3-Point Stepper Control with PID_3Step

SIMATIC S7-1200

Application • May 2013

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SIMATIC

3-Point Stepper Control with PID_3Step

Technology object PID_3Step

Problem 1

Solution 2

Function Mechanisms of this Application 3

Startup of the Application 4

Operating the Application 5

Internet Link Specifications 6

History 7

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Table of Contents

Warranty and Liability **4**

1 Problem **6**

1.1 Overview 6

2 Solution **7**

2.1 Solution overview 7
2.2 Description of the core functionality 9
2.3 Required Hardware and Software Components 11

3 Function Mechanisms of this Application **13**

3.1 Main [OB1] 14
3.1.1 HMI [FC7] 14
3.1.2 Simulation_Main [FC1] 14
3.2 Cyclic interrupt [OB200] 15
3.2.1 Switch [FC4] 16
Scale_Int2Real [FC3] 17
3.2.2 PID_3Step_2 [FB1131] 18
3.2.3 Simulation_OB200 [FC2] 19
VALVE [FB101] 20
Scale_Real2Real [FC6] 22
PROC_C [FB100] 23
Scale_ Real2Int [FC5] 24

4 Startup of the Application **25**

4.1 Hardware adjustment 25
4.1.1 Input signal 25
4.1.2 Output signal 26
4.2 Configuration instructions 28
4.3 Commissioning the 3-point stepper controller 33
4.4 HMI project part 36
4.4.1 Configuring the HMI 36
Loading the HMI project part into the KTP1000 37
Starting PC runtime 38

5 Operating the Application **39**

5.1 Overview 39
5.2 Overview of application-unspecific screens 40
5.2.1 Home screen 40
5.2.2 Support description 40
5.2.3 Overview 41
5.2.4 Operating screen 42
5.2.5 System functions 43
5.2.6 Time setting 43
5.3 Overview of application-specific screens 44
5.3.1 Mixer tap 45
5.3.2 Trend view 47
5.3.3 Tuning 49
5.3.4 Monitoring 50
5.3.5 Configuration 52
5.3.6 Simulation 53

6 Internet Link Specifications **54**

7 History **54**

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1 Problem

1.1 Overview

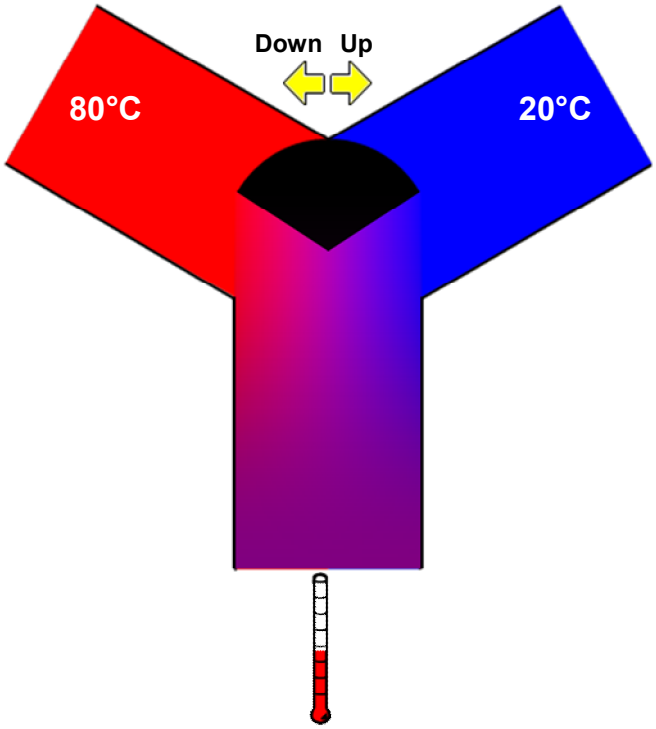
Introduction

The valve of a mixer tap shall be controlled according to a desired given temperature.

Overview of the automation task

The figure below provides an overview of the automation task.

Figure 1-1



Description of the automation task

A three-way mixing valve with valve actuator is used. One feed supplies hot water (e.g. 80°C) and the other one cold water (e.g. 20°C). Varying the water supply from 20°C to 80°C via the valve position can yield any water outlet temperature between these given temperatures.

This is referred to as a **3-point stepper control**:

1. The valve is controlled towards “more hot water” (digital output “Up”)

or

2. the valve is controlled towards “more cold water” (digital output “Down”)

or

3. the valve is not controlled at all.

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2 Solution

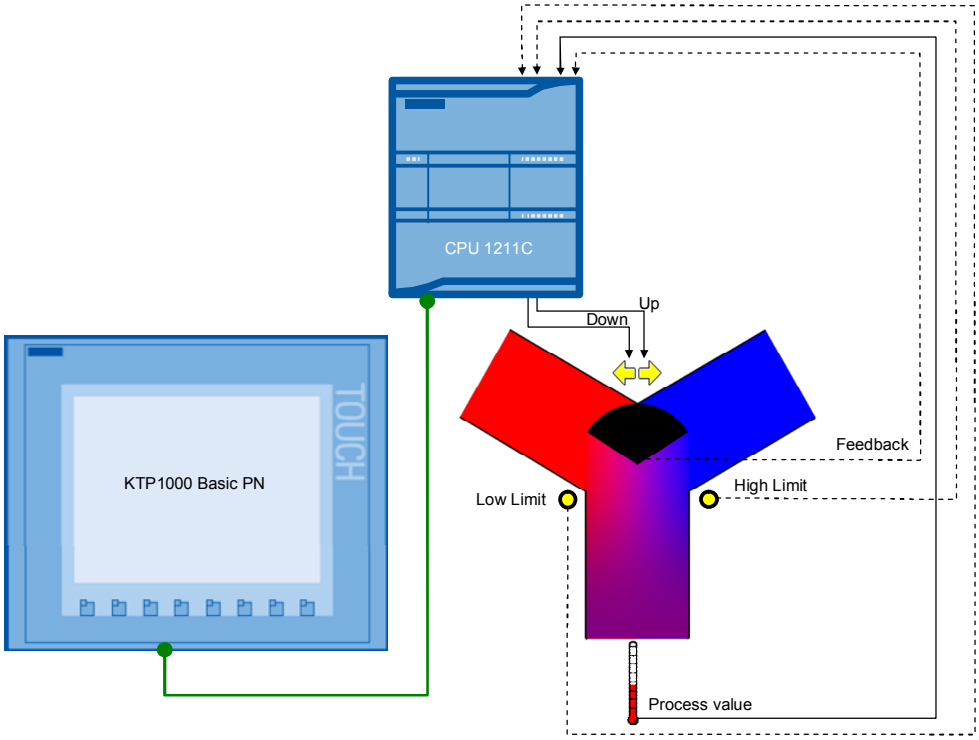
2.1 Solution overview

For SIMATIC S7-1200 as of firmware V2.0, the development environment STEP 7 V11 provides the “PID_3Step” 3-point stepper control block.
This instruction was especially developed for controlling valves or actuators with integrated behavior.It offers a simple and quick configuration and commissioning of your 3-point stepper control application.
For this application the version 1.1 of “PID_3Step” is used.

Display

The following figure displays the most important components of the solution:

Figure 2-1



Within a control loop (here the mixer tap), the technology object “PID_3Step” continuously acquires the measured process value (here the temperature) and compares it with the setpoint value (given via the KTP1000 Basic PN).
From the resulting control deviation, PID_3Step calculates an output value through which the process value reaches the setpoint value as quickly and steadily as possible. The output value is converted into the digital control of the valve (“Up”/“Down”).
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.

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- 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.

The 3-point stepper control is possible in the following versions:

- without end position feedback or valve position feedback
- with end position feedback of the valve only (Low & High Limit)
- with valve position feedback only (Feedback)
- with end position and valve position feedback

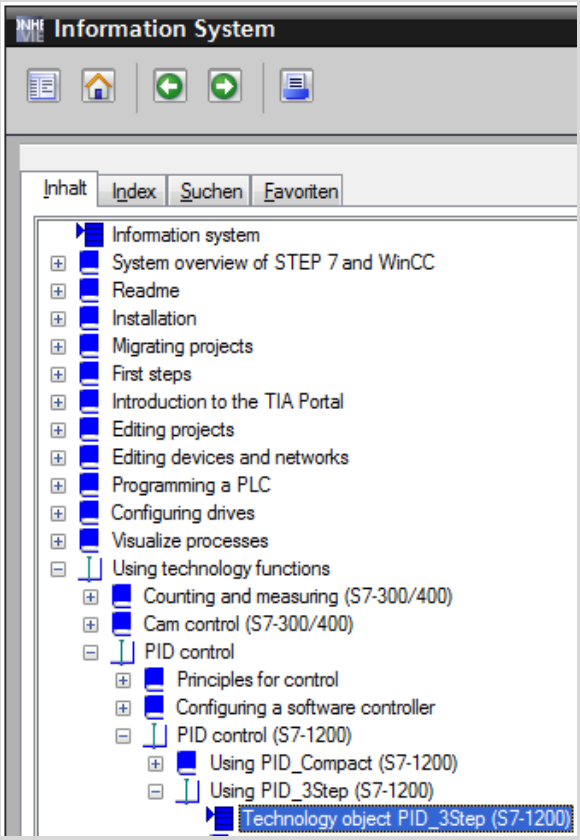
Any SIMATIC S7-1200 control offers two analog inputs for evaluating sensors with an output voltage of 0 to 10 V (e.g. for temperature and valve position).
For temperature recording, thermocouples and resistance thermometers can also be connected via expansion modules.

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Note

A more detailed description on “PID_3Step” is available in the

- STEP 7 Basic V11 Manual (\4\) → Chapter 11.1.3.2 or the
- STEP 7 V11 Online Help:

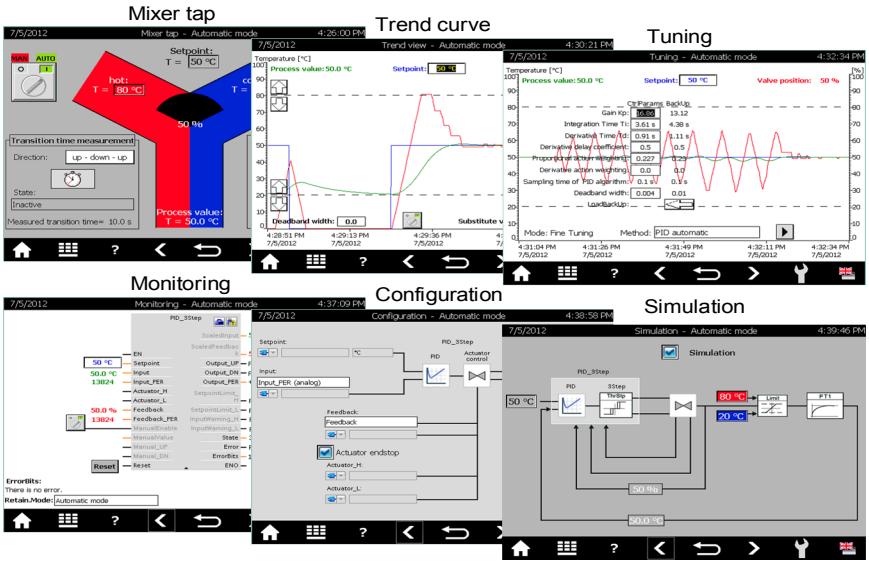


2.2 Description of the core functionality

The core functionality of the application lies in the operation of the “PID_3Step” 3-point stepper controller via an HMI.

Overview and description of the user interface

Figure 2-2



The operation of the application consists of the following 6 pictures:

- Mixer tap
- Trend view
- Tuning
- Monitoring
- Configuration
- Simulation

The operation of the screens is described in greater detail in chapter 5.

Advantage of this solution

The application enables you to use any configuration options and commissioning features via a KTP 1000 Basic operator panel or via the HMI simulation integrated in WinCC V11 Basic.

The application on hand offers you the following advantages:

- Switching between automatic and manual mode
- Transition time measurement of the valve
- Visualization of the valve position
- Trend curves of setpoint, process value and control value
- Switching between the real controlled system and the simulation
- Disturbance value control in simulation mode
- Specifying the behavior in the case of errors and their simulation
- Specifying the dead band width for energy saving operation

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- Manually specified control parameter and automatic tuning
- Online monitoring of the “PID_3Step” controller block
- Modifying the configuration during runtime

Delimitation

This application gives you an overview of the “PID_3Step” technology object for operating a 3-point stepper controller via SIMATIC S7-1200.
You can adopt the application example to adjust your 3-point stepper control conveniently via KTP 1000 Basic and adapt it to your automation task.

The application was tested via the simulation of the controlled system.
For the actual operation, the application example must be adapted to your used valve with actuator and temperature sensors used:

- Digital control in 2 directions or analog control?
- Required voltage and output for the control?
- Signal properties when feeding back the valve position resp. limit switch detection?
- Signal properties of the used temperature sensor.

The application is no substitute for the configuration screen of the PID_3Step wizard, since it defines the default values in the instance data block which are decisive for the restart after a power failure.

Apart from the “PID_3Step” control block, STEP 7 V11 also provides the “PID_Compact” for the SIMATIC S7-1200. This is a universally usable PID controller for continuous controlled systems. It also contains the advantages of automatic tuning, as well as the operating modes automatic and manual. According to the template of this application example, an HMI user interface can also be designed for the “PID_Compact”.

Note

Further information on technology object “PID_Compact” is available in the

- S7-1200 Manual (\1\) → Chapter 9.2.2 and the
- STEP 7 Basic V11 Manual (\4\) → Chapter 11.1.3.1 .

Required knowledge

Basic knowledge of PID control is assumed.

