Application about Control Technology

applications & TOOLS

Temperature Recording in the S7-CPU by Means of Pt100 Resistivity Thermometer and SITRANS TK-L Measuring Transducer

Application Description

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Foreword

Objective of the application

This application was created to provide the user with the following:

- A modifiable and expandable example of an industrial temperature measurement and
- the illustration of a convenient option of operating and visualizing a control using a touch panel.

This application shows how using a SIMATIC controller, a PT100 resistivity thermometer and a SITRANS TK-L measuring transducer the temperature of a medium is determined and actions are performed depending on defined temperature levels.

- This topic is particularly relevant in the chemical industry as well as the beverage industry.

Main contents of this application

The following main points are discussed in this application:

- Layout, functionality and application of resistivity thermometers,
- STEP7 program for temperature measurement in a production process
- Connecting a touch panel for process control and plant monitoring using WinCC flexible.

Delimitation

This application does not include a description of

- the SIMATIC STEP 7 engineering tool,
- the WinCC flexible visualization software.

Basic knowledge of these topics is required.

Structure of the document

The documentation of this application is divided into the following main parts.

Part	Description
Application Description	Provides a general overview of the contents. You will learn about the components used (standard hardware and software components and the specially created software).
Function Principles and Program Structures	This part describes the detailed function processes of the involved hardware and software components, the solution structures and – where useful – the specific implementation of this application. This part is necessary if you want to learn about the interaction of the solution components, for example in order to use them as the basis for own development.
Structure, Configuration and Operation of the Application	This part leads you step by step through the structure, important configuration steps, commissioning and operation of the application.
Appendix	In this chapter you will find further information on e.g. literature, glossary etc.

Reference to Automation and Drives Service & Support

This entry originates from the internet application portal of the A&D Service and Support. It has the entry ID **23541638**. The direct link to the download page of this entry is available in /2/.

Table of Contents

Application Description

Content

You are provided with a general overview of the contents. You will learn about the components used (standard hardware and software components and the specially created software).

The displayed performance data illustrate the performance capability of this application.

1 Automation Task

Here you find information on …

the automation task discussed in the documentation on hand.

1.1 Overview

Introduction

During mixing processes it is necessary to acquire the temperature of a lye, a bath an ingredient or the basic liquid for the purpose of…

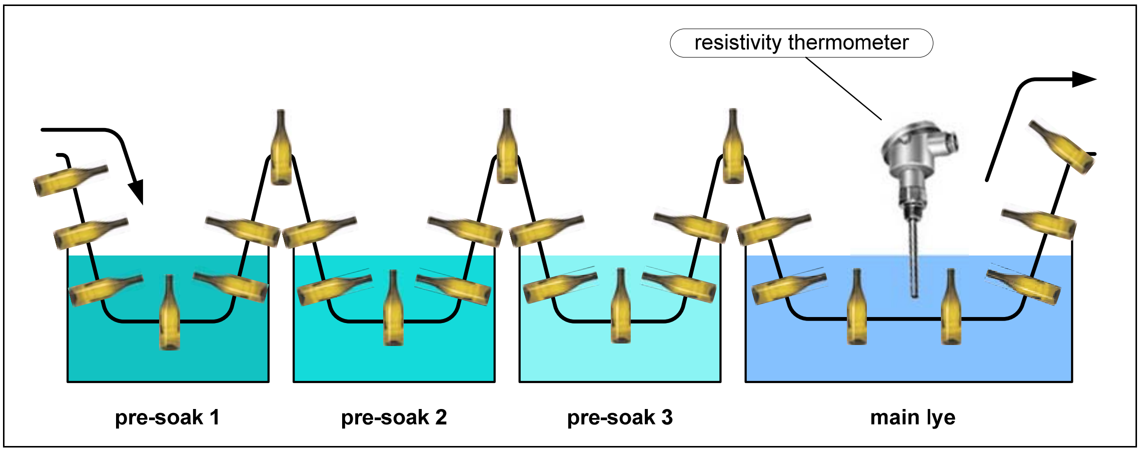
- Ensuring an ideal and constant working temperature within a process step,
- detecting the permissible minimum / maximum temperature of a medium,
- determining temperatures for visualizing them or for triggering various actions in the production process

in a reliable way with suitable means that meet the respective process requirements. On a PLC these measuring data are used to control the technical process or for monitoring purposes. An HMI (human machine interface, e.g. a touch panel) enables visual monitoring of temperature values and defining new rated or limit temperature values.

Overview of the automation task

The below figure shows an example of a possible field of application for this application.

Figure 1-1: Bottle cleaning in the beverage industry



Description of the automation task

The temperature of the main lye is to be measured with the resistivity thermometer. Automatic actions are to be started depending on certain temperatures of the main lye. These actions are to …

- inform personnel when the temperature of the main lye is 5°C below a set point value.
- reduce the velocity of the bottle transportation if the temperature of the main lye is 6 °C below a set point value.
- stop the process completely if the temperature of the main lye is 8 C below a set point value.

The above actions are represented in the application by the setting of digital outputs and in software terms by jumping to program parts where a respective user defined action can be programmed.

Temperature recording

A low pressure screw-in resistivity thermometer with PT 100 measuring resistance is used as temperature sensor. The resistivity thermometer is connected to an analogue input of the controller via a measuring transducer, which supplies a current of 4mA...20mA that is proportional to the temperature.

To meet your requirements, the resistivity thermometer is amongst others available in the following versions.

- With one or two measuring resistances,
- in different lengths,
- with or without neck tube,
- with or without explosion protection,
- with or without integration option for the measuring transducer.

See chapter 2.4 for performance data of the thermometer and the measuring transducer.

1.2 Requirements

This application is realized in a STEP7 project. It is to meet the requirements listed below:

Sensor requirements

- The temperature of a liquid shall be acquired with a thermometer.
- The encoder is to be designed as screw-in PT100 resistivity thermometer (in accordance with DIN 43765) with measuring transducer.
- The encoder shall be capable to detect a temperature range of 10…100°C and to image it onto an analogue signal of 4…20mA by means of the measuring transducer.
- The thermometer has a protective tube of stainless steel.

Controller requirements

- The controller shall calculate the temperature of the liquid in degrees Celsius using the signal from the measuring transducer.
- The controller shall divide the permissible, user defined overall temperature range into seven sections which each have one digital output (Q 4.0…Q 4.6) assigned to. The DO with the temperature section of the current temperature value is controlled. It should be easy for the user to change the temperature section.
- Underrun or overrun of the lower or upper temperature limit of the overall temperature range should be indicated by a blinking digital output (e.g. for connecting a signal lamp). The blinking should require acknowledgement.
- The respectively last limit temperature violation is to be logged by the time stamp of the CPU. If there has been no temperature violation since the start of the CPU, the time stamp of the startup shall be logged.

HMI requirements

- The HMI is to be realized by a touch panel (screen diagonal 6 inches).
- The following information is to be displayed:
  - Current temperature of the liquid (bar-type display and value),
  - violation of the temperature limits (minimum and maximum temperature, display by blinking marks),
  - date and time of the last limit temperature violation,
  - current temperature with regard to the user defined temperature sections (graphically by marks).

- The following operations are to be possible:
  - Input/modification of the temperature section limits,
  - acknowledging of the limit temperature violations
  - switching of the language English↔German
  - terminating the runtime

Note The above-mentioned requirements are met by the application software without need for additional programming overhead or entering parameters in data blocks.

2 Automation Solution

Here you find information on …

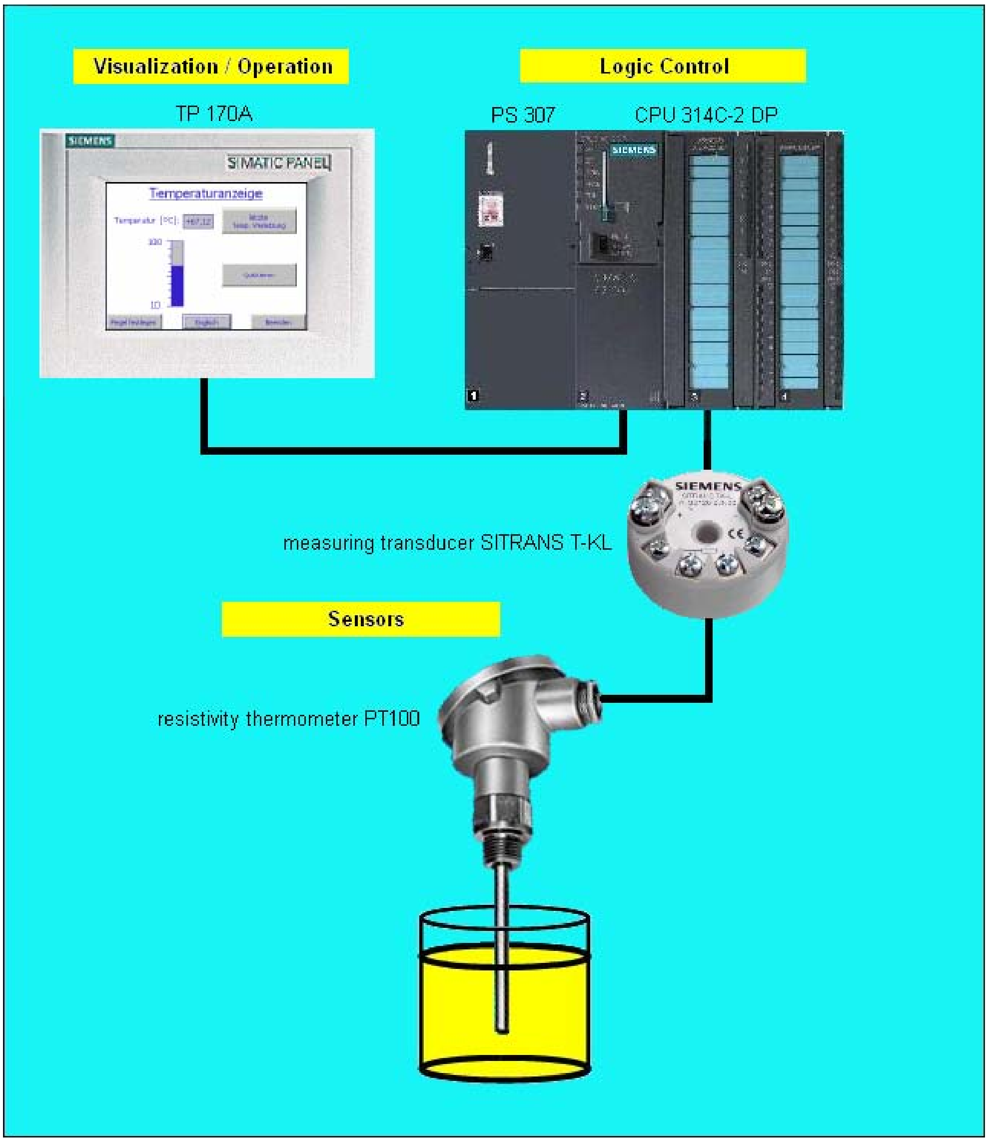
the solution selected for the automation task.

2.1 Overview of the overall solution

Display

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

Figure 2-1: Hardware overview of the automation solution



Structure

A SIMATIC CPU 314C-2 DP is the key element of the application. This central processing unit already includes the digital and analog inputs and outputs required by the application. The switching output of the measuring transducer is directly connected to the analog input integrated in the central processing unit. The TP170A touch panel is connected to the MPI of the controller via a PROFIBUS cable. All components of the application are supplied with 24V DC by the power supply PS 307.

2.2 Description of the core functionality

2.2.1 Overview and description of the user interface

A TP 170A touch panel is used as HMI. The display/HMI is realized as three screens:

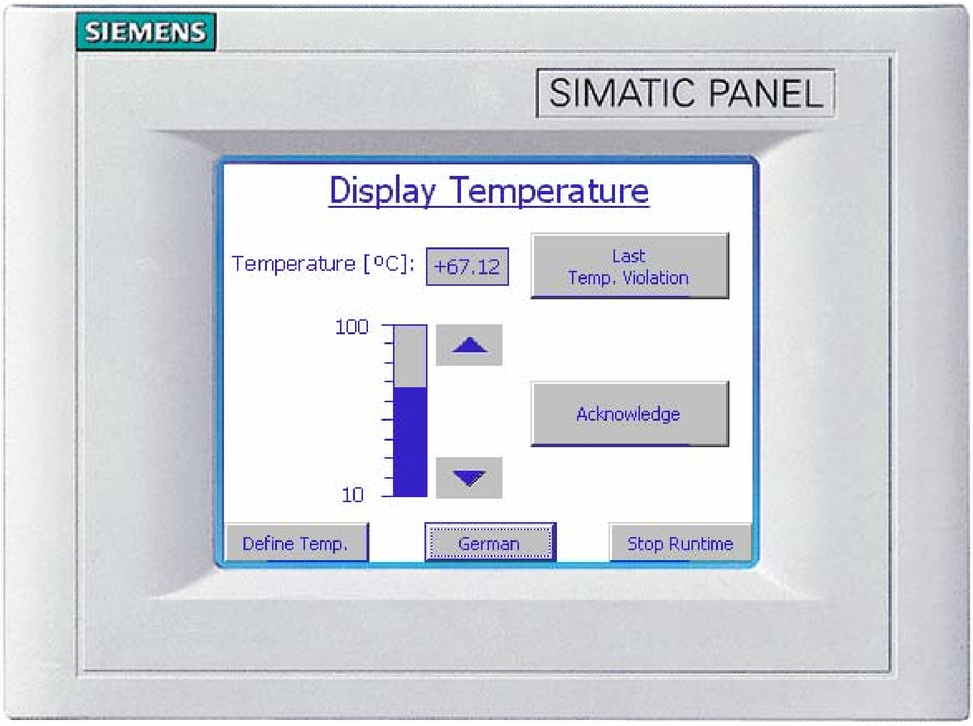
- Display Temperature (start picture)
- Define Temperatures
- Temperature Violations

The release of the temperature recording and the acknowledgement of a limit temperature violation are realized via digital inputs.

