle time of the OB). PwmPeriode should be at least 10 times the PID_Temp sampling time.

If the sampling time of the PID algorithm is not an integer multiple of PwmPeriode, each last period of the PWM within the sampling time of the PID algorithm is extended accordingly.

Example for OutputHeat_PWM



① PID_Temp sampling time = 100.0 ms (cycle time of the calling cyclic interrupt OB, CycleTime.Value tag)

② PID algorithm sampling time = 2000.0 ms (Retain.CtrlParams.Heat.Cycle tag)

③ Time period of the PWM for heating = 600.0 ms (Config.Output.Heat.PwmPeriode tag)

8.4 PID basic functions

8.4.1 CONT_C

8.4.1.1 Description CONT_C

The CONT_C instruction is used on SIMATIC S7 automation systems to control technical processes with continuous input and output variables. You can assign parameters to enable or disable sub-functions of the PID controller and adapt it to the process. In addition to the functions in the setpoint and process value branches, the instruction implements a complete PID controller with continuous output value output and the option of manually influencing the value of the output value.

Application

You can use the controller as a PID fixed setpoint controller, or in multi-loop control systems, also as a cascade, blending or ratio controller. The functions of the controller are based on the PID control algorithm of the sampling controller with an analog signal, if necessary extended by including a pulse shaper stage to generate pulse-width modulated output signals for two or three step controllers with proportional actuators.

Call

The CONT_C instruction has an initialization routine that is run through when input parameter COM_RST = TRUE is set. During initialization, the integral action is set to the initialization value I_ITVAL. All the signal outputs are set to zero. COM_RST = FALSE has to be set after the initialization routine has been completed.

The calculation of the values in the control blocks is only correct if the block is called at regular intervals. You should therefore call the control blocks in a cyclic interrupt OB (OB 30 to OB 38). Enter the sampling time in the CYCLE parameter.

If you call the instruction CONT_C as a multiple instance DB, no technology object is created. No parameter assignment interface or commissioning interface is available. You must assign parameters for CONT_C directly in the multiple instance DB and commission it via a watch table.

Error information

The error message word RET_VAL is not evaluated by the block.

8.4.1.2 How CONT_C works

Setpoint branch

The setpoint is entered in floating-point format at the SP_INT input.

Process value branch

The process value can be input in I/O or floating-point format. The function CRP_IN converts the I/O value PV_PER to a floating-point format -100 to +100 % in accordance with the following rule:

Output of CRP_IN = PV_PER * 100 / 27648

The PV_NORM function scales the output of CRP_IN according to the following rule:

Output of PV_NORM = (output of CRP_IN) *PV_FAC + PV_OFF

PV_FAC has a default of 1 and PV_OFF a default of 0.

Forming the error signal

The difference between the setpoint and process value is the error signal. To suppress a minor sustained oscillation due to manipulated variable quantization (e.g. with a pulse width modulation with PULSEGEN), the error signal is applied to a dead band (DEADBAND). With DEADB_W = 0, the dead band is switched off.

PID Algorithm

The PID algorithm operates as a position algorithm. The proportional, integral (INT), and differential (DIF) actions are connected in parallel and can be activated or deactivated individually. This allows P, PI, PD, and PID controllers to be configured. Pure I controllers are also possible.

Manual value processing

It is possible to switch over between manual and automatic mode. In manual mode, the manipulated variable is corrected to a manually selected value.

The integral action (INT) is set internally to LMN - LMN_P - DISV and the derivative action (DIF) is set to 0 and synchronized internally. Changeover to automatic mode is therefore bumpless.

Manipulated value processing

You can use the LMNLIMIT function to limit the manipulated value to selected values. Alarm bits indicate when a limit is exceeded by the input variable.

The LMN_NORM function normalizes the output of LMNLIMIT according to the following rule:

LMN = (output of LMNLIMIT) * LMN_FAC + LMN_OFF

LMN_FAC has a default of 1 and LMN_OFF a default of 0.

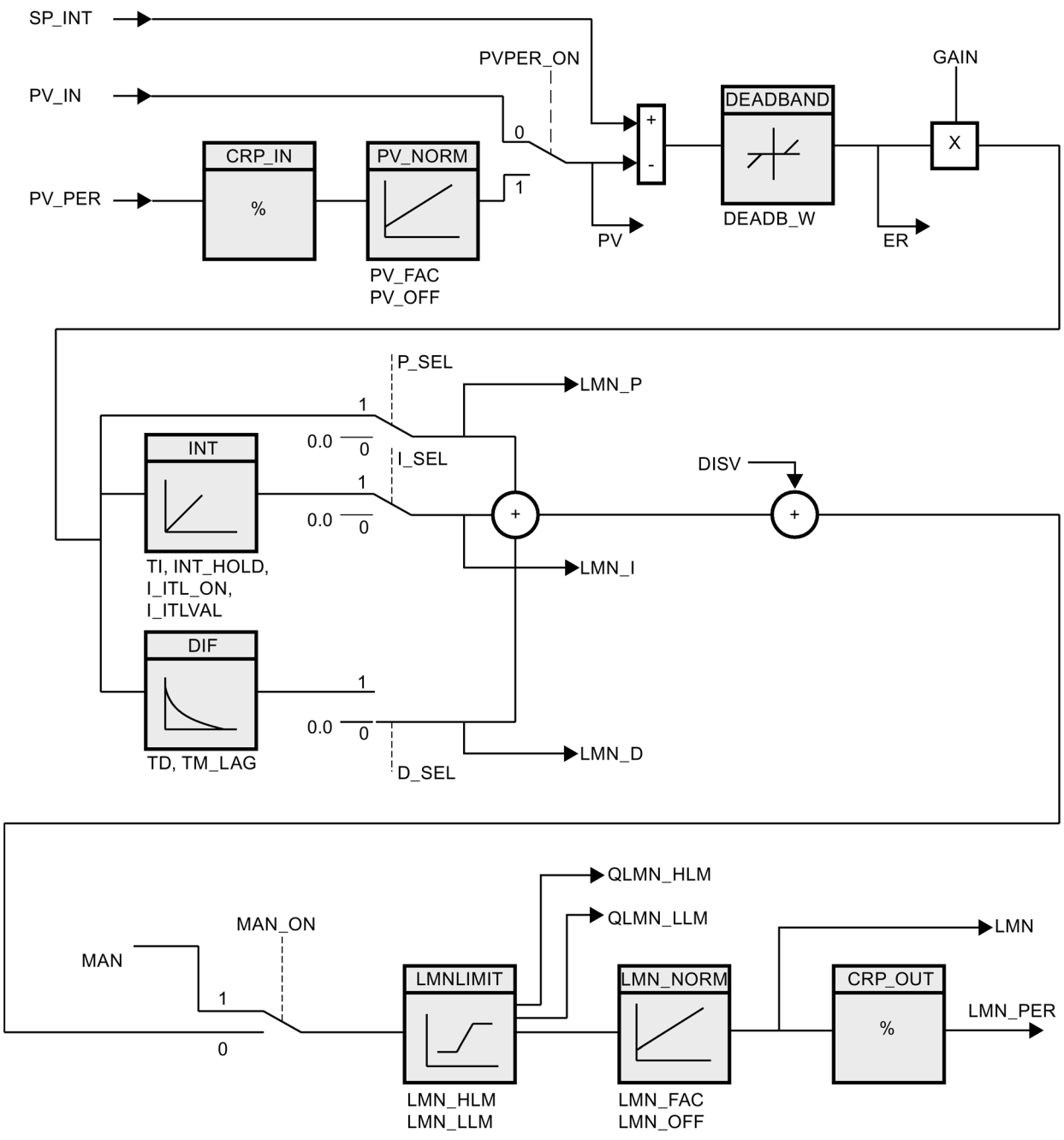
The manipulated value is also available in I/O format. The CRP_OUT function converts the LMN floating-point value to a I/O value according to the following rule:

LMN_PER = LMN * 27648 / 100

Feedforward control

A disturbance variable can be added at the DISV input.

8.4.1.3 CONT_C block diagram



8.4.1.4 Input parameter CONT_C

Parameters	Data type	Default	Description
COM_RST	BOOL	FALSE	The instruction has an initialization routine that is processed when the "Restart" input is set.
MAN_ON	BOOL	TRUE	If the input "Enable manual mode" is set then the control loop is interrupted. A manual value is set as the manipulated value.
PVPER_ON	BOOL	FALSE	If the process value is to be read in from the I/Os, the PV_PER input must be interconnected with the I/Os and the "Enable process value I/Os" input must be set.
P_SEL	BOOL	TRUE	The PID actions can be switched on and off individually in the PID algorithm. P-action is on when the "Enable P-action" input is set.
I_SEL	BOOL	TRUE	The PID actions can be switched on and off individually in the PID algorithm. I action is on when the input "I-action on" is set.
INT_HOLD	BOOL	FALSE	The output of the integral action can be frozen. For this the input "I-action hold" must be set.
I_ITL_ON	BOOL	FALSE	The output of the integral action can be set at the I_ITLVAL input. For this the input "Set I-action" must be set.
D_SEL	BOOL	FALSE	The PID actions can be switched on and off individually in the PID algorithm. D-action is on when the input "Enable D-action" is set.
CYCLE	TIME	T#1s	The time between block calls must be constant. The "Sampling time" input specifies the time between block calls. CYCLE >= 1ms
SP_INT	REAL	0.0	The input "Internal setpoint" is used to specify a setpoint. Permissible are values from -100 to 100 % or a physical variable 1).
PV_IN	REAL	0.0	At the "Process value input" you can assign parameters to a commissioning value or you can interconnect an external process value in floating-point format. Permissible are values from -100 to 100 % or a physical variable 1).
PV_PER	WORD	W#16#0000	The process value in I/O format is interconnected with the controller at the "Process value I/0" input.
MAN	REAL	0.0	The "Manual value" input is used to set a manual value using the operator interface functions. Permissible are values from -100 to 100 % or a physical variable 2).
GAIN	REAL	2.0	The "Proportional gain" input specifies controller amplification.
TI	TIME	T#20s	The "Integration time" input determines the time response of the integral action. TI >= CYCLE
TD	TIME	T#10s	The "Derivative action time" input determines the time response of the derivative action. TD >= CYCLE
TM_LAG	TIME	T#2s	Time lag of the D-action The algorithm of the D-action contains a delay for which parameters can be assigned at the input "Time lag of the D-action". TM_LAG >= CYCLE/2
DEADB_W	REAL	0.0	A dead band is applied to the system deviation. The "Dead band width" input determines the size of the dead band. DEADB_W >= 0.0 (%) or a physical variable 1)

Parameters	Data type	Default	Description
LMN_HLM	REAL	100.0	The manipulated value is always restricted to a high limit and low limit. The "High limit of manipulated value" input specifies the high limit. Permissible are real values starting at LMN_LLM or a physical variable 2).
LMN_LLM	REAL	0.0	The manipulated value is always restricted to a high limit and low limit. The "Low limit of manipulated value" input specifies the low limit. Permissible are real values up to LMN_HLM or a physical variable 2).
PV_FAC	REAL	1.0	The "Process value factor" input is multiplied by the process value. The input is used to scale the process value range.
PV_OFF	REAL	0.0	The input "Process value offset" is added to the process value. The input is used to scale the process value range.
LMN_FAC	REAL	1.0	The "Manipulated value factor" input is multiplied with the manipulated value. The input is used to scale the manipulated value range.
LMN_OFF	REAL	0.0	The input "Manipulated value offset" is added to the process value. The input is used to scale the manipulated value range.
I_ITLVAL	REAL	0.0	The output of the integral action can be set at the I_ITL_ON input. The initialization value is applied to the input "Initialization value of the I-action." Permissible are values of -100.0 to 100.0 (%) or a physical variable 2).
DISV	REAL	0.0	For feedforward control, the disturbance variable is interconnected to the "Disturbance variable" input. Permissible are values of -100.0 to 100.0 (%) or a physical variable 2).

1) Parameters in the setpoint and process value branches with the same unit

2) Parameters in the manipulated value branch with the same unit

8.4.1.5 Output parameters CONT_C

Parameter	Data type	Default	Description
LMN	REAL	0.0	The effective "Manipulated value" is output in floating point format at the "Manipulated value" output.
LMN_PER	WORD	W#16#0000	The manipulated value in I/O format is interconnected on the input "Manipulated value I/O" with the controller.
QLMN_HLM	BOOL	FALSE	The manipulated value is always restricted to a high limit and low limit. The output "High limit of manipulated value reached" indicates that the high limit has been reached.
QLMN_LLM	BOOL	FALSE	The manipulated value is always restricted to a high limit and low limit. The output "Low limit of manipulated value reached" indicates that the low limit has been reached.
LMN_P	REAL	0.0	The "P-action" output contains the proportional action of the manipulated variable.
LMN_I	REAL	0.0	The "I-action" output contains the integral action of the manipulated variable.
LMN_D	REAL	0.0	The "D-action" output contains the derivative action of the manipulated variable.
PV	REAL	0.0	The effective process value is output at the "Process value" output.
ER	REAL	0.0	The effective system deviation is output at the "Error signal" output.

8.4.2 CONT_S

8.4.2.1 Description CONT_S

The CONT_S instruction is used on SIMATIC S7 automation systems to control technical processes with binary output value output signals for actuators with integrating behavior. During parameter assignment, you can activate or deactivate sub-functions of the PI step controller to adapt the controller to the controlled system. In addition to the functions in the process value branch, the instruction implements a complete proportional-plus-integral-action controller with binary output value output and the option of manually influencing the value of the output value. The step controller operates without a position feedback signal.

Application

You can use the controller as a PI fixed setpoint controller or in secondary control loops in cascade, blending or ratio controllers, however you cannot use it as the primary controller. The functions of the controller are based on the PI control algorithm of the sampling controller supplemented by the functions for generating the binary output signal from the analog actuating signal.

Call

The CONT_S instruction has an initialization routine that is run through when input parameter COM_RST = TRUE is set. All the signal outputs are set to zero. COM_RST = FALSE has to be set after the initialization routine has been completed.

The calculation of the values in the control blocks is only correct if the block is called at regular intervals. You should therefore call the control blocks in a cyclic interrupt OB (OB 30 to OB 38). Enter the sampling time in the CYCLE parameter.

If you call the instruction CONT_S as a multiple instance DB, no technology object is created. No parameter assignment interface or commissioning interface is available. You must assign parameters for CONT_S directly in the multiple instance DB and commission it via a watch table.

Error information

The error message word RET_VAL is not evaluated by the block.

8.4.2.2 Mode of operation CONT_S

Setpoint branch

The setpoint is entered in floating-point format at the SP_INT input.

Process value branch

The process value can be input in I/O or floating-point format. The function CRP_IN converts the I/O value PV_PER to a floating-point format -100 to +100 % in accordance with the following rule:

Output of CRP_IN = PV_PER * 100 / 27648

The PV_NORM function normalizes the output of CRP_IN according to the following rule:

Output of PV_NORM = (output of CRP_IN) * PV_FAC + PV_OFF

PV_FAC has a default of 1 and PV_OFF a default of 0.

