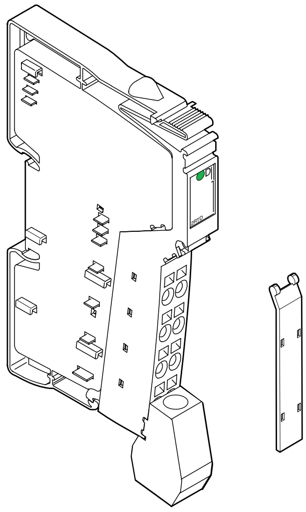
IB IL TEMP 2 RTD (-PAC)



Inline Terminal With Two Analog Input Channels for the Connection of Temperature Shunts (RTD)

AUTOMATIONWORX

Data Sheet
5755_en_04

1 Description

The terminal is designed for use within an Inline station. This terminal provides a two-channel input module for resistive temperature sensors. This terminal supports platinum and nickel sensors according to the DIN standard and SAMA Directive. In addition, sensors Cu10, Cu50, Cu53 as well as KTY81 and KTY84 are supported.

The measuring temperature is represented by 16-bit values in two process data words (one word per channel).

Features

– Two inputs for resistive temperature sensors
– Configuration of channels via the bus system
– Measured values can be represented in three different formats
– Connection of sensors in 2, 3, and 4-wire technology

This data sheet is only valid in association with the IL SYS INST UM E user manual or the Inline system manual for your bus system.

Make sure you always use the latest documentation.
It can be downloaded at www.download.phoenixcontact.com.

A conversion table is available on the Internet at www.download.phoenixcontact.com/general/7000_en_00.pdf.

This data sheet is valid for the products listed on the following page:

Table of Contents

2 Ordering Data

Products

Description	Type	Order No.	Pcs./Pkt.
Inline terminal with two resistive temperature sensor inputs, without accessories	IB IL TEMP 2 RTD	2726308	1
Inline terminal with two resistive temperature sensor inputs, complete with accessories (connector and labeling field)	IB IL TEMP 2 RTD-PAC	2861328	1

A connector with shield connection is needed for the complete fitting of the IB IL TEMP 2 RTD terminal.

Accessories

Description	Type	Order No.	Pcs./Pkt.
Inline shield connector for analog Inline terminals	IB IL SCN-6 SHIELD	2726353	5

Documentation

Description	Type	Order No.	Pcs./Pkt.
User manual: "Automation Terminals of the Inline Product Range"	IL SYS INST UM E	2698737	1
User manual: "Configuring and Installing the INTERBUS Inline Product Range"	IB IL SYS PRO UM E	2743048	1

3 Technical Data

General Data	
Housing dimensions (width x height x depth)	12.2 mm x 120 mm x 66.6 mm
Weight	46 g (without connector); 67 g (with connector)
Operating mode	Process data mode with 2 words
Connection method for sensors	2, 3, and 4-wire technology
Ambient temperature (operation)	-25°C to +55°C
Ambient temperature (storage/transport)	-25°C to +85°C
Permissible humidity (operation/storage/transport)	10% to 95% according to DIN EN 61131-2
Permissible air pressure (operation/storage/transport)	70 kPa to 106 kPa (up to 3000 m above sea level)
Degree of protection	IP20 according to IEC 60529
Class of protection	Class 3 according to VDE 0106, IEC 60536
Connection data for Inline connector	
Connection method	Spring-cage terminals
Conductor cross-section	0.2 mm^2 to 1.5 mm^2 (solid or stranded), 24 - 16 AWG

Interface	
Local bus	Data routing

Transmission Speed	
IB IL TEMP 2 RTD; IB IL TEMP 2 RTD-PAC	500 kbps

Power Consumption	
Communications power U_L	7.5 V
Current consumption at U_L	43 mA (typical)
I/O supply voltage U_{ANA}	24 V DC
Current consumption at U_{ANA}	11 mA (typical)
Total power consumption	590 mW (typical)

Supply of the Module Electronics and I/O Through the Bus Coupler/Power Terminal

Connection method	Potential routing

Analog Inputs

Number	Two inputs for resistive temperature sensors
Connection of the signals	2, 3 or 4-wire, shielded sensor cable
Sensor types that can be used	Pt, Ni, Cu, KTY
Characteristics standards	According to DIN/according to SAMA
Conversion time of the A/D converter	120 µs, typical
Process data update	Depending on the connection method
Both channels in 2-wire technology	20 ms
One channel in 2-wire technology/one channel in 4-wire technology	20 ms
Both channels in 3-wire technology	32 ms

Safety Equipment

None

Electrical Isolation

To provide electrical isolation between the logic level and the I/O area, it is necessary to provide the bus coupler supply U_{BK} and the I/O supply (U_M/U_S) from separate power supply units. Interconnection of the power supply units in the 24 V area is not permitted.