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2.3 Required Hardware and Software Components

The application was generated with the following components:

Hardware components

Table 2-1

Component	No.	Order number	Note
SIMATIC HMI KTP1000 BASIC COLOR PN	1	6AV6647-0AF11-3AX0	Optional (can also be simulated via WinCC V11 Basic Runtime)
COMPACT SWITCH MODULE CSM 1277	1	6GK7277-1AA10-0AA0	
STROMVERSORGUNG S7-1200 PM1207	1	6EP1332-1SH71	
CPU 1211C, DC/DC/RELAY, 6DI/4DO/2AI	1	6ES7211-1HD30-0XB0	Firmware V2.2 (\2\) max. current per relay output: 2 A (valve control)
Three-way mixing valve with actuator motor and control for 2 directions	1	Valve manufacturer	Optional with digital end position feedback or analog valve position feedback (0 to 10V)
Temperature sensors protection class: IPX8 (permanent submersion) measuring range: 0 to 100□	1	Electrical retail	Executable as analog signal encoder, thermocouple or resistance thermometer
SIGNAL BOARD SB 1231, 1 AI, (12 bit resolution)	1	6ES7231-4HA30-0XB0	Optional (when using a temperature sensor with 0 to 20 mA current output)
SIGNAL BOARD SB 1231 RTD	1	6ES7231-5PA30-0XB0	Optional (when using a resistance thermometer)
SIGNAL BOARD SB 1231 TC, 1 AI	1	6ES7231-5QA30-0XB0	Optional (when using a thermocouple)
Programming device	1		With Ethernet connection
Ethernet line TP CORD RJ45/RJ45 2M	3	6XV1870-3QH20	
Line protection switch	1	5SX2116-6	1 pol. B, 16A
Standard mounting rail	1	6ES5 710-8MA11	35mm

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Standard software components

Table 2-2

Component	No.	Order number	Note
SIMATIC STEP 7 Basic V11	1	6ES7822-0AA01-0YA0	- contains WinCC; - with Service Pack 2 (\5\) Update 4 (\6\)
SIMATIC STEP 7 Basic Upgrade V11	1	6ES7822-0AA01-0YE0	(Optional) only for upgrading STEP 7 Basic V10.5

Sample files and projects

The following list includes all files and projects used in this example.

Table 2-3

Component	Note
62154322_S7-1200_PID_3Step_v1d0.zip	<This zip file includes the STEP 7 project.>
62154322_S7-1200_PID_3Step_de.pdf	This document.

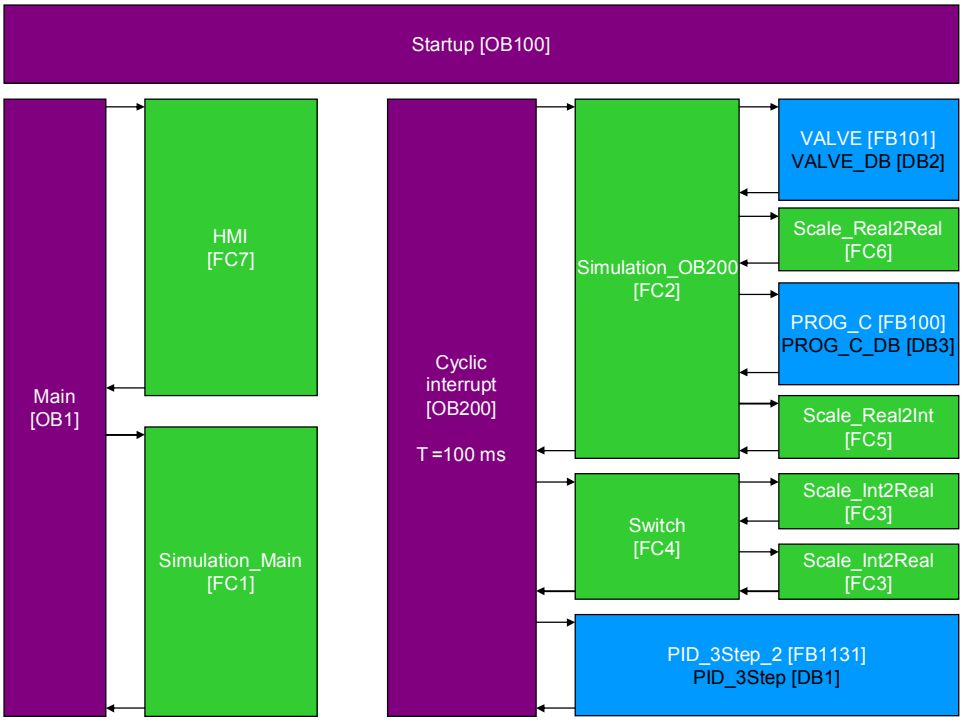
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3 Function Mechanisms of this Application

General overview

Figure 3-1 shows the temporal sequence of the block calls in the control part of the application project.

Figure 3-1



The control project part consists of the operation blocks:

- Startup [OB100] for initialization
- Main [OB1], from where the functions for the HMI transfer are called
- Cyclic interrupt [OB200], which calls the 3-point stepper controller cyclically every 100 milliseconds using the simulation blocks.

The parameter transfer between the functions occurs with instance data blocks:

- PID_3Step [DB1]
- VALVE_DB [DB2]
- PROG_C_DB [DB3]

as well as the data blocks:

- tags [DB4] (contains all tags not required for the simulation of the controlled system
- tags [DB4] (contains all tags required for the simulation of the controlled system).

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3.1 Main [OB1]

The functions for the HMI transfer are called from the operation block “Main”.

3.1.1 HMI [FC7]

Figure 3-2



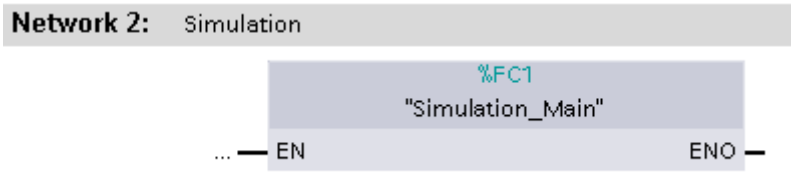
The “HMI” function defines tags which the KTP1000 requires for the display, such as:

- Visibility tags
- Synchronization times
- Value transfers
- Feasibility conditions

Further descriptions are available in the network headers.

3.1.2 Simulation_Main [FC1]

Figure 3-3



The “Simulation_Main” function defines tags required for the simulation of the controlled system, such as:

- Disturbance values
- Referencing
- Visibility of simulation tags

Further descriptions are available in the network headers.

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3.2 Cyclic interrupt [OB200]

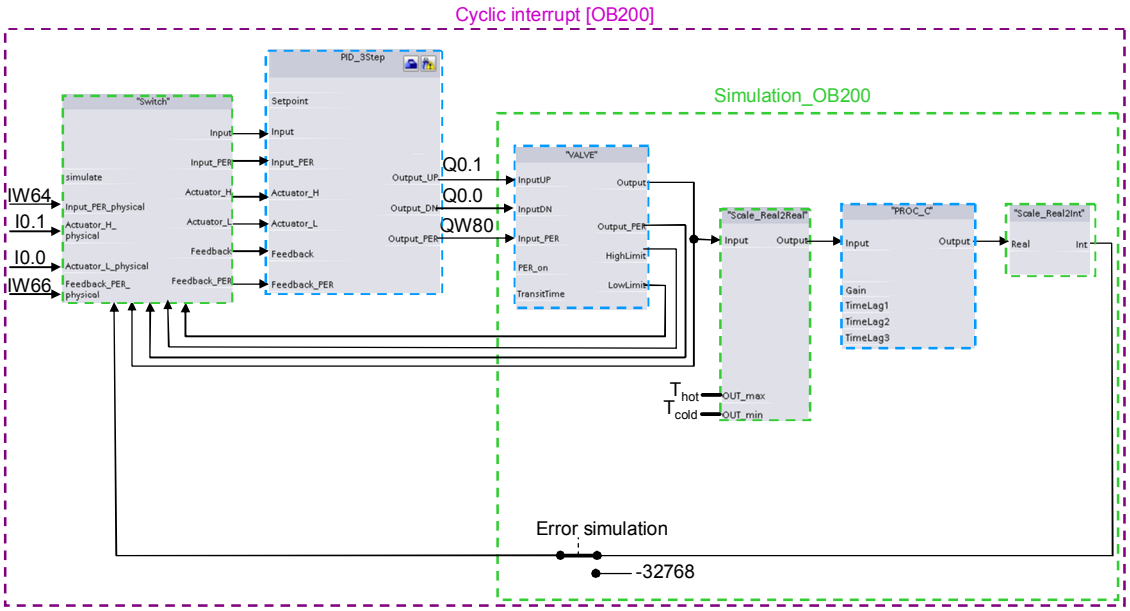
The actual program (the call of the “PID_3Step” 3-point stepper controller) occurs in the cyclic interrupt OB, since discrete software controls must be called up in a defined time interval for optimizing the controller quality.

100ms were set as a constant time interval for the scan time of OB200.

Program overview

In the cyclic interrupt OB the entire simulated control circuit is calculated.

Figure 3-4



Explanation of the configuration

The “Switch” function enables you to switch between a real controlled system (signal evaluation via the control periphery) or a simulation of the controlled system.
The selected signals are then transferred to the “PID_3Step” 3-point stepper control as input parameters. From the control deviation = setpoint - process value, depending on the PID parameters, it calculates the control value transferred digitally or analog to the PLC periphery outputs and the valve simulation block “VALVE”.
“VALVE” simulates the actuator and, depending on the transition time, it calculates limit switch signals and the valve position, which are feed back internally to the “Switch”.
The valve position is, depending on the inflow temperatures T_{cold} and T_{hot}, converted to the temperature setpoint for the system via the “Scale_Real2Real” function.
The “PROG_C” block simulates a PT1 system behavior and outputs the actual temperature value, which is converted into an analog value via “Scale_Real2Int”.
For operating the error simulation, a faulty value (-32768) is transferred to the “Switch” instead of the actual temperature value.

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3.2.1 Switch [FC4]

The “Switch” function is used for switching between the signal evaluation via the PLC periphery or internally calculated simulated input signals for transfer to the “PID_3Step” 3-point stepper control.

Figure 3-5

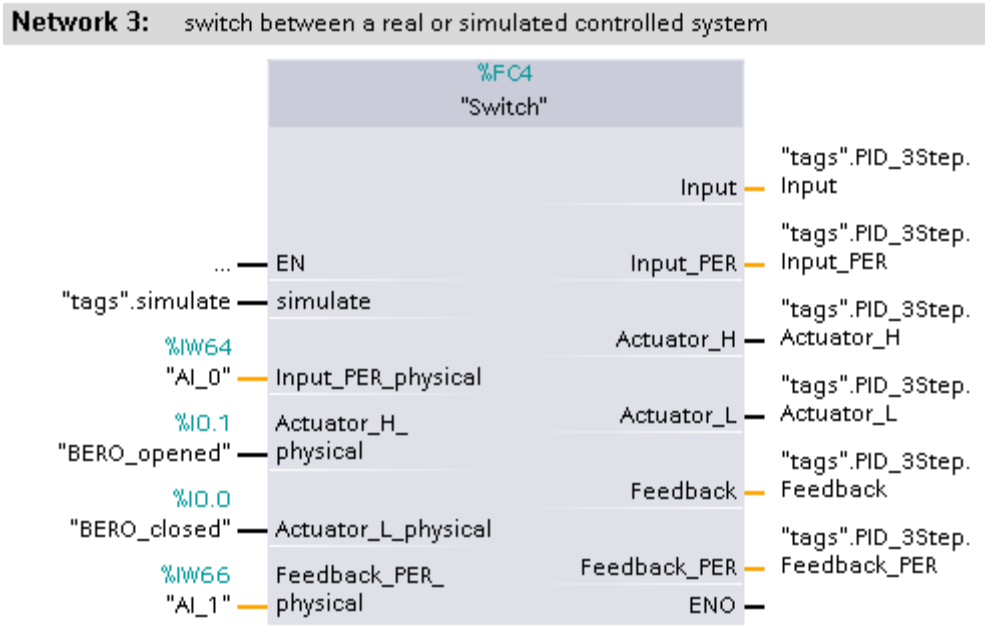


Table 3-1

	Name	Data type	Description
Input	simulate	Bool	FALSE = input parameter TRUE = internal simulation parameters are transferred to the outputs
	Input_PER_physical	Int	Analog periphery input signal for the process value
	Actuator_H_physical	Bool	Upper limit switch signal of the valve
	Actuator_L_physical	Bool	Lower limit switch signal of the valve
	Feedback_PER_physical	Int	Analog periphery input signal for the valve position feedback
Output	Input	Real	Process value transfer to PID_3Step
	Input_PER	Int	Analog process value transfer to PID_3Step
	Actuator_H	Bool	Transfer of the upper limit switch signal to PID_3Step
	Actuator_L	Bool	Transfer of the lower limit switch signal to PID_3Step
	Feedback	Real	Transfer of the valve position feedback to PID_3Step
	Feedback_PER	Int	Transfer of the analog valve position feedback to PID_3Step

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Note

All inputs must be assigned (even if some are not required due to the controller configuration).

The simulated input variables are deliberately not directed outwards, since the user only needs to adjust the real periphery inputs to its hardware configuration.

For “simulate” = FALSE, the “Input” and “Feedback” parameters are calculated from the analog values “Input_PER” and “Feedback_PER” using the “Scale_Int2Real” function.

Scale_Int2Real [FC3]

The “Scale_Int2Real” function is used for converting an analog value (data type: Int) into a floating-point number (data type: Real) within predefined boundaries.

Figure 3-6

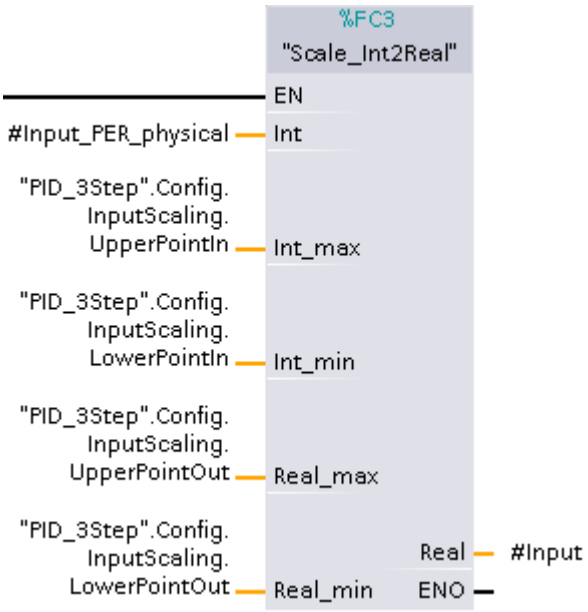


Table 3-2

	Name	Data type	Description
Input	Int	Int	Analog value to be converted
	Int_max	Real	Upper limit of the analog value
	Int_min	Real	Lower limit of the analog value
	Real_max	Real	Upper limit of the floating-point output value
	Real_min	Real	Lower limit of the floating-point output value
Output	Real	Real	Floating-point output value

Note

The specified input limits “Int_max” and “Int_min” are intentionally defined as “Real”, in order to guarantee the compatibility with the specified limits in the instance data block of “PID_3Step”.

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3.2.2 PID_3Step_2 [FB1131]

STEP 7 V11 provides the “PID_3Step” technology object with the installation. This function block was especially developed for controlling valves or actuators with integrated behavior.