Forming the error signal

The difference between the setpoint and process value is the error signal. To suppress a small constant oscillation due to the manipulated variable quantization (for example, due to a limited resolution of the manipulated value by the control valve), a dead band is applied to the error signal (DEADBAND). With DEADB_W = 0, the dead band is switched off.

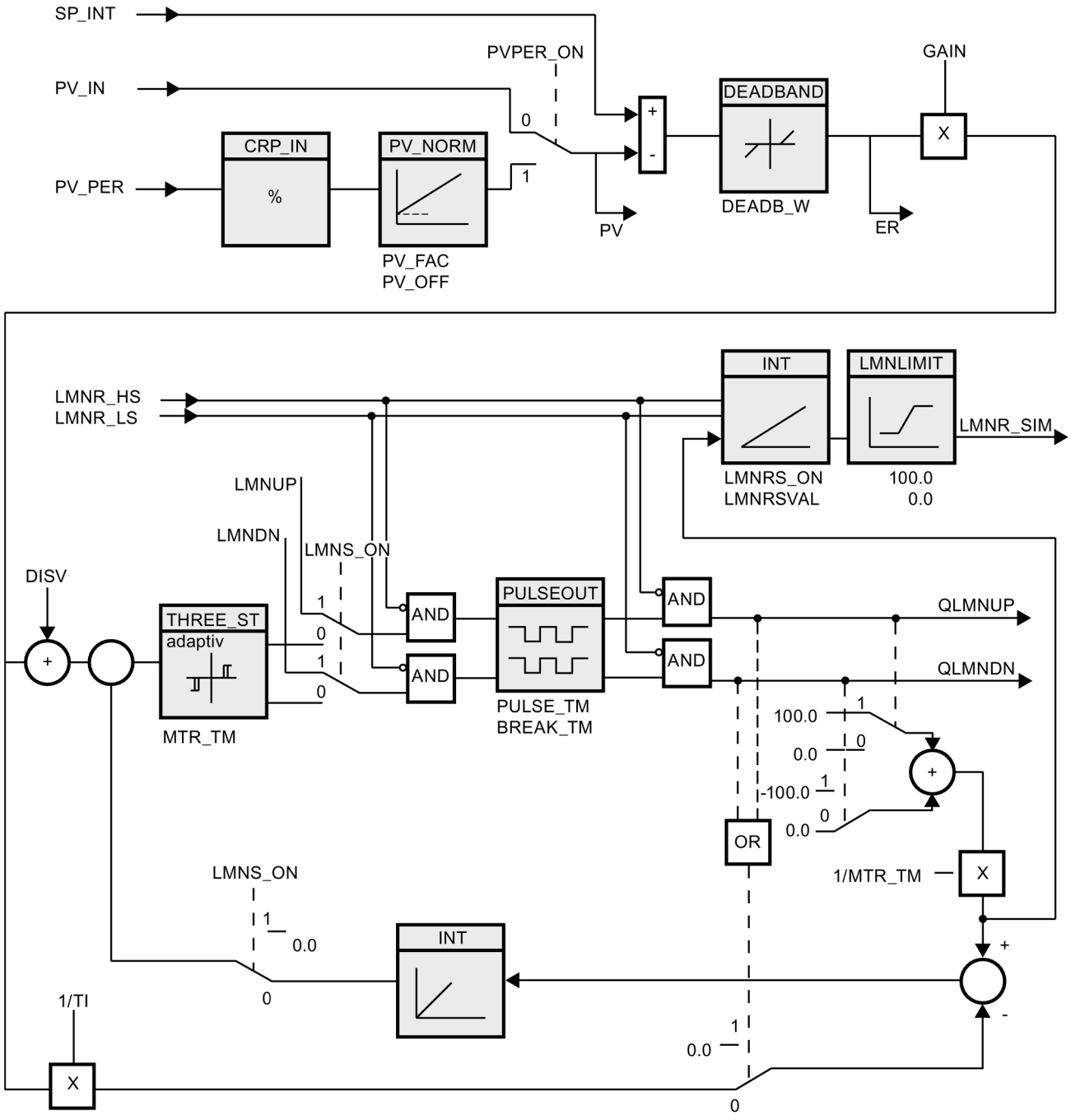
PI step algorithm

The instruction operates without position feedback. The I-action of the PI algorithm and the assumed position feedback signal are calculated in **one** integral action (INT) and compared with the remaining P-action as a feedback value. The difference is applied to a three-step element (THREE_ST) and a pulse shaper (PULSEOUT) that generates the pulses for the control valve. The switching frequency of the controller can be reduced by adapting the response threshold of the three-step element.

Feedforward control

A disturbance variable can be added at the DISV input.

8.4.2.3 Block diagram CONT_S



8.4.2.4 Input parameters CONT_S

Parameters	Data type	Default	Description
COM_RST	BOOL	FALSE	The block has an initialization routine that is processed when the "Restart" input is set.
LMNR_HS	BOOL	FALSE	The signal "Control valve at high endstop" is interconnected at the input "High endstop signal of position feedback". LMNR_HS=TRUE means: The control valve is at high endstop.
LMNR_LS	BOOL	FALSE	The signal "Control valve at low endstop" is interconnected on the input "Low endstop signal of position feedback". LMNR_LS=TRUE means The control valve is at low endstop.
LMNS_ON	BOOL	FALSE	Manipulated value signal processing is switched to manual mode at the "Enable manual mode of manipulated signal".
LMNUP	BOOL	FALSE	The output signal QLMNUP is operated in manual mode of the manipulated value signals at the input "Manipulated value signal up".
LMNDN	BOOL	FALSE	The output signal QLMNDN is operated in manual mode of the manipulated value signals at the input "Manipulated value signal down"
PVPER_ON	BOOL	FALSE	If the process value is to be read from the I/O then the input PV_PER must be interconnected with the I/O and the input "Enable process value I/O" must be set.
CYCLE	TIME	T#1s	The time between block calls must be constant. The "Sampling time" input specifies the time between block calls. CYCLE >= 1ms
SP_INT	REAL	0.0	The input "Internal setpoint" is used to specify a setpoint. Permissible are values from -100 to 100 % or a physical variable [1].
PV_IN	REAL	0.0	At the "Process value input" you can assign parameters to a commissioning value or you can interconnect an external process value in floating-point format. Permissible are values from -100 to 100 % or a physical variable [1].
PV_PER	WORD	W#16#0000	The process value in I/O format is interconnected with the controller at the "Process value I/O" input.
GAIN	REAL	2.0	The "Proportional gain" input specifies controller amplification.
TI	TIME	T#20s	The "Integration time" input determines the time response of the integral action. TI >= CYCLE
DEADB_W	REAL	1.0	A dead band is applied to the system deviation. The "Dead band width" input determines the size of the dead band. Permissible are values from 0 to 100 % or a physical variable [1].
PV_FAC	REAL	1.0	The "Process value factor" input is multiplied by the process value. The input is used to scale the process value range.
PV_OFF	REAL	0.0	The input "Process value offset" is added to the process value. The input is used to scale the process value range.
PULSE_TM	TIME	T#3s	You can assign a minimum pulse time at the parameter "Minimum pulse time". PULSE_TM >= CYCLE
BREAK_TM	TIME	T#3s	You can assign a minimum break time at the parameter "Minimum break time". BREAK_TM >= CYCLE

Parameters	Data type	Default	Description
MTR_TM	TIME	T#30s	The time required by the actuator to move from limit stop to limit stop is entered at the "Motor actuating time" parameter. MTR_TM >= CYCLE
DISV	REAL	0.0	For feedforward control, the disturbance variable is interconnected to the "Disturbance variable" input. Permissible are values from -100 to 100 % or a physical variable [2].

[1] Parameters in setpoint and process value branches with identical unit

[2] Parameters in the manipulated value branch with same unit

8.4.2.5 Output parameters CONT_S

Parameters	Data type	Default	Description
QLMNUP	BOOL	FALSE	If the output "Manipulated value signal up" is set then the control valve should be open.
QLMNDN	BOOL	FALSE	If the output "Manipulated value signal down" is set then the control valve should be closed.
PV	REAL	0.0	The effective process value is output at the "Process value" output.
ER	REAL	0.0	The effective system deviation is output at the "Error signal" output.

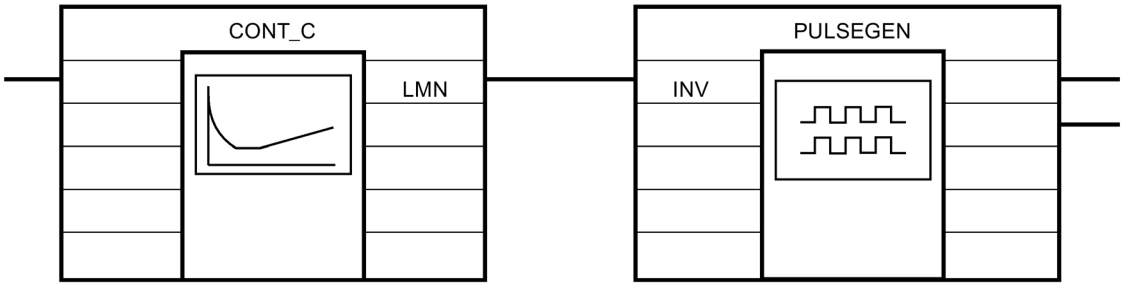
8.4.3 PULSEGEN

8.4.3.1 Description PULSEGEN

The instruction PULSEGEN serves as the structure of a PID controller with impulse output for proportional actuators. PULSEGEN transforms the input value INV (= LMN of the PID controller) through modulation of the impulse width in an impulse sequence with a constant period duration, which corresponds with the cycle time with which the input value is updated.

Application

You can use the PULSEGEN instruction to configure two- or three-step PID controllers with pulse width modulation. The function is normally used in conjunction with the continuous controller CONT_C.



Call

The PULSEGEN instruction has an initialization routine that is run through when input parameter COM_RST = TRUE is set. All the signal outputs are set to zero. COM_RST = FALSE has to be set after the initialization routine has been completed.

The calculation of the values in the control blocks is only correct if the block is called at regular intervals. You should therefore call the control blocks in a cyclic interrupt OB (OB 30 to OB 38). Enter the sampling time in the CYCLE parameter.

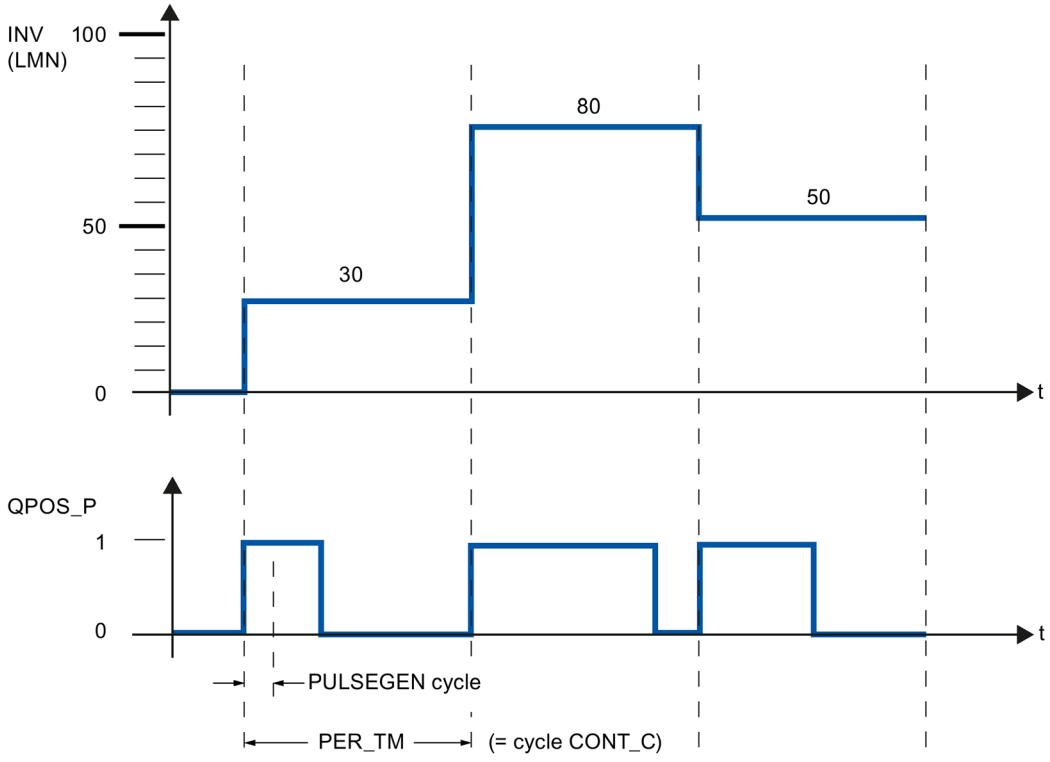
Responses in the event of an error

The error message word RET_VAL is not evaluated by the block.

8.4.3.2 Mode of operation PULSEGEN

Impulse width modulation

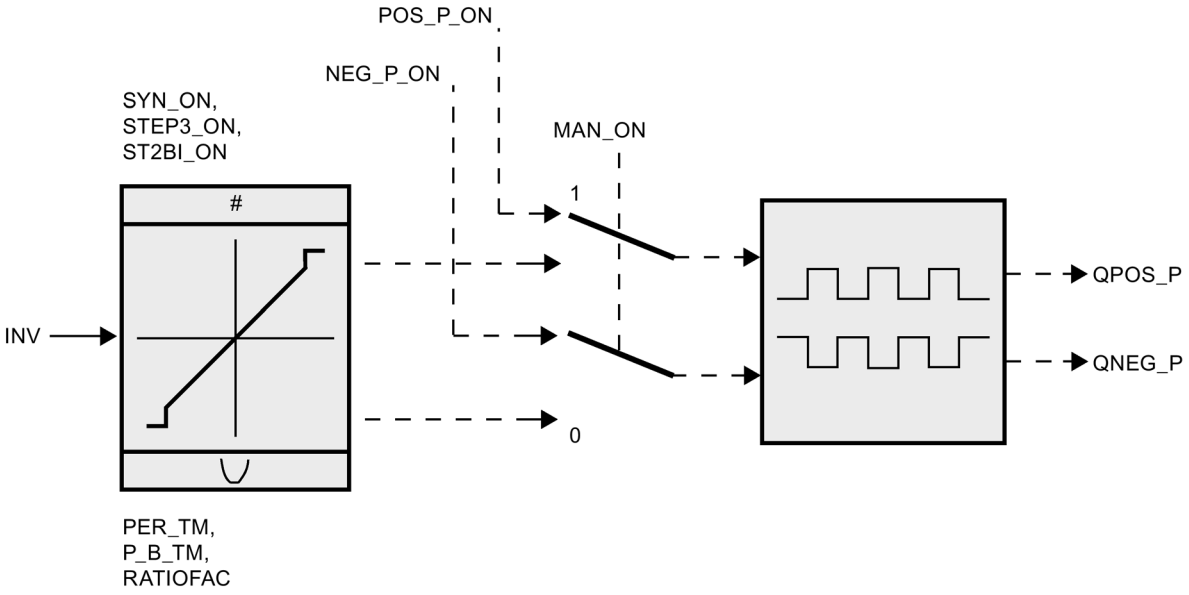
The duration of a pulse per period duration is proportional to the input variable. The cycle assigned via PER_TM is not identical to the processing cycle of the PULSEGEN instruction. Rather, a PER_TM cycle is made up of several processing cycles of the PULSEGEN instruction, whereby the number of PULSEGEN calls per PER_TM cycle determines the accuracy of the pulse width.