The user-defined area with the current temperature, as well as temperature limit violations, are additionally signaled to the touch panel display by digital output bits.

TP 170A – "Display Temperature" screen (start picture)

Figure 2-2: Display Temperature (start picture)



Provided that the touch panel has already been loaded with the HMI software created in WinCC flexible, the above start screen – which is to be considered the main screen – is displayed when applying the supply voltage. The screen contains the following elements:

1. Display of temperature
   It is displayed as a °C value as well as a bar diagram (range 10…100°C). The calculation and display of the current temperature is only performed if it has been enabled via input I 0.0. At I 0.0 = 0 the last recorded temperature value is displayed. Outside the range (temperature <10°C, >100°C), parameterized at the measuring transducer, the respective extreme values 10°C or 100°C will be displayed.

2. Display and acknowledgement of limit temperature violations
   A limit temperature violation occurs if the following limit values specified in DB10 are violated:

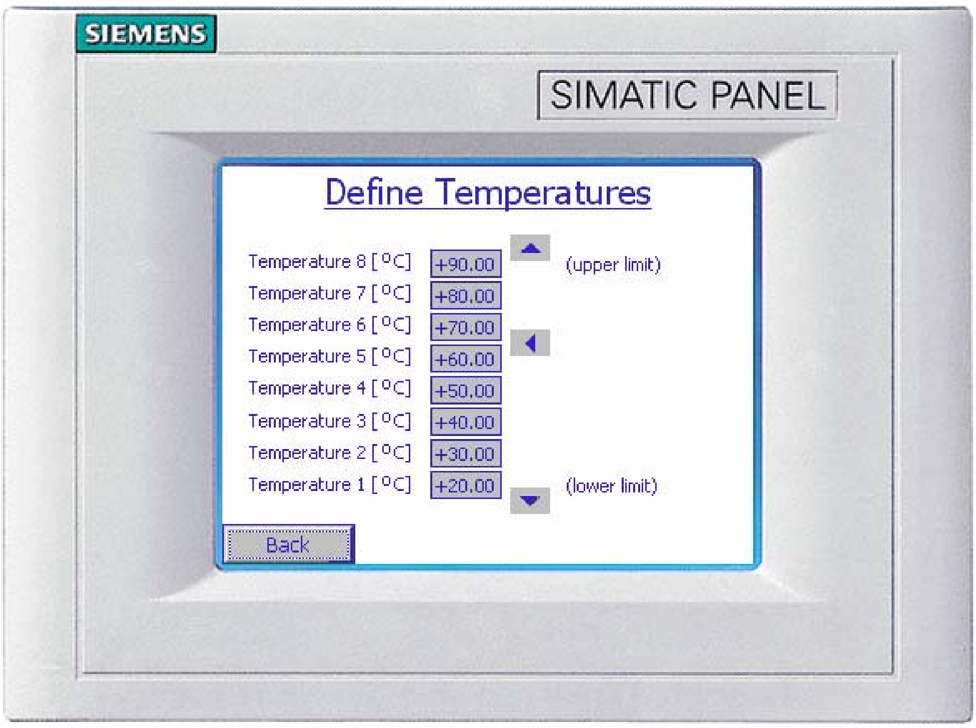
   - Temperature too low
     T_comp [1] (default value 20°C)
   - Temperature too high
     T_comp [8] (default value 90°C)

   A temperature too low or too high is indicated by two blinking marks on the right side of the bar diagram (). If the temperature is outside the permitted limits, the blinking marks are invisible. A limit temperature violation requires acknowledgement. The respective blinking mark only disappears if the temperature is within the permitted range and the alarm has been reset with the "*Acknowledge*" button. Limit values can be changed in the *"Define Temperatures"* screen.

3. "*Last Temp. Violation*" button
   This button takes you to the *"Temperature Violations"* screen. This screen displays the time stamp of the last insufficient or excess temperature.
4. "Define Temp" button
   This button takes you to the *"Define Temperatures"* screen. There you can specify eight temperatures for process control or display purposes.
5. Switching of the user interface language
   With this button you can switch between the languages English and German. By default, the setting is on English and the button is labeled "*German*". In case of German user interface language, the button is labeled "*English*".
6. Stopping Runtime
   The button "*Stop Runtime*" terminates the Runtime in order to reload the touch panel, for example.

TP 170A – "Define Temperatures" screen

Figure 2-3: Define Temperatures



The *“Define Temp.”* button in the *“Display Temperature”* screen takes you to the *“Define Temperatures”* screen. Here you specify the discrete filling levels which you can use for process control or display purposes.

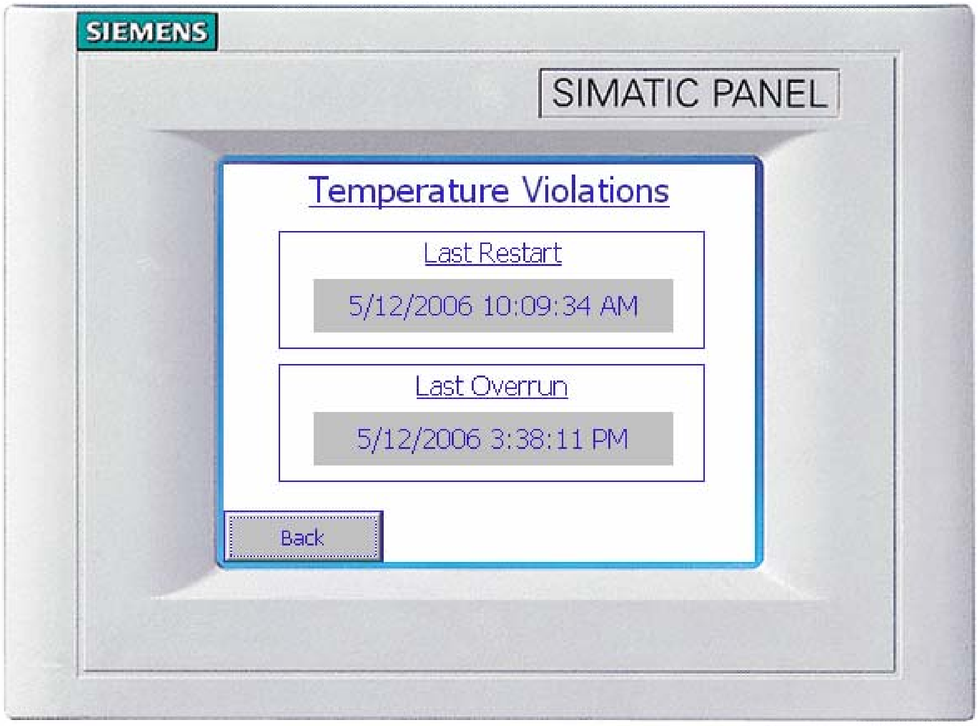
1. Entering the temperature values
   If you are using the example project, the values from TP 170A – “Define Temperatures” screen
2. are already entered as reference temperature values. When selecting (touching) the respective gray-shaded I/O box, a numerical keyboard is displayed on the screen with which you can enter the desired value and apply it using the Enter key. All temperatures have to be within the measuring range, which has been specified by means of the configuration software SIPROM TK of the measuring transducer (in the application example 10…100°C). The input value is rounded to two decimals. “*Temperature”* corresponds to the lowest, “*Temperature 8”* to the highest definable temperatures. For the input, the following must apply:Temperature n < temperature n+1 (n=1…7)

   The falling below Temperature 1 (insufficient temperature) or the exceeding of Temperature 8 (excess temperature) releases the limit temperature violation which must be acknowledged.
3. Display of the current temperature range
   The area between defined, neighboring comparison temperatures, in which the current temperature value is located, is displayed by a mark ( ) on the right next to the input fields for the temperature.
4. Display of temperature violations
   Temperature violations requiring acknowledgement in this screen are, analog to the “*Display Temperatur”* screen, also displayed as blinking marks ( ).

Use the “*Back*” button located at the bottom of the display to return to the “*Display Temperature*” screen.

TP 170A – "Temperature Violations" screen

Figure 2-4: Temperature Violations



The *"Last Temp.Violation"* button in the *"Display Temperature"* screen takes you to the *"Temperature Violations"* screen.

1. Display in the upper frame
   - If since the last restart of the CPU no insufficient temperature has taken place, then the time stamp of the last restart is displayed.
   - If since the last restart of the CPU at least one insufficient temperature has been detected, the time stamp of the last falling below the minimum temperature is displayed.
2. Display in the bottom frame
   - If since the last restart of the CPU no excess temperature has taken place, then the time stamp of the last restart is displayed.
   - If since the last restart of the CPU at least one excess temperature has been detected, the time stamp of the last exceeding of the maximum temperature is displayed.

Use the "*Back*" button located at the bottom of the display to return to the "*Display Temperature*" screen.

Digital input bits

Table 2-1

Input	Meaning	Note
I 0.0	Release of the temperature recording (released = 1)	
I 0.1	Acknowledging of a limit temperature violation (Acknowledging = edge 0→1)	Identical with the *"Acknowledge"* button in the *"Display Temperature"* screen