Common Potentials

24 V main voltage U_M, 24 V segment voltage U_S, and GND have the same potential. FE is a separate potential area.

Separate Potentials in the Terminal

Test Distance	Test Voltage
7.5 V supply (bus logic) / 24 V analog supply (analog I/O)	500 V AC, 50 Hz, 1 min
7.5 V supply (bus logic) / functional earth ground	500 V AC, 50 Hz, 1 min
24 V analog supply (analog I/O) / functional earth ground	500 V AC, 50 Hz, 1 min

Error Messages to the Higher-Level Control or Computer System

Failure of the internal voltage supply	Yes
Failure of or insufficient communications power U_L	Yes, I/O error message sent to the bus coupler

Error Messages via Process Data

I/O error/user error	Yes (see page 15)

Approvals

Information on current approvals can be found on the Internet at www.download.phoenixcontact.com.

4 Local Diagnostic Indicators

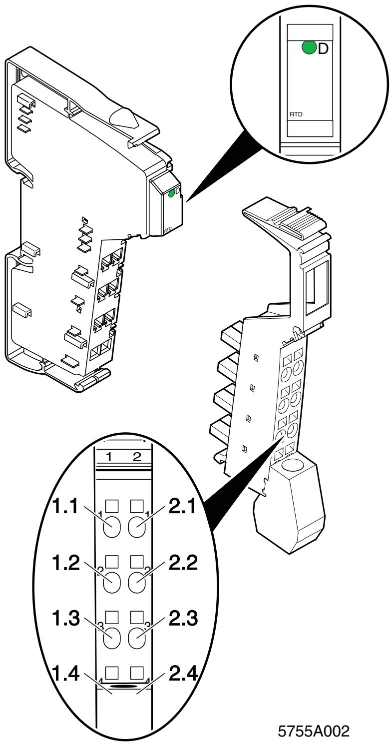


Figure 1 Terminal with appropriate connector

4.1 Local Diagnostic Indicator

Desig.	Color	Meaning
D	Green	Diagnostics

4.2 Function Identification

Green

4.3 Terminal Point Assignment for 2/3-Wire Termin.

Terminal Points	Signal	Assignment
1.1	**I_1+**	RTD of sensor 1
1.2	**I_1-**	Constant current supply
1.3	**U_{1-}**	Measuring input of sensor 1
2.1	**I_2+**	RTD of sensor 2
2.2	**I_2-**	Constant current supply
2.3	**U_{2-}**	Measuring input of sensor 2
1.4, 2.4	**Shield**	Shield connection (channel 1 and 2)

4.4 Terminal Point Assignment for 4-Wire Termin. on Channel 1 and 2-Wire Termin. on Channel 2

Terminal Points	Signal	Assignment
1.1	**I_1+**	RTD of sensor 1
1.2	**I_1-**	Constant current supply
1.3	**U_1-**	Measuring input of sensor 1
2.3	**U_1+**	Measuring input of sensor 1
2.1	**I_2+**	RTD of sensor 2
2.2	**I_2-**	Constant current supply
1.4, 2.4	**Shield**	Shield connection (channel 1 and 2)

In 4-wire technology a sensor can only be connected to channel 1.

5 Safety Notes

During configuration, ensure that no isolating voltage is specified between the analog inputs and the local bus. During thermistor detection this, for example, means that the user has to provide signals with **safe isolation**, if applicable.

6 Installation Instructions

High current flowing through potential jumpers U_M and U_S leads to a temperature rise in the potential jumpers and inside the terminal. Observe the following instructions to keep the current flowing through the potential jumpers of the analog terminals as low as possible:

> **Create a separate main circuit for all analog terminals**
>
> If this is not possible in your application and if you are using analog terminals in a main circuit together with other terminals, place the analog terminals behind all the other terminals at the end of the main circuit.