An input variable of 30% and 10 PULSEGEN calls per PER_TM mean the following:

- "One" at the QPOS_P output for the first three calls of PULSEGEN (30% of 10 calls)
- "Zero" at the QPOS_P output for seven further calls of PULSEGEN (70% of 10 calls)

Block diagram



Accuracy of the manipulated value

With a "Sampling ratio" of 1:10 (CONT_C calls to PULSEGEN calls) the accuracy of the manipulated value in this example is restricted to 10%, in other words, set input values INV can only be simulated by a pulse duration at the QPOS_P output in steps of 10 %.

The accuracy is increased as the number of PULSEGEN calls per CONT_C call is increased.

If PULSEGEN is called, for example, 100 times more often than CONT_C, a resolution of 1 % of the manipulated value range is achieved.

Note

The reduction ratio of the call frequency must be programmed by the user.

Automatic synchronization

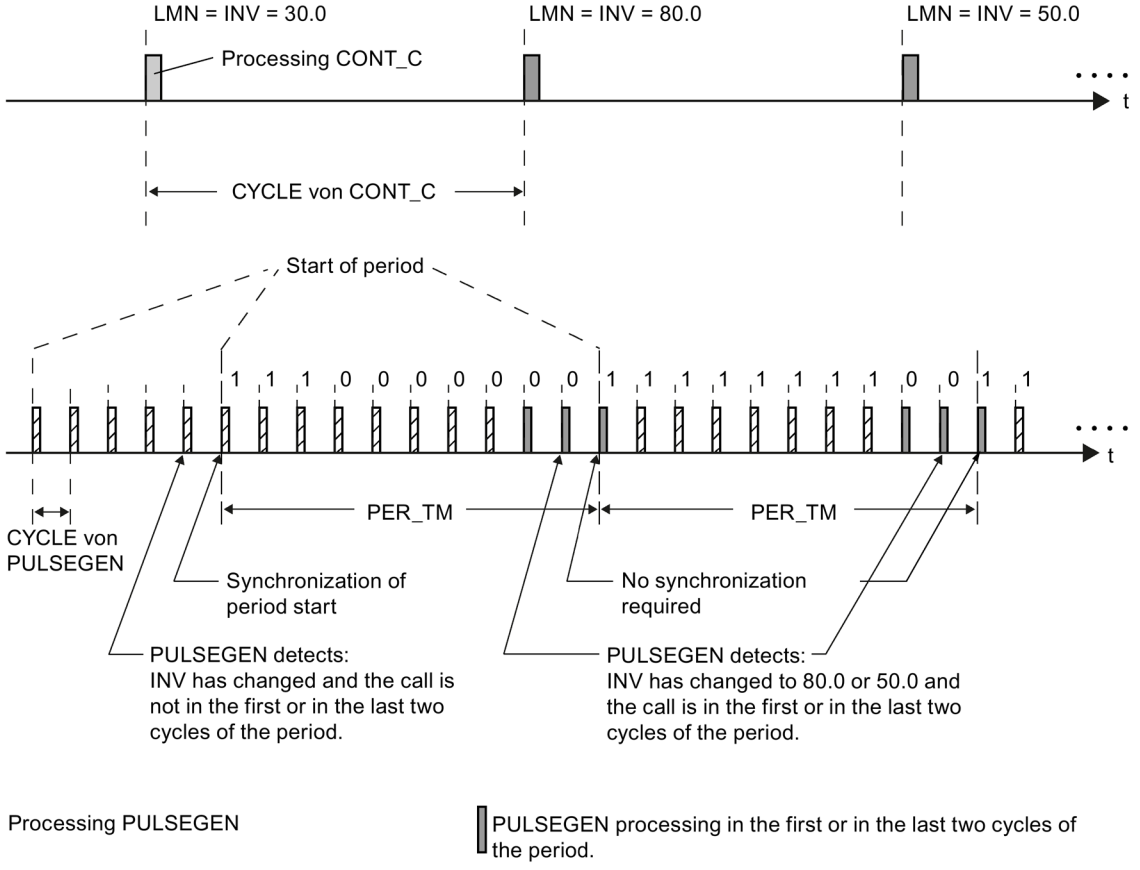
It is possible to automatically synchronize the pulse output with the instruction that updates the input variable INV (e.g. CONT_C). This ensures that a change in the input variable is output as quickly as possible as a pulse.

The pulse shaper evaluates the input value INV at intervals corresponding to the period duration PER_TM and converts the value into a pulse signal of corresponding length.

Since, however, INV is usually calculated in a slower cyclic interrupt class, the pulse shaper should start the conversion of the discrete value into a pulse signal as soon as possible after the updating of INV.

To allow this, the block can synchronize the start of the period using the following procedure:

If INV changes and if the block call is not in the first or last two call cycles of a period, a synchronization is performed. The pulse duration is recalculated and in the next cycle is output with a new period.



The automatic synchronization is switched off, if SYN_ON = FALSE.

Note

The start of a new period and subsequent synchronization usually leads to a certain imprecision when the old value of INV (i.e. of LMN) is mapped to the pulse signal.

8.4.3.3 Mode of operation PULSEGEN

Modes

Depending on the parameters assigned to the pulse shaper, PID controllers with a three-step output or with a bipolar or unipolar two-step output can be configured. The following table illustrates the setting of the switch combinations for the possible modes.

Mode	MAN_ON	STEP3_ON	ST2BI_ON
Three-step control	FALSE	TRUE	Any
Two-step control with bi-polar Manipulating range (-100 % to 100 %)	FALSE	FALSE	TRUE
Two-step control with unipolar Manipulating range (0 % to 100 %)	FALSE	FALSE	FALSE
Manual mode	TRUE	Any	Any

Manual mode in two/three-step control

In the manual mode (MAN_ON = TRUE), the binary outputs of the three-step or two-step controller can be set using the signals POS_P_ON and NEG_P_ON regardless of INV.

Control	POS_P_ON	NEG_P_ON	QPOS_P	QNEG_P
Three-step control	FALSE	FALSE	FALSE	FALSE
	TRUE	FALSE	TRUE	FALSE
	FALSE	TRUE	FALSE	TRUE
	TRUE	TRUE	FALSE	FALSE
Two-step control	FALSE	Any	FALSE	TRUE
	TRUE	Any	TRUE	FALSE

8.4.3.4 Three-step control

Three-step control

In "Three-step control" mode, it is possible to generate three statuses of the actuating signal. For this, the status values of the binary output signals QPOS_P and QNEG_P are assigned to the respective operating statuses of the actuator. The table shows the example of a temperature control:

Output signals	Heat	Off	Cool
QPOS_P	TRUE	FALSE	FALSE
QNEG_P	FALSE	FALSE	TRUE

The pulse duration is calculated from the input variable via a characteristic curve. The form of the characteristic curve is defined by the minimum pulse duration or minimum interval and the ratio factor. The normal value for the ratio factor is 1.

The "doglegs" in the curves are caused by the minimum pulse duration or minimum interval.

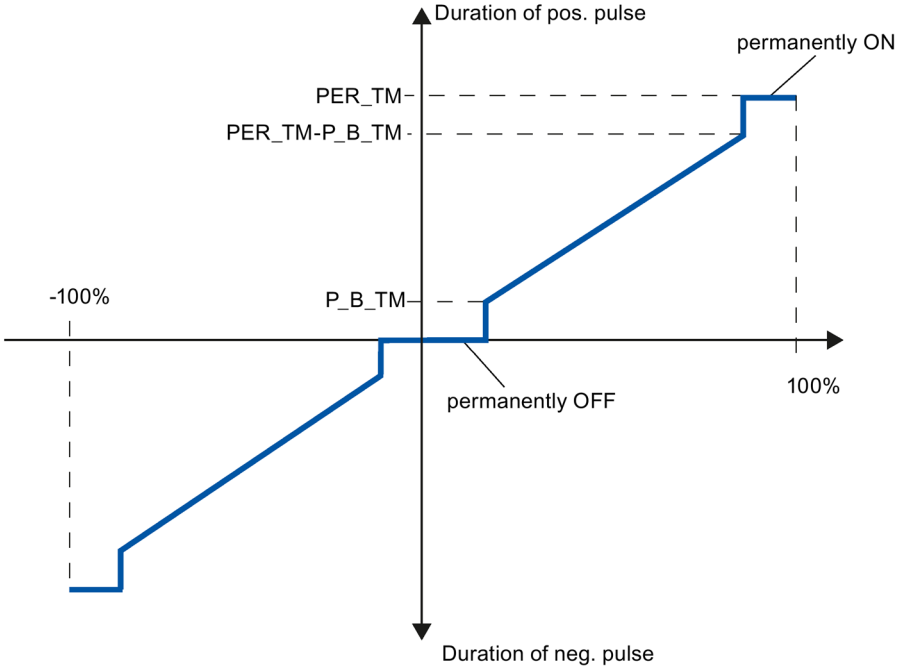
Minimum pulse duration or minimum interval

A correctly assigned minimum pulse duration or minimum interval P_B_TM can prevent short on/off times, which reduce the working life of switching elements and actuators. Small absolute values of input variable LMN that would otherwise generate a pulse duration shorter than P_B_TM are suppressed. Large input values that would generate a pulse duration longer than PER_TM - P_B_TM are set to 100% or -100%.

The duration of positive or negative pulses is calculated by multiplying the input variable (in %) by the period duration:

Pulse duration = INV / 100 * PER_TM

The following figure shows a symmetrical characteristic curve of the three-step controller (ratio factor = 1).



Asymmetrical three-step control

Using the ratio factor RATIOFAC, the ratio of the duration of positive to negative pulses can be changed. In a thermal process, for example, this would allow different system time constants for heating and cooling.

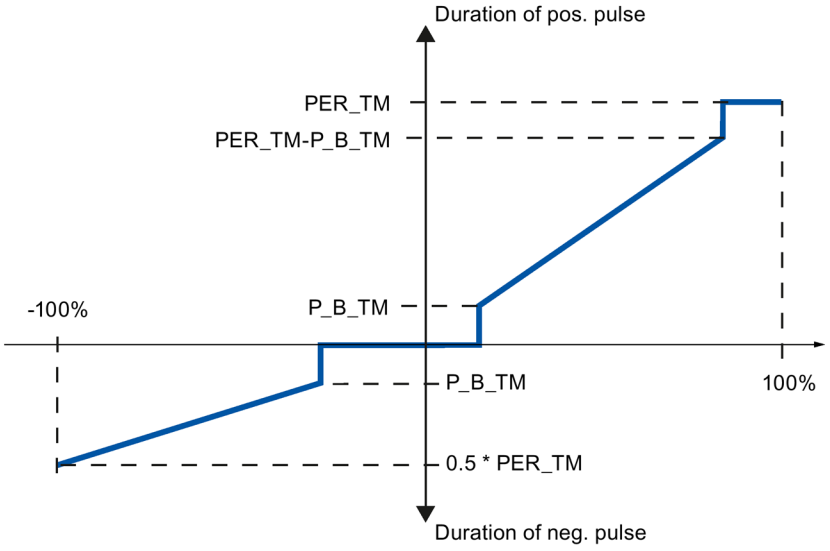
Ratio factor < 1

The pulse duration at the negative pulse output, calculated by multiplying the input variable by the period duration, is multiplied by the ratio factor.

Positive pulse duration = INV /100 * PER_TM

Negative pulse duration = INV / 100 * PER_TM * RATIOFAC

The following figure shows the asymmetrical characteristic curve of the three-step controller (ratio factor = 0.5):



Ratio factor > 1

The pulse duration at the positive pulse output, calculated by multiplying the input variable by the period duration, is divided by the ratio factor.

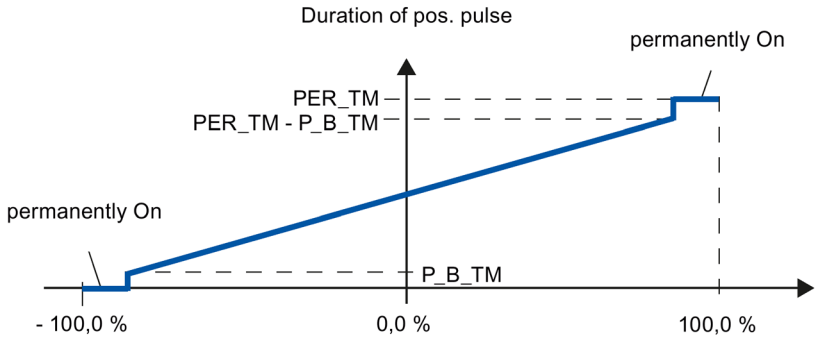
Positive pulse duration = INV / 100 * PER_TM / RATIOFAC

Negative pulse duration = INV / 100 * PER_TM

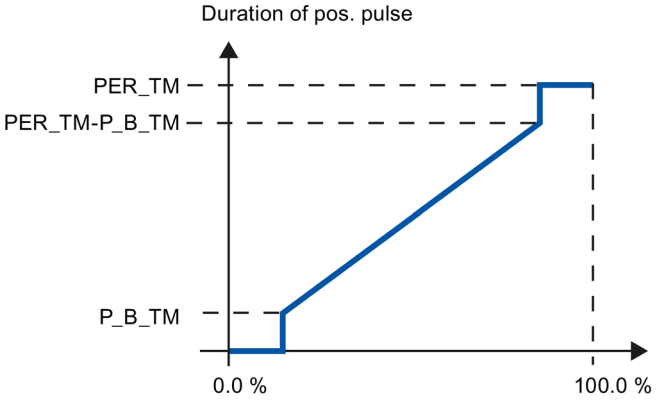
8.4.3.5 Two-step control

In two-step control, only the positive pulse output QPOS_P of PULSEGEN is connected to the on/off actuator. Depending on the manipulated value range used, the two-step controller has a bipolar or a unipolar manipulated value range.