Digital output bit

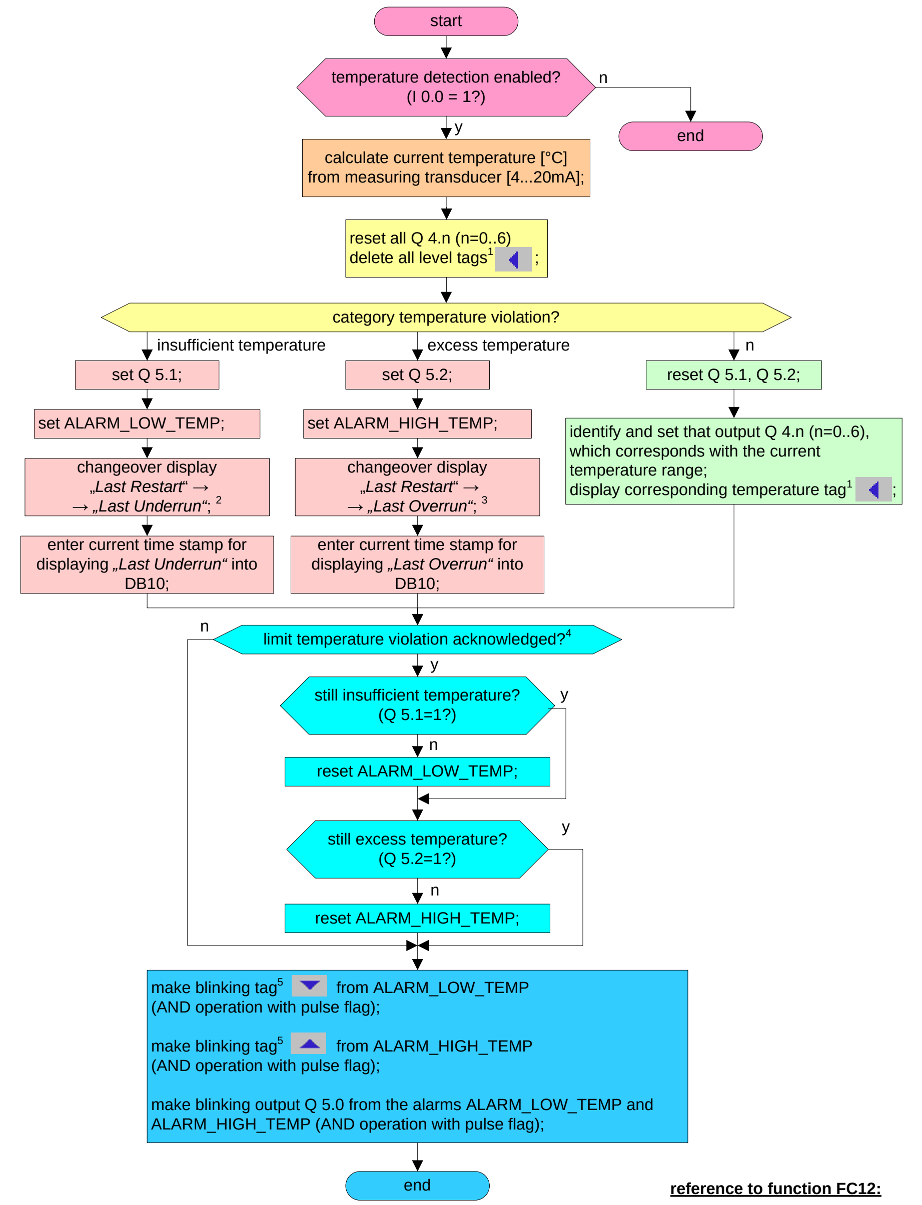
Table 2-2

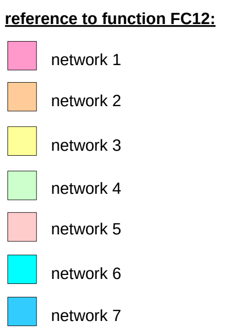
Output	Meaning	Note
Q 4.0	Temperature measuring value between temperature 1 and 2	These output bits correspond to the position of the display mark ( ) in the *"Define Temperatures"* screen at the touch panel.
Q 4.1	Temperature measuring value between temperature 2 and 3	
Q 4.2	Temperature measuring value between temperature 3 and 4	
Q 4.3	Temperature measuring value between temperature 4 and 5	
Q 4.4	Temperature measuring value between temperature 5 and 6	
Q 4.5	Temperature measuring value between temperature 6 and 7	
Q 4.6	Temperature measuring value between temperature 7 and 8	
Q 5.0	There is an insufficient or excess temperature. The output is blinking. Resetting the output occurs by acknowledgment of the limit temperature violation.	The function is identical with the blinking marks ( ) in the *"Display Temperature"* and *"Define Temperatures"* screens at the touch panel.
Q 5.1	There is an insufficient temperature: The measuring value is below temperature 1	
Q 5.2	There is an excess temperature: The measuring value is above temperature 8	

2.2.2 Process sequence of the main functionality

The following flowchart illustrates main functionality "Temperature Recording". The process is realized in function FC12.

Figure 2-5: Flowchart of the core functionality





[1] temperature tags in touchpanel picture „*Temperature Violations*“

[2] changeover text from „*Last Restart*“ *to* „*Last Underrun*“ in touchpanel picture „*Temperature Violations*“

[3] changeover text from „*Last Restart*“ to „*Last Overrun*“ in touchpanel picture „*Temperature Violations*“

[4] acknowledgement by means of button „*Acknowledge*“ in touchpanel picture „*Display Temperature*“ or via pulse at I 0.1

[5] blinking tags to display a category temperature violation in touchpanel pictures „*Display Temperature*“ and „*Temperature Violations*“

2.3 Required hardware and software components

The application was developed and tested with the following components. Please consider that configuration changes in the sample project are possibly required in case of deviations from the listed components and that screen shots in this document can differ from your screen contents.

To realize the sample project, you additionally require:

- PG or PC with corresponding communications processor (e.g. CP5512) and Microsoft ® Windows 2000 Professional or Windows XP Professional operating system.
- An MPI cable.

Hardware components

Table 2-3: Hardware components

Component	No.	MLFB / Order number	Note
SIMATIC S7-300, RAIL L=480MM	1	6ES7390-1AE80-0AA0	This is the shortest available rail.
SIMATIC S7-300,LOAD POWER SUPP. PS 307, 120/230 V AC, 24 V DC, 2A	1	6ES7307-1BA00-0AA0	Or similar
SIMATIC S7-300, CPU 314C-2 DP COMPAKT	1	6ES7314-6CF02-0AB0	The compact version was only used because of the integrated DO/DI.
SIMATIC S7, MICRO MEMORY CARD F. S7-300/C7/ET 200S IM151 CPU, 3.3 V NFLASH, 64 KBYTES	1	6ES7953-8LF11-0AA0	Or larger
SIMATIC S7-300, FRONT CONNECTOR 392 WITH SCREW CONTACTS, 40-PIN	2	6ES7392-1AM00-0AA0	Also available with spring force terminals
SIMATIC TOUCH PANEL TP170A BLUE MODE STN-DISPLAY MPI/PROFIBUS-DP INTERFACE	1	6AV6545-0BA15-2AX0	Configurable with ProTool/Lite from version V5.2, SP1 and WinCC flexible Compact from version 2004

Component	No.	MLFB / Order number	Note
SIMATIC NET, CONN. CABLE 830-2 F. PROFIBUS, PREASSEMBLED CABLE WITH 2 SUB-D-CONNECTORS 9-POLE, SWITCHABLE TERMINATING RESISTORS, 3 M	1	6XV1830-2AH30	2-wire shielded cable with PROFIBUS connectors for connecting the TP 170A to the CPU. For alternatives see /6/.
LOW-PRESSURE SCREW-IN RESISTANCE THERMOMETER W/O NECK TUBE,G1/2, MOUNT. LENGTH 230 MM PROTECTIVE TUBE MAT. NO. 1.4571 1 PT100 MEAS. RESISTOR IN CERAMIC	1	7MC1006-3DA16	Or equivalent component Specified type has high tilting lid for picking up the measuring transducer;
HEADMOUNTED TEMPERATURE TRANSMITTER SITRANS TK-L FOR PT100; LOOP POWERED 4-20 MA; PROGRAMMABLE; WITHOUT GALVANIC ISOLATION; WITHOUT EXPLOSION PROTECTION	1	7NG3120-0JN00	For installation into sensor head (Type B) of resistivity thermometer;
MODEM FOR SITRANS TK	1	7NG3190-6KB	For operation and parameterizing of the measuring transducer

Note The resistivity thermometer with integrated measuring transducer is available under the order number *7MC1006-3DA16-ZK00*.

Standard software components

Table 2-4: Standard software components

Component	No.	MLFB / Order number	Note
SIMATIC S7, STEP7 V5.4, FLOATING LICENSE FOR 1 USER, E-SW, SW AND DOCU. ON CD, LICENSE KEY ON FD, CLASS A, 5 LANGUAGES (G,E,F,I,S), EXECUTABLE UNDER WIN2000PROF/XPPROF, REFERENCE-HW: S7-300/400, C7	1	6ES7810-4CC08-0YA5	For order information, system requirements and compatibility of STEP7 V5.4 see /7/. The application runs also under STEP7, V5.3.

Component	No.	MLFB / Order number	Note
WINCC FLEXIBLE 2005 COMPACT ENGINEERING-SW,FLOATING LICENSE LICENSE KEY ON FD SW AND DOCUMENTATION ON CD IN GER/EN/IT/FR/SP, EXEC. UNDER WIN2000/XPPROF FOR CONFIGURATION OF SIMATIC PANELS UPTO SERIES 170	1	6AV6611-0AA01-1CA5	TP170A requires at least WinCC flexible **Compact**.
SOFTWARE SIPROM TK FOR SITRANS TK	1	7NG3190-8KB	Software for measuring transducer configuration

Example files and projects

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

Table 2-5: Example files and projects

Component	Note
23541638_Temperaturmessung_V20.zip	This zip file contains the STEP 7 project

Note

Visualization by means of a touch panel is an integrated part of the STEP7 project. The “temperature measurement” functionality is also met without visualization.

2.4 Performance data

Resistivity thermometer

Table 2-6: Data of the PT100-resistivity thermometer 7MC1006-3DA1x

Criterion	Data / Comment
Design	According to DIN 43765: Screw-in thermometer
Protective tube	yes
Form	Similar to 2G, DIN 43772; cylindrical, 9 mm (0.35 inch) diameter, wall thickness 1 mm (0.04 inch)
Loading capacity	to 20 bar (290.1 psi) (loading capacity dependent on material, temperature, flow rate, mounting length etc., see DIN 43772 for details
Screw socket	G½; suitable is gasket 21 x 26, similar to form C or D, DIN 7603
Measuring insert	Replaceable, with measuring insert tube (6 mm diameter (0.24 inch) made of stainless steel; terminal block with clamping springs
Response times (to VDI/VDE 3 522) • In water with flow velocity v = 0.4 m/s (1.31 ft/s) • In air with flow velocity v = 1 m/s (99.97 cm/s)	 $t_{0,5}$ = 25 s, $t_{0,9}$ = 75 s t 0.5 = 2 min; t 0.9 = 6.3 s
Explosion protection	II 1/2G EEx ia IIC T4/T6

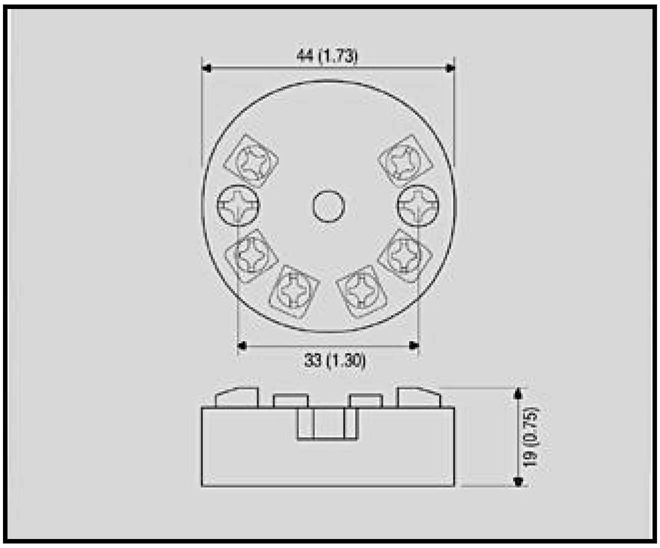
Measuring transducer

Table 2-7: Data of the SITRANS TK-L measuring transducer 7NG3120-0JN00

Criterion		Data / Comment
Input	Measured variable	Temperature
	Sensor type	Pt 100 (DIN IEC 751)
	Voltage measurement	Temperature-linear
	Type of connection	Two, three or four-wire system
	Resolution	14 bit
	Measuring accuracy • Span < 250 °C (450°F) • Span > 250 °C (450°F)	 < 0.25°C (0,45°F) < 0.1% of span
	Repeatability	< 0.1°C (0.18°C)
	Measuring current	0.3 mA
	Measuring cycle	0.7 s

Criterion		Data / Comment
	Measured range	-200 ... 850°C (-328 ... +1562°F)
	Measured span	> 25 °C (45 °F)
	Unit	°C or °F
	Offset	Programmable, max. 10°C (18°F)
	Line resistance	max. 20 Ω/line
	Overload capability	35 V DC
	Noise rejection	50 and 60 Hz
Output	Output signal	4 ... 20 mA, 2-wire
	Power supply	DC 8 ... 35 V (28 V with Ex)
	Underrange/overrange limits	3,5/23 mA (programmable)
	Filter time	0…30 s
	Protection	Against reversed polarity
	Resolution	12 bit
	Accuracy • Power supply effect • Temperature drift	< 0.1% of span < 0.01% of span/V typ. 0,003%/°C (0,0016%/°F) max. 0,01%/°C (0,0056%/°F)
Rated conditions	Ambient temperature	-40 ... +85 °C (-40 ... +85.00 °C)
	Relative humidity	< 98%, with condensation
	Electromagnetic compatibility • Interference immunity • Emitted interference	 According to EN 50082-2 According to EN 50081-1
Design	Weight	50 g (0.11 lb)
	Dimensions	see Figure 2-6: Dimensions of the SITRANS TK-L measuring transducer 7NG3120-0JN00
	Material	Molded plastic
	Degree of protection • Housing • Terminals	 IP40 IP00

Figure 2-6: Dimensions of the SITRANS TK-L measuring transducer 7NG3120-0JN00



Application software

Table 2-8: Performance data of the application software

Criterion	Performance data	Additional note
Program size	Project: 15.9 MB Project (.zip) 2.96 MB MMC: 2636 bytes RAM: 1318 bytes	
Maximum cycle time	4 ms	For CPU according to Table 2-3
Temperature range	10…100°C	
Delay of ready status after restart	10 s	
Resolution of temperature display at the touch panel	2 decimals	Unit: °C
Number of HMI screens	3	

Function Principles and Program Structures

Content

This part describes the detailed functions and functional sequences of the involved hardware and software components, the solution structures and – where useful – the specific implementation of this application.

It is only required to read this part if you are interested in details on the solution components and their interaction.

3 General Function Mechanisms

Here you find information on …

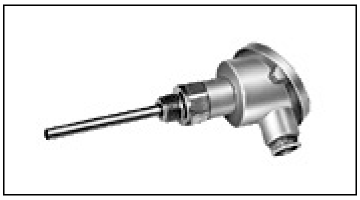
the general function mechanisms which apply with regard to temperature recordings.

3.1 Possibilities of temperature recordings

Resistivity thermometers or **thermocouples** are often used for reading a temperature. These two measuring principles will be described in the following.