Figure 3-7

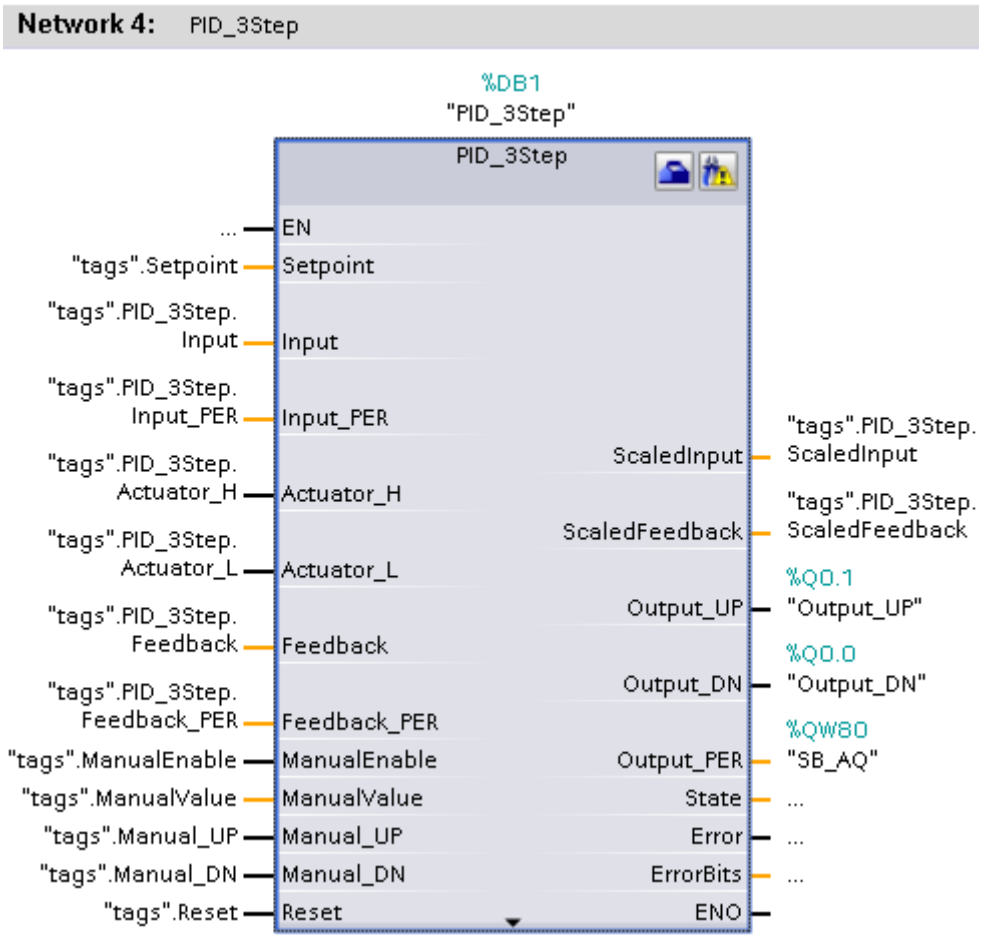


Table 3-3

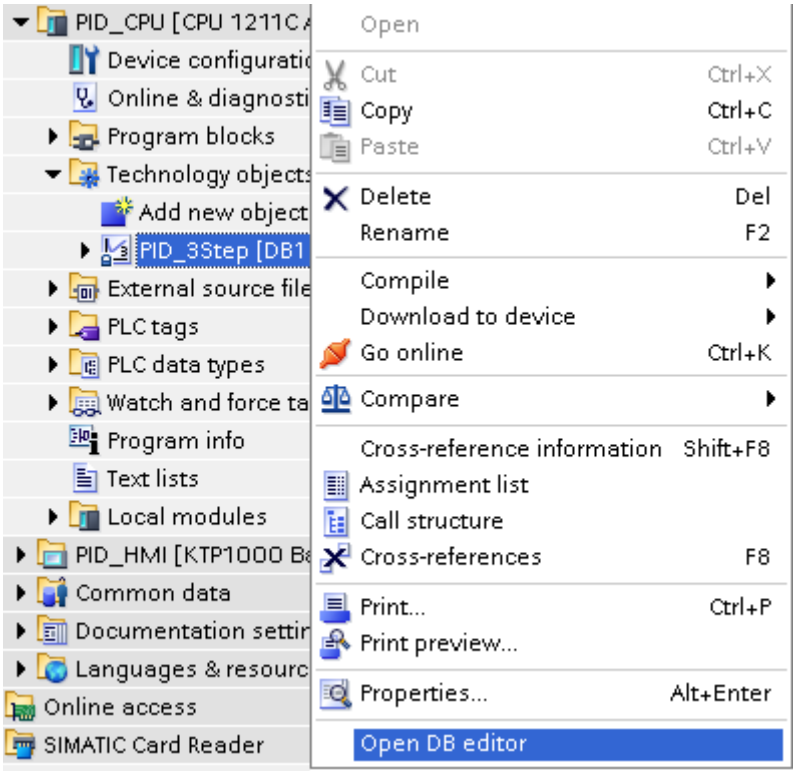
	Name	Data type	Description
Input	Setpoint	Real	Setpoint for PID control
	Input	Real	Current value from process
	Input_PER	Word	Current value from peripheral input
	Actuator_H	Bool	Valve reached high limit
	Actuator_L	Bool	Valve reached low limit
	Feedback	Real	Valve position feedback
	Feedback_PER	Word	Valve position feedback peripheral input
	ManualEnable	Bool	Enable manual operation
	ManualValue	Real	Manual value - only in analog mode or with feedback signal
	Manual_UP	Bool	Manual open valve - lower to upper edge triggered
	Manual_DN	Bool	Manual close valve - lower to upper edge triggered
	Reset	Bool	Reset control values
Output	ScaledInput	Real	Current value after scaling
	ScaledFeedback	Real	Valve position after scaling
	Output_UP	Bool	Control value to open valve

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	Name	Data type	Description
	Output_DN	Bool	Control value to close valve
	Output_PER	Word	Analog output value
	State	Int	Current mode of operation
	Error	Bool	Error flag
	ErrorBits	DWord	Error message

"PID_3Step" is called in the "Cyclic interrupt" (OB200) cyclic interrupt.
The instance data block DB1 for "PID_3Step" is available in the "Technology objects" folder:
It can be opened via right-click -> "Open DB editor".
Apart from the inputs and outputs, the application also accesses the static tags of "PID_3Step".

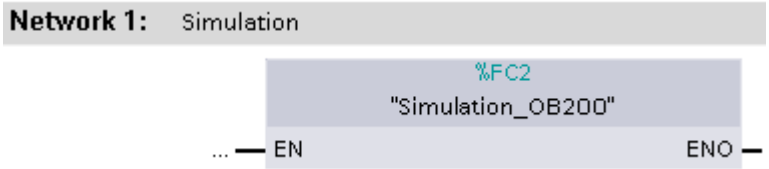
Figure 3-8



A detailed description of the 3-point stepper controller is available in the STEP 7 V11 online help. Select function block "PID_3Step" in the program call (see Figure 3-7) and press F1.

3.2.3 Simulation_OB200 [FC2]

Figure 3-9



All functions are called from the "Simulation_OB200" function required for the simulation of the controlled system:

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- VALVE [FB101]
- Scale_Real2Real [FC6]
- PROC_C [FB100]
- Scale_ Real2Int [FC5]

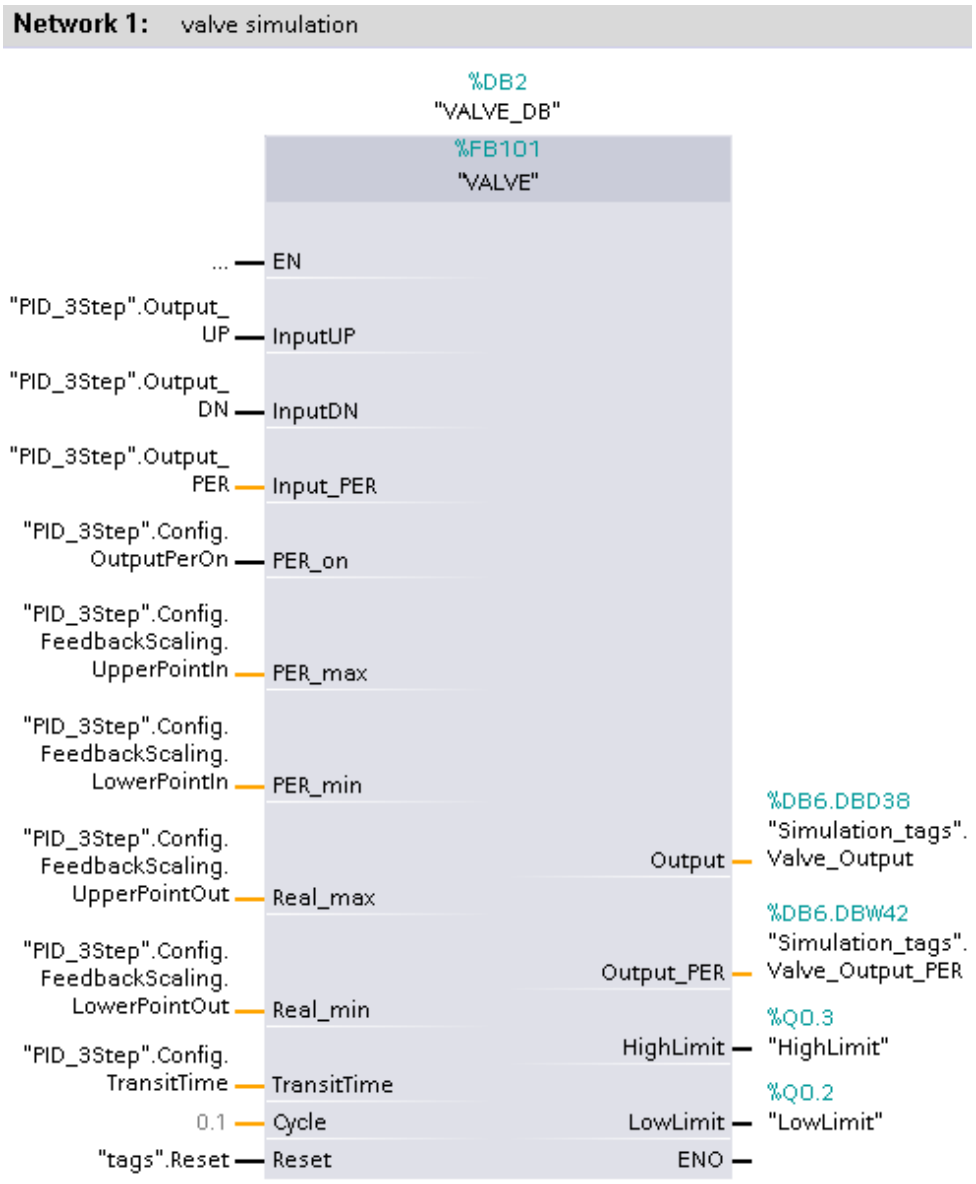
The “Simulation_OB200” is called in the same cyclic interrupt as the 3-point stepper controller “PID_3Step”.

Further information is available in the network headers as well as in the description below.

VALVE [FB101]

The “VALVE” function block simulates the actuator and, depending on the transition time, it calculates the valve position and sets the limit switch signals

Figure 3-10



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Table 3-4

	Name	Data type	Description
Input	InputUP	Bool	Control signal “Open valve”
	InputDN	Bool	Control signal “Close valve”
	Input_PER	Int	Analog control value of PID_3Step
	PER_on	Bool	Selection switch, whether InputUP/InputDN or Input_PER is used (Input_PER is used for TRUE)
	PER_max	Real	Upper limit of the analog value of the valve position
	PER_min	Real	Lower limit of the analog value of the valve position
	Real_max	Real	Upper limit of the converted floating-point value for the valve position
	Real_min	Real	Lower limit of the converted floating-point value for the valve position
	TransitTime	Real	Transition time of the valve between the end positions
	Cycle	Real	Call interval of the cyclic interrupt
	Reset	Bool	Input for the reset
Output	Output	Real	Calculated valve position (within the “Real_min” and “Real_max” limits)
	Output_PER	Int	Calculated analog valve position (within the “PER_min” and “PER_max” limits)
	HighLimit	Bool	Simulated upper valve end position
	LowLimit	Bool	Simulated lower valve end position

Depending on the “PER_on” input setting, the valve position is calculated from the digital control signals “InputUP” and “InputDN” or from the analog control value “Input_PER” of the “PID_3Step” 3-point stepper controller.

The limits for converting the valve position between analog value and floating-point number are adopted from the instance data block of “PID_3Step”.
The specified input limits “PER_max” and “PER_min” are intentionally defined as “Real”, in order to guarantee the compatibility with the specified limits in the instance data block of “PID_3Step”.

When activating the “Reset” input, the calculation of the valve position starts at the lower end position.

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Scale_Real2Real [FC6]

The “Scale_Real2Real” function is used for converting a floating-point number (data type: Real) into a different floating-point number (data type: Real) within predefined limits.

Figure 3-11

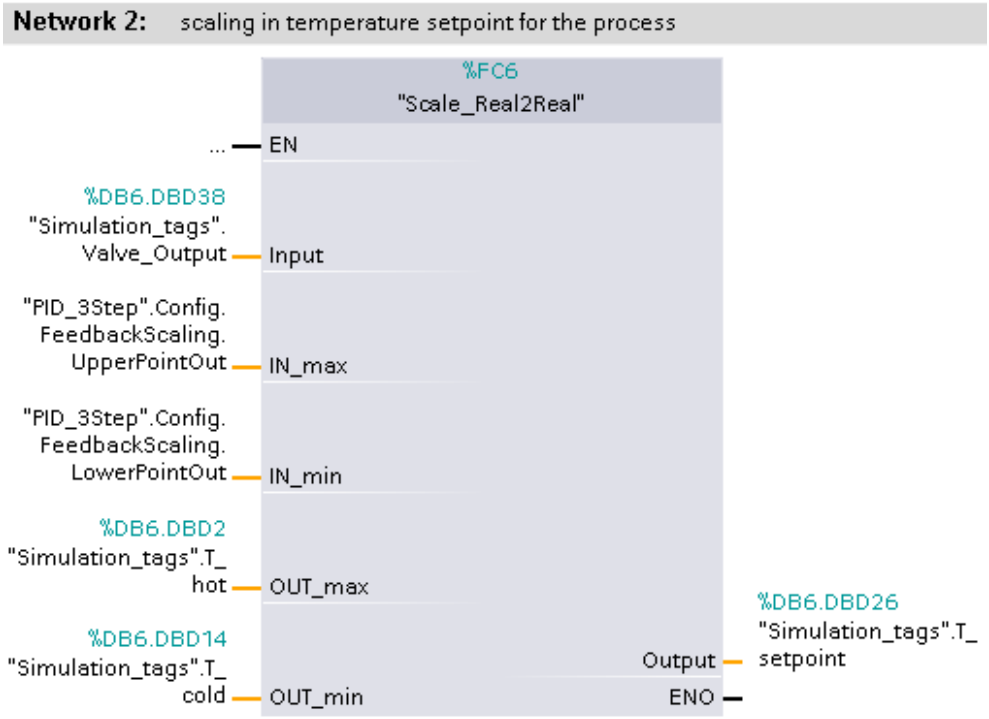


Table 3-5

	Name	Data type	Description
Input	Input	Real	Floating-point value to be converted
	IN_max	Real	Upper limit of the floating-point input value
	IN_min	Real	Lower limit of the floating-point input value
	OUT_max	Real	Upper limit of the floating-point output value
	OUT_min	Real	Lower limit of the floating-point output value
Output	Real	Real	Floating-point output value

This function is used for converting the simulated valve position in the temperature setpoint value as input parameter for the PT1 controlled system simulation.
This temperature setpoint value must be converted to the limits of the water feed into the mixer tap.