Two-step control with bipolar manipulated variable range (-100% to 100%)



Two-step control with unipolar manipulated variable range (0% to 100%)



The negated output signal is available at QNEG_P if the connection of the two-step controller in the control loop requires a logically inverted binary signal for the actuating pulses.

Pulse	Actuator On	Actuator Off
QPOS_P	TRUE	FALSE
QNEG_P	FALSE	TRUE

8.4.3.6 Input parameters PULSEGEN

The values of the input parameters are not limited in the block. There is no parameter check.

Parameters	Data type	Default	Description
INV	REAL	0.0	At the input parameter "Input variable" an analog manipulated variable is connected. Values from -100 to 100 % are permitted.
PER_TM	TIME	T#1s	At the parameter "Period duration" the constant period duration of the pulse width modulation is entered. This corresponds to the sampling time of the controller. The ratio between the sampling time of the pulse shaper and the sampling time of the controller determines the accuracy of the pulse width modulation. PER_TM >=20*CYCLE
P_B_TM	TIME	T#50 ms	You can assign a minimum pulse/break time at the parameter "Minimum pulse/break time". P_B_TM >= CYCLE
RATIOFAC	REAL	1.0	Using the "Ratio factor" input parameter the ratio of the duration of positive to negative pulses can be changed. In a thermal process, this would, for example, allow different time constants for heating and cooling to be compensated (for example, in a process with electrical heating and water cooling). Values from 0.1 to 10.0 are permitted.
STEP3_ON	BOOL	TRUE	At the input parameter "Enable three-step control" the appropriate mode is activated. In three-step control both output signals are active.
ST2BI_ON	BOOL	FALSE	At the input parameter "Enable two-step control for bipolar manipulated value range" you can select from the modes "Two-step control for bipolar manipulated value range" and "Two-step control for unipolar manipulated value range". STEP3_ON = FALSE is required.
MAN_ON	BOOL	FALSE	Setting the input parameter "Enable manual mode" allows the output signals to be set manually.
POS_P_ON	BOOL	FALSE	For manual mode three-step control, the output signal QPOS_P can be operated on the input parameter "Positive pulse on". In manual mode with two-step control, QNEG_P is always set inversely to QPOS_P.
NEG_P_ON	BOOL	FALSE	For manual mode three-step control, the output signal QNEG_P can be operated on the input parameter "Negative pulse on". In manual mode with two-step control, QNEG_P is always set inversely to QPOS_P.
SYN_ON	BOOL	TRUE	By setting the input parameter "Enable synchronization", it is possible to synchronize the pulse output automatically with the block that updates the input variable INV. This ensures that a change in the input variable is output as quickly as possible as a pulse.
COM_RST	BOOL	FALSE	The block has an initialization routine that is processed when the input "Restart" is set.
CYCLE	TIME	T#10ms	The time between block calls must be constant. The "Sampling time" input specifies the time between block calls. CYCLE >= 1ms

8.4.3.7 Output parameter PULSEGEN

Parameters	Data type	Default	Description
QPOS_P	BOOL	FALSE	The output parameter "Output signal positive pulse" is set if a pulse will be output. In three-step control, this is always the positive pulse. In two-step control, the QNEG_P is always set inversely to QPOS_P.
QNEG_P	BOOL	FALSE	The output parameter "Output signal negative pulse" is set if a pulse will be output. In three-step control, this is always the negative pulse. In two-step control, QNEG_P is always set inversely to QPOS_P.

8.4.4 TCONT_CP

8.4.4.1 Description TCONT_CP

The instruction TCONT_CP is used to control temperature processes with continuous or pulsed control signals. The controller functionality is based on the PID control algorithm with additional functions for temperature processes. To improve the control response with temperature processes, the block includes a control zone and reduction of the proportional component if there is a setpoint step change.

The instruction can set the PI/PID parameters itself using the controller optimization function.

Application

The controller controls one actuator; in other words, with one controller you can either heat or cool but not both. If you use the block for cooling, GAIN must be assigned a negative value. This inversion of the controller means that if the temperature rises, for example, the manipulated variable LMN and with it the cooling action is increased.

Call

The instruction TCONT_CP must be called equidistant. To achieve this, use a cyclic interrupt priority class (for example, OB35 for an S7-300).

The TCONT_CP instruction has an initialization routine that is run through when input parameter COM_RST = TRUE is set. During initialization, the integral action is set to the initialization value I_ITVAL. All the signal outputs are set to zero. Following execution of the initialization routine, the block sets COM_RST back to FALSE. If you require initialization when the CPU restarts, call the block in OB100 with COM_RST = TRUE.

If you call the instruction TCONT_CP as a multiple instance DB, no technology object is created. No parameter assignment interface or commissioning interface is available. You must assign parameters for TCONT_CP directly in the multiple instance DB and commission it via a watch table.

See also

Operating principle of the pulse generator (Page 465)

Block diagram TCONT_CP (Page 468)

8.4.4.2 Mode of operation TCONT_CP

Setpoint branch

The setpoint is entered at input SP_INT in floating-point format as a physical value or percentage. The setpoint and process value used to form the control deviation must have the same unit.

Process value options (PVPER_ON)

Depending on PVPER_ON, the process value can be read in, in the I/O or floating-point format.

PVPER_ON	Process Value Input
TRUE	The process value is read in via the analog I/Os (PIW xxx) at input PV_PER.
FALSE	The process value is acquired in floating-point format at input PV_IN.

Process value format conversion CRP_IN (PER_MODE)

The CRP_IN function converts the I/O value PV_PER to floating-point format depending on the PER_MODE switch according to the following rules:

PER_MODE	Output of CRP_IN	Analog Input Type	Unit
0	PV_PER * 0.1	Thermoelements; PT100/NI100; standard	°C;°F
1	PV_PER * 0.01	PT100/NI100; climate;	°C;°F
2	PV_PER * 100/27648	Voltage/current	%

Process value scaling PV_NORM (PF_FAC, PV_OFFS)

The PV_NORM function calculates the output of CRP_IN according to the following rule:

"Output of PV_NORM" = "Output of CRP_IN)" * PV_FAC + PV_OFFS

It can be used for the following purposes:

- Process value adjustment with PV_FAC as process value factor and PV_OFFS as process value offset.
- Scaling of temperature to percentage

  You want to enter the setpoint as a percentage and must now convert the measured temperature value to a percentage.
- Scaling of percentage to temperature

  You want to enter the setpoint in the physical temperature unit and must now convert the measured voltage/current value to a temperature.

Calculation of the parameters:

- PV_FAC = range of PV_NORM/range of CRP_IN;
- PV_OFFS = LL (PV_NORM) - PV_FAC * LL(CRP_IN);

  where LL: Low limit

The scaling is switched off with the default values (PV_FAC = 1.0 and PV_OFFS = 0.0). The effective process value is output at the PV output.

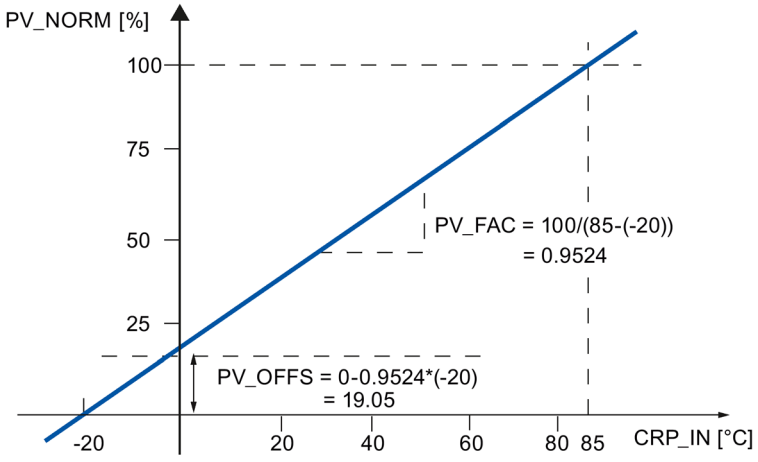
Note

With pulse control, the process value must be transferred to the block in the fast pulse call (reason: mean value filtering). Otherwise, the control quality can deteriorate.

Example of Process Value Scaling

If you want to enter the setpoint as a percentage, and you have a temperature range of -20 to 85 °C applied to , CRP_IN you must normalize the temperature range as a percentage.

The diagram below shows an example of adapting the temperature range -20 to 85 °C to an internal scale of 0 to 100 %:



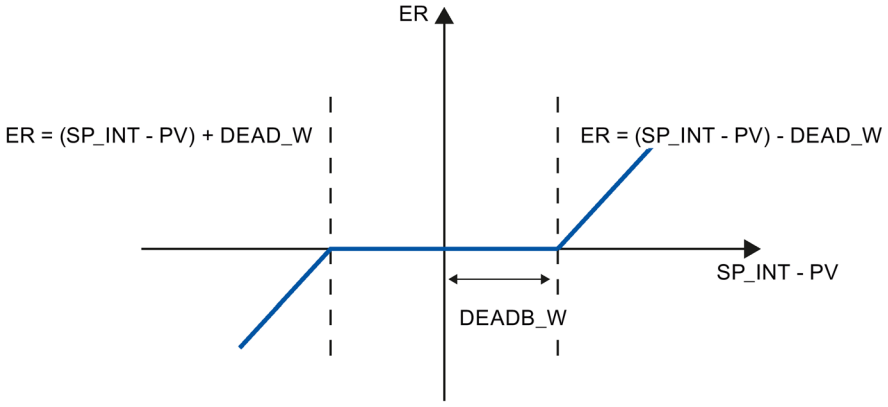
Forming the control deviation

The difference between the setpoint and process value is the control deviation before the dead band.

The setpoint and process value must exist in the same unit.

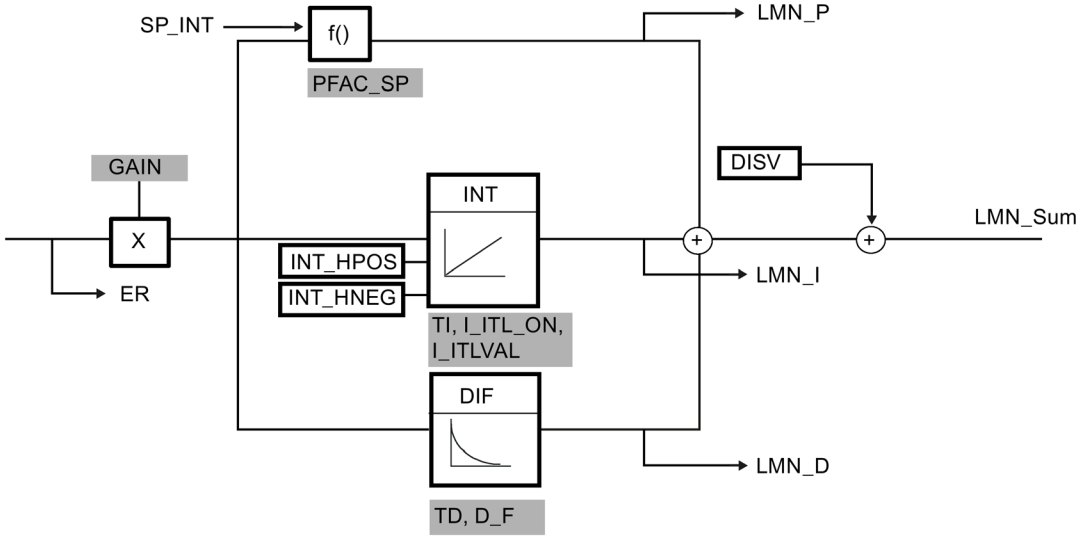
Dead band (DEADB_W)

To suppress a minor sustained oscillation due to the manipulated variable quantization (for example, in pulse width modulation with PULSEGEN) a dead band is applied to the (DEADBAND) control deviation. With DEADB_W = 0.0, the dead band is disabled. The effective control deviation is indicated by the ER parameter.



PID Algorithm

The following figure shows the block diagram of the PID algorithm.



PID Algorithm (GAIN, TI, TD, D_F)

The PID algorithm operates as a position algorithm. The proportional, integral (INT), and derivative (DIF) actions are connected in parallel and can be activated or deactivated individually. This allows P, PI, PD, and PID controllers to be configured.

Controller tuning supports PI and PID controllers. Controller inversion is implemented using a negative GAIN (cooling controller).

If you set TI and TD to 0.0, you obtain a pure P controller at the operating point.

The step response in the time range is:

$$LMN\_Sum(t) = GAIN*ER(0)(1+\frac{1}{TI} * t+D\_F * e^{\frac{-t}{TD/D\_F}}$$

Where:

LMN_Sum(t) the manipulated variable in the controller's automatic mode

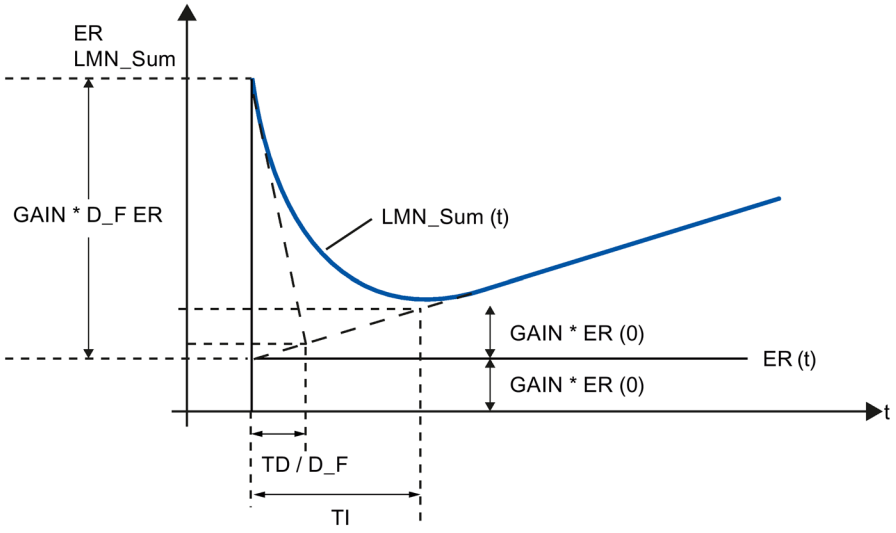
ER (0) is the step height of the normalized control deviation

GAIN is the controller gain

TI is the integration time

TD is the derivative action time

D_F is the derivative factor



Integral action (TI, I_ITL_ON, I_ITLVAL)

In manual mode, it is corrected as follows: LMN_I = LMN - LMN_P - DISV.

If the output value is limited, the integral action is halted. If the control deviation moves the integral action back in the direction of the output range, the integral action is enabled again.