Resistivity thermometer

Figure 3-1: Low-pressure screw-in resistance thermometer



A resistivity thermometer consists of

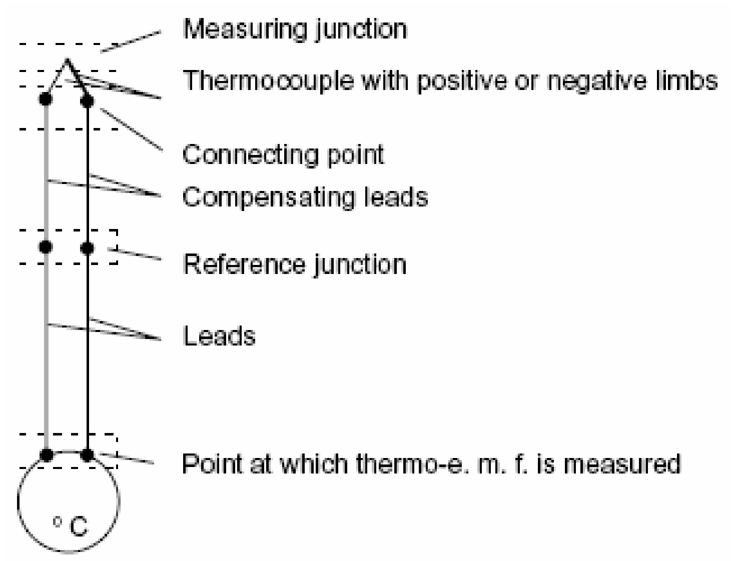
- a measuring resistance,
- the respectively necessary installation and connection locations.

The measuring resistance changes almost proportionally to the temperature. Therefore the measured voltage drop is also proportional to the temperature, when supplied with constant power. The measuring signal is transmitted through copper cables - according to measuring principle 2-, 3-, or 4-wire measuring – as analog signal either directly or via a measuring transducer to the following processing electronics.

The measuring resistance is made of platinum (**Pt**) or nickel (Ni) and adjusted to **100** Ω ± 0.12 Ω at 0°C (therefore the designation Pt100). The dependency of the resistor from temperature as well as the permitted deviations are standardized (specified in DIN EN 60 751 (IEC 751)).

Thermocouple

Figure 3-2: Design of a thermocouple in principle



A thermocouple consists of the thermocouple (measuring sensors) and the respectively necessary installation and connection parts. The thermocouple is composed of two wires, which are of different metals or metal alloys and which ends are soldered or welded together.

Because of the different material combinations there are different types of thermocouples, e.g. K, J, N (for example K stands for the transition between a nickel-chrome alloy and nickel). Irrespective of the type of the thermocouple, the measuring principle is the same for all types.

A thermocouple always records a temperature difference, thus for determining the temperature of the measuring location, the free ends at a comparison location must always be kept at an equal and known temperature.

The thermocouples can be extended from their connection point to the comparison point by means of equalizing wires. The equalizing wires are made of the same material as the wires of the thermocouple. The feed lines are made of copper.

The influence of temperature fluctuations at the comparison point can be compensated by means of an equalizing circuit.

Property comparison

Table 3-1: Resistivity thermometer and thermocouple in comparison

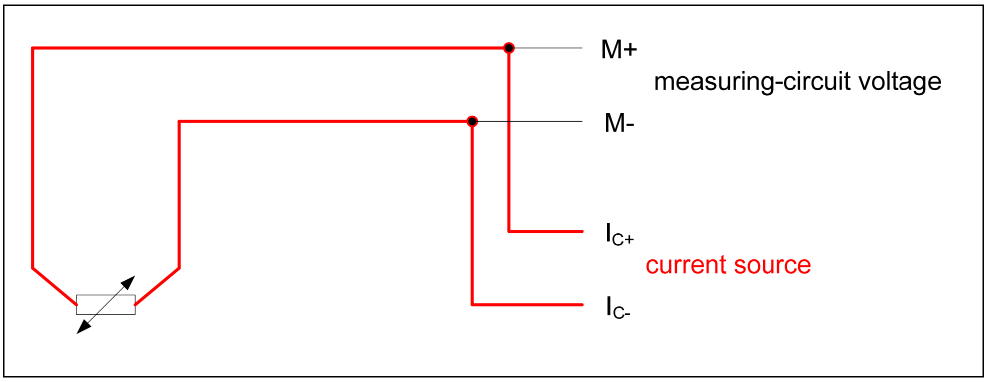
	Resistivity thermometer	Thermocouple	Note
Sensitivity	☺	☹	
Accuracy	☺	☹	
Long time stability	☺	☹	
Trigger time at temperature changes	☹	☺	
Suitability for high temperatures	☹	☺	Resist.therm. < approx. 700°C Thermocouple > approx. 1800°C

3.2 2-, 3- and 4-line connection at resistivity thermometers

The device (controller, measuring transducer, AL module, electronics...) processing the temperature signal, usually offers three possibilities to connect the resistivity thermometer.

2-line connection

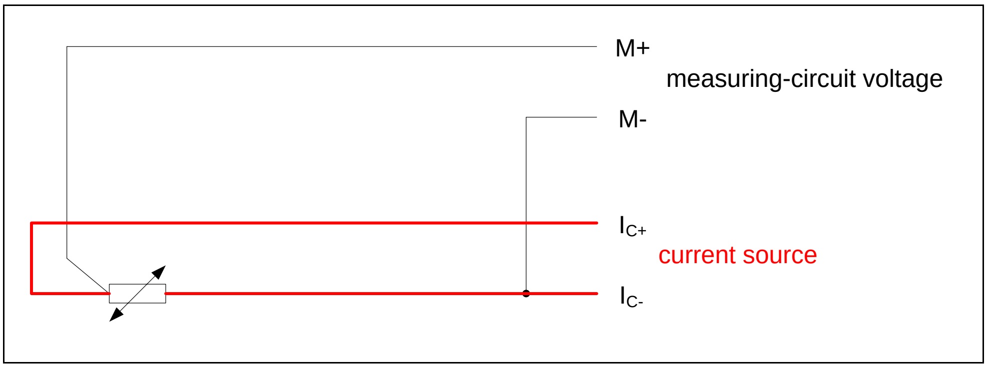
Figure 3-3: 2-line connection of a resistivity thermometer



For the measuring signal and the load independent current the same forth and back lines are used. So the line losses are displayed in the measuring result.

3-line connection

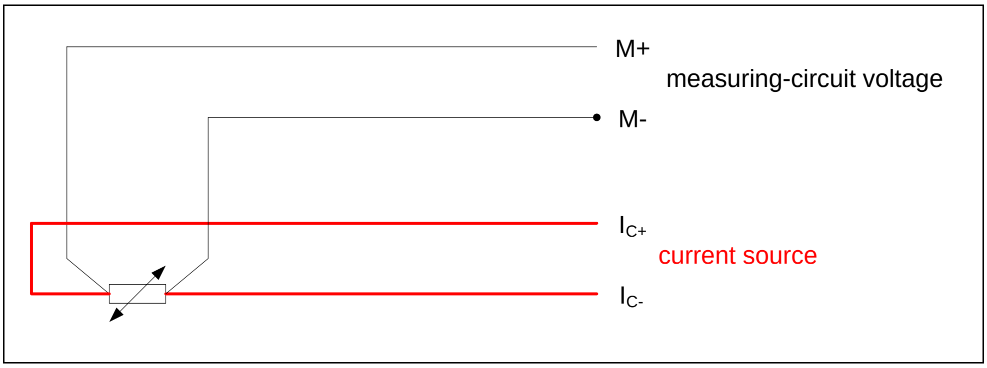
Figure 3-4: 3-line connection of a resistivity thermometer



One of the feed lines to the resistivity thermometer is used for both the measuring signal and the load independent current. So the line losses of this one feed line are displayed in the measuring result.

4-line connection

Figure 3-5: 4-line connection of a resistivity thermometer



Two separate line pairs are used for the load independent current and the measuring voltage. So there are hardly any line losses in the almost currentless measuring lines.

3.3 Connection to the controller

Direct connection

In the S7-300/400 module spectrum there are analog input modules which operate the measuring types “resistivity thermometer/resistance” and Temperature“ directly. In the respective handbooks /8/ and /9/ you can find everything on connection types like 2-, 3- and 4-line connection, on measuring principles and temperature compensation at thermocouples.

Connection via measuring transducer

Because long feed lines to the measuring sensors are object to loss and interferences, the direct connection of a temperature sensor to an analog input module (even with 3 or 4 line connection) is only sensible if the sensor can be positioned close to the input module. In case of bigger distances between sensor and analog module a **measuring transducer** should be used, which is positioned as close as possible to the temperature sensor and whose current output (4…20mA) transmits the measuring signal without interferences to the controller, also over long distances. Furthermore it is possible -regarding to the S7-300 module spectrum- to use an AL of the CPU314C-2 DP - as in the given application example- instead of a separate AL module.

Measuring transducers are available for resistivity thermometers as well as thermocouples. There are mechanical versions for sensor head installation, rail mounting and installed into a field housing, for rough industrial use on the market.

Measuring transducers are usually configured with a configuration software (see table 2-4).

Note

Find an overview on the SITRANS T temperature measuring devices in /10/.

You can find details on the measuring transducer, used in this application, in its operation manual /11/.

4 Explanations on the Example Program

Here you find information on …

- how the measured value reaches the controller
- the structure of the STEP7 program
- the functions of the individual blocks and networks.

4.1 Measured value processing

Reading the measuring value

The 4…20 mA signal of the measuring transducer is fed into the controller at the analog input AI 0 (connection see Table 5-2, point 5). The integrated A/D converter converts the analog signal into a digital Periphery Input Word (PIW), which is accessed by the FC12 function. The electrical parameter to be converted and the PIW address to which the data value is to be filed is parameterized in HW Config.