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PROC_C [FB100]

Function block “PROC_C” simulates the continuous behavior of a controlled system PT3.

Figure 3-12

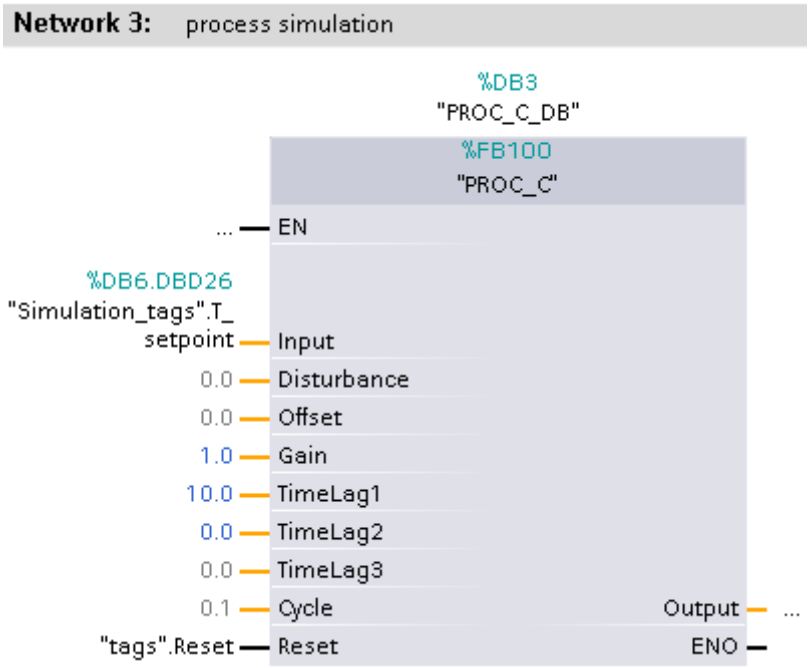


Table 3-6

	Name	Data type	Description
Input	Input	Real	Input value of the simulation of the controlled system
	Disturbance	Real	Disturbance value
	Offset	Real	Output offset
	Gain	Real	Gain factor
	TimeLag1	Real	Delay time 1 (deactivation for TimeLag1=0.0)
	TimeLag2	Real	Delay time 2 (deactivation for TimeLag2=0.0)
	TimeLag3	Real	Delay time 3 (deactivation for TimeLag3=0.0)
	Cycle	Real	Call interval of the cyclic interrupt
	Reset	Bool	Input for the reset
Output	Output	Real	Calculated output value of the simulation of the controlled system

The output value is calculated using the following formula:

$$Output = \frac{Gain \cdot (Input + Disturbance)}{(TimeLag1 \cdot s + 1) \cdot (TimeLag2 \cdot s + 1) \cdot (TimeLag3 \cdot s + 1)} + Offset$$

s = Laplace operator

In the application on hand, controlled system simulation block “PROC_C” is designed as controlled system PT1 with a delay time of 10 seconds (“TimeLag2” and “TimeLag3” are disabled).

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Scale_ Real2Int [FC5]

The “Scale_Real2Int” function is used for converting a floating-point number (data type: Real) into an analog value (data type: Int) within predefined limits.

Figure 3-13

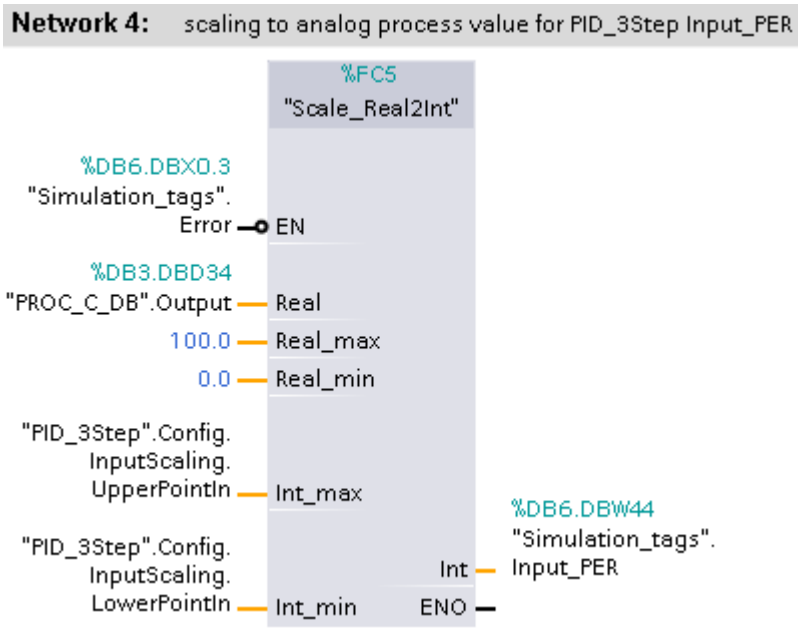


Table 3-7

	Name	Data type	Description
Input	Real	Real	Floating-point input value to be converted
	Real_max	Real	Upper limit of the floating-point input value
	Real_min	Real	Lower limit of the floating-point input value
	Int_max	Real	Upper limit of the analog output value
	Int_min	Real	Lower limit of the analog output value
Output	Int	Int	Analog output value

The specified output limits “Int_max” and “Int_min” are intentionally defined as “Real”, in order to guarantee the compatibility with the specified limits in the instance data block of “PID_3Step”.

The conversion of the controlled system output (actual temperature value) into an analog value is necessary to be able to simulate the behavior in the case of an error.
For a real controlled system, an error occurs when the process value sensor fails (e.g. due to wire break).
In the simulation this is achieved by overwriting the analog process value with a value outside the measuring range (-32768) (see Figure 3-4).

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4 Startup of the Application

4.1 Hardware adjustment

The application was realized with a CPU 1211C, which provides 2 integrated analog inputs for receiving voltage signals from 0 to 10 V.

Depending on the design of your selected valve, the hardware configuration of your S7-1200 might need adjustment.
The configuration options of S7-1200 for operating the “PID_3Step” 3-point stepper controller are introduced below.

4.1.1 Input signal

The periphery acquires the controlled value as an analog value. “PID_3Step” offers the conversion of the analog value into the physical unit in the configuration screen.

The modules for the analog value acquisition are listed below.

Controlled value acquisition and valve position feedback

Table 4-1

Analog inputs	Order number	Type		Resolution
		Voltage	Current	
2 x onboard	any CPUs	0 to 10V	no	10 bits
SB 1231 AI 1 x 12 Bit	6ES7231-4HA30-0XB0	±10V, ±5V, ±2.5V	0 to 20 mA	11 bits plus sign
SM 1231 AI 4 x 13 Bit	6ES7231-4HD30-0XB0	±10V, ±5V, ±2.5V	0 to 20 mA	12 bits plus sign
SM 1231 AI 8 x 13 Bit	6ES7231-4HF30-0XB0	±10V, ±5V, ±2.5V	0 to 20 mA	12 bits plus sign
SM 1234 AI 4 x 13 Bit / AO 2 x 14 Bit	6ES7234-4HE30-0XB0	±10V, ±5V, ±2.5V	0 to 20 mA	12 bits plus sign
SM 1231 AI 4 x 16 Bit	6ES7231-5ND30-0XB0	±10V, ±5V, ±2.5V, ±1.25V	0 to 20 mA or 4 mA to 20 mA	15 bits plus sign

Controlled value acquisition (temperature)

Table 4-2

Thermocouple	Order number	Type	Resolution	
		Temperature / Voltage	Temperature	Voltage
SB 1231 AI 1 x 16 Bit TC	6ES7231-5QA30-0XB0	Floating TC and mV	0.1 °C/0.1 °F	15 bits plus sign
SM 1231 AI 4 x 16 Bit TC	6ES7231-5QD30-0XB0	Floating TC and mV	0.1 °C/0.1 °F	15 bits plus sign
SM 1231 AI 8 x 16 Bit TC	6ES7231-5QF30-0XB0	Floating TC and mV	0.1 °C/0.1 °F	15 bits plus sign

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Table 4-3

Resistance thermometer	Order number	Type	Resolution	
		Temperature / resistance	Temperature	Resistance
SB 1231 AI 1 x 16 Bit RTD	6ES7231-5PA30-0XB0	Module-referenced RTD and Ω	0.1 °C/0.1 °F	15 bits plus sign
SM 1231 AI 4 x RTD x 16 Bit	6ES7231-5PD30-0XB0	Module-referenced RTD and Ω	0.1 °C/0.1 °F	15 bits plus sign
SM 1231 AI 8 x RTD x 16 Bit	6ES7231-5PF30-0XB0	Module-referenced RTD and Ω	0.1 °C/0.1 °F	15 bits plus sign

4.1.2 Output signal

"PID_3Step" offers the control of the value via 2 digital outputs (in 2 directions) or via an analog output.

Digital outputs

Depending on the power consumption of your digital valve control, you can choose between S7-1200 controllers with transistor or relay outputs:

Table 4-4

Digital outputs	Voltage range	Current (max.)
Transistor	20.4 to 28.8 V	0.5 A
Relay	5 to 250 V	2 A

Analog outputs

Table 4-5

Analog outputs	Order number	Type	
		Voltage (resolution)	Current (resolution)
CPU 1215C	any controllers 1215C	no	0 to 20 mA (10 bits)
SB 1232 AO 1 x 12 Bit	6ES7232-4HA30-0XB0	±10 V (12 bits)	0 to 20 mA (11 bits)
SM 1232 AO 2 x 14 Bit **SM** 1232 AO 4 x 14 Bit **SM** 1234 AI 4 x 13 Bit / AO 2 x 14 Bit	6ES7232-4HB30-0XB0 6ES7232-4HD30-0XB0 6ES7234-4HE30-0XB0	±10 V (14 bits)	0 to 20 mA (13 bits)

Note

SB = signal board (each CPU has a slot for a signal board)
SM = signal module

- up to 2 signal modules can be connected to CPU 1212C
- up to 8 signal modules can be connected to CPU 1214C/1215C

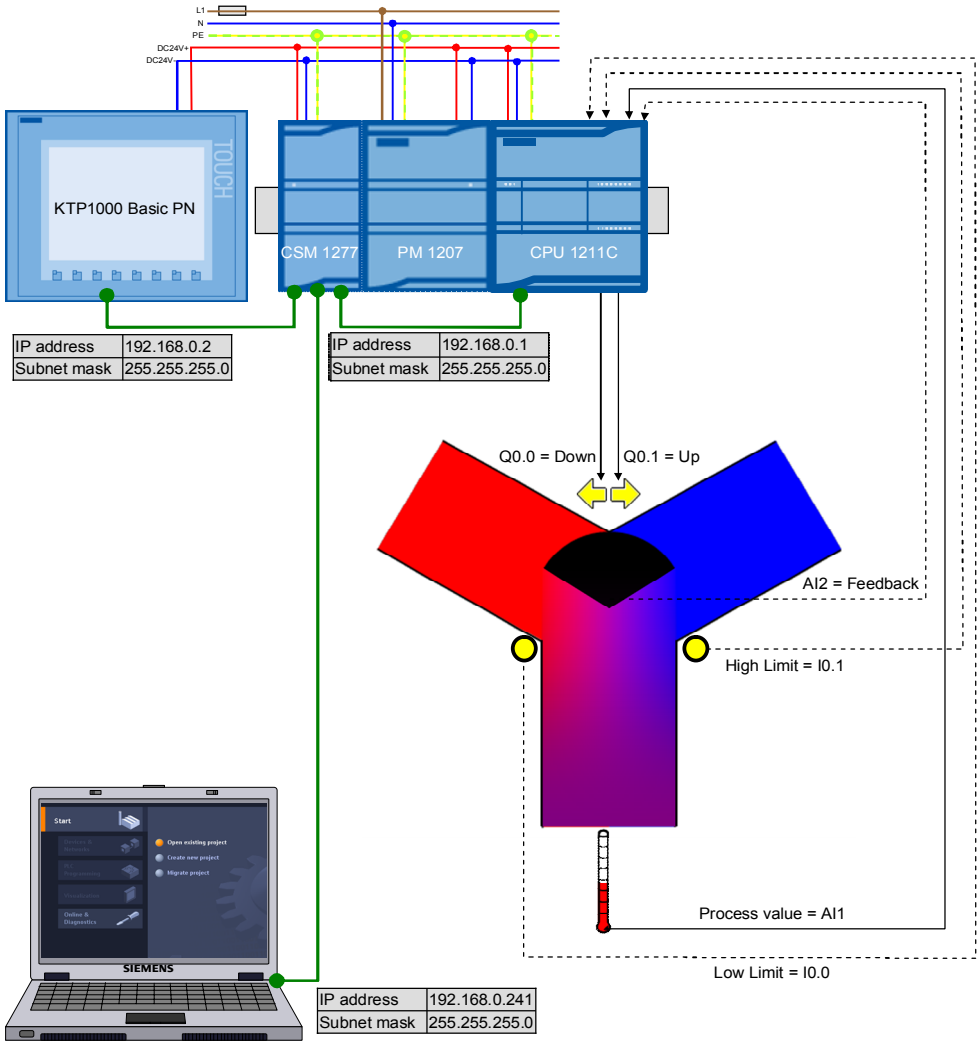
Further information for selecting your periphery and its wiring is available in Chapter A "Technical Data" of the S7-1200 Manual (\1\).
Integrating the 1215C CPUs and signal module 1231 AI 4 x 16 Bit into STEP 7 V11 SP2 Upd 4 requires the Hardware Support Package 0026 (\3\).