The integral action is also modified by the following measures:

- The integral action of the controller is deactivated by TI = 0.0
- Weakening of the proportional action when setpoint changes occur
- Control zone
- The output value limits can be modified online

Weakening of the proportional action when setpoint changes occur (PFAC_SP)

To prevent overshoot, you can weaken the proportional action using the parameter "Proportional factor for setpoint changes" (PFAC_SP). Using PFAC_SP, you can select continuously between 0.0 and 1.0 to decide the effect of the proportional action when the setpoint changes:

- PFAC_SP = 1.0: Proportional action has full effect if the setpoint changes
- PFAC_SP = 0.0: Proportional action has no effect if the setpoint changes

The weakening of the proportional action is achieved by compensating the integral action.

Derivative action (TD, D_F)

- The derivative action of the controller is deactivated by TD = 0.0
- If the derivative action is active, the following relationship should apply:

  TD = 0.5 * CYCLE * D_F

Parameter Settings of a P or PD Controller with Operating Point

In the user interface, deactivate the integral action (TI = 0.0) and possibly also the derivative action (TD = 0.0). Then make the following parameter settings:

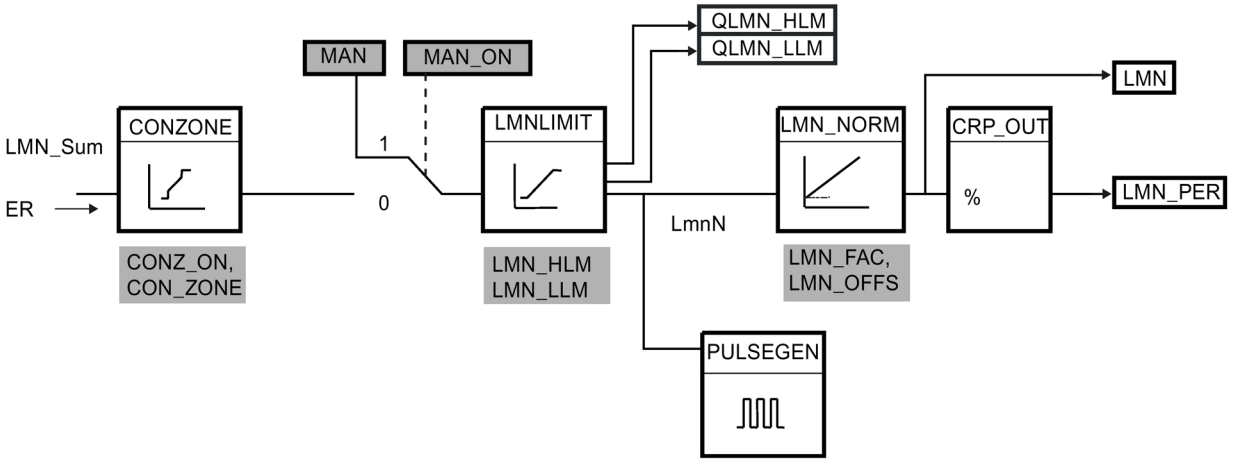
- I_ITL_ON = TRUE
- I_ITLVAL = operating point;

Feedforward control (DISV)

A disturbance variable can be added at the DISV input.

Calculating the output value

The diagram below is the block diagram of the output value calculation:



Parameter configuration interface

Instruction call interface

Parameter configuration interface, call interface

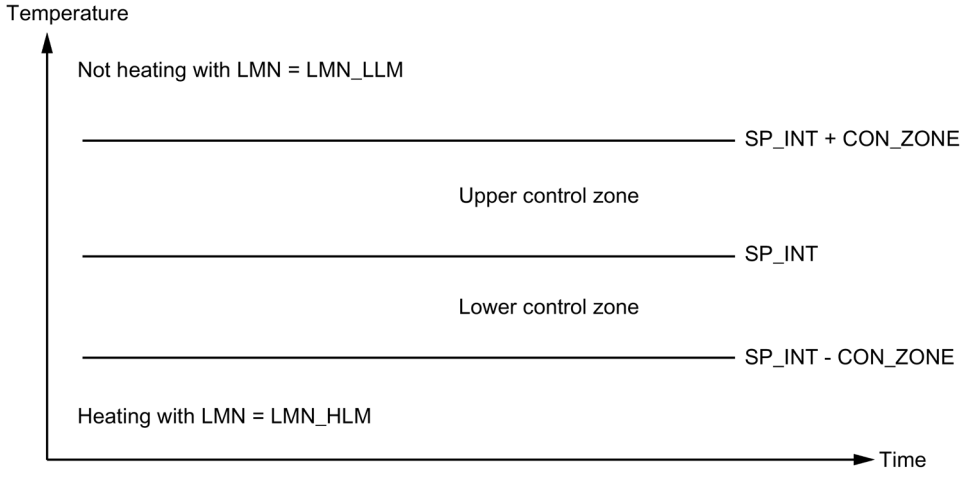
Control zone (CONZ_ON, CON_ZONE)

If CONZ_ON = TRUE, the controller operates with a control zone. This means that the controller operates according to the following algorithm:

- If process value PV exceeds the setpoint SP_INT by more than CON_ZONE, the value LMN_LLM is output as the manipulated variable.
- If the process value PV falls below setpoint SP_INT by more than CON_ZONE, LMN_HLM is output.
- If the process value PV is within the control zone (CON_ZONE), the output value takes its value from the PID algorithm LMN_Sum.

Note

Changing the manipulated variable from LMN_LLM or LMN_HLM to LMN_Sum occurs under compliance of a hysteresis of 20% of the control zone.



Note

Before enabling the control zone manually, make sure that the control zone band is not too narrow. If the control zone band is too small, oscillations will occur in the manipulated variable and process value.

Advantage of the Control Zone

When the process value enters the control zone, the D-action causes an extremely fast reduction of the manipulated variable. This means that the control zone is only useful when the D-action is activated. Without a control zone, only the reducing P-action would essentially reduce the manipulated variable. The control zone leads to faster settling without overshoot or undershoot if the output minimum or maximum manipulated variable is a long way from the manipulated variable required for the new operating point.

Manual value processing (MAN_ON, MAN)

You can change over between manual and automatic mode. In manual mode, the manipulated variable is corrected to a manually selected value.

The integral action (INT) is set internally to LMN - LMN_P - DISV and the derivative action (DIF) is set to 0 and synchronized internally. Changeover to automatic mode is therefore bumpless.

Note

The MAN_ON parameter has no effect during tuning.

Output value limit LMNLIMIT (LMN_HLM, LMN_LLM)

The LMNLIMIT function is used to limit the output value to the limits LMN_HLM and LMN_LLM. If these limits are reached, this is indicated by the message bits QLMN_HLM and QLMN_LLM.

If the output value is limited, the integral action is halted. If the control deviation moves the integral action back in the direction of the output range, the integral action is enabled again.

Changing the Manipulated Value Limits Online

If the range of the output value is reduced and the new unlimited value of the output value is outside the limits, the integral action and therefore the output value shifts.

The output value is reduced by the same amount as the output value limit changed. If the output value was unlimited prior to the change, it is set exactly to the new limit (described here for the high output value limit).

Scaling of output value LMN_NORM (LMN_FAC, LMN_OFFS)

The LMN_NORM function normalizes the output value according to the following rule:

LMN = LmnN * LMN_FAC + LMN_OFFS

It can be used for the following purposes:

- Output value scaling with LMN_FAC as output value factor and LMN_OFFS as output value offset.

The output value is also available in I/O format. The CRP_OUT function converts the LMN floating-point value to an I/O value according to the following rule:

LMN_PER = LMN * 27648/100

The scaling is switched off with the default values (LMN_FAC = 1.0 and LMN_OFFS = 0.0). The effective output value is sent to output LMN.

Save controller parameters SAVE_PAR

If you classify the current controller parameters as utilizable, you can save these before a manual change in structure parameters provided specifically for this in the instance DB of the instruction TCONT_CP. If you optimize the controller, the saved parameters are overwritten by the values that were valid prior to tuning.

PFAC_SP, GAIN, TI, TD, D_F, CONZ_ON and CONZONE are written to the structure PAR_SAVE.

Reloading Saved Controller Parameters UNDO_PAR

The last controller parameter settings you saved can be activated for the controller again using this function (in manual mode only).

Change between PI and PID parameters LOAD_PID (PID_ON)

Following tuning, the PI and PID parameters are stored in the PI_CON and PID_CON structures. Depending on PID_ON, you can use LOAD_PID in manual mode to write the PI or PID parameters to the effective controller parameters.

PID parameters PID_ON = TRUE	PI parameters PID_ON = FALSE
• GAIN = PID_CON.GAIN • TI = PID_CON.TI • TD = PID_CON.TD	• GAIN = PI_CON.GAIN • TI = PI_CON.TI

Note

The controller parameters are only written back to the controller with UNDO_PAR or LOAD_PID, if the controller gain is not equal to 0:

With LOAD_PID, the parameters are only copied if the corresponding GAIN <> 0 is (either the PI or PID parameters). This strategy takes into account the situation that no tuning has yet been made or that PID parameters are missing. If PID_ON = TRUE and PID.GAIN = FALSE, PID_ON is set to FALSE and the PI parameter is copied.

- D_F, PFAC_SP are preset by the the tuning. These can then be modified by the user. LOAD_PID does not change these parameters.
- With LOAD_PID, the control zone is always recalculated (CON_ZONE = 250/GAIN), even if CONZ_ON = FALSE.

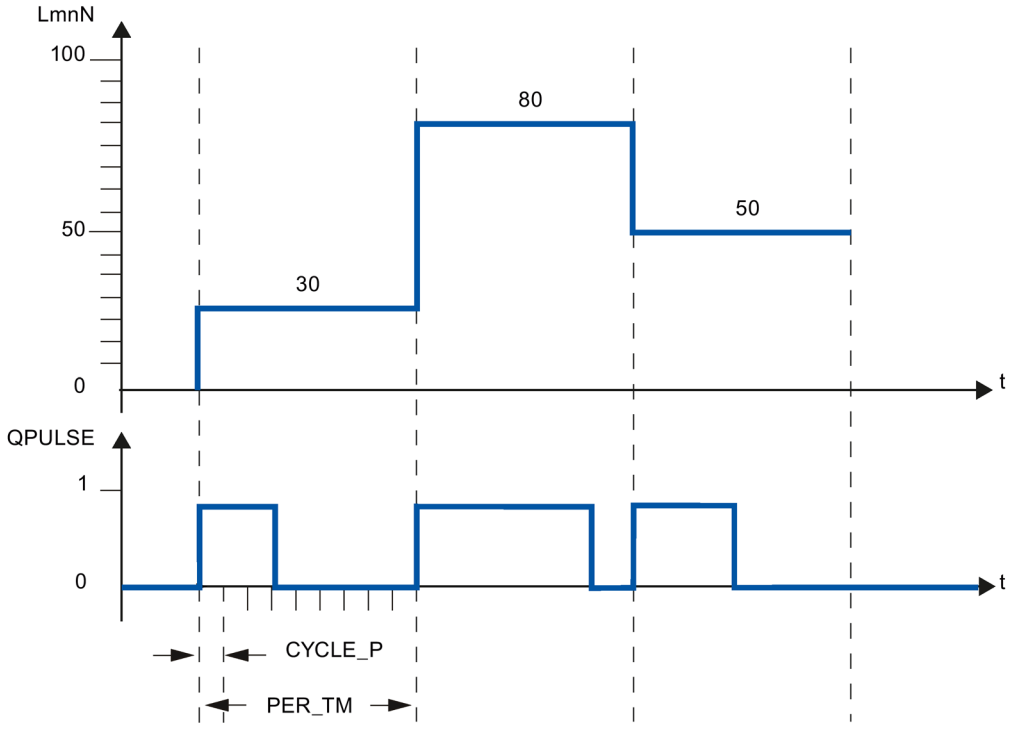
See also

Operating principle of the pulse generator (Page 465)

Block diagram TCONT_CP (Page 468)

8.4.4.3 Operating principle of the pulse generator

The function PULSEGEN transforms the analog manipulated value LmnN through pulse width module into an impulse sequence with the period duration PER_TM. PULSEGEN is switched on with PULSE_ON = TRUE and is processed in the cycle CYCLE_P.



A manipulated value of LmnN = 30% and 10 PULSEGEN calls per PER_TM therefore means:

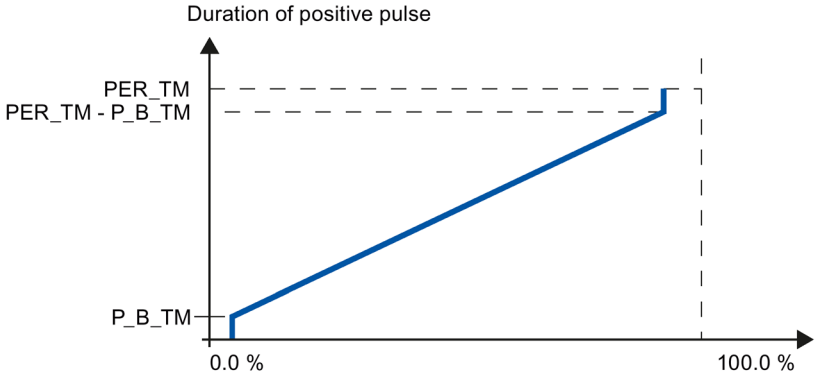
- TRUE at output QPULSE for the first three PULSEGEN calls (30% of 10 calls)
- FALSE at output QPULSE for seven further PULSEGEN calls (70% of 10 calls)

The duration of a pulse per pulse repetition period is proportional to the manipulated variable and is calculated as follows:

Pulse duration = PER_TM * LmnN /100

By suppressing the minimum pulse or break time, the characteristic curve of the conversion develops "knees" in the start and end regions.

The following diagram illustrates two-step control with a unipolar manipulated variable range (0% to 100%):



Minimum pulse or minimum break time (P_B_TM)

Short on or off times hinder the lifespan of actuators and fine controlling units. These can be avoided by setting a minimum pulse duration or minimum break time P_B_TM.

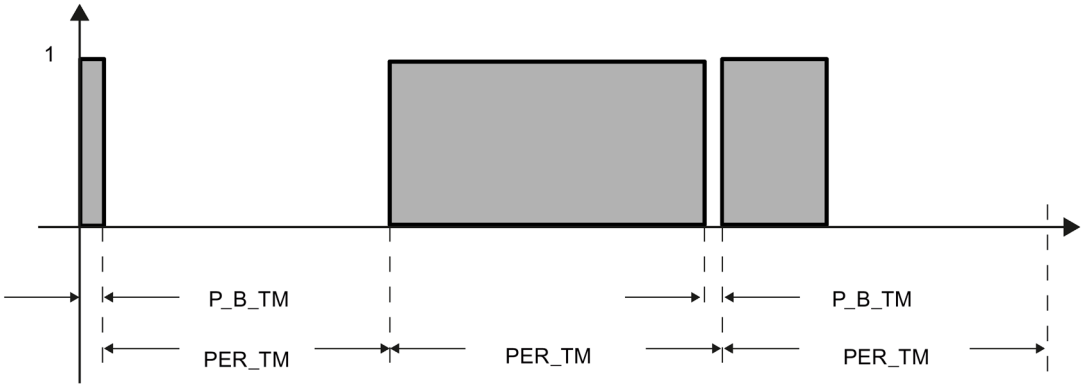
Small absolute values at the input variable LmnN that could otherwise generate a pulse duration shorter than P_B_TM are suppressed.