7 Internal Circuit Diagram

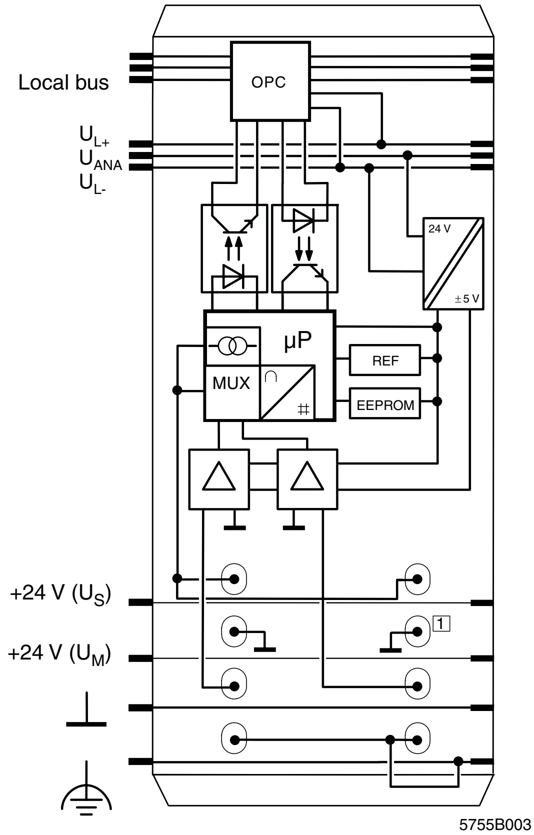
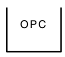
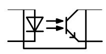
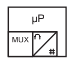


Figure 2 Internal wiring of the terminal points

Key:

	Protocol chip
	Optocoupler
	DC/DC converter with electrical isolation
	Microprocessor with multiplexer and analog/digital converter
	Reference voltage
	Electrically erasable programmable read-only memory
	Amplifier

> Other symbols used are explained in the IL SYS INST UM E user manual or in the system manual for your bus system.

8 Electrical Isolation

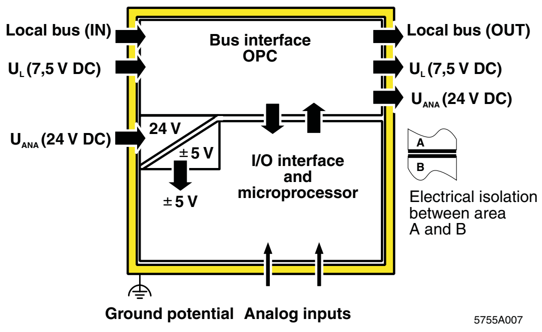


Figure 3 Electrical isolation of the individual function areas

9 Connection Notes

9.1 Thermocouple Connection

In 4-wire technology a sensor can only be connected to channel 1. In this case, the sensor on channel 2 can only be connected in 2-wire technology!

9.2 Shield Connection

The connection examples show how to connect the shield (Figure 4).

Connect the shielding to the Inline terminal using the shield connection clamp. The clamp connects the shield directly to FE on the terminal side. Additional wiring is not necessary.

Isolate the shield at the sensor.

9.3 Sensor Connection in 4-Wire Technology

Always connect temperature shunts using shielded, twisted-pair cables.

10 Connection Examples

When connecting the shield at the terminal you must insulate the shield on the sensor side (shown in gray in Figure 4 and Figure 5).

Use a connector with shield connection when installing the sensors. Figure 4 shows the connection schematically (without shield connector).