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Hardware installation

The figure below shows the hardware setup of the application.

Figure 4-1



Installing the hardware

Table 4-6

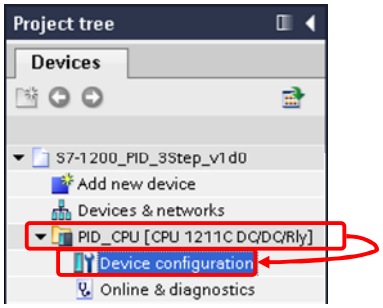
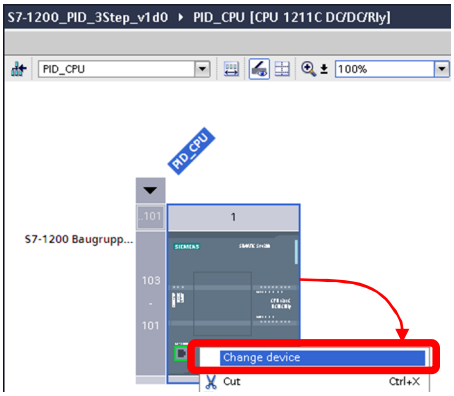
No.	Instruction	Remarks
1	Adjust the periphery of S7-1200 to the valve you are using.	see chapter 4.1
2	Mount all required S7-1200 components on a top-hat rail.	see chapter 2.3
3	Wire and connect all required components as described.	S7-1200 Manual (\1\) Chapter A "Technical Data"
4	Finally, activate the voltage supply for the SIMATIC PM 1207.	

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4.2 Configuration instructions

Adjusting the device configuration

Table 4-7

No.	Instructions	Remarks
1.	Network the S7-1200 controller with your programming device. Assign the Ethernet parameters as shown in Figure 4-1	Assign IP address to S7-1200: S7-1200 Manual (\1\) → Chapter 5.6.4
2.	Open the project file (ap11) with STEP 7 V11.	Table 2-3
3.	Open the device configuration of the “PID_CPU” controller.	
4.	Adjust the device configuration in the project to the real hardware configuration for your used valve and temperature sensor (chapter 4.1). When using a different CPU, select the configured CPU and activate “Change device” via right-click. Further options for adding modules to the configuration are available in the S7-1200 Manual (\1\) → Chapter 5.3.	

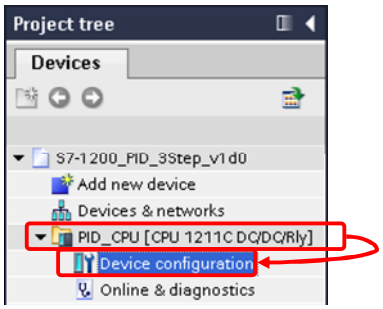
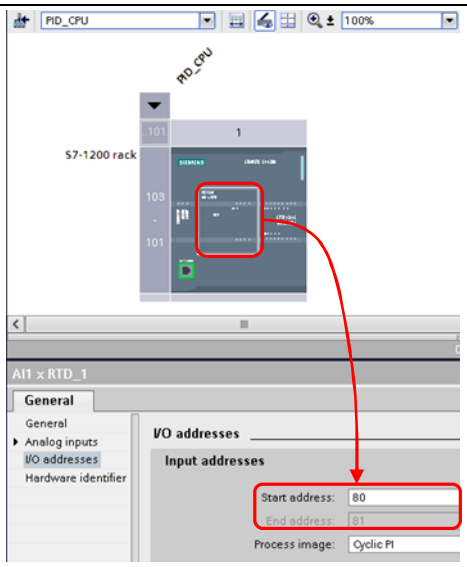
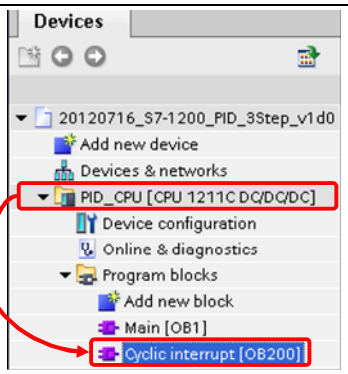
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Transferring the I/O addresses

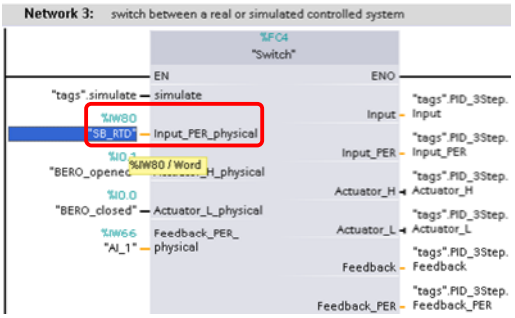
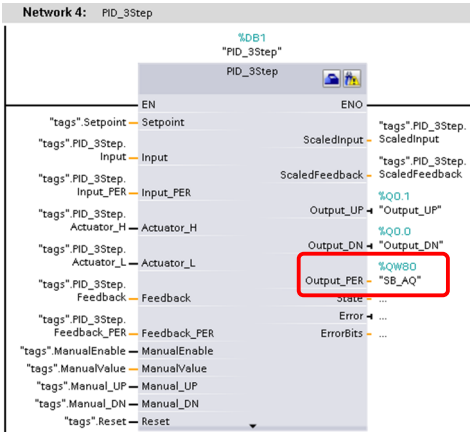
Depending on the changed configuration, the input or output addresses of the added hardware must be transferred to the program.

This is illustrated at the example of a signal board 1231 AI 1 x 16 Bit RTD:

Table 4-8

No.	Instruction	Remarks
1.	Open the device configuration of the “PID_CPU” controller.	
2.	In the device view of the CPU you select the signal board 1231 AI 1 x 16 Bit RTD. Read the input address of the signal board in menu item “I/O addresses”: • Start address: 80 • End address: 81 meaning: The address via which the analog value of SB 1231 AI 1 x 16 Bit RTD is read, is: **IW80**	
3.	Open the OB200 “Cyclic interrupt” in the control unit of the project.	

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No.	Instruction	Remarks
4.	Since the process value is read via the signal board as the temperature, you transfer input word **IW80** to the “Input_PER_physical” parameter of the “switch” function in network 3. Furthermore, you have the option to adjust the • digital input addresses for the end positions of the valve (Actuator_H_ physical / Actuator_L_ physical) • analog input address for the feedback signal of the valve position (Feedback_PER_ physical)	
5.	In network 4 you transfer the address of the analog output if using a valve with analog control. Furthermore, you can also change the digital control signals for the periphery: • Output_UP • Output_DN	

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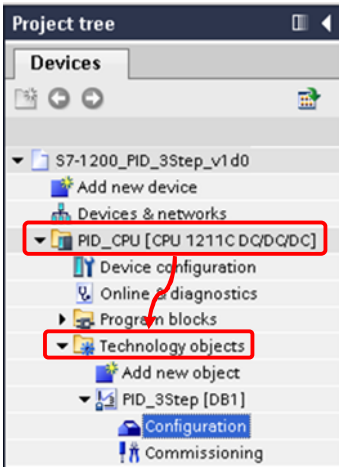
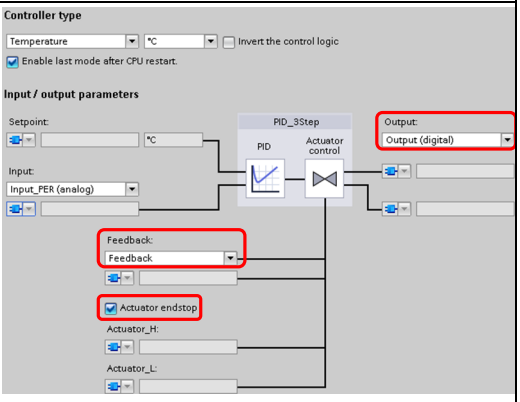
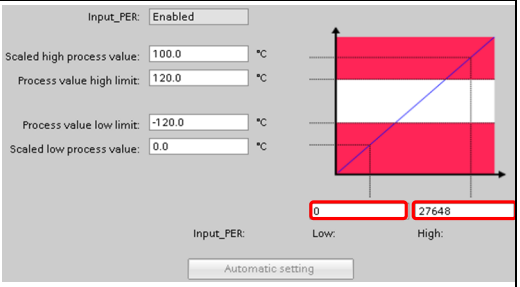
Configuring the PID controller

The configuration of the “PID_3Step” technology object defines the function principle of the 3-point stepper controller.

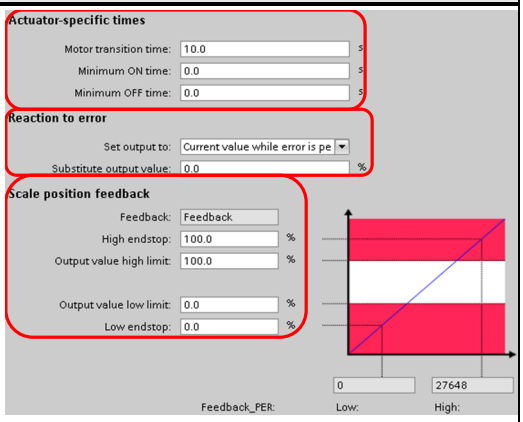
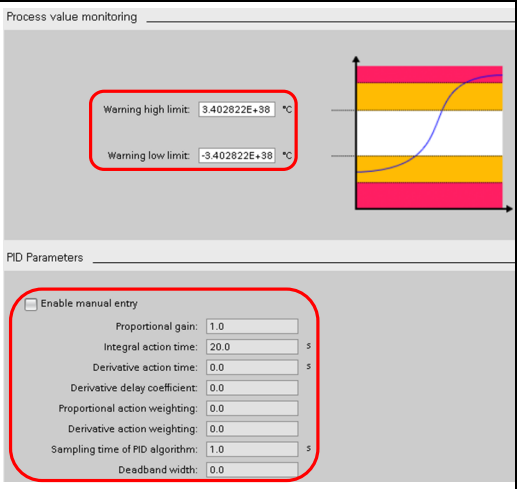
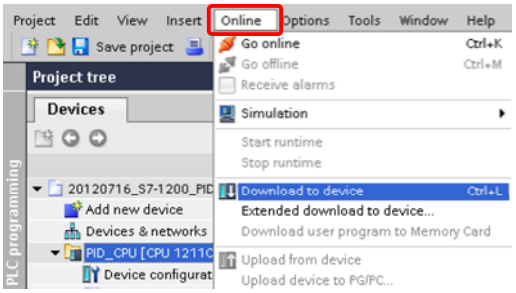
The settings made determine the default values used by the PID controller when restarting after a cold or warm start (e.g. power failure).

A further description is available in the S7-1200 Manual (\1\) → Chapter 9.2.6 and in the STEP 7 Basic V11 manual (\4\) → Chapter 11.1.3.2.

Table 4-9

No.	Instruction	Remarks
1.	Open the configuration editor by selecting CPU -> Technology objects -> PID_3Step -> Configuration.	
2.	Open the **Basic settings**: Here you determine the properties of the valve you are using: • digital or analog control • does the valve provide a feedback of the valve position • does the valve have digital end position switches **Note:** Setting the controller type (here: Temperature) with the unit (here: °C) is only performed for labeling the axis correctly in the commissioning wizard (see chapter 4.3).	
3.	Open the **Process value settings**: Here you determine the limits of the process value (Input_PER). **Note:** Please ensure that the correct settings for lower and upper process value (here: -120 to +120°C), since the controller turns inactive when these limits are violated!	

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No.	Instruction	Remarks
4.	Open the **Actuator settings**. **Actuator-specific times** If your used valve does not give any position feedback, neither analog nor digital, the motor transition time must be specified here as precisely as possible. For adjusting the actuator inertia you can specify minimal switch ON/OFF times. **Reaction to error** Determine whether the current valve position or a substitute output value as a percentage shall be approached while the error is pending. **Scaling the position feedback** When using a valve with position feedback (Feedback_PER), you determine the limits here.	
5.	Open the **Advanced settings**: **Process value monitoring** Here you can specify warning limits where a respective warning bit will be activated when exceeded or fallen short of. **PID Parameters** Here you can specify the control parameters manually if you do not wish to use automatic tuning function. These values are written to the instance data block of the “PID_3Step” and adopted as actual values after a cold start (loading project into the controller).	
6.	Save the project. Select the program folder of the S7-1200 and transfer the program to the controller via “Online/Download to device”. Make sure that the LED of the S7-1200 controller indicates the “RUN” status.	

Note

The CPUs of the S7 1200 series apply changes to **DB start values** only during the next **STOP-RUN** transition.

Please consider this behavior when making changes to the data blocks.

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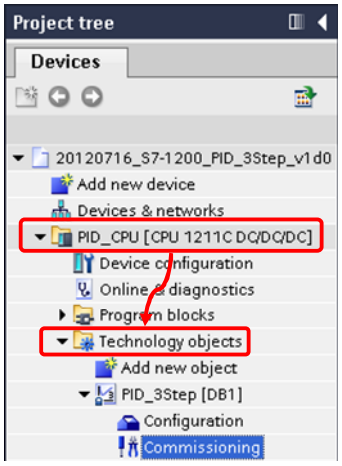
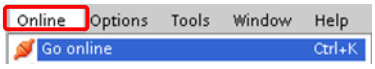
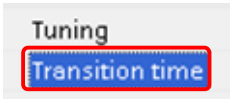
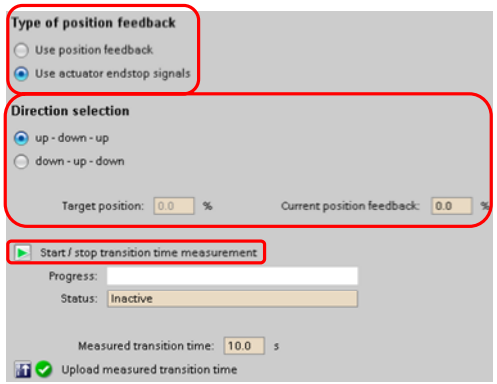
4.3 Commissioning the 3-point stepper controller

Configure the 3-point stepper controller in the commissioning editor for the automatic settings during startup and for the automatic setting during operation.