Large input values that would generate a pulse duration greater than PER_TM - P_B_TM are set to 100%. This reduces the dynamics of pulse generation.

Set values of P_B_TM ≤ 0,1 * PER_TM are recommended for the minimum pulse duration and the minimum break duration.

The "knees" in the curves in the diagram above are caused by the minimum pulse or minimum break times.

The following schematic illustrates the switching response of the pulse output:



Accuracy of pulse generation

The smaller the pulse generator CYCLE_P is compared to the period duration PER_TM, the more precise the pulse width modulation is. To achieve sufficiently accurate control, the following relationship should apply:

CYCLE_P ≤ PER_TM/50

The manipulated value is transformed with a resolution of ≤ 2 % into an impulse.

Note

When calling the controller in the pulse shaper cycle, you must note the following:

Calling the controller in the pulse shaper cycle will cause the process value to be averaged. As a result, at output PV, different values may be at input PV_IN and PV_PER. If you want to track the setpoint value, you must save the process value at input parameter PV_IN at the call times for complete controller processing (QC_ACT = TRUE). For pulse shaper calls occurring between these times, you must supply the input parameters PV_IN and SP_INT with the saved process value.

See also

Description TCONT_CP (Page 455)

Mode of operation TCONT_CP (Page 456)

Block diagram TCONT_CP (Page 468)

Input parameters TCONT_CP (Page 470)

Output parameters TCONT_CP (Page 471)

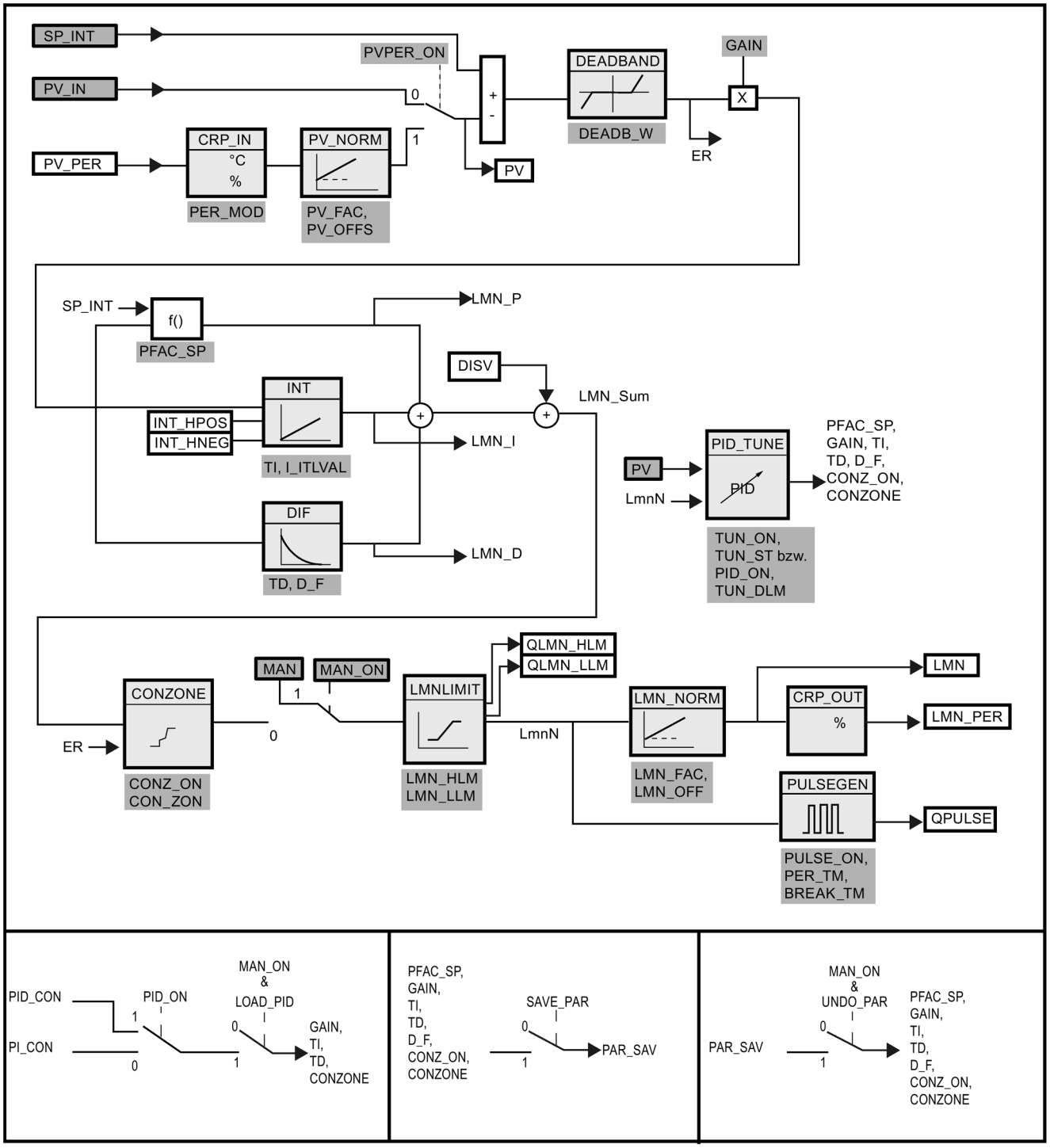
In/out parameters TCONT_CP (Page 472)

Static variables TCONT_CP (Page 473)

Parameter STATUS_H (Page 478)

Parameters STATUS_D (Page 479)

8.4.4.4 Block diagram TCONT_CP



See also

Description TCONT_CP (Page 455)
Mode of operation TCONT_CP (Page 456)
Operating principle of the pulse generator (Page 465)
Input parameters TCONT_CP (Page 470)
Output parameters TCONT_CP (Page 471)
In/out parameters TCONT_CP (Page 472)
Static variables TCONT_CP (Page 473)
Parameter STATUS_H (Page 478)
Parameters STATUS_D (Page 479)

8.4.4.5 Input parameters TCONT_CP

Parameters	Address	Data type	Default	Description
PV_IN	0.0	REAL	0.0	At the "Process value input" you can assign parameters to a commissioning value or you can interconnect an external process value in floating-point format. The valid values depend on the sensors used.
PV_PER	4.0	INT	0	The process value in I/O format is interconnected with the controller at the "Process value I/O" input.
DISV	6.0	REAL	0.0	For feedforward control, the disturbance variable is interconnected to the "Disturbance variable" input.
INT_HPOS	10.0	BOOL	FALSE	The output of the integral action can be held in the positive direction. For this, the input INT_HPOS must be set to TRUE. In a cascade control, INT_HPOS of the primary controller is connected to QLMN_HLM of the secondary controller.
INT_HNEG	10.1	BOOL	FALSE	The output of the integral action can be held in the negative direction. For this, the input INT_HNEG must be set to TRUE. In a cascade control, INT_HNEG of the primary controller is connected to QLMN_LLM of the secondary controller.
SELECT	12.0	INT	0	If the pulse shaper is on, there are several ways of calling the PID algorithm and pulse shaper: • SELECT = 0: The controller is called in a fast cyclic interrupt priority class and the PID algorithm and pulse shaper are processed. • SELECT = 1: The controller is called in OB1 and only the PID algorithm is processed. • SELECT = 2: The controller is called in a fast cyclic interrupt priority class and only the pulse shaper is processed. • SELECT = 3: The controller is called a slow cyclic interrupt priority class and only the PID algorithm is processed.

See also

Operating principle of the pulse generator (Page 465)

Block diagram TCONT_CP (Page 468)

8.4.4.6 Output parameters TCONT_CP

Parameter	Address	Data type	Default	Description
PV	14.0	REAL	0.0	The effective process value is output at the "Process value" output. The valid values depend on the sensors used.
LMN	18.0	REAL	0.0	The effective "Manipulated value" is output in floating point format at the "Manipulated value" output.
LMN_PER	22.0	INT	0	The manipulated value in I/O format is interconnected with the controller on the output "Manipulated value I/O".
QPULSE	24.0	BOOL	FALSE	The manipulated value is pulse-width-modulated at the QPULSE output.
QLMN_HLM	24.1	BOOL	FALSE	The manipulated value is always restricted to a high limit and low limit. The output QLMN_HLM signals that the high limit has been reached.
QLMN_LLM	24.2	BOOL	FALSE	The manipulated value is always restricted to a high limit and low limit. The output QLMN_LLM signals that the low limit has been reached.
QC_ACT	24.3	BOOL	TRUE	This parameter indicates whether continuous control component will be processed the next time the block is called (relevant only when SELECT has the value 0 or 1).

See also

Operating principle of the pulse generator (Page 465)
Block diagram TCONT_CP (Page 468)
Parameter STATUS_H (Page 478)
Parameters STATUS_D (Page 479)

8.4.4.7 In/out parameters TCONT_CP

Parameters	Address	Data type	Default	Description
CYCLE	26.0	REAL	0.1 s	Sets the sampling time for the PID algorithm. In phase 1, the tuner calculates the sampling time and enters it in CYCLE. CYCLE > 0.001 s
CYCLE_P	30.0	REAL	0.02 s	At this input, you set the sampling time for the pulse shaper action. In phase 1, the TCONT_CP instruction calculates the sampling time and enters it in CYCLE_P. CYCLE_P > 0.001 s
SP_INT	34.0	REAL	0.0	The input "Internal setpoint" is used to specify a setpoint. The valid values depend on the sensors used.
MAN	38.0	REAL	0.0	The "Manual value" input is used to set a manual value. In automatic mode, it tracks the manipulated value.
COM_RST	42.0	BOOL	FALSE	The block has an initialization routine that is processed when the COM_RST input is set.
MAN_ON	42.1	BOOL	TRUE	If the input "Enable manual mode" is set then the control loop is interrupted. The manual value MAN is set as manipulated value.

See also

Operating principle of the pulse generator (Page 465)
Block diagram TCONT_CP (Page 468)

8.4.4.8 Static variables TCONT_CP

Parameters	Address	Data type	De-fault	Description
DEADB_W	44.0	REAL	0.0	A deadband is applied to the control deviation. The "Deadband width" input determines the size of the deadband. The valid values depend on the sensors used.
I_ITLVAL	48.0	REAL	0.0	The output of the integrator can be set at the I_ITL_ON input. The initialization value is applied to the "Initialization value of the I-action" input. During a restart COM_RST = TRUE, the I-action is set to the initialization value. Values from -100 to 100 % are permitted.
LMN_HLM	52.0	REAL	100.0	The output value is always restricted to a high limit and low limit. The "Manipulated value high limit" input specifies the high limit. LMN_HLM > LMN_LLM
LMN_LLM	56.0	REAL	0.0	The output value is always restricted to a high limit and low limit. The "Manipulated value low limit" input specifies the low limit. LMN_LLM < LMN_HLM
PV_FAC	60.0	REAL	1.0	The "Process value factor" input is multiplied by the "Process value I/O". The input is used to scale the process value range.
PV_OFFS	64.0	REAL	0.0	The "Process value offset" input is added to the "Process value I/O". The input is used to scale the process value range.
LMN_FAC	68.0	REAL	1.0	The "Output value factor" input is multiplied with the output value. The input is used to scale the output value range.
LMN_OFFS	72.0	REAL	0.0	The "Output value offset" input is added to the output value. The input is used to scale the output value range.
PER_TM	76.0	REAL	1.0 s	The period duration of the pulse width modulation is entered at the PER_TM parameter. The relationship of the period duration to the sampling time of the pulse shaper determines the accuracy of the pulse width modulation. PER_TM ≥ CYCLE
P_B_TM	80.0	REAL	0.02 s	You can assign a minimum pulse or break time at the parameter "Minimum pulse/break time". P_B_TM is internally limited to > CYCLE_P.
TUN_DLMN	84.0	REAL	20.0	Process excitation for controller tuning results from a output value step change at TUN_DLMN. Values from -100 to 100 % are permitted.

Parameters	Address	Data type	De-fault	Description
PER_MODE	88.0	INT	0	You can use this switch to enter the type of I/O module. The process value at input PV_PER is then scaled as follows at the PV output. • PER_MODE = 0: Thermoelements; PT100/NI100; standard PV_PER * 0.1 Unit: °C, °F • PER_MODE = 1: PT100/NI100; climate PV_PER * 0.01 Unit: °C, °F • PER_MODE = 2: Current/voltage PV_PER * 100/27648 Unit: %
PVPER_ON	90.0	BOOL	FALSE	If the process value is to be read in from the I/Os, the PV_PER input must be interconnected with the I/Os and the "Enable process value I/Os" input must be set.
I_ITL_ON	90.1	BOOL	FALSE	The output of the integrator can be set at the I_ITLVAL input. The "Set I-action" input must be set for this.
PULSE_ON	90.2	BOOL	FALSE	If PULSE_ON = TRUE is set, the pulse shaper is activated.
TUN_KEEP	90.3	BOOL	FALSE	The mode changes to automatic only when TUN_KEEP changes to FALSE.
ER	92.0	REAL	0.0	The effective control deviation is output at the "Control deviation" output. The valid values depend on the sensors used.
LMN_P	96.0	REAL	0.0	The "P-action" output contains the proportional action of the manipulated tag.
LMN_I	100.0	REAL	0.0	The "integral action" output contains the integral action of the manipulated tag.
LMN_D	104.0	REAL	0.0	The "D-action" output contains the derivative action of the manipulated tag.
PHASE	108.0	INT	0	The current phase of controller tuning is indicated at the PHASE output. • PHASE = 0: No tuning mode; automatic or manual mode • PHASE = 1: Ready to start tuning; check parameters, wait for excitation, measure the sampling times • PHASE = 2: Actual tuning: Searching for point of inflection with constant output value. Entering the sampling time in instance DB. • PHASE = 3: Calculating process parameters. Saving valid controller parameters prior to tuning. • PHASE = 4: Controller design • PHASE = 5: Following up the controller to the new manipulated tag • PHASE = 7: Validating the process type
STATUS_H	110.0	INT	0	STATUS_H indicates the diagnostic value via the search for the point of inflection during the heating process.
STATUS_D	112.0	INT	0	STATUS_D indicates the diagnostic value via the controller design during the heating process.
QTUN_RUN	114.0	BOOL	0	The tuning manipulated tag has been applied, tuning has started and is still in phase 2 (searching for point of inflection).