Figure 4-1: HW Config

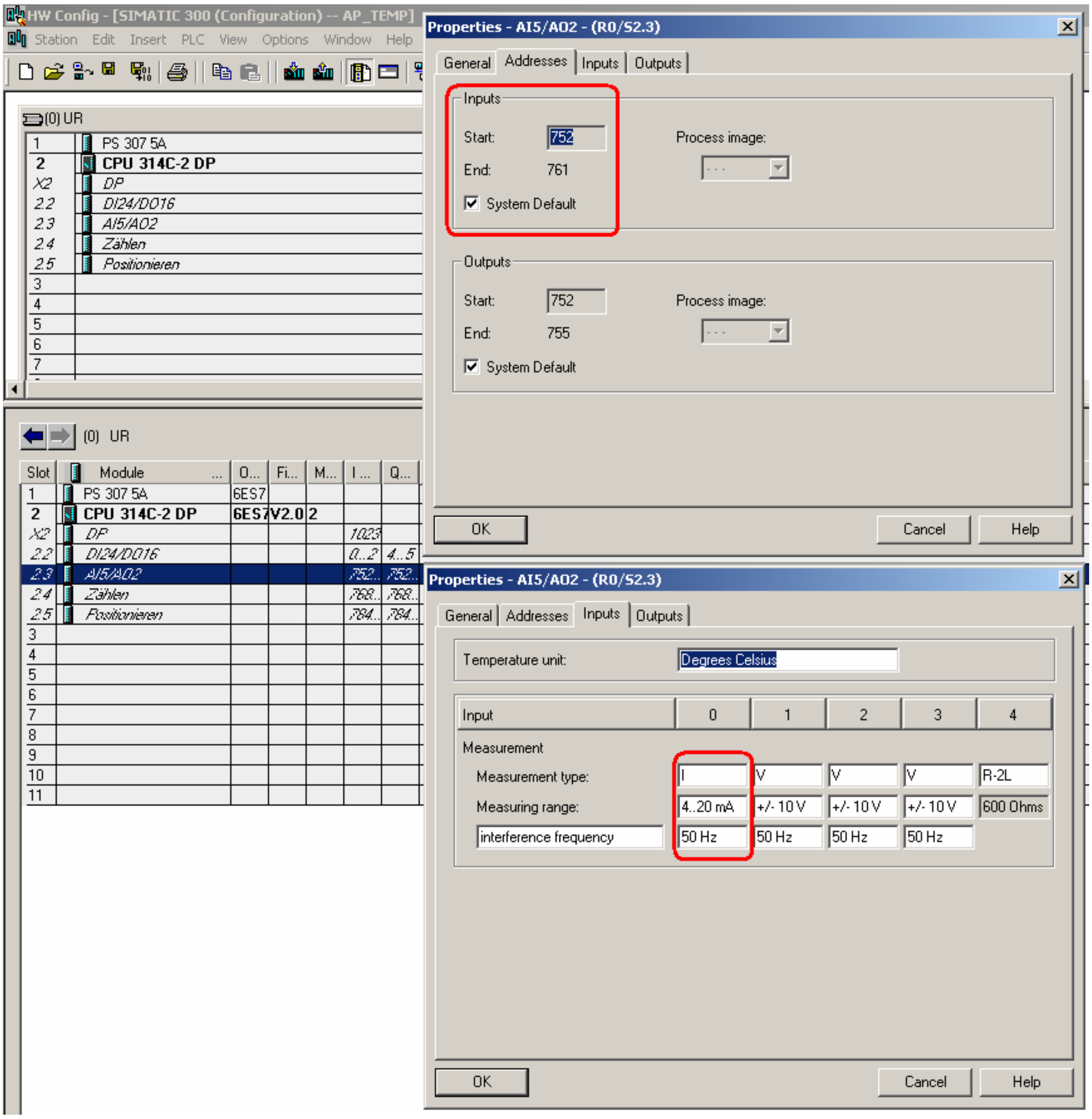


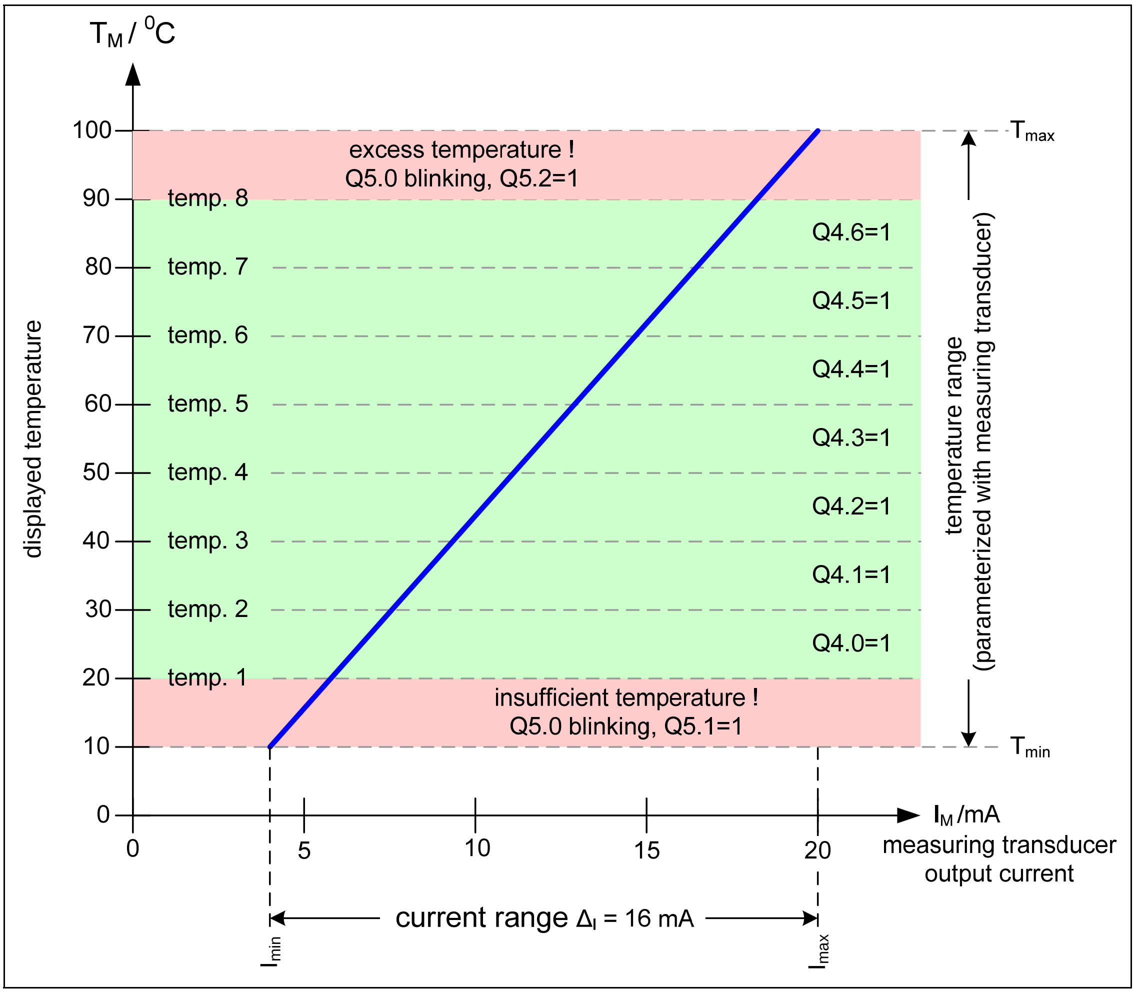
Figure 4-1 shows, that the measuring range is set to 4…20mA and that the result of the A/D conversion is transferred to PIW 752. For the PIW address, the system requirements remain unchanged. The above settings are part of the application example. You need not change anything in the hardware configuration.

During A/D conversion the selected measured range (4…20mA) is projected to a digital value range of 0…27648. For the purpose of transparent program design, this value range is converted back to a real number range 4.0 ... 20.0 using the library function “SCALE”, which is called in FC 12. This will be the starting point for calculating the temperature.

Calculating the temperature

Dependency of the temperature from the load-independent current, which the measuring transducer provides can be depicted as a straight line with positive inclination. This correlation is illustrated in Figure 4-2.

Figure 4-2: Correlation measuring transducer current – displayed temperature



The following mathematical equation can be derived from the graphic:

$$T_M = (I_M - I_{min}) \cdot (T_{max} - T_{min}) / Ä_I + T_{min}];$$

T_M: measured temperature (°C) [*“PARAMETERS”.T*]

I_M: output current of the measuring transducer (mA) [*# I*]

I_{min}: min. current value (= 4 mA)

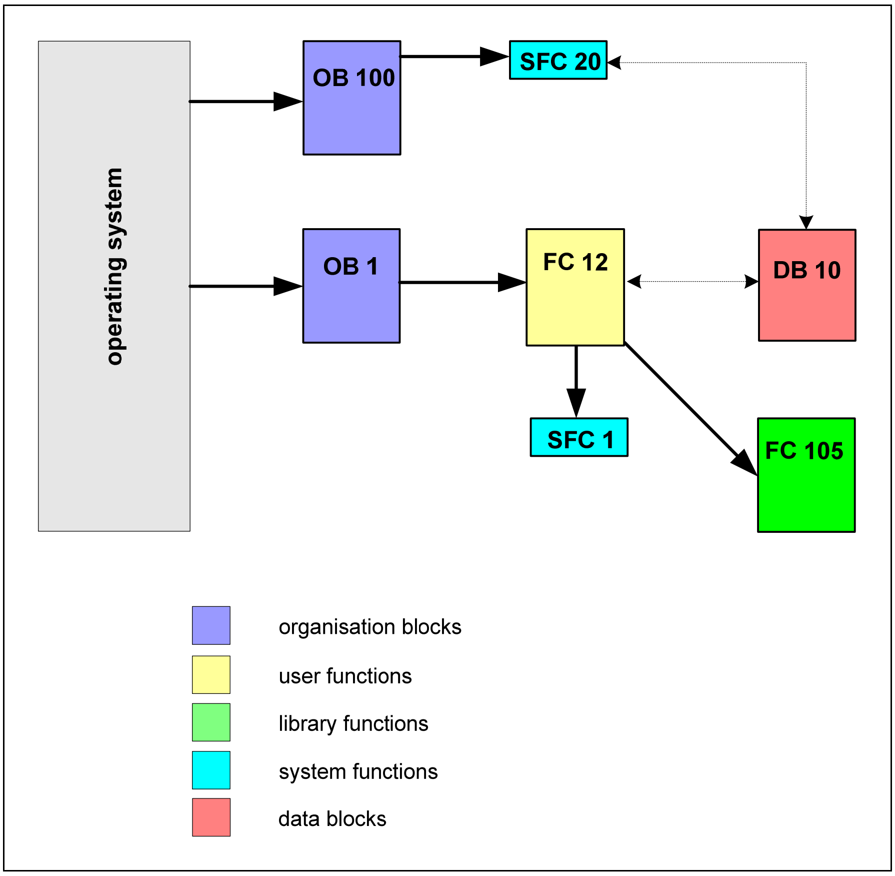
T_{max}: upper limit of the measuring range
(to be configured at the measuring transducer)

T_{min}: lower limit of the measuring range
(to be configured at the measuring transducer)

Δ_I: current rise of the detecting range (= 16 mA)

4.2 The structure of the STEP7 program

Figure 4-3: Structure of the STEP7 program



The block architecture of the STEP7 operating system ensures the structuredness of the program.

Table 4-1: Used software blocks

Block	Explanation
OB 1	Organization block (called by the operating system) for the cyclic program processing. Calls user function FC 12 after the *"re-start_delay_time"* has elapsed (see explanation on OB100).
OB 100	Organization block (called by the operating system) which is processed once during restart of the CPU. This block ensures... 1. by setting the memory bit *"trigger_restart_delay",* that after a restart, the evaluation of the measuring transducer signal is performed with a delay (10sec). This prevents the software, when switching on the power supply, from detecting a non-existent limit temperature violation due to the ready delay of the sensor and the measuring transducer. The set memory bit "*trigger_restart_delay"* starts the *"re-start_delay_time"* in OB1. 2. that the time stamp of the last restart is displayed in the respective fields on the *"Temperature Violations"* screen at the touch panel until an actual insufficient or excess temperature occurs.
FC 12	This user function block is the main program of the application. It contains the following realized features: • Evaluation of the measuring transducer signal • Detecting, processing and acknowledging the limit temperature violations • Detecting the current temperature sections • Realizing of the blinking marks. A detailed description is provided below this table.
DB 10	User data and parameter
FC105	The library function "*Scaling Values*" (SCALE)from the "TI-S7 Converting Blocks" folder of the Standard Library converts an integer into a real value, which in physical units is scaled between bottom and a top limit value. See FC105 online help. In this application the FC105 scales the analog value which is read in correspondence with the temperature.
SFC 1	System function (implemented in the CPU) for reading the CPU clock. See SFC1 online help.
SFC 20	System function (implemented in the CPU) for copying a memory area. In this application, SFC20 is used to transfer the restart time stamps from the start information of OB100 to the DB10. See SFC20 online help.

4.3 FC 12 (MAIN) in detail

The detailed description refers to the STEP7 project of which all symbols and comments were created in English. To provide a clear reference to the program code, headings, variable names, etc. were not translated in the following sections.

The color coding of the networks corresponds with the one in the flowchart in Figure 2-5.

Table 4-2: Detailed description of FC 12

NW	Explanation
1	**Release** A logic 1 at I 0.0 releases the processing of the block.
2	**Calculating the Temperature** The called function SCALE (FC105) converts the integer value 0…27648 from PEW 752 , which corresponds to the measuring transducer output current, into a REAL variable 4.0…20.0 (local variable # I). According to the relationship $T_M = (I_M - I_{min}) \cdot (T_{max}-T_{min})/\Delta_I + T_{min}$ the temperature T_M is calculated. See chapter 4.1.
3	**Detect Limit Violation** • Unconditional resetting of the digital outputs (in AB 4), which characterize the current level section. This also deletes the level marks at the touch panel. • If he current temperature (*"PARAMETERS".T)* is below temperature 1 *("PARAMETERS".T comp. [1])*, the program goes to jump label *"LOW"* in network 5. • If he current temperature (*"PARAMETERS".T)* is above temperature 8 *("PARAMETERS".T comp. [8])*, the program goes to jump label *"HIGH"* in network 5. Addressing of temperatures 1 and 8 is performed via pointer.
4	**Detect Range of the Actual Value** • Indicator length A5.1 *("Q_temp_below_MIN")* and A5.2 *("Q_temp_above_MAX")* for a limit value violation are reset automatically. • The level section in which the current temperature currently moves is detected. To do this, the current temperature (*"PARAMETERS".T*) is compared to the 8 reference temperatures *("PARAMETERS".T_comp [n])* one by one until the current section is detected. Digital output Q 4.n (n = 0…6) is set accordingly. Addressing of the 8 reference temperatures is performed in a loop via pointer.

<table>
<tr><th>NW</th><th>Explanation</th></tr>
<tr><td>5</td><td>
Processing Limit Violation
This network is linked to if a limit temperature violation has been detected in network 3.

In case of insufficient temperature…

the indicator output Q 5.1 ("Q_temp_below_MIN") is set.
the ("ALARM_LOW_TEMP") bit representing the blinking mark ▼ is set.
the display “Last Restart” is switched to display “Last Underrun” in touch panel screen “Temperature Violations” (resetting "no_low_temp_violation").
time stamp SFC 1 (READ_CLK) is written to DB 10 at the moment of falling below limit temperature ("PARAMETERS".timestamp_T_low) and so displayed in the touch panel screen “Temperature Violation“.

In case of excess temperature…

the indicator output Q 5.2 ("Q_temp_above_MAX") is set.
the ("ALARM_HIGH_TEMP") bit representing the blinking mark ▲ is set.
the display “Last Restart” is switched to display “Last Overrun” in touch panel screen “Temperature Violations” (resetting "no_high_temp_violation").
time stamp SFC 1 (READ_CLK) is written to DB 11 at the moment of exceeding limit temperature ("PARAMETERS".timestamp_T_high) and so displayed in the touch panel screen “Temperature Violation.

</td></tr>
</table>

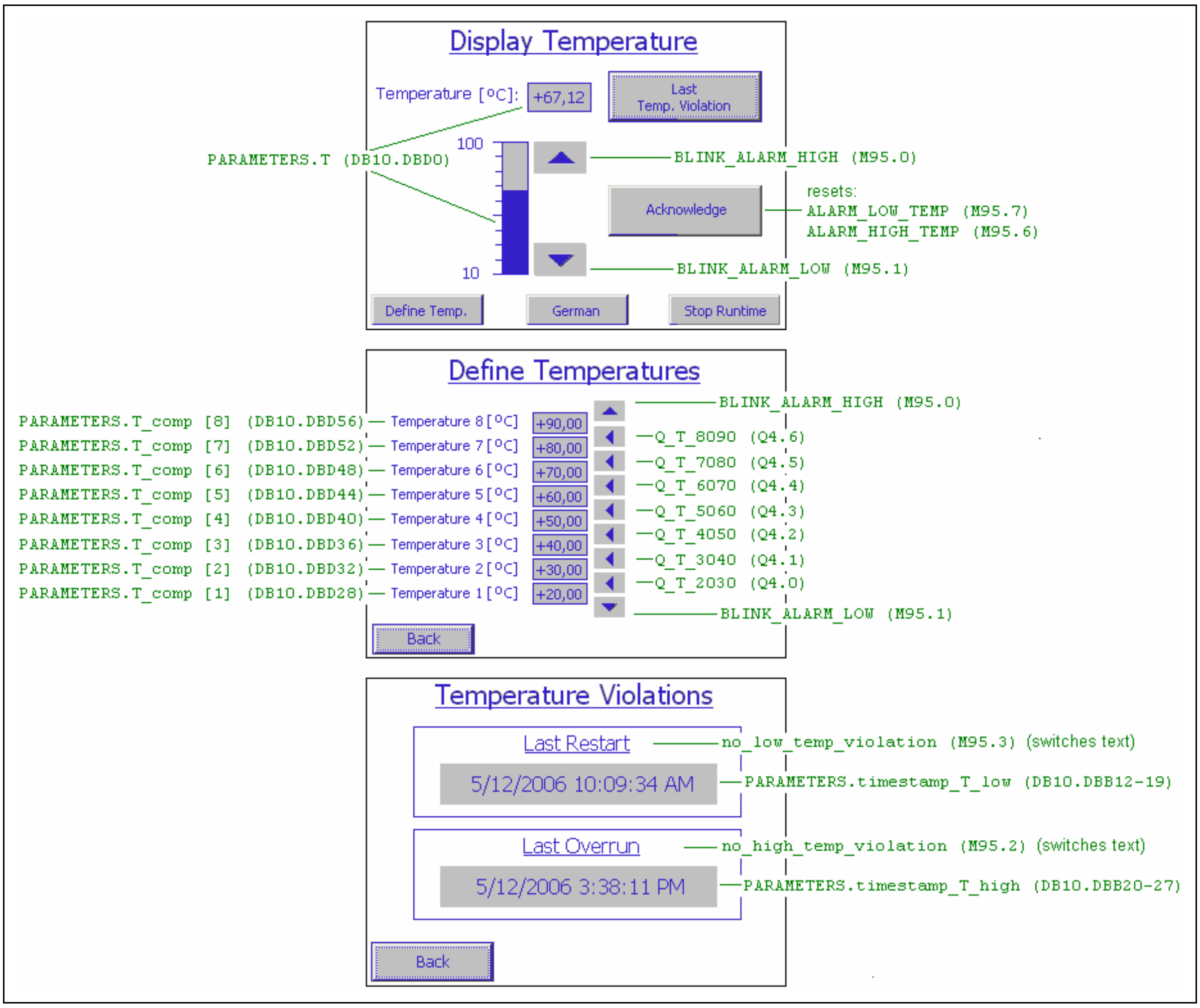
NW	Explanation
6	**Acknowledgement** A limit temperature violation displayed at the touch panel by means of blinking marks , and at the controller by means of blinking digital output Q 5.0, must be acknowledged. The alarms only disappear if alarm bits *"ALARM_LOW_TEMP"* or *"ALARM_HIGH_TEMP"* are reset via input I 0.1 *"I_acknowledge"* – as far as the temperature is back in the permitted range. Pressing the "*Acknowledge*" button in the touch panel screen "*Display Temperature*" has the same function as network 6.
7	**Blinking of Alarm Display** The blinking function of the blinking marks  and of output Q 5.0 *("Q_toggle_ALARM")* is realized by means of an AND logic connection of the respective alarm bit with the 1Hz clock memory bit (M 0.5)[1] *("blinking").* The output Q 5.0 blinks at insufficient **or** excess temperature.

[1] The clock memory bit is activated and addressed in the CPU Properties in HWConfig.
In order to reach a steady blinking of the blinking marks at the touch panel, a transmission cycle of 100s was defined for the blinking marks *"BLINK_ALARM_LOW"* and *"BLINK_ALARM_HIGH"* in WinCC flexible. The other variables are transmitted 1x per hour.

4.4 The variables at the touch panel

The figure below shows the correlation between the data of the controller and the HMI screens.

Figure 4-4: Control data in the HMI screens



Structure, Configuration and Operation of the Application

Content

This part leads you step by step through the structure, important configuration steps, commissioning and operation of the application.

5 Installation and Commissioning

Here you find information on …

how you install the hard and software, which configurations and settings have to be made and which steps are necessary to the commissioning of the example.

Please follow the descriptions, manuals and delivery information, which are supplied with the respective products, in any case.

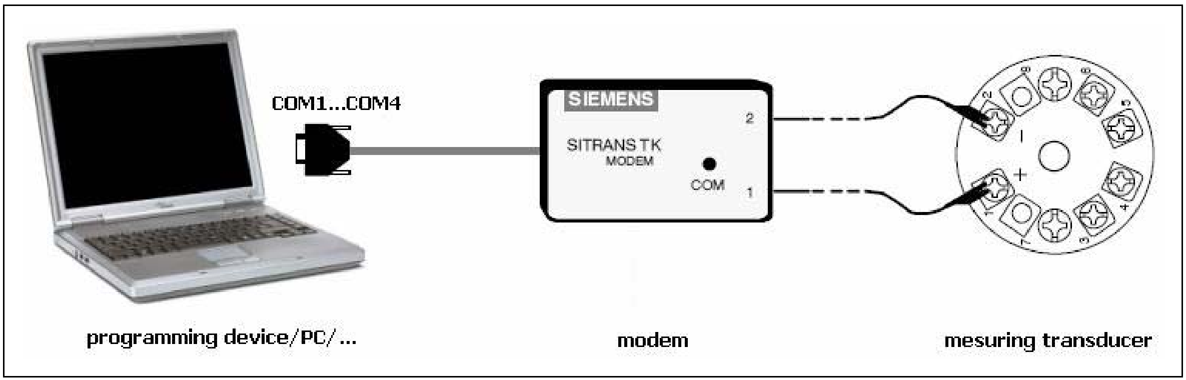
5.1 Parameterizing the SITRANS TK-L measuring transducer

Before installing the hardware components, the SITRANS TK-L measuring transducer has to be configured. For this reason you need both software (SIPROM TK, see Table 2-4) and hardware (modem for SITRANS TK, see Table 2-3).

SIPROM TK is Windows based and is delivered on disc. Install SIPROM TK on your development system in correspondence with the supplied operation manual /12/.

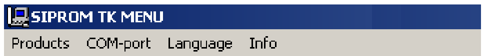
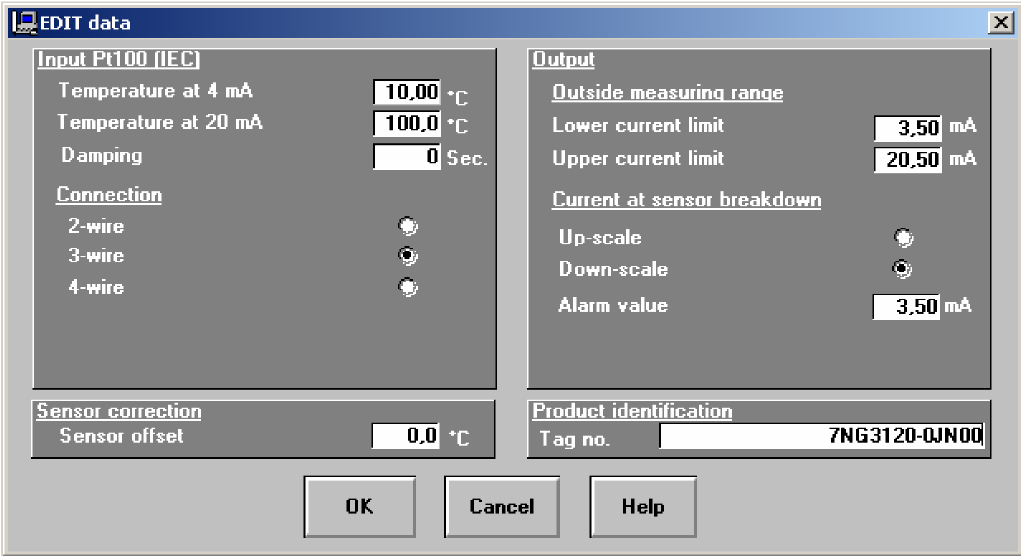
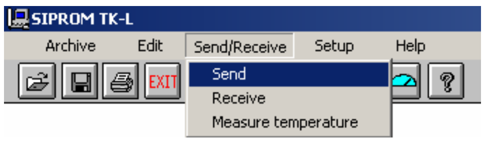
Connect the measuring transducer to an available COM interface (COM1...COM4) of your development system (PG/PC) via the SITRANS TK modem, according to the following image. There must not be anything connected to the measuring transducer except of the modem, not even blind wires.

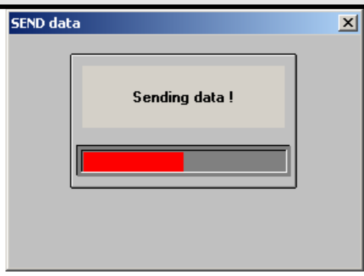
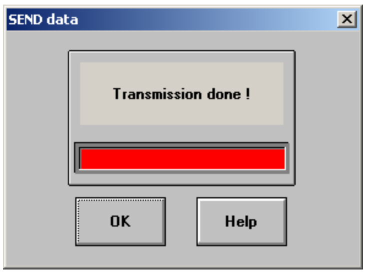
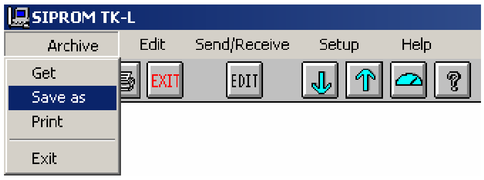
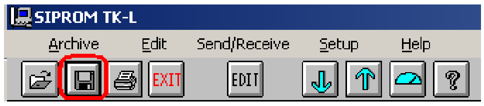
Figure 5-1: Connection of measuring transducer to PG/PC/…



Configure the measuring transducer in accordance with the following table.

Table 5-1: Parameterizing the SITRANS TK-L measuring transducer

No.	Instructions	Note
5.	Start SIPROM TK via “*Start > Programs > Siemens Process Instruments > SIPROM TK”* and select the desired language under “*Language*”.	
6.	Select the available interface under “*COM-port*”.	
7.	Select SITRANS TK-L under “*Products*”.	
8.	Open the editing mask via “*Edit > PT100”*.	
9.	Fill out the mask “*EDIT data*” in accordance with the following image and close the dialog via “*OK*”. 	
10.	Send the data via “*Send/Receive > Send*” to the measuring transducer	 The transmission process is displayed. • in SIPROM TK,

No.	Instructions	Note
		 • at the modem by flashing (green) of the LED.
11.	Quit the completed transmission with *"OK"*.	
12.	OPTIONAL! You can save the configuration via "*Archive > Save as"* or via the button with the disc symbol. To open the saved configurations later on, go to "*Archive > Get*".	  Only use folders with max. 8 characters as storage location. The file name (*.Dat) may also only have a maximum of 8 characters. As default file name the first 8 characters of the "*Product identification*" entered into the editing mask (see step5) are entered.
13.	Quit the configuration via "*Archive > Exit*".	By doing this you will get back to the SIPROM TK MENU.
14.	Quit SIPROM TK via "*Products > Exit*".	

Note You can find details on the modem and on the software SIPROM TK in the corresponding operation manual /12/.

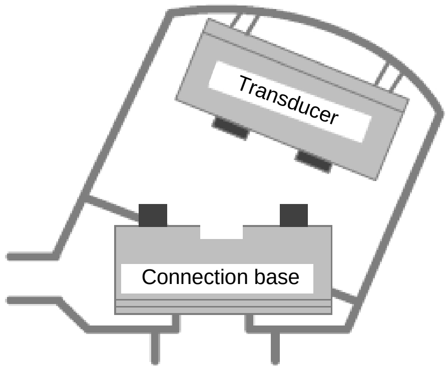
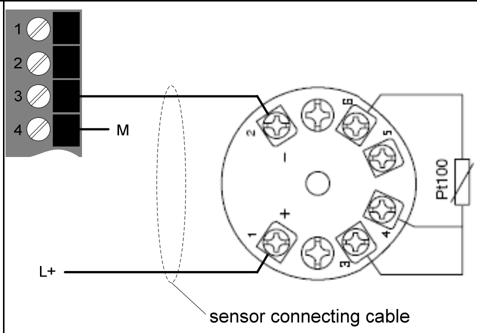
5.2 Installation of hardware and software

Hardware set up and wiring

Please find the hardware components in the Table 2-3. All components can be supplied with 24V DC via the PS307 load power unit. For the hardware configuration, follow the instructions listed in the table below:

Table 5-2: Setup of the hardware

No.	Instructions	Note
1.	On the profile rail arrange the following hardware components from the left to the right and screw them down: Power supply (PS), CPU 314C-2 DP;	
2.	Screw the front connectors into the two slots.	
3.	Bolt together CPU and rack.	

No.	Instructions	Note
4.	Mount the measuring transducer into the lid of the connection head at the resistivity thermometer.	
5.	Connect the resistivity thermometer to the analog input AI 0 (left front-plug) of the CPU via the measuring transducer[2] . The pin assignment is printed on the inside of the cover.	 Connection cable: • Max. wire diameter 2.5 mm^2; • lay separated from wires with voltage >60 V; • use cables with twisted wires; • use shielded cable if necessary; See /11/ for details on the measuring transducer.
6.	Wire the power supply (L+, M) for the used DI/DO part of the CPU (right front plug). The pin assignment is printed on the inside of the cover.	
7.	Connect input I 0.0 (Release) – if necessary via a switch – to L+.	
8.	Connect input I 0.1 (Acknowledge) – if necessary via a button – to L+.	
9.	Wire the power supply of the TP170A.	

[2] In this case, the Pt100 element is connected with three-wire circuit. But because of the position of the measuring transducer in the vicinity of the Pt100 element the connection type plays hardly any role.

No.	Instructions	Note
10.	Use the Profibus cable to connect the MPI of the S7-CPU to the IF1B interface of the TP170A.	Use a plug with PG socket at the CPU in order to be able to connect your development system (PG, PC) in addition. The cable from Table 2-3 meets these requirements.
11.	Set the DIP switches on the rear of the TP170A to DP/MPI mode.	
12.	Connect the MPI of the CPU to the MPI of your PG/PC.	Plug the MPI cable on the CPU leading to the PG/PC in the PG socket of the PROFIBUS connector.

Note Further information on setting up an S7-300 automation system is available in /3/.

Installation of the standard software

It is a precondition that the software specified in Table 2-4 is installed on your PG/PC. If you use a PC or notebook as development system, it is required that it is equipped with a communications processor (e.g. CP5512 PC card for notebooks).

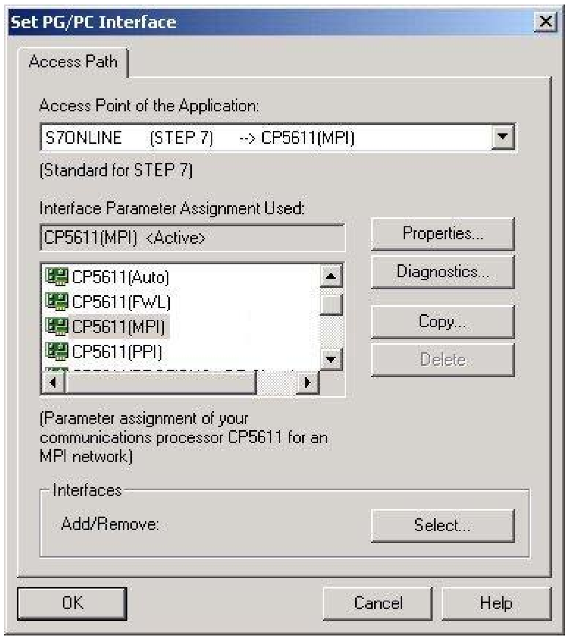
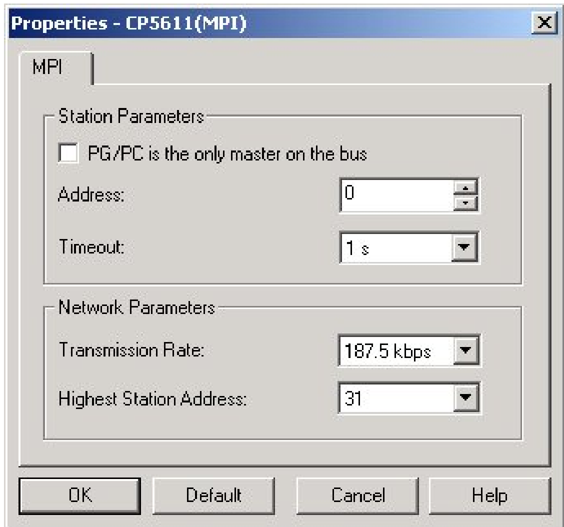
5.3 Loading of the application software

Requirements:

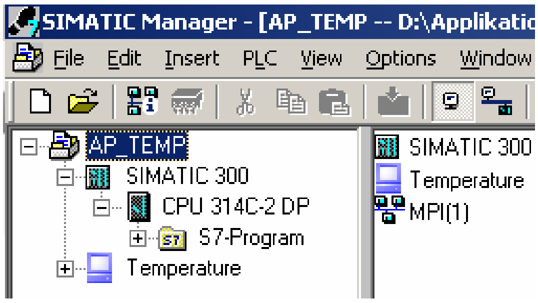
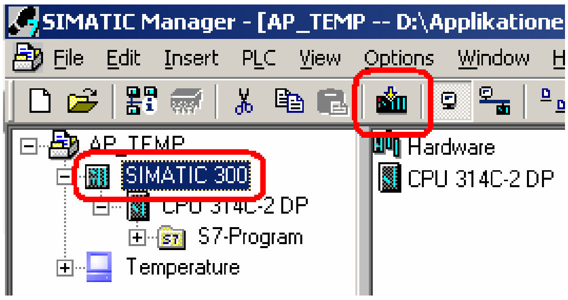
1. The hardware installation is completed.
2. All components are supplied with voltage.
3. The CPU is switched to STOP with the mode switch.

Loading the application software to the CPU

Table 5-3: Loading the application software to the CPU

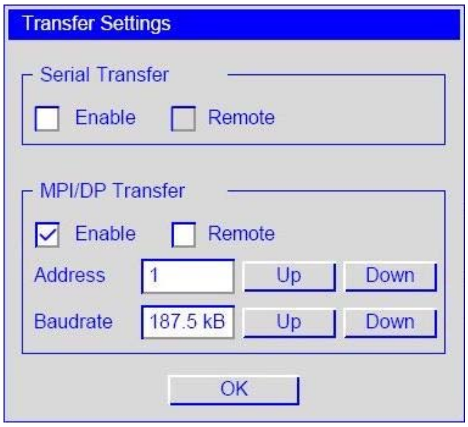
No.	Instructions	Note
1.	Set the PG/PC interface. In the control panel of your development system, open the "*Set PG/PC Interface*" dialog box.	 If the interface has already been set, continue with point 5.
2.	Select the following settings: • Access Point of the Application: *S7ONLINE (STEP7) → CPxxxx(MPI)* • Interface Parameter Assignment Used: *CPxxxx(MPI)* The CP type depends on the development system used. If the above access point is not included in the list box, create it via the <*Add/Delete*> entry (also in the " Access Point of the Application " list box). Then click the "*Properties…*" button.	
3.	Enter the MPI address of the development system (in this application the address "0") and the other bus parameters as shown in the figure on the right. Quit the dialog box with "OK".	
4.	Click "*OK*" to close the "*Set PG/PC Interface*" window and exit the control panel.	
5.	Open the SIMATIC Manager.	

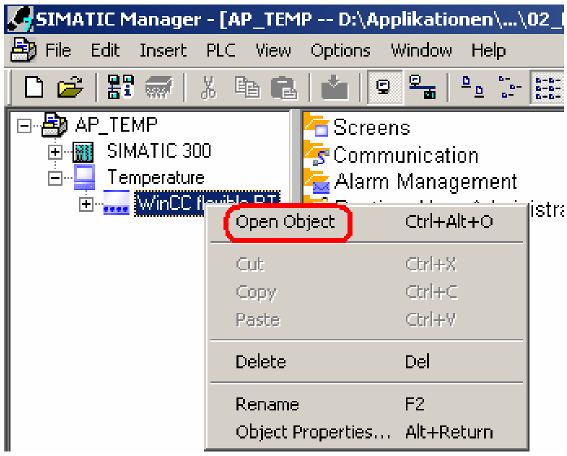
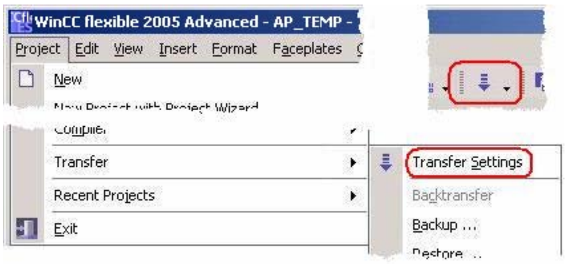
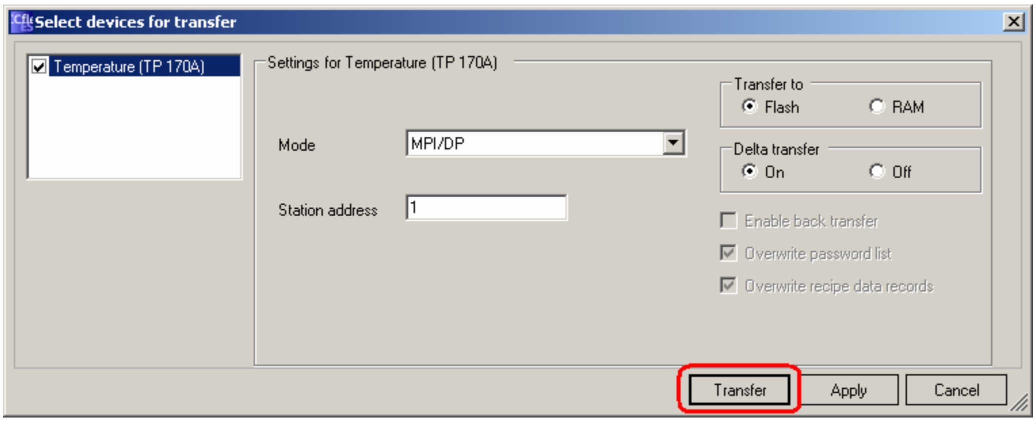
Application Resistivity Thermometer ID Number: 23541638

No.	Instructions	Note
6.	Extract the project: 1. Select the project "23541638_Temperaturmessung _V20.zip" via the menu "File > Retrieve…". 2. Select a target directory for the extracted project folder. 3. After extracting, you are asked in the SIMATIC Manager whether you want to open the project. Answer with "Yes". The figure on the right shows the extracted project.	
7.	Select the SIMATIC station and load the project to the S7-CPU via the "*PLC > Download*" menu or the corresponding button.	

Load the application software into the panel

Table 5-4: Load the application software into the panel

No.	Instructions	Note
1.	Make sure that the transfer settings on the TP170A are correct. Click the "*Config*" button in its start menu to display the "*Transfer Settings*" screen form. Make the settings as shown in the screen shot on the right and close the dialog box with "OK".	
2.	In the start menu of the panel – to which you have now returned – click the "*Transfer*" button.	You go to the transfer mode of the panel.

<table>
<tr><th>No.</th><th>Instructions</th><th>Note</th></tr>
<tr><td>3.</td><td>In the development system, open the WinCC flexible project “Temperature” via the context menu (right mouse button) as shown on the right.</td><td>
</td></tr>
<tr><td>4.</td><td>Select “Project > Transfer > Transfer Settings” or click the corresponding button.</td><td>
</td></tr>
<tr><td>5.</td><td colspan="2">Make the settings as shown in the screen shot below.


Click “Transfer” to start the data transfer.
Answer the question “Do you want to overwrite the existing password list on the device?” (at least) when transferring your configuration for the first time with “Yes”.
After the end of the transmission, the touch panel will switch to the starting image (Figure 2-2) set in WinCC flexible.</td></tr>
</table>

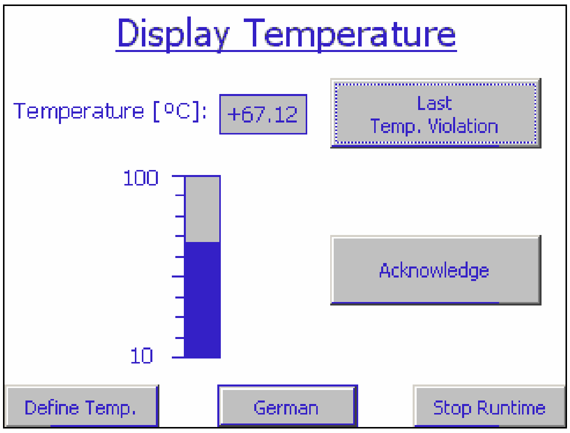
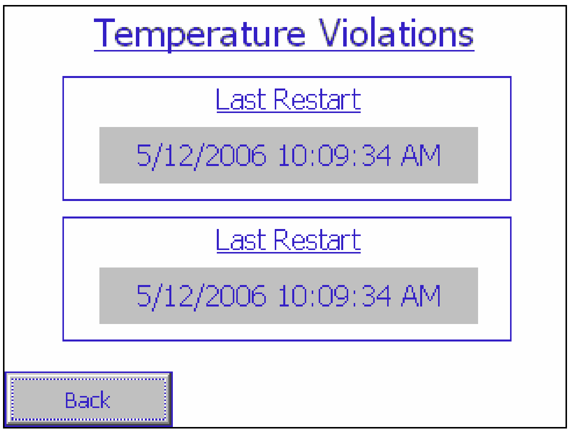
Note The above table of steps describes the loading of the TP170A via MPI. However, the configuration can also be transferred to the panel serially. For more information please refer to /4/ and /5/.

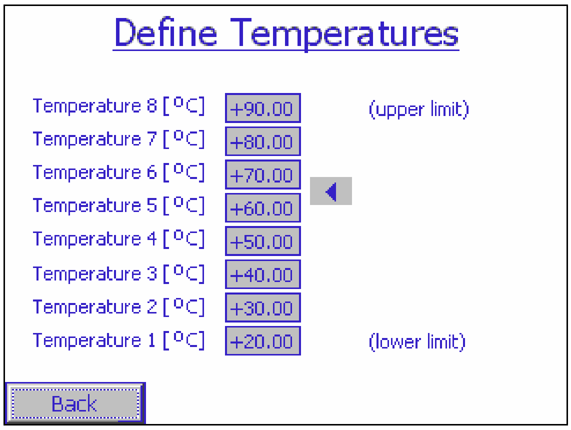
5.4 Startup

Requirements:

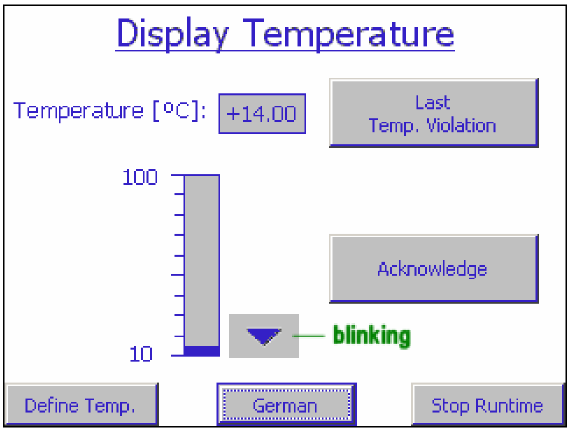
1. The hardware and software installation as described in chapters 5.1 to 5.3 is completed.
2. The current temperature is within the permissible range (20...90 °C).
3. The temperature recording is enabled (I 0.0 = 1).

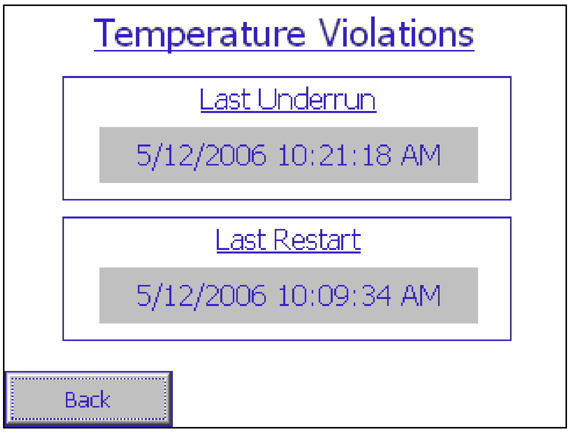
Table 5-5: Commissioning of the simulation

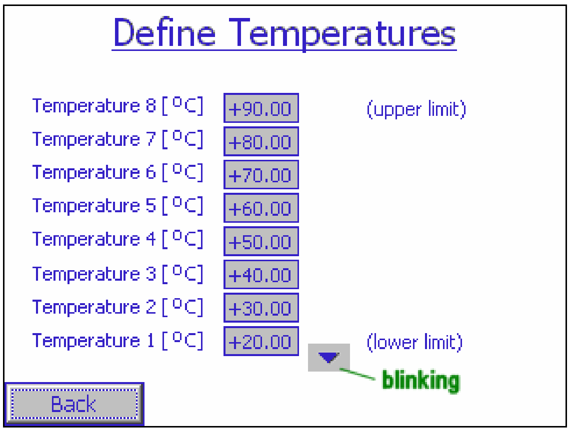
No.	Instructions	Response
1.	Switch the ... 2. power supply on, 3. CPU to RUN.	After a delay time of 10 s the touch panel shows the following screen. The temperature display (values and bars) correspond to the current conditions. 
2.	Press the “Last Temp. Violation” button to change to the according screen.	The time stamp of the last restart is displayed in the top as well as the bottom half of the screen. 

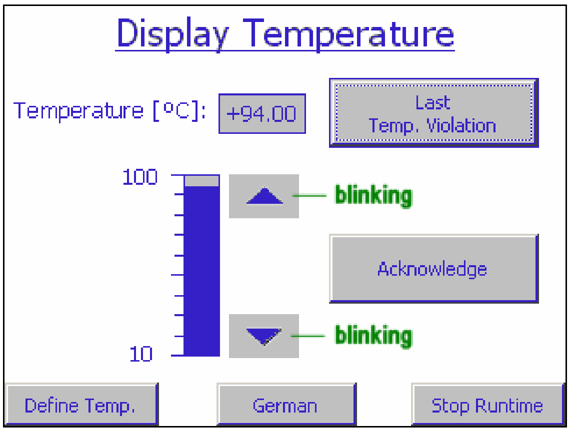
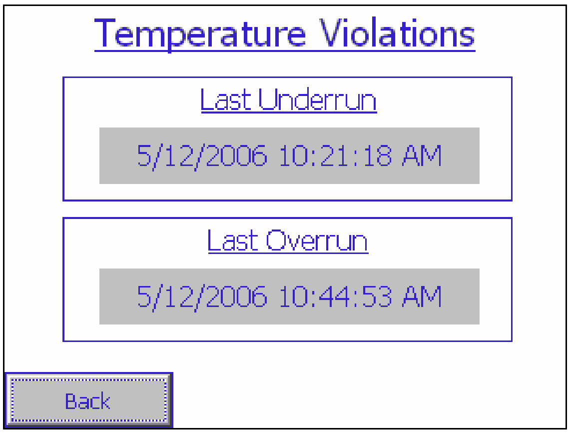
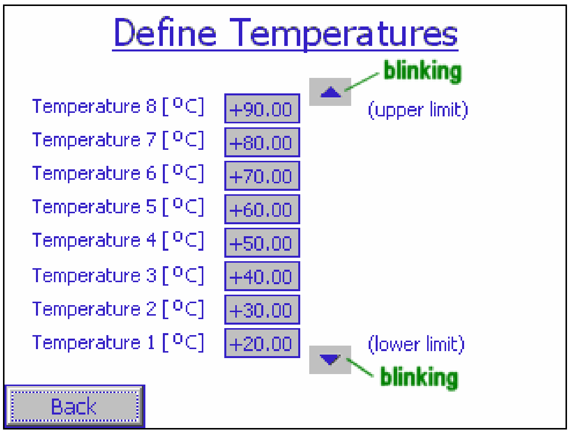
No.	Instructions	Response
3.	1. Press the *“Back”* button to return to the temperature display. 2. Press the *“Define Temp”* button to change to the according screen.	The level mark is in the section of the current temperature. 
4.	Change the actual temperature: 20°C < actual temperature <90°C	Value and bar are correctly displayed in the *“Display Temperature”* view. The level mark in the *“Define Temperatures”* view always jumps to the current temperature section.

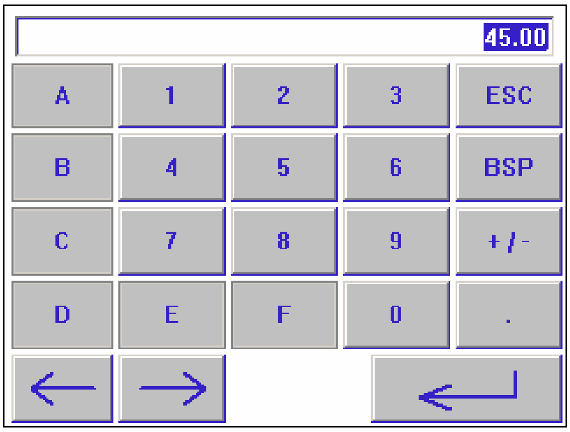
<table>
<tr><th>No.</th><th>Instructions</th><th>Response</th></tr>
<tr><td>5.</td><td>Reduce the actual temperature to < 20°C.</td><td>This gives you the following screen contents:






</td></tr>
</table>

No.	Instructions	Response
6.	Increase the actual temperature to >90°C.	This gives you the following screen contents:   
7.	Bring the temperature back to the permitted range and acknowledge the temperature violation with the *"Acknowledge"* button in the *"Display Temperature"* screen.	The blinking marks in the *"Display Temperature"* and *"Define Temperatures"* screens disappear. The contents of the *"Temperature Violations"* screen remain unchanged.

No.	Instructions	Response
8.	Select the *"Define Temperatures"* screen and change, for example, the temperature 4 to 45°C by touching the respective I/O box.	A key pad for value input appears.  Complete your entry with 
9.	Vary the actual temperature in the 30…50°C range.	The temperature display (level mark in the *"Define Temperatures"* screen) corresponds with the changed temperature range limit.

Appendix and Literature

6 Literature

6.1 References on hardware and software of this application

This list includes documents/entries referred to in this application.

Table 6-1: References on hardware and software of this application

	Title
/1/	Siemens A&D Customer Support http://www.ad.siemens.de/support
/2/	Reference to this entry http://support.automation.siemens.com/WW/view/en/23541638
/3/	Operating Instructions S7-300, CPU 31xC and CPU 31x: Installation http://support.automation.siemens.com/WW/view/en/13008499
/4/	Operating Instructions TP 170micro, TP 170A, TP 170B, OP 170B (WinCC flexible) http://support.automation.siemens.com/WW/view/en/19082123
/5/	User's manual WinCC flexible 2005 Compact / Standard / Advanced http://support.automation.siemens.com/WW/view/en/18796010
/6/	FAQ 1070096 Which connectors and cables do I need to connect an OP/PG to an S7-controller? Is there a standard cable? http://support.automation.siemens.com/WW/view/en/1070096
/7/	FAQ 22445076 Information on STEP7 V5.4 http://support.automation.siemens.com/WW/view/en/22445076
/8/	Automation system S7-300 module data Reference manual http://support.automation.siemens.com/WW/view/en/8859629
/9/	Automation systems S7-400, M7-400 module data Reference manual http://support.automation.siemens.com/WW/view/en/19539653
/10/	Product overview SITRANS T temperature measuring devices http://pia.khe.siemens.com/efiles/feldg/files/kataloge/fi01_ge/sitranst_produktuebersicht_fi01ge.pdf
/11/	Operation manual for SITRANS TK-L measuring transducer http://support.automation.siemens.com/WW/view/en/7306608
/12/	Operation manual for the modem for SITRANS TK and for the SIPROM TK software http://support.automation.siemens.com/WW/view/en/13973961

6.2 Further literature

This list is by no means exhaustive and only gives a selection of appropriate sources.

Table 6-2: Further literature

	Title
/13/	Hans Berger Automating with STEP7 in STL and SCL Publicis Corporate Publishing ISBN 3-89578-242-4 Book presentation: http://books.publicis-erlangen.de/de/produkte/techinhan/auto/index.cfm?bookid=5816
/14/	Elmar Schrüfer Elektrische Messtechnik [Electrical Measurement Techniques] HANSER technical book 2004 Fachbuchverlag Leipzig ISBN 3-44621-809-2

7 History

Table 7-1 History

Version	Data	Modification
V1.0	07/23/02	First edition (BID 12372960)
V2.0	07/03/06	Complete revision