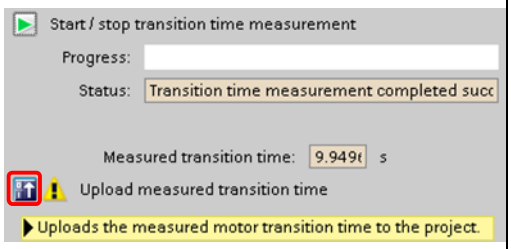
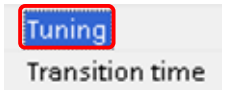
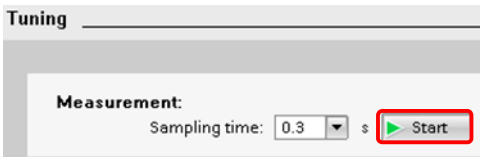
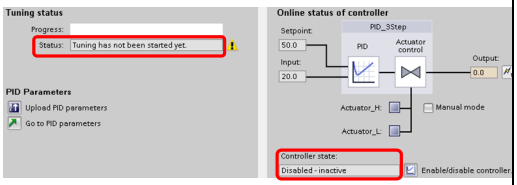
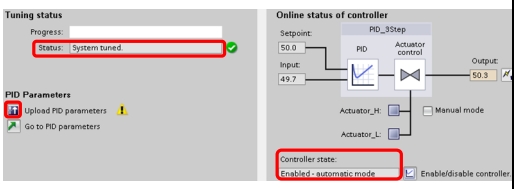
The settings made determine the default values used by the PID controller when restarting after a cold or warm start (e.g. power failure).

A further description is available in the S7-1200 Manual (\1\) → Chapter 9.2.7 and in the STEP 7 Basic V11 manual (\4\) → Chapter 11.1.3.2.

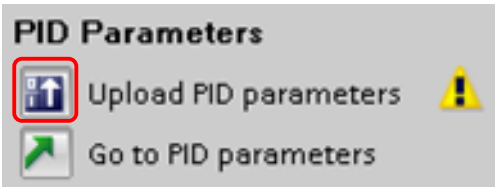
Table 4-10

No.	Instruction	Remarks
1.	Open the configuration editor by selecting CPU -> Technology objects -> PID_3Step -> Commissioning.	
2.	Connect the programming device online with the CPU.	
3.	In the commissioning editor you open the screen for Tuning the transition time.	
4.	Depending on the type of the position feedback you can measure the transition time of your valve here: • When using the stop signals of the actuator you can decide whether the selected direction shall be “up-down-up” or “down-up-down”. • When using the position feedback, you must assign a target position with a distance of at least 50% from the current position feedback. • Without position feedback, the transition time must be specified as precisely as possible. Start the transition time measurement.	

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No.	Instruction	Remarks
5.	After completion, upload the measured transition time into the project. The measured transition time is written to the instance data block of “PID_3Step” as the start value and restarts with this transition time after a cold or warm start (e.g. power failure).	
6.	Go to the Tuning screen in the commissioning editor.	
7.	Start the measurement.	
8.	Without manual preassignment of the PID parameters (Table 4-9, step 5) the status indicates that tuning has not been started yet, and after the first startup of the CPU the controller is in disabled (inactive) mode.	
9.	From the inactive state only pretuning can be started. Selecting “Fine tuning” starts pretuning followed by a fine tuning. Enter a setpoint ideally in the central area of the process value range (e.g. via a monitoring table; in the project the start value of the setpoint has already been predefined). Start the pretuning process.	
10.	After successful pretuning, the controller goes to automatic mode. The determined values can be viewed via “Go to PID parameters”. “Upload PID parameters” writes the determined values as start values into the instance data block of “PID_3Step”.	
11.	Enter a setpoint ideally in the central area of the process value range (e.g. via a monitoring table; in the project the start value of the setpoint has already been predefined). In automatic mode you can now directly start the fine tuning.	

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No.	Instruction	Remarks
12.	After successfully terminating the fine tuning you can upload the PID parameters in return as start values to the instance data block of “PID_3Step”.	

Note The PID parameters are stored retentively in the instance data block of the “PID_3Step” 3-point stepper controller.
During a warm start (restored power) the last processed values remain.
The start values are only loaded during cold start (transferring the project in STOP mode).

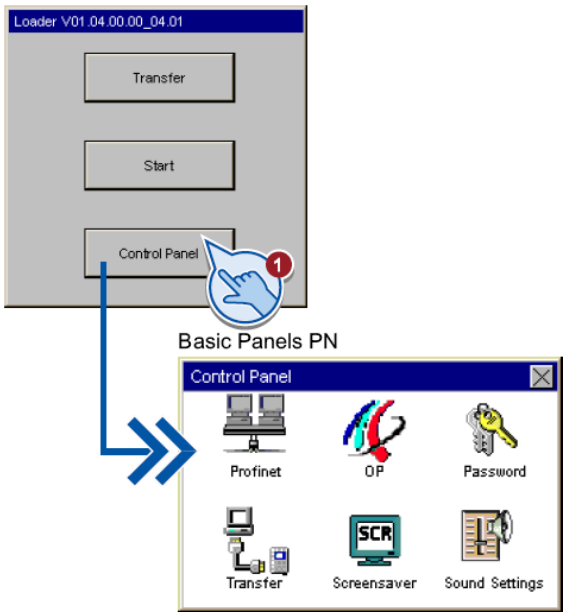
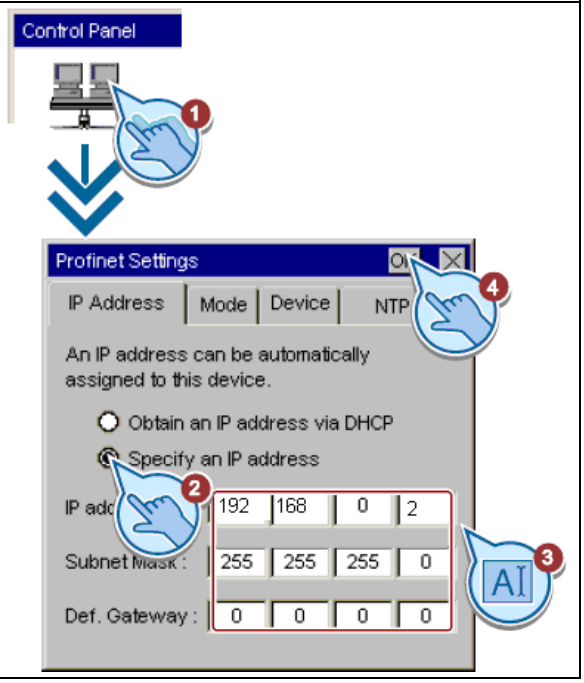
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4.4 HMI project part

4.4.1 Configuring the HMI

If the KTP1000 is used as operator panel, then the project-specific IP address (see Figure 4-1) must be set.

Table 4-11

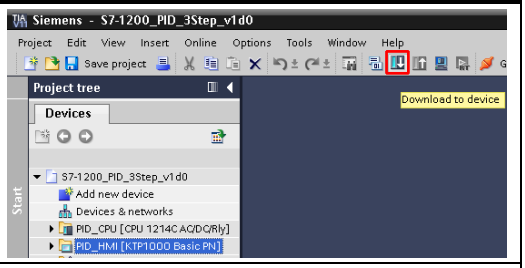
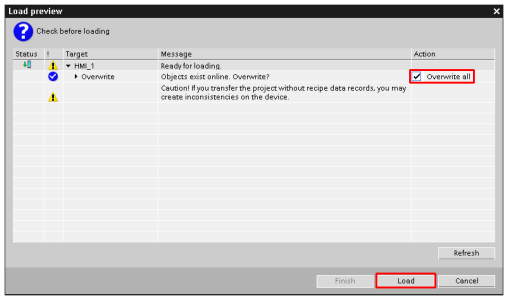
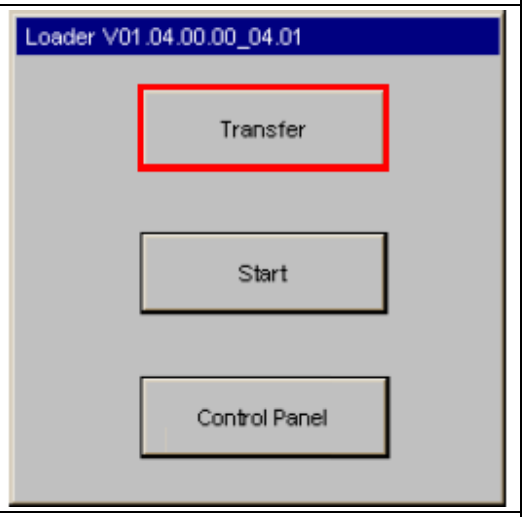
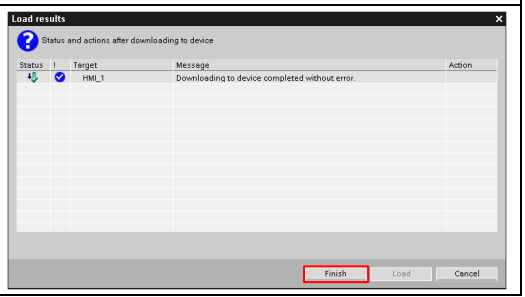
No.	Instruction	Remarks
1.	• Select the “Control Panel” button to open the properties of the control panel of the Boot Loader.	
2.	• Select the “Profinet” button to open the “Profinet Settings” dialog box. • Select the specific address. • Enter the - IP address = 192.168.0.2 and - Subnet Mask= 255.255.255.0 into the input fields via the screen keyboard. • Select “OK” to close the dialog box and apply the entries.	

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Loading the HMI project part into the KTP1000

For the transfer, connect your PG/PC to the HMI either directly or using the CSM1277 switch.

Table 4-12

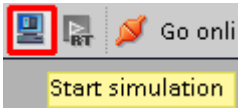
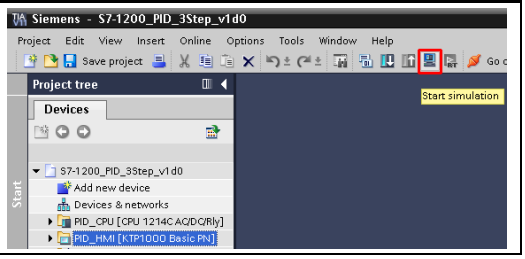
No.	Instruction	Remarks
1.	• Select the “PID_HMI [KTP1000 Basic PN]” operator panel folder. • Select the “Download to device” button to download the HMI project part to the KTP1000.	
2.	• If required, enable the “Overwrite all” option. • Select the “Load” button.	
3.	• Depending on the operator panel setting, you have to trigger the transfer in the Loader menu of the KTP1000 using the “Transfer” button.	
4.	• Once the successful result message is displayed, select the “Finish” button to finish downloading.	

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Starting PC runtime

If the PG/PC is to be used as operator panel, start the PC runtime as follows:

Table 4-13

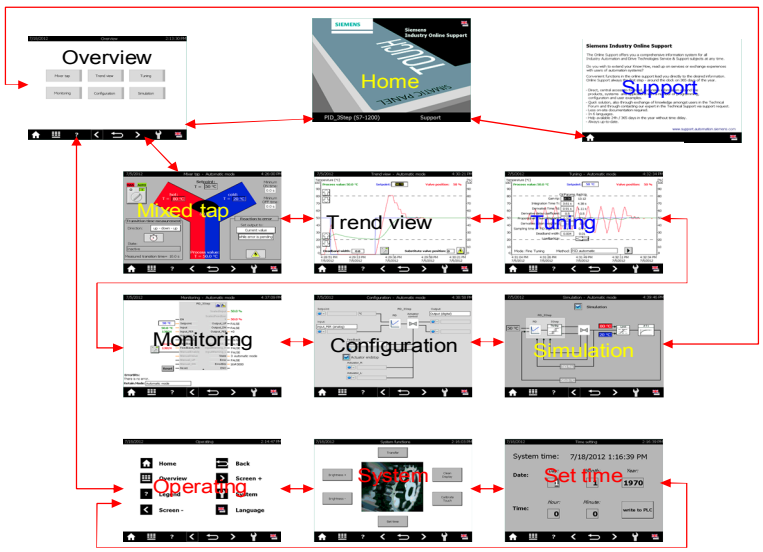
No.	Instruction	Remarks
1.	• Select the “PID_HMI [KTP1000 Basic PN]” operator panel folder. • Click the “Start simulation” button. 	

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5 Operating the Application

5.1 Overview

Figure 5-1



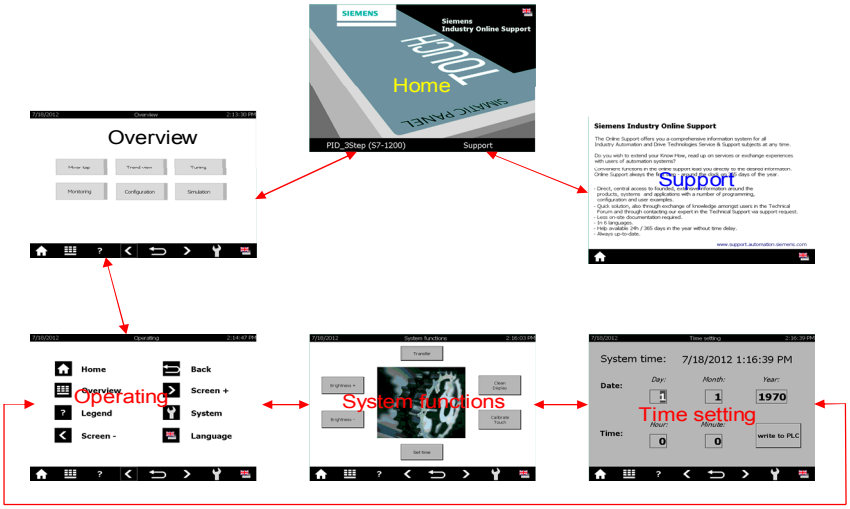
The user interface consists of 12 screens:

- Home screen (Welcome)
- Support (Information on the Siemens Industry Online Support)
- Overview of application-specific screens:
  - Mixer tap
  - Trend view
  - Tuning
  - Monitoring
  - Configuration
  - Simulation
- Operation (explanation of the symbol)
- System functions of the HMI panel
- Time setting for synchronization between CPU and HMI

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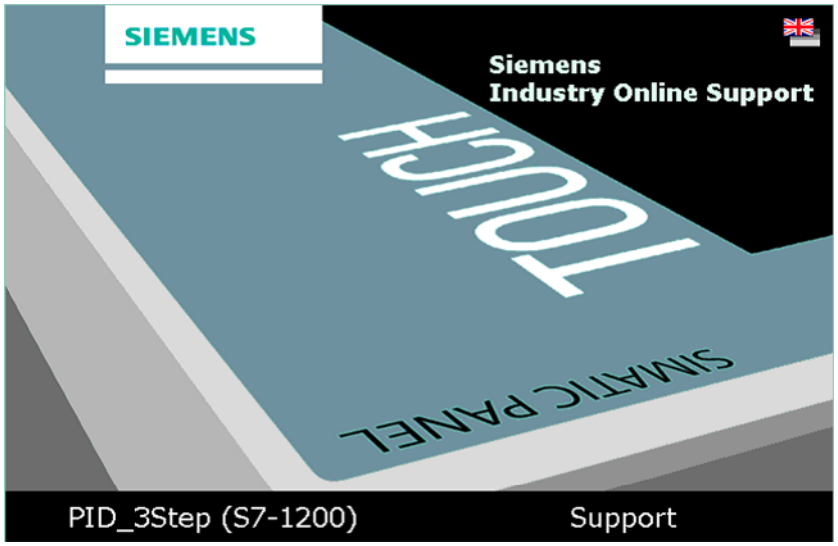
5.2 Overview of application-unspecific screens