Parameters	Address	Data type	De-fault	Description
PI_CON	116.0	STRUCT		PI controller parameters
GAIN	+0.0	REAL	0.0	PI controller gain %/phys. unit
TI	+4.0	REAL	0.0 s	PI integration time [s]
PID_CON	124.0	STRUCT		PID controller parameters
GAIN	+0.0	REAL	0.0	PID controller gain
TI	+4.0	REAL	0.0s	PID integration time [s]
TD	+8.0	REAL	0.0s	PID derivative action time [s]
PAR_SAVE	136.0	STRUCT		The PID parameters are saved in this structure.
PFAC_SP	+0.0	REAL	1.0	Proportional factor for setpoint changes Values from 0.0 to 1.0 are permitted.
GAIN	+4.0	REAL	0.0	Controller gain %/phys. unit
TI	+8.0	REAL	40.0 s	Integration time [s]
TD	+12.0	REAL	10.0 s	Derivative action time (s)
D_F	+16.0	REAL	5.0	Derivative factor Values from 5.0 to 10.0 are permitted.
CON_ZONE	+20.0	REAL	100.0	Control zone band If the control deviation is greater than the control zone band, the high output value limit is output as output value. If the control deviation is less than the negative control zone band, the low output value limit is output as the output value. CON_ZONE ≥ 0.0
CONZ_ON	+24.0	BOOL	FALSE	Enable control zone
PFAC_SP	162.0	REAL	1.0	PFAC_SP specifies the effective P-action when there is a setpoint change. This is set between 0 and 1. • 1: P-action has full effect if the setpoint changes. • 0: P-action has no effect if the setpoint changes. Values from 0.0 to 1.0 are permitted.
GAIN	166.0	REAL	2.0	The "Proportional gain" input specifies controller amplification. The direction of control can be reversed by giving GAIN a negative sign. %/phys. unit
TI	170.0	REAL	40.0 s	The "Integration time" (integral-action time) input defines the integrator's time response.
TD	174.0	REAL	10.0 s	The "Derivative-action time" (rate time) input decides the time response of the differentiator.
D_F	178.0	REAL	5.0	The derivative factor decides the lag of the D-action. D_F = derivative-action time/"Lag of the D-action" Values from 5.0 to 10.0 are permitted.

Parameters	Address	Data type	De-fault	Description
CON_ZONE	182.0	REAL	100.0	If the control deviation is greater than the control zone band, the high output value limit is output as output value. If the control deviation is less than the negative control zone band, the low output value limit is output as the output value. The valid values depend on the sensors used.
CONZ_ON	186.0	BOOL	FALSE	You can use CONZ_ON =TRUE to enable the control zone.
TUN_ON	186.1	BOOL	FALSE	If TUN_ON=TRUE, the output value is averaged until the output value excitation TUN_DLMN is enabled either by a setpoint step-change or by TUN_ST=TRUE.
TUN_ST	186.2	BOOL	FALSE	If the setpoint is to remain constant during controller tuning at the operating point, a output value step-change by the amount of TUN_DLMN is activated by TUN_ST=1.
UNDO_PAR	186.3	BOOL	FALSE	Loads the controller parametersPFAC_SP, GAIN, TI, TD, D_FCONZ_ON and CON_ZONE from the data structure PAR_SAVE (only in manual mode).
SAVE_PAR	186.4	BOOL	FALSE	Saves the controller parameters PFAC_SP, GAIN, TI, TD, D_F, CONZ_ON and CON_ZONE in the data structure PAR_SAVE.
LOAD_PID	186.5	BOOL	FALSE	Loads the controller parametersGAIN, TI,TD depending on PID_ON from the data structure PI_CON or PID_CON (only in manual mode)
PID_ON	186.6	BOOL	TRUE	At the PID_ON input, you can specify whether or not the tuned controller will operate as a PI or PID controller. • PID controller: PID_ON = TRUE • PI controller: PID_ON = FALSE With certain process types it is nevertheless possible that only a PI controller will be designed despite PID_ON = TRUE.
GAIN_P	188.0	REAL	0.0	Identified process gain. In the case of process type I, GAIN_P tends to be estimated too low.
TU	192.0	REAL	0.0	Identified time lag of the process. TU ≥ 3*CYCLE
TA	196.0	REAL	0.0	Identified recovery time of the process. In the case of process type I, TA tends to be estimated too low.
KIG	200.0	REAL	0.0	Maximum process value rise at manipulated tag excitation from 0 to 100 % [1/s] GAIN_P = 0.01 * KIG * TA
N_PTN	204.0	REAL	0.0	The parameter specifies the order of the process. "Non-integer values" are also possible. Values from 1.01 to 10.0 are permitted.
TM_LAG_P	208.0	REAL	0.0	Time constants of a PTN model (practical values only for N_PTN >= 2).
T_P_INF	212.0	REAL	0.0	Time from process excitation until the point of inflection.
P_INF	216.0	REAL	0.0	Process value change from process excitation until the point of inflection. The valid values depend on the sensors used.
LMN0	220.0	REAL	0.0	Output value at the start of tuning Detected in phase 1 (mean value). Values from 0 to 100 % are permitted.
PV0	224.0	REAL	0.0	Process value at the start of tuning
PVDT0	228.0	REAL	0.0	Process value slew rate at start of tuning [1/s] Sign adapted.

Parameters	Address	Data type	Default	Description
PVDT	232.0	REAL	0.0	Current process value slew rate [1/s] Sign adapted.
PVDT_MAX	236.0	REAL	0.0	Max. change in the process value per second [1/s] Maximum derivative of the process value at the point of inflection (sign adapted, always > 0); is used to calculate TU and KIG.
NOI_PVDT	240.0	REAL	0.0	Noise action in PVDT_MAX in % The higher the noise action, the less accurate (less aggressive) the control parameters.
NOISE_PV	244.0	REAL	0.0	Absolute noise in process value Difference between maximum and minimum process value in phase 1.
FIL_CYC	248.0	INT	1	Number of cycles of the mean value filter The process value is determined through FIL_CYC cycles. FIL_CYC is increased from 1 to a max. of 1024 if needed.
POI_CMAX	250.0	INT	2	Maximum number of cycles after point of inflection This time is used to find another (i.e. better) inflection point for measuring noise. The tuning is completed only after this time.
POI_CYCL	252.0	INT	0	Number of cycles after inflection point

See also

Operating principle of the pulse generator (Page 465)

Block diagram TCONT_CP (Page 468)

8.4.4.9 Parameter STATUS_H

STATUS_H	Description	Remedy
0	Default, or no/no new controller parameters	
10000	Tuning completed + suitable controller parameters found	
2xxxx	Tuning completed + controller parameters uncertain	
2xx2x	Point of inflection not reached (only if excited via setpoint step-change)	If the controller oscillates, weaken the controller parameters, or repeat the test with a smaller manipulated value difference TUN_DLMN.
2x1xx	Estimation error (TU < 3*CYCLE)	Reduce CYCLE and repeat attempt. Special case for PT1-only process: Do not repeat test, if necessary reduce controller parameters.
2x3xx	Estimation error TU too high	Repeat test under better conditions.
21xxx	Estimation error N_PTN < 1	Repeat test under better conditions.
22xxx	Estimation error N_PTN > 10	Repeat test under better conditions.
3xxxx	Tuning canceled in phase 1 owing to faulty parameter assignment:	
30002	Effective manipulated value differential < 5%	Correct manipulated value differential TUN_DLMN.
30005	The sampling times CYCLE and CYCLE_P differ by more than 5% of the measured values.	Compare CYCLE and CYCLE_P with the cycle time of the cyclic interrupt priority class and note any loop scheduler. Check CPU load. An excessively loaded CPU can result in prolonged sampling times that are inconsistent with CYCLE or CYCLE_P.

Note

If you cancel tuning in phase 1 or 2, STATUS_H = 0 is set. However, STATUS_D still displays the status of the last controller calculation.

The higher the value of STATUS_D, the higher the order of the control process, the greater the TU/TA ratio and the gentler the controller parameters will be.

See also

Operating principle of the pulse generator (Page 465)

Block diagram TCONT_CP (Page 468)

8.4.4.10 Parameters STATUS_D

STATUS_D	Description
0	No controller parameters were calculated.
110	N_PTN <= 1.5 Process type I fast
121	N_PTN > 1.5 Process type I
200	N_PTN > 1.9 Process type II (transition range)
310	N_PTN >= 2.1 Process type III fast
320	N_PTN > 2.6 Process type III
111, 122, 201, 311, 321	Parameters have been corrected from phase 7.

Note

The higher the value of STATUS_D, the higher the order of the control process, the greater the TU/TA ratio and the gentler the controller parameters will be.

See also

Operating principle of the pulse generator (Page 465)

Block diagram TCONT_CP (Page 468)

8.4.5 TCONT_S

8.4.5.1 Description TCONT_S

The TCONT_S instruction is used on SIMATIC S7 automation systems to control technical temperature processes with binary manipulated value output signals for actuators with integrating behavior. The functionality is based on the PI control algorithm of the sampling controller. The step controller operates without a position feedback signal.

Application

You can also use the controller in a cascade control as a secondary position controller. You specify the actuator position via the setpoint input SP_INT. In this case, you must set the process value input and the parameter TI (integration time) to zero. An application might be, for example, temperature control with heating power control using pulse-break activation and cooling control using a butterfly valve. To close the valve completely, the manipulated variable (ER*GAIN) should be negative.

Call

The instruction TCONT_S must be called equidistant. To achieve this, use a cyclic interrupt priority class (for example, OB35 for an S7-300). The sampling time is specified at the CYCLE parameter.

If you call the instruction TCONT_S as a multiple instance DB, no technology object is created. No parameter assignment interface or commissioning interface is available. You must assign parameters for TCONT_S directly in the multiple instance DB and commission it via a watch table.

CYCLE sampling time

The CYCLE sampling time match the time difference between two calls (cycle time of the cyclic interrupt OB taking into account the reduction ratios).

The controller sampling time should not exceed 10% of the calculated integration time of the controller (TI). Generally, you must set the sampling time to a much lower value to achieve the required accuracy of the step controller.

Required accuracy G	MTR_TM	CYCLE = MTR_TM*G	Comment
0.5 %	10 s	0.05 s	The sampling time is determined by the required accuracy of the step controller.

Start-up

The TCONT_S instruction has an initialization routine that is run through when input parameter COM_RST = TRUE is set. Following execution of the initialization routine, the block sets COM_RST back to FALSE. All outputs are set to their initial values. If you require initialization when the CPU restarts, call the block in OB100 with COM_RST = TRUE.

See also

Block diagram TCONT_S (Page 485)

8.4.5.2 Mode of operation TCONT_S

Setpoint branch

The setpoint is entered at input SP_INT in floating-point format as a physical value or percentage. The setpoint and process value used to form the control deviation must have the same unit.

Process value options (PVPER_ON)

Depending on PVPER_ON, the process value can be read in, in the I/O or floating-point format.

PVPER_ON	Process Value Input
TRUE	The process value is read in via the analog I/Os (PIW xxx) at input PV_PER.
FALSE	The process value is acquired in floating-point format at input PV_IN.

Process value format conversion CRP_IN (PER_MODE)

The CRP_IN function converts the I/O value PV_PER to floating-point format depending on the PER_MODE switch according to the following rules:

PER_MODE	Output of CRP_IN	Analog Input Type	Unit
0	PV_PER * 0.1	Thermoelements; PT100/NI100; standard	°C;°F
1	PV_PER * 0.01	PT100/NI100; climate;	°C;°F
2	PV_PER * 100/27648	Voltage/current	%

Process value scaling PV_NORM (PF_FAC, PV_OFFS)

The PV_NORM function calculates the output of CRP_IN according to the following rule:

"Output of PV_NORM" = "Output of CRP_IN)" * PV_FAC + PV_OFFS

It can be used for the following purposes:

- Process value adjustment with PV_FAC as process value factor and PV_OFFS as process value offset.
- Normalization of temperature to percentage

  You want to enter the setpoint as a percentage and must now convert the measured temperature value to a percentage.
- Normalization of percentage to temperature

  You want to enter the setpoint in the physical temperature unit and must now convert the measured voltage/current value to a temperature.

Calculation of the parameters:

- PV_FAC = range of PV_NORM/range of CRP_IN;
- PV_OFFS = LL (PV_NORM) - PV_FAC * LL(CRP_IN);

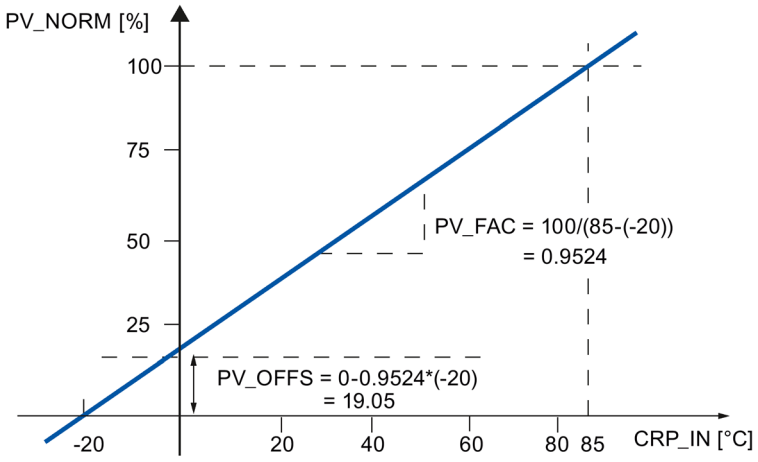
  where LL: low limit

The normalization is switched off with the default values (PV_FAC = 1.0 and PV_OFFS = 0.0). The effective process value is output at the PV output.

Example of Process Value Normalization

If you want to enter the setpoint as a percentage, and you have a temperature range of -20 to 85 °C applied to , CRP_IN you must normalize the temperature range as a percentage.

The following diagram shows an example of adapting the temperature range -20 to 85 °C to an internal scale of 0 to 100 %:



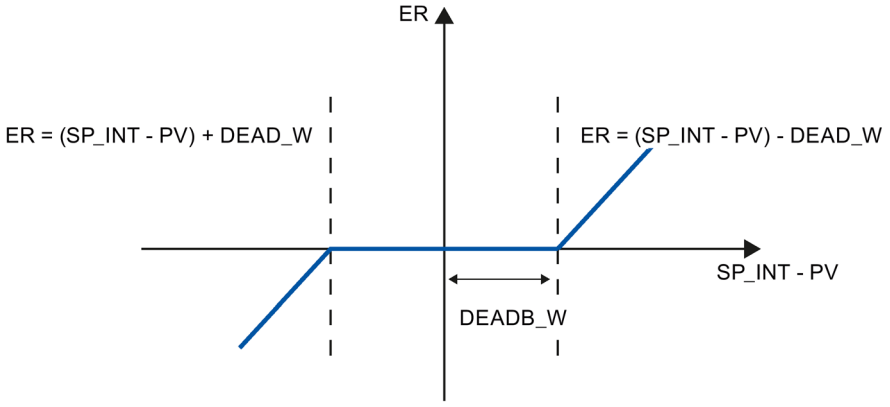
Forming the control deviation

The difference between the setpoint and process value is the control deviation before the dead band.