Connection of Passive Sensors

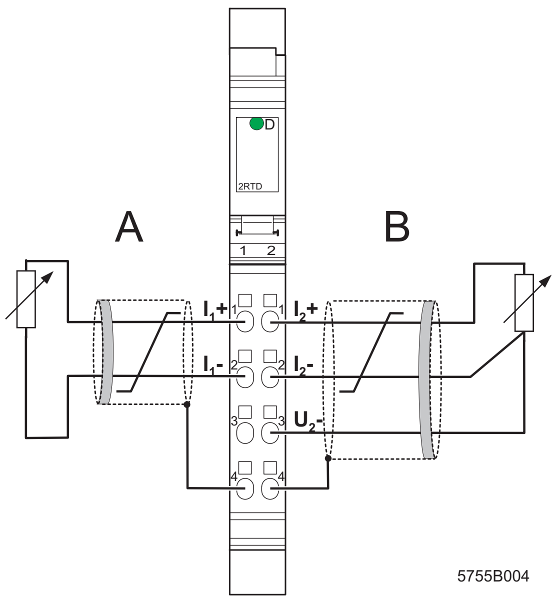


Figure 4 Connection of sensors in 2 and 3-wire technology with shield connection

A Channel 1; 2-wire technology

B Channel 2; 3-wire technology

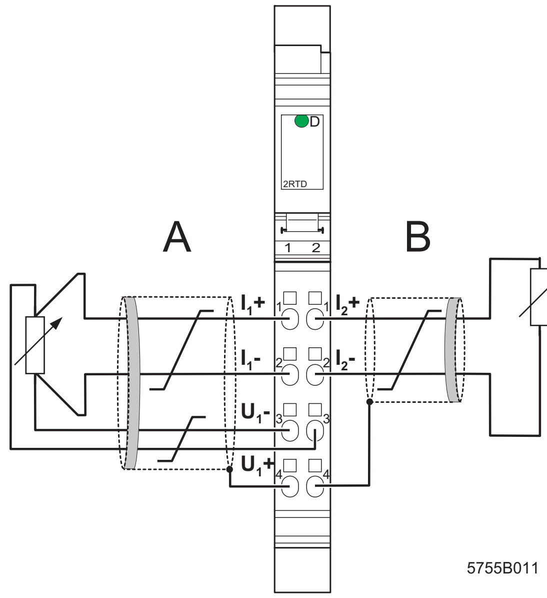


Figure 5 Connection of sensors in 4 and 2-wire technology with shield connection

A Channel 1; 4-wire technology

B Channel 2; 2-wire technology

11 Programming Data

Local Bus (INTERBUS)

ID code	$7F_{hex}$ (127_{dec})
Length code	02_{hex}
Input address area	4 bytes
Output address area	4 bytes
Parameter channel (PCP)	0 bytes
Register length (bus)	4 bytes

Other Bus Systems

For the configuration data of other bus systems, please refer to the appropriate electronic device data sheet (e.g., GSD, EDS).

12 Process Data

12.1 Output Data Words for Configuring the Terminal (See Page 11)

(Word.bit) view	Word	Word 0															
	Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(Byte.bit) view	Byte	Byte 0								Byte 1							
	Bit	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Channel 1	Assignment	Configuration		Connection method		R_0				Resolution		Format		Sensor type			

(Word.bit) view	Word	Word 1															
	Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(Byte.bit) view	Byte	Byte 2								Byte 3							
	Bit	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Channel 2	Assignment	Configuration		Connection method		R_0				Resolution		Format		Sensor type			

12.2 Assignment of Terminal Points to the Input Data Words (See Page 14)

(Word.bit) view	Word	Word 0															
	Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(Byte.bit) view	Byte	Byte 0								Byte 1							
	Bit	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Terminal points channel 1	Signal	Terminal point 1.1: I_1+ sensor 1															
	Signal reference	Terminal point 1.2: I_1- sensor 1								Terminal point 1.3 U_1- sensor 1							
	Shielding (FE)	Terminal point 1.4															

(Word.bit) view	Word	Word 1															
	Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(Byte.bit) view	Byte	Byte 2								Byte 3							
	Bit	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Terminal points channel 2	Signal	Terminal point 2.1: I_2+ sensor 2															
	Signal reference	Terminal point 2.2: I_2- sensor 2								Terminal point 2.3 U_1+ sensor 2							
	Shielding	Terminal point 2.4															

12.3 OUT Process Data

The terminal channels can be configured using the two process data output words. The following configuration options exist for each channel independent of the other channel:

- Connection type of the sensor
- Value of reference resistance R_0
- Resolution settings
- Selecting the formats for the representation of measured values
- Setting the sensor type

With regard to the connection method the two channels are dependent on each other. If 4-wire mode is activated for channel 1, channel 2 can only be operated using 2-wire connection method. 4-wire connection method is only available for channel 1.

Configuration errors are indicated by the corresponding error code, as long as the IB standard format is configured as the format for representing the measured values.

The configuration settings are only stored in a volatile memory. They must be transmitted in each bus cycle.

After the Inline station has been powered up, the "Measured value invalid" message (error code 8004_{hex}) appears in the IN process data words. After 1 s (maximum) the preset configuration is accepted and the first measured value is available.

Default:

Connection:	2-wire technology
R_0:	100 Ω
Resolution:	0.1°C
Format:	Format 1 (IB standard)
Sensor type:	Pt100 (DIN)

If you change the configuration, the corresponding channel is re-initialized. The "Measured value invalid" message (error code 8004_{hex}) appears in the process data output words for 100 ms (maximum).

If the configuration is invalid, the "Configuration invalid" message is output (error code 8010_{hex}).

Please note that extended diagnostics is only possible if IB standard is configured as the format for representing the measured values. Since this format is preset on the terminal, it can be used straight away after power up.

One process data output word is available for the configuration of each channel.

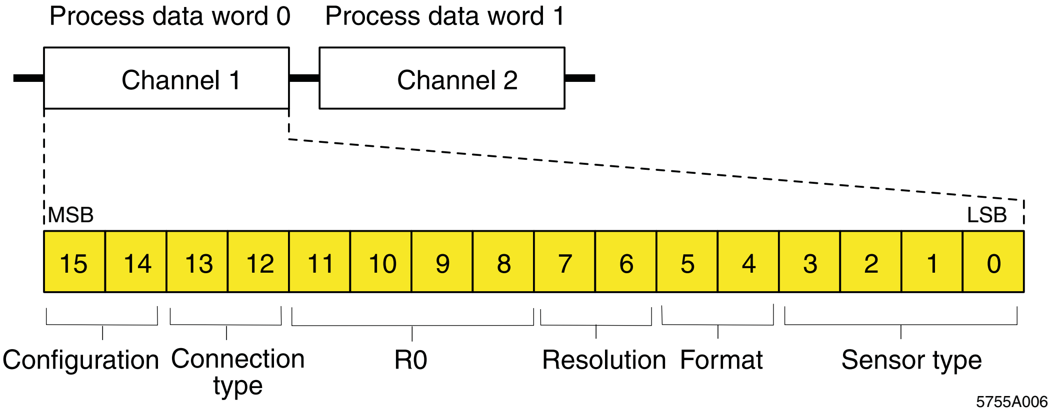


Figure 6 Process data output words

Bit 15 and Bit 14:

You must set bit 15 of the corresponding output word to 1 to configure the terminal or a certain channel. If bit 15 = 0, the pre-set configuration is active. Bit 14 is of no importance at present, therefore it should be set to 0.

Bit 13 and Bit 12:

Code		Connection Method
dec	bin	
0	**00**	**3-wire**
1	01	2-wire
2	10	4-wire (channel 1 only)
3	11	Reserved

Bit 11 to Bit 8

Code		R_0 [Ω]
dec	bin	
0	**0000**	**100**
1	0001	10
2	0010	20
3	0011	30
4	0100	50
5	0101	120
6	0110	150
7	0111	200

Code		R_0 [Ω]
dec	bin	
8	1000	240
9	1001	300
10	1010	400
11	1011	500
12	1100	1000
13	1101	1500
14	1110	2000
15	1111	3000 (can be set)

Bit 7 and Bit 6:

Code		Resolution for Sensor Type			
dec	bin	0 to 10	13	14	15
0	**00**	**0.1°C**	**1%**	**0.1 Ω**	**1 Ω**
1	01	0.01°C	0.1%	0.01 Ω	0.1 Ω
2	10	0.1°F	Reserved	Reserved	Reserved
3	11	0.01°F			

Bit 5 and Bit 4:

Code		Format
dec	bin	
0	**00**	**Format 1: IB standard (15 bits + sign bit with extended diagnostics)** **Compatible with ST format**
1	01	Format 2 (12 bits + sign bit + 3 diagnostic bits)
2	10	Format 3 (15 bits + sign bit)
3	11	Reserved

Bit 3 to Bit 0:

Code		Sensor Type
dec	bin	
0	**0000**	Pt DIN
1	0001	Pt SAMA
2	0010	Ni DIN
3	0011	Ni SAMA
4	0100	Cu10
5	0101	Cu50
6	0110	Cu53
7	0111	Ni1000 (Landis & Gyr)

Code		Sensor Type
dec	bin	
8	1000	Ni500 (Viessmann)
9	1001	KTY81-110
10	1010	KTY84
11	1011	Reserved
12	1100	Reserved
13	1101	Potentiometer [%]
14	1110	Linear R: 0 through 400 Ω
15	1111	Linear R: 0 through 4000 Ω

12.4 IN Process Data

On each channel the measured values are transmitted to the controller board or the computer by means of the IN process data words.

The three formats for representing the input data are shown in Figure 7. For more detailed information on the formats, please refer to Section "Formats for Representing Measured Values" on page 16.

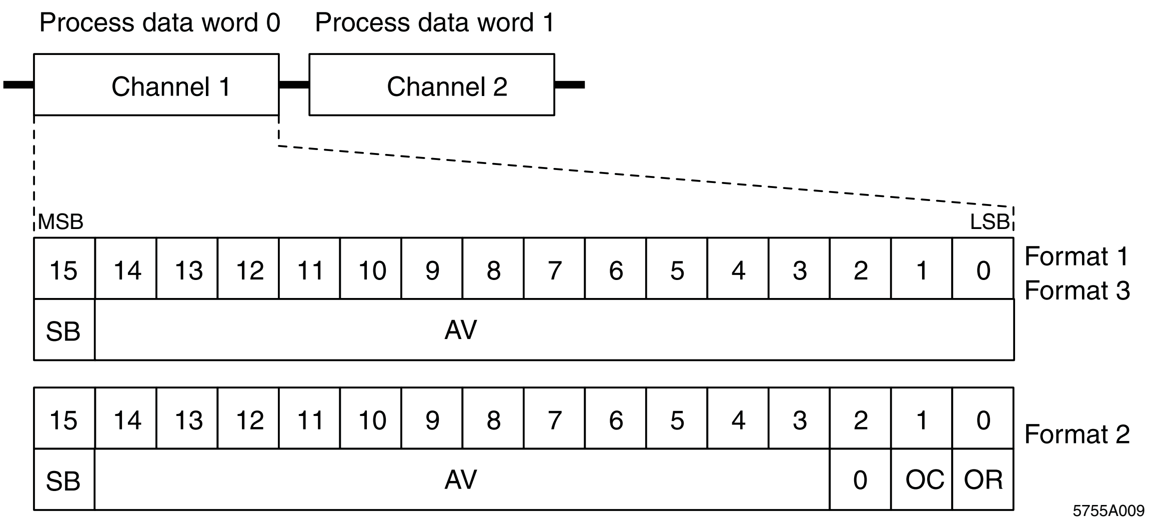


Figure 7 Sequence of the IN process data words and representation of the bits of the first process data word in the different formats

MSB Most significant bit
LSB Least significant bit
SB Sign bit
AV Analog value
0 Reserved
OC Open circuit/short circuit
OR Overrange

The "IB standard" process data format 1 supports extended diagnostics.
The following error codes are possible:

Code (hex)	Error
8001	Overrange
8002	Open circuit or short circuit (only available for the temperature range)
8004	Measured value invalid / no valid measured value available
8010	Invalid configuration
8040	Terminal faulty
8080	Underrange

Open Circuit/Short Circuit Detection:

Open circuit is detected according to the following table:

Faulty Sensor Cable	Temperature Measuring Range			Resistance Measuring Range		
	2-Wire	3-Wire	4-Wire	2-Wire	3-Wire	4-Wire
I+	Yes	Yes	Yes	Yes	Yes	No
I-	Yes	Yes	Yes	Yes	Yes	No
U+	–	–	Yes	–	–	Yes
U-	–	Yes	Yes	–	Yes	Yes

Yes	Open circuit/short circuit is detected.
–	The cable is not connected when using this connection method.
No	Open circuit/short circuit is not detected because the value is a valid measured value.

13 Formats for Representing Measured Values

13.1 Format 1: IB Standard (Default Setting)

The measured value is represented in bits 14 through 0. An additional bit (bit 15) is available as a sign bit.

This format supports extended diagnostics. Values > 8000_{hex} indicate an error. The error codes are listed on on page 15.

Measured value representation in format 1 (IB standard; 15 bits)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SB	AV														

SB Sign bit
AV Analog value

Typical Analog Values Depending on the Resolution

Sensor Type (Bits 3 to 0)		**0 to 10**	**13**	**14**	**15**
Resolution (Bits 7 and 6)		**00_{bin} / 10_{bin}**	**00_{bin}**	**00_{bin}**	**00_{bin}**
Process Data Item (= Analog Value)		**0.1°C / 0.1°F [°C] / [°F]**	**1% [%]**	**0.1 Ω [Ω]**	**1 Ω [Ω]**
hex	**dec**				
8002	–	Open circuit	–	–	–
8001	–	Overrange (see page 21)	–	400	4000
2710	10000	1000.0	–	–	–
0FA0	4000	400.0	4000 (40 x R_0)	400	4000
00A0	10	1.0	10 (0.10 x R_0)	1.0	10
0001	1	0.1	1 (0.01 x R_0)	0.1	1
0000	0	0	0	0	0
FFFF	-1	-0.1	–	–	–
FC18	-1000	-100.0	–	–	–
8080		Underrange (see page 21)	–	–	–
8002		Short circuit	–	–	–

Sensor Type (Bits 3 to 0)		0 to 10	13	14	15
Resolution (Bits 7 and 6)		**01_{bin} / 11_{bin}**	**01_{bin}**	**01_{bin}**	**01_{bin}**
Process Data Item (= Analog Value)		**0.01°C / 0.01°F [°C] / [°F]**	**0.1% [%]**	**0.01 Ω [Ω]**	**0,.1 Ω [Ω]**
hex	**dec**				
8002	–	Open circuit	–	–	–
8001	–	> 325.12 Overrange (see page 21)	–	325.12	3251.2
2710	10000	100.00	1000.0 (10 x R_0)	100.00	1000.0
03E8	4000	10.00	100.0 (1 x R_0)	10.00	100.0
0001	1	0.01	0.1 (0.01 x R_0)	0.01	0.1
0000	0	0	0	0	0
FFFF	-1	-0.01	–	–	–
D8F0	-10000	-100.00	–	–	–
8080		Underrange (see page 21)	–	–	–
8002		Short circuit	–	–	–

If the measured value is outside the representation area of the process data, the "Overrange" or "Underrange" error message is displayed.

13.2 Format 2

This format can be selected for each channel using bits 5 and 4 (bit combination 01_{bin}) of the corresponding process data output word.

The measured value is represented in bits 14 through 3. The remaining 4 bits are sign and error bits.

Measured value representation in format 2 (12 bits)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SB	AV												0	OC	OR

SB Sign bit
AV Analog value
0 Reserved
OC Open circuit/short circuit
OR Overrange

Typical Analog Values Depending on the Resolution

Sensor Type (Bits 3 to 0)		RTD Sensor (0 to 13)	
Resolution (Bits 7 and 6)		00_{bin} / 10_{bin}	01_{bin} / 11_{bin}
Process Data Item (= Analog Value)		0.1°C / 0.1°F	0.01°C / 0.01°F
hex	dec	[°C] / [°F]	[°C] / [°F]
xxxx xxxx xxxx $xxx1_{bin}$		Overrange (AV = positive final value from the table on page 21)	
2710	10000	1000.0	100.00
03E8	1000	100.0	10.00
0008	8	0.8	0.08
0000	0	0	0
FFF8	-8	-0.8	-0.08
FC18	-1000	-100.0	-10.00
xxxx xxxx xxxx $xxx1_{bin}$		Underrange (AV = negative final value from the table on page 21)	
xxxx xxxx xxxx $xx1x_{bin}$		Open circuit/short circuit (AV = negative final value from the table on page 21)	

AV Analog value
x Can accept values 0 or 1

> If the measured value is outside the representation area of the process data, bit 0 is set to 1.
>
> In the event of an open circuit/short circuit, bit 1 is set to 1.

13.3 Format 3

This format can be selected for each channel using bits 5 and 4 (bit combination 10_{bin}) of the corresponding process data output word.

The measured value is represented in bits 14 through 0. An additional bit (bit 15) is available as a sign bit.

Measured value representation in format 3 (15 bits)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SB	AV														

SB Sign bit AV Analog value

Typical Analog Values Depending on the Resolution

Sensor Type (Bits 3 to 0)		RTD Sensor (0 to 10)	Linear Resistance (15)
Resolution (Bits 7 and 6)		00_{bin} / 10_{bin}	00_{bin}
Process Data Item (= Analog Value)		0.1°C / 0.1°F [°C] / [°F]	1 Ω [Ω]
hex	dec		
7FFF	32767	–	> 2048
Upper limit value* + 1 LSB		Overrange	–
7D00	32000	–	2000
2710	10000	1000.0	625
000A	10	1	0.625
0001	1	0.1	0.0625
0000	0	0	0
FFFF	-1	-0.1	–
FC18	-1000	-100.0	–
Lower limit value* - 1 LSB		Underrange	–
Lower limit value* - 2 LSB		Open circuit/short circuit	–

Sensor Type (Bits 3 to 0)		RTD Sensor (0 to 10)	Linear Resistance (15)
Resolution (Bits 7 and 6)		01_{bin} / 11_{bin}	01_{bin}
Process Data Item (= Analog Value)		0.01°C / 0.01°F [°C] / [°F]	0,1 Ω [Ω]
hex	dec		
7FFF	32767	–	> 4096
Upper limit value* + 1 LSB		Overrange	–
7D00	32000	320.00	4000
2710	10000	100.0	1250
0001	1	0.1	0.125
0000	0	0	0
FFFF	-1	-1.0	–
D8F0	-10000	-100.0	–
Lower limit value* - 1 LSB		Underrange	–
Lower limit value* - 2 LSB		Open circuit/short circuit	–

* The limit values can be found on page 21.

14 Measuring Ranges

14.1 Measuring Ranges Depending on the Resolution (Format IB Standard)

Resolution	Temperature Sensors
00	-273°C up to +3276.8°C resolution: 0.1°C
01	-273°C up to +327.68°C resolution: 0.01°C
10	-459°F up to +3276.8°F resolution: 0.1°F
11	-459°F up to +327.68°F resolution: 0.01°F

Temperature values can be converted from °C to °F with this formula:

$$T\,[°F] = T\,[°C] \times \frac{9}{5} + 32$$

Where:

T [°F] Temperature in °F
T [°C] Temperature in °C

14.2 Input Measuring Values

No.	Input	Sensor Type	Measuring Range (Software-Supported) Lower Limit	Measuring Range (Software-Supported) Upper Limit
0	Temperature sensors	Pt R_0 10 Ω to 3000 Ω acc. to DIN	-200°C	+850°C
1		Pt R_0 10 Ω to 3000 Ω acc. to SAMA	-200°C	+850°C
2		Ni R_0 10 Ω to 3000 Ω acc. to DIN	-60°C	+180°C
3		Ni R_0 10 Ω to 3000 Ω acc. to SAMA	-60°C	+180°C
4		Cu10	-70°C	+500°C
5		Cu50	-50°C	+200°C
6		Cu53	-50°C	+180°C
7		Ni1000 L&G	-50°C	+160°C
8		Ni500 (Viessmann)	-60°C	+250°C
9		KTY81-110	-55°C	+150°C
10		KTY84	-40°C	+300°C
11	Reserved			
12				
13	Relative potentiometer range		0%	4 kΩ / R_0 x 100% (400%, maximum)
14	Linear resistance measuring range		0 Ω	400 Ω
15			0 Ω	4000 Ω

The number (No.) corresponds to the code of the sensor type in bit 3 through bit 0 of the process data output word.

15 Measuring Errors

15.1 Systematic Measuring Errors During Temperature Measurement Using Resistance Thermometers

When measuring temperatures using resistance thermometers, systematic measuring errors are often the cause of incorrectly measured results.

There are three main ways to connect the sensors: 2, 3, and 4-wire technology.

4-Wire Technology

4-wire technology is the most precise way of measuring (see Figure 8).

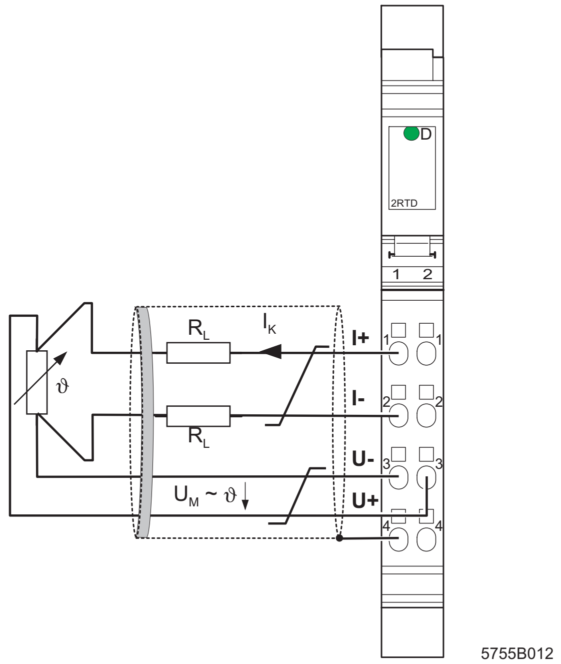


Figure 8 Connection of resistance thermometers in 4-wire technology

In 4-wire technology, a constant current is sent through the sensor via the I+ and I- cables. Two further cables U+ and U- can be used to tap and measure the temperature-related voltage at the sensor. The cable resistances have absolutely no effect on the measurement.

3-Wire Technology

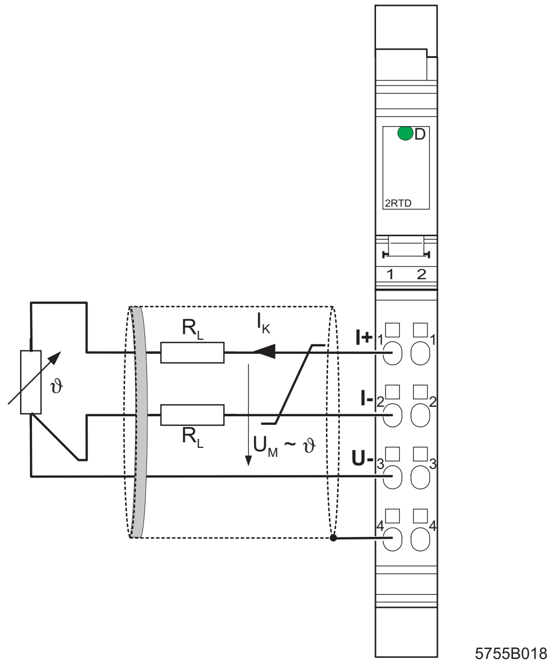


Figure 9 Connection of resistance thermometers in 3-wire technology

In 3-wire technology, the effect of the cable resistance on the measured result in the terminal is eliminated or minimized by multiple measuring of the temperature-related voltage and