Figure 5-2



5.2.1 Home screen

Figure 5-3



The Home screen takes you to:

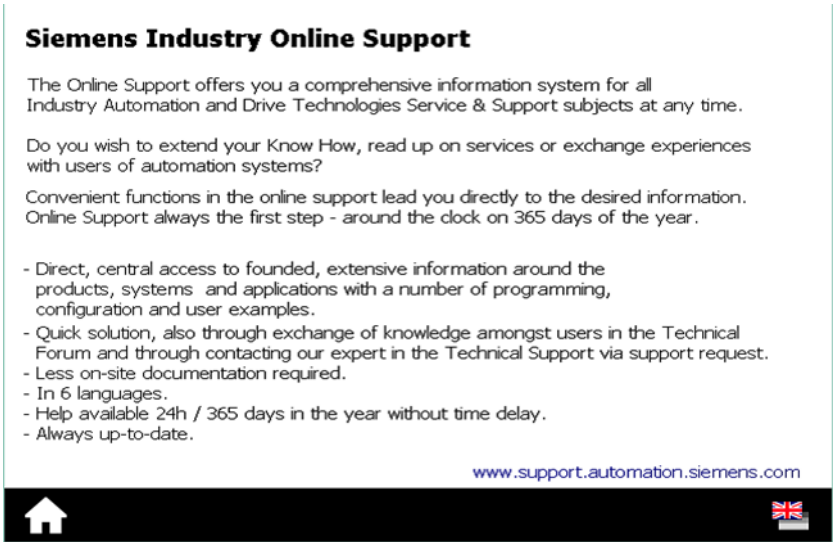
- the Overview via the “PID_3Step (S7-1200)” button or function keys F1 to F4
- the support information via the “Support” button or function keys F5 to F8

5.2.2 Support description

This support description gives information on the Siemens Industry Online Support.

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Figure 5-4

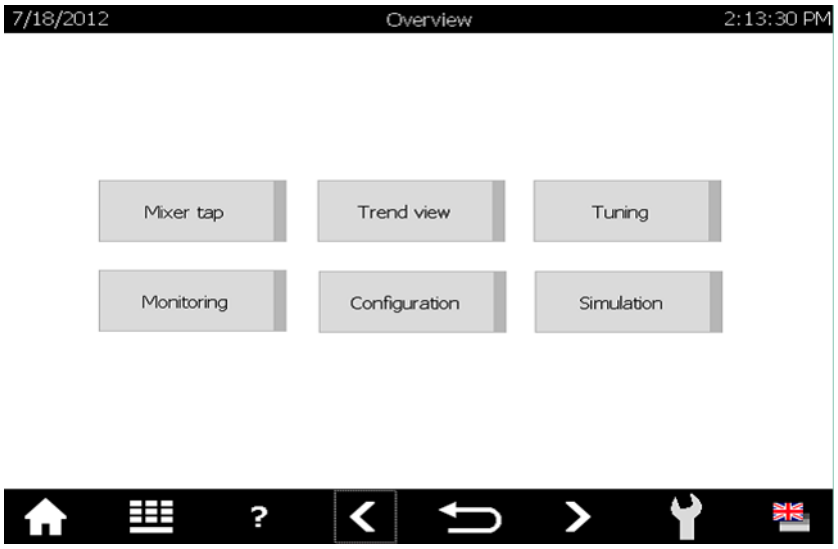


-  or F8 enables you to toggle between German and English language.
-  or F1 takes you back to the Home screen.

5.2.3 Overview

The Overview screen takes you to the application-specific screens via the respective button.

Figure 5-5



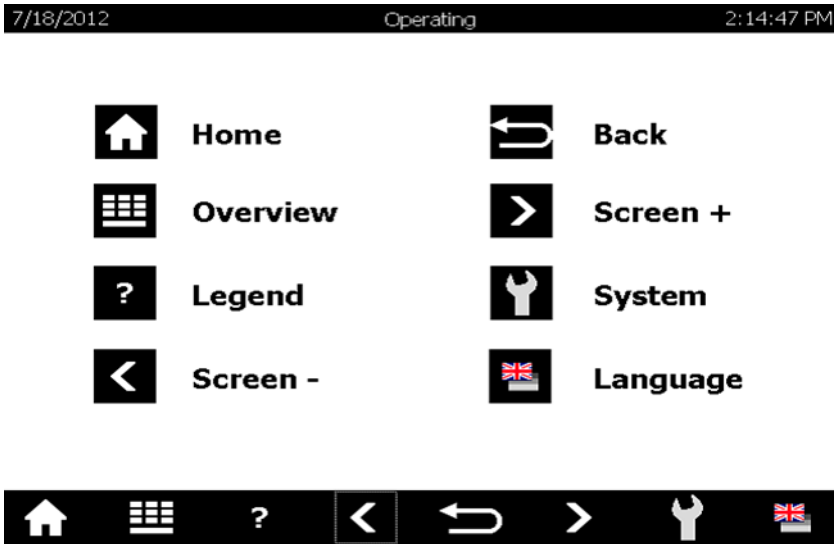
- The header contains the date, the screen title and the local time.
-  or F3 takes you to the explanation of symbols in the footer.

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5.2.4 Operating screen

The Operating screen explains the task of the individual symbols in the footer.

Figure 5-6

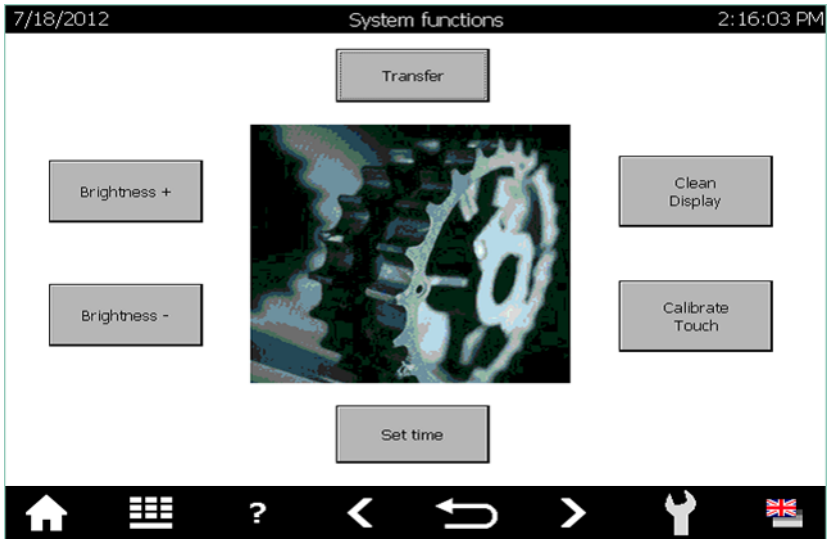


- or F1 takes you to the Home screen (Figure 5-3).
- or F2 takes you to the Overview screen (Figure 5-5).
- or F3 takes you to the Operating screen (this screen).
- or F4 takes you to the previous screen in the list:
  - unspecific application screens (Operating, System functions and Time setting) or
  - specific application screens (Overview, Mixer tap, Trend view, Tuning, Monitoring, Configuration and Simulation).
- or F5 takes you to the last screen called up.
- or F6 takes you to the next screen in the list:
  - unspecific application screens or
  - specific application screens.
- or F7 takes you to the System functions (Figure 5-7).
- or F8 enables you to toggle between German and English language.

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5.2.5 System functions

Figure 5-7



The HMI system functions enable you to:

- go to the transfer mode (where you can make settings in the control panel)
- change the screen brightness (Brightness +/-)
- temporally switch the touch panel to non-responsive, to clean it
- calibrate the touch panel
- go to Time setting.

5.2.6 Time setting

Figure 5-8



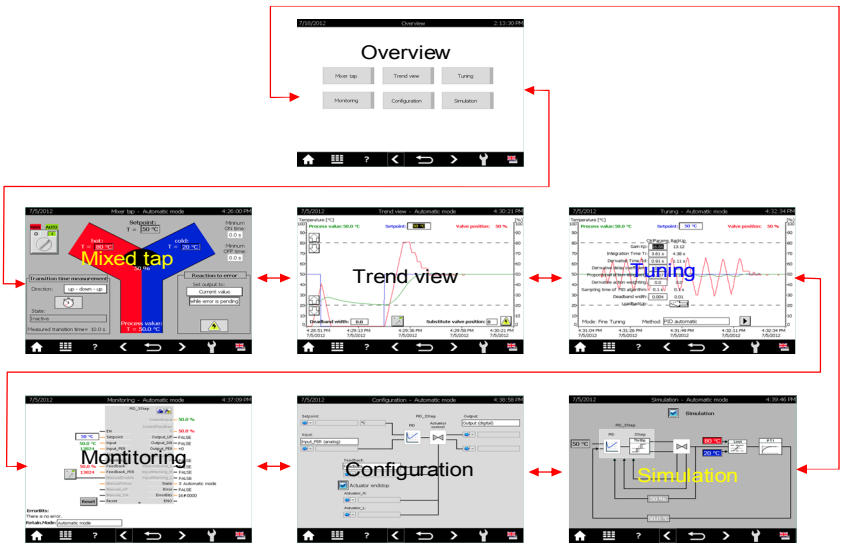
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The application includes time synchronization between CPU and HMI.

This screen enables you to set the CPU system time.
Depending on the CPU settings for time zone and daylight saving time, there is an offset between system and local time, which is synchronized via the HMI time in the header.

5.3 Overview of application-specific screens

Figure 5-9



The Overview screen (Figure 5-5) takes you to the application-specific screens via the respective button.

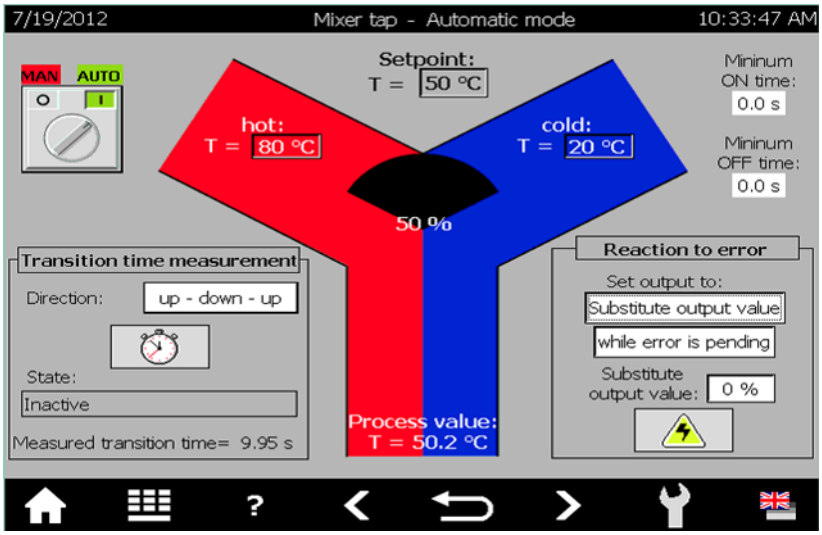
- or F4 takes you to the “Simulation”.
- or F6 takes you to the “Mixer tap”.

The sequence of the application-specific screens is shown in Figure 5-9.

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5.3.1 Mixer tap

Figure 5-10



The “Mixer tap” screen shows the mixer tap with the inflow of hot and cold water.

The vertical ratio of hot and cold water in the outflow is animated depending on the valve position.

The header of all application-specific screens also contains the operating status of the “PID_3Step” 3-point stepper controller as well as date, screen title and local time.

Manual and automatic mode



enables you to switch between manual and automatic mode.

In automatic mode, you can assign the mixer temperature setpoint via Setpoint: T = 50 °C (value range 1 to 99 °C).

In manual mode you can

- specify the valve position via Valve position : 50 % (value range 0 to 100 %) when using a valve with continuous position feedback
- change the valve position by +/-5% via  when using a valve without continuous position feedback.

Transition time

Depending on the type of the position feedback you can measure the transition time of your valve in automatic mode:

- When using the stop signals of the actuator you can choose between the direction up - down - up or down - up - down.
- When using the continuous position feedback, the application sets the target position to
  - NewOutput: 0 % at current valve position >= 50%
  - NewOutput: 100 % at current valve position <50%

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- Without position feedback (stop signals or continuous position feedback), the transition time must be specified as precisely as possible via Target transition time: 9.95 s.

With position feedback you start the transition time measurement via .

The actual status is displayed: Close valve completely

After successful measurement, the measured transition time is displayed:
Measured transition time= 9.95 s

NOTICE	**In order to start up with the measured transition time after a power failure, this value must be written to the instance data block of "PID_3Step" as a start value. The commissioning wizard offers this function (Table 4-10, Step 5).**

Actuator switching times

For adjustment to possible actuator inertia you can vary

- the Mininum ON time: (minimal switch-on time) and
- the Mininum OFF time: (minimal switch-off time).

NOTICE	**In order to start up with these settings after a power failure, this value must be written to the instance data block of "PID_3Step" as a start value. The configuration wizard offers this function (Table 4-9, Step 4) after downloading the instance data block.**

Reaction to error

Determine whether in case of an error

- the current valve position Current value or
- a substitute output value Substitute output value must be specified via Substitute output value: (value range 0 to 100 %)
  - for the duration of the error while error is pending or
  - permanently
shall be controlled.