The setpoint and process value must exist in the same unit.

Dead band (DEADB_W)

To suppress a minor sustained oscillation due to the manipulated variable quantization (for example, in pulse width modulation with PULSEGEN) a dead band is applied to the (DEADBAND) control deviation. With DEADB_W = 0.0, the dead band is switched off.



PI step controller algorithm

The instruction TCONT_S operates without position feedback. The I-action of the PI algorithm and the assumed position feedback signal are calculated in an integrator (INT) and compared as a feedback value with the remaining P-action. The difference is applied to a three-step element (THREE_ST) and a pulse shaper (PULSEOUT) that generates the pulses for the control valve. Adapting the response threshold of the three-step element reduces the switching frequency of the controller.

Weakening of the P-action when setpoint changes occur

To prevent overshoot, you can weaken the P-action using the "Proportional factor for setpoint changes" parameter (PFAC_SP). Using PFAC_SP, you can now select continuously between 0.0 and 1.0 to decide the effect of the P-action when the setpoint changes:

- PFAC_SP = 1.0: P-action has full effect if the setpoint changes
- PFAC_SP = 0.0: P-action has no effect if the setpoint changes

As in the case of the continuous controller, a value of PFAC_SP < 1.0 can reduce the overshoot if the motor run time MTR_TM is small compared with the recovery time TA and the ratio is TU/TA < 0.2. If MTR_TM reaches 20% of TA, only a slight improvement can still be achieved.

Feedforward control

A disturbance variable can be added at the DISV input.

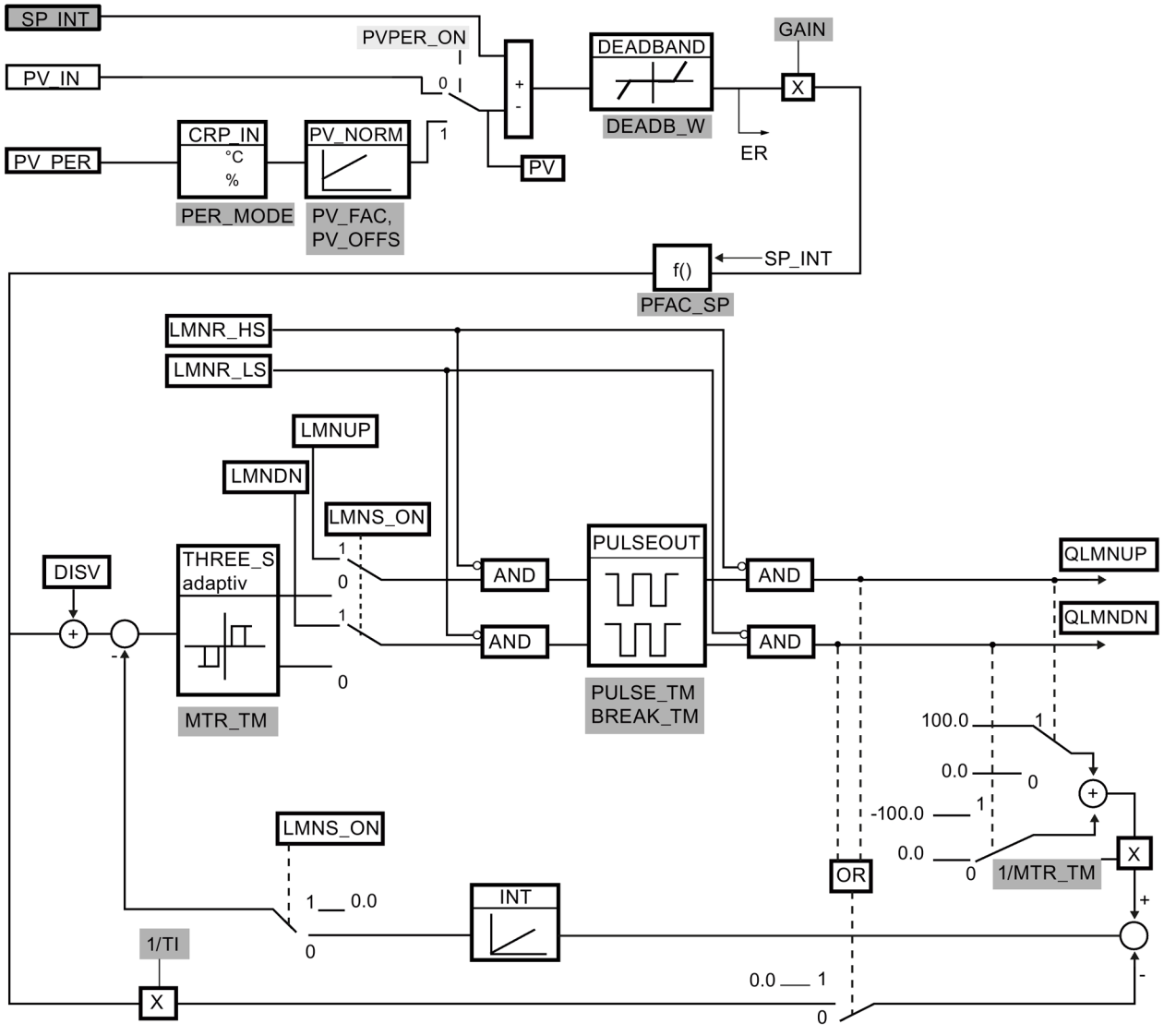
Manual value processing (LMNS_ON, LMNUP, LMNDN)

With LMNS_ON, you can change between manual and automatic mode. In manual mode, the actuator is halted and the integral action (INT) is set to 0 internally. Using LMNUP and LMNDN, the actuator can be adjusted to OPEN and CLOSED. Switching over to automatic mode therefore involves a bump. As a result of the GAIN, the existing control deviation leads to a step change in the internal manipulated variable. The integral component of the actuator, however, results in a ramp-shaped excitation of the process.

See also

Block diagram TCONT_S (Page 485)

8.4.5.3 Block diagram TCONT_S



Parameter configuration interface

Instruction call interface

Parameter configuration interface, call interface

See also

Description TCONT_S (Page 480)
Mode of operation TCONT_S (Page 481)
Input paramters TCONT_S (Page 487)
Output parameters TCONT_S (Page 488)
In/out parameters TCONT_S (Page 488)
Static variables TCONT_S (Page 489)

8.4.5.4 Input paramters TCONT_S

Parameters	Address	Data type	Default	Description
CYCLE	0.0	REAL	0.1 s	At this input, you enter the sampling time for the controller. CYCLE ≥ 0.001
SP_INT	4.0	REAL	0.0	The input "Internal setpoint" is used to specify a setpoint. The valid values depend on the sensors used.
PV_IN	8.0	REAL	0.0	At the "Process variable input" you can assign parameters to a commissioning value or you can interconnect an external process value in floating-point format. The valid values depend on the sensors used.
PV_PER	12.0	INT	0	The process value in I/O format is interconnected with the controller at the "Process value I/O" input.
DISV	14.0	REAL	0.0	For feedforward control, the disturbance variable is interconnected to the "Disturbance variable" input.
LMNR_HS	18.0	BOOL	FALSE	The signal "Control valve at high endstop" is interconnected on the input "High endstop signal of position feedback". • LMNR_HS=TRUE: The control valve is at high endstop.
LMNR_LS	18.1	BOOL	FALSE	The signal "Control valve at low endstop" is interconnected on the input "Low endstop signal of position feedback". • LMNR_LS=TRUE: The control valve is at low endstop.
LMNS_ON	18.2	BOOL	TRUE	Manipulated value signal processing is switched to manual mode at the "Enable manual mode of manipulated signal".
LMNUP	18.3	BOOL	FALSE	In manual mode of manipulated signals, the output parameter QLMNUP is operated at the input parameter "Manipulated signal up".
LMNDN	18.4	BOOL	FALSE	In manual mode of the manipulated signals, the output parameter QLMNDN is operated at the input parameter "Manipulated signal down".

See also

Block diagram TCONT_S (Page 485)

8.4.5.5 Output parameters TCONT_S

Parameters	Address	Data type	Default	Description
QLMNUP	20.0	BOOL	FALSE	If the output "Manipulated value signal up" is set then the control valve should be open.
QLMNDN	20.1	BOOL	FALSE	If the output "Manipulated value signal down" is set then the control valve should be closed.
PV	22.0	REAL	0.0	The effective process value is output at the "Process value" output.
ER	26.0	REAL	0.0	The effective system deviation is output at the "Error signal" output.

See also

Block diagram TCONT_S (Page 485)

8.4.5.6 In/out parameters TCONT_S

Parameters	Address	Data type	Default	Description
COM_RST	30.0	BOOL	FALSE	The block has an initialization routine that is processed when the COM_RST input is set.

See also

Block diagram TCONT_S (Page 485)

8.4.5.7 Static variables TCONT_S

Parameters	Address	Data type	Default	Description
PV_FAC	32.0	REAL	1.0	The "Process value factor" input is multiplied by the process value. The input is used to scale the process value range.
PV_OFFS	36.0	REAL	0.0	The input "Process value offset" is added to the process value. The input is used to scale the process value range. The valid values depend on the sensors used.
DEADB_W	40.0	REAL	0.0	A deadband is applied to the control deviation. The "Deadband width" input determines the size of the deadband. DEADB_W ≥ 0.0
PFAC_SP	44.4	REAL	1.0	PFAC_SP specifies the effective P-action when there is a setpoint change. • 1: P-action has full effect if the setpoint changes. • 0: P-action has no effect if the setpoint changes. Values from 0.0 to 1.0 are permitted.
GAIN	48.0	REAL	2.0	The "Proportional gain" input specifies controller amplification. The direction of control can be reversed by giving GAIN a negative sign. %/phys. unit
TI	52.0	REAL	40.0 s	The "Integration time" (integral-action time) input defines the integrator's time response.
MTR_TM	56.0	REAL	30 s	The runtime from endstop to endstop of the control valve is entered at the "Motor actuating time" parameter. MTR_TM ≥ CYCLE
PULSE_TM	60.0	REAL	0.0 s	A minimum pulse time can be configured at the "Minimum pulse time" parameter.
BREAK_TM	64.0	REAL	0.0 s	You can assign a minimum break time at the parameter "Minimum break time".
PER_MODE	68.0	INT	0	You can use this switch to enter the type of I/O module. The process value at input PV_PER is then scaled as follows at the PV output. • PER_MODE = 0: Thermoelements; PT100/NI100; standard PV_PER * 0.1 Unit: °C, °F • PER_MODE = 1: PT100/NI100; climate PV_PER * 0.01 Unit: °C, °F • PER_MODE = 2: Current/voltage PV_PER * 100/27648 Unit: %
PVPER_ON	70.0	BOOL	FALSE	If the process value is to be read in from the I/Os, the PV_PER input must be interconnected with the I/Os and the "Enable process value I/Os" input must be set.

See also

Block diagram TCONT_S (Page 485)

8.4.6 Integrated system functions

8.4.6.1 CONT_C_SF

CONT_C_SF

The instruction CONT_C_SF is integrated in the S7-300 compact CPUs. The instruction must not be transmitted to the S7-300 CPU during loading. The scope of function corresponds with the instruction CONT_C.

See also

Description CONT_C (Page 433)
How CONT_C works (Page 434)
CONT_C block diagram (Page 436)
Input parameter CONT_C (Page 437)
Output parameters CONT_C (Page 438)

8.4.6.2 CONT_S_SF

CONT_S_SF

The instruction CONT_S_SF is integrated in the S7-300 compact CPUs. The instruction must not be transmitted to the S7-300 CPU during loading. The scope of function corresponds with the instruction CONT_S.

See also

Description CONT_S (Page 439)
Mode of operation CONT_S (Page 440)
Block diagram CONT_S (Page 441)
Input parameters CONT_S (Page 442)
Output parameters CONT_S (Page 443)

8.4.6.3 PULSEGEN_SF

PULSEGEN_SF

The instruction PULSEGEN_SF is integrated in the S7-300 compact CPUs. The instruction must not be transmitted to the S7-300 CPU during loading. The scope of function corresponds with the instruction PULSEGEN.

See also

Description PULSEGEN (Page 444)

Mode of operation PULSEGEN (Page 445)

Mode of operation PULSEGEN (Page 448)

Three-step control (Page 449)

Two-step control (Page 452)

Input parameters PULSEGEN (Page 453)

Output parameter PULSEGEN (Page 454)

Service & Support

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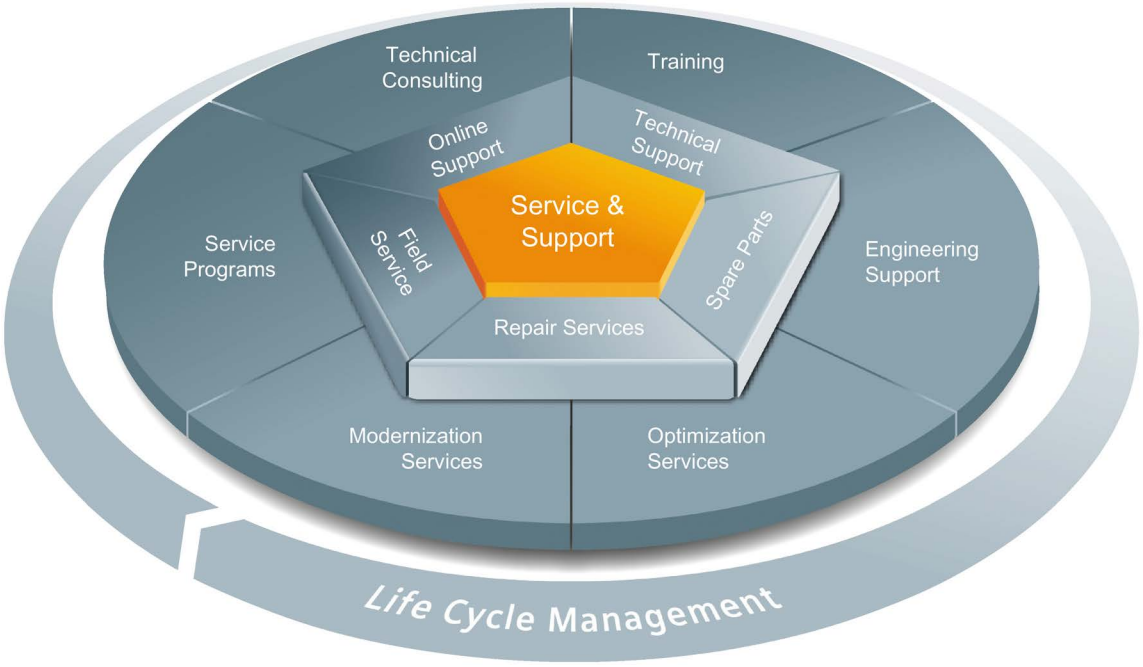

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