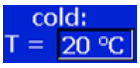
NOTICE	**In order to save this presetting through a power failure, this value must be written to the instance data block of "PID_3Step" as a start value. The configuration wizard offers this function (Table 4-9, Step 4) after downloading the instance data block.**

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Controlled system simulation

In controlled system simulation

- in automatic mode, the behavior can be simulated in the case of an error via  (switching on and off)
- the hot water temperature via 

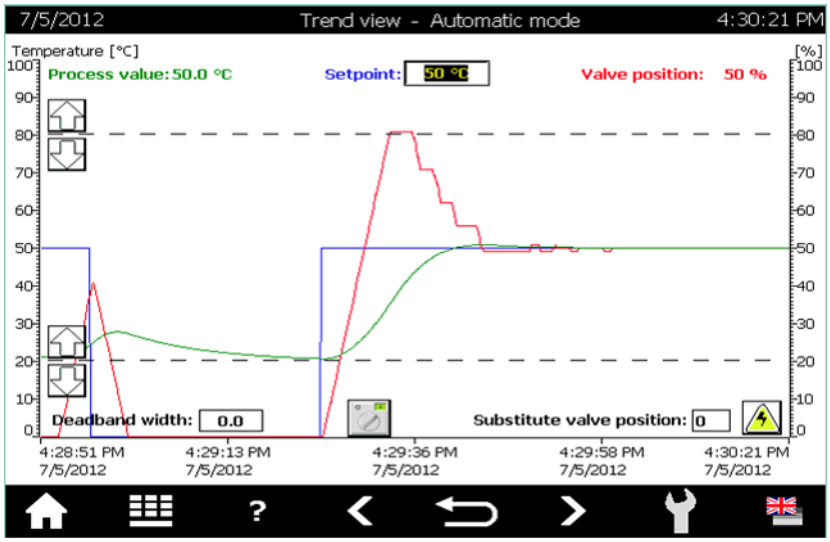
in the range between 70 to 90 °C.
- the cold water temperature via 

in the range between 10 to 30 °C.

can be varied for disturbance value control.

5.3.2 Trend view

Figure 5-11



The “Trend view” screen shows the time sequence over 90 seconds.

- the mixing temperature Setpoint (scale left)
- the actual mixing temperature value Process value (scale left)
- the valve position Valve position (scale right)

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Manual and automatic mode

 enables you to switch between manual and automatic mode.

In automatic mode, you can assign the mixer temperature setpoint via Setpoint: 49 °C (value range 1 to 99 °C).

In manual mode you can

- specify the valve position via Manual value: 48 % (value range 0 to 100 %) when using a valve with continuous position feedback
- change the valve position by +/-5% via  when using a valve without continuous position feedback.

Deadband width

The deadband suppresses the noise component in the steady controller state.

Specify the size of the deadband via Deadband width: 0.4.
The deadband is off if the deadband width is 0.0.
The smaller the deadband width you choose, the more exactly the attempt of the controller to adjust the controller to the process value. This higher precision, however, often leads to a more frequent control of the valve.

Reaction to error

If the presetting has been made, that in the case of an error the substitute output value is controlled, you can specify it via Substitute valve position: 33.

Controlled system simulation

In controlled system simulation, the behavior can be simulated in automatic mode in the case of an error via  (switching on and off)

The dashed lines represent the inflow temperatures:

- the upper one for hot water (range between 70 to 90 °C) and
- the bottom one for cold water (range between 10 to 30 °C).

In controlled system simulation mode, the respective inflow temperature can be varied

- by +10°C via  and
- by -10°C via 

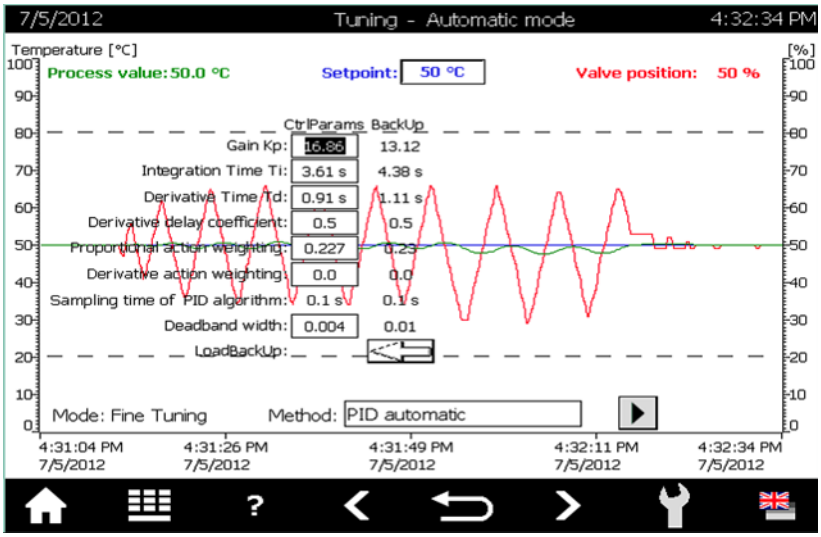
for disturbance value control.

When specifying the setpoint above the hot or below the cold water temperature, the simulated actual temperature value is limited by this.

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5.3.3 Tuning

Figure 5-12



The Tuning screen provides the following options

- for pretuning from the inactive controller state or
- fine tuning from the automatic mode.

For pretuning you can chose between the following tuning methods:

- Chien, Hrones, Reswick PID
- Chien, Hrones, Reswick PI

For fine tuning you can chose between the following tuning methods:

- PID automatic
- PID fast
- PID slow
- Ziegler-Nichols PID
- Ziegler-Nichols PI
- Ziegler-Nichols P

Pressing  starts the selected tuning method.

Note Enter a setpoint value as close to the central field of the process value range to avoid cancelling the tuning by reaching the limit.

During tuning, the setpoint is frozen, the tuning status and the percentage progress is displayed.

You can cancel the tuning via  and return to the start mode (Pretuning -> Inactive, Fine tuning -> Automatic mode).

After successful tuning, the determined controller parameters are displayed in the “CtrlParams” column and the controller parameters prior to tuning are moved to the “BackUp” column.

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The secured “BackUp“ parameter set can be loaded back into the controller with .

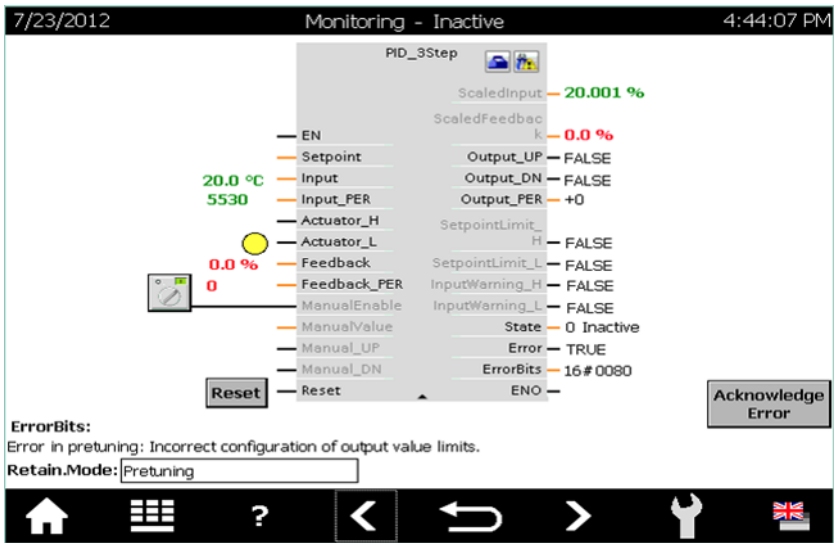
The current controller parameters (“CtrlParams”) can also be edited manually.

Note

The current controller parameter set (“CtrlParams”) is retentive and will be saved after power failure.
In order to use these parameters for starting after a cold start, they must be written as a start value into the instance DB of “PID_3Step”.
The commissioning wizard offers this function (Table 4-10, Step 10).

5.3.4 Monitoring

Figure 5-13



The Monitoring screen shows the online status of the “PID_3Step” 3-point stepper controller.

You can:

- view all inputs and outputs
- edit the following parameters:
  - setpoint in automatic mode (“Setpoint”)
  - Switching between manual and automatic mode (“ManualEnable”)
  - Manual specification of the position in manual mode for valves with position feedback (“ManualValue”)
  - Step-by-step position change in manual mode for valves without position feedback (“Manual_UP” and “Manual_DN”)
  - Resetting the 3-point stepper controller (“Reset”)

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Note In this application, the Reset button performs a restart of the “PID_3Step”, “VALVE” and “PROC_C” blocks.
The actual values of the controller are reset here.
The PID parameters, however, are retained.
Subsequently, the controller starts again in automatic mode.

The operating mode of the 3-point stepper controller can be changed via the Retain.Mode parameter. A value change at the input is important here.

Note In manual mode (activated via “ManualEnable” = “True”), the “Retain.Mode” cannot be changed, since the static state “True” at “ManualEnable” has a higher priority than a value change at “Retain.Mode”.

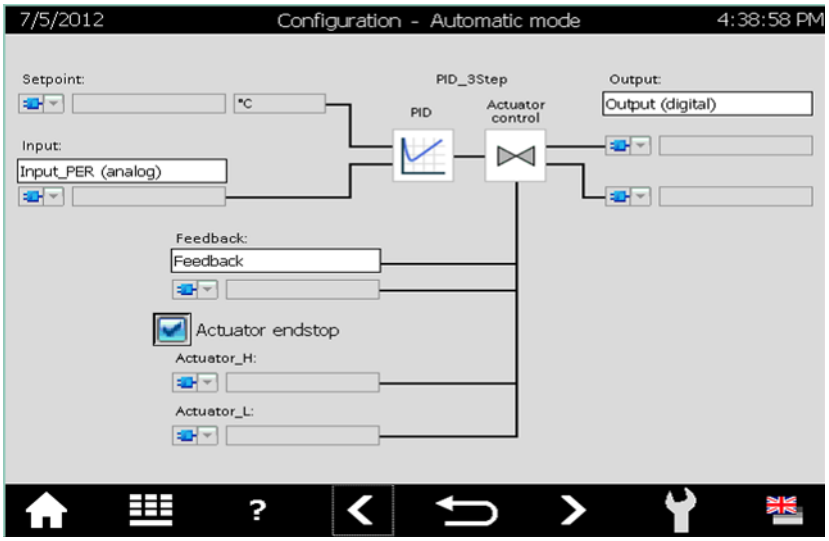
In the case of errors (“Error” = TRUE), the “ErrorBits” output gives the error code and the textual description.
The occurring error messages are also displayed globally.
However, errors leading to an inactive controller must be acknowledged via Acknowledge Error. Thus the “Retain.Mode” parameter is synchronized with the “State” controller status, and its value change deletes the error buffer.

Note The complete description of the error messages is available in the S7-1200 Manual (\1\) → Chapter 9.2.5.

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5.3.5 Configuration

Figure 5-14



The configuration screen matches the basic settings of the configuration wizard (Table 4-9, Step 2).

Here, you can change the following specifications during runtime:

- Process value input: floating-point number (“Input”) or analog (“Input_PER”)
- Position feedback of the valve:
  - No Feedback (default)
  - feedback signal via floating-point number (“Feedback”)
  - analog feedback signal (“Feedback_PER”)
- Valve provides end stop signals or not
- Control value output: via 2 direction control [“Output (digital)”] or analog (“Output_PER”)

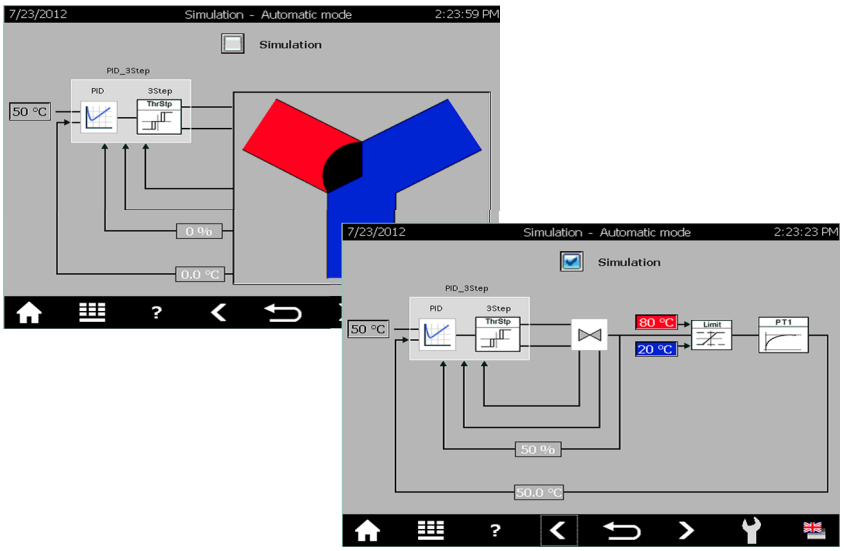
This screen offers the getting to know the settings of the 3-point stepper controller and its characteristics (especially for the simulation mode).

NOTICE	**In order to save this configuration through a power failure, these values must be written to the instance data block of “PID_3Step” as a start value. The configuration wizard offers this function (Table 4-9, Step 2) after downloading the instance data block.**

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5.3.6 Simulation

Figure 5-15

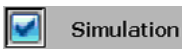


The Simulation screen enables switching between a real and a simulated control system.

The block diagram of the “PID_3Step” 3-point stepper controller is displayed with:

- the setpoint specification
- the process value
- the valve feedback:
  - position feedback
  - end stop signal “closed”
  - end stop signal “open”
- the digital valve control signals
  - open
  - close.

If the simulation is not switched on, the controller receives the signals from the PLC periphery (Table 4-8, Step 4).

When the simulation 

is switched on, the screen shows the block diagram structure as the input signals for the controller are calculated:

The digital valve control signals feed a valve simulation , which supplies the valve feedback.

The percentage value of the valve position feedback is limited 

by the hot 

and cold 

water temperature and supplies the setpoint temperature value for the controlled system.

The output of the controlled system simulation block PT1 

supplies the actual temperature value.

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6 Internet Link Specifications

This list is not complete and only represents a selection of relevant information.

Table 6-1

	Subject	Title
\1\	S7-1200 Programmable Controller System Manual	http://support.automation.siemens.com/WW/view/en/36932465
\2\	CPU Firmware 2.2	http://support.automation.siemens.com/WW/view/en/41886031/133100
\3\	**H**ardware **S**upport **P**ackage (**HSP)** 0026	http://support.automation.siemens.com/WW/view/en/54164095
\4\	STEP 7 Basic V11.0 SP2 System Manual	http://support.automation.siemens.com/WW/view/en/57199536
\5\	Service Pack 2 for STEP 7 V 11	http://support.automation.siemens.com/WW/view/en/56750498
\6\	Update 4 for STEP 7 V 11 SP2	http://support.automation.siemens.com/WW/view/en/58112582
\7\	SIMATIC S7-1200 Easy Book	http://support.automation.siemens.com/WW/view/en/39710145

7 History

Table 7-1

Version	Date	Modifications
V1.0	08/2012	First version
V1.1	05/2013	Modification of FB100 “PROC_C” to be compatible with STEP 7 V12 (no changes in the documentation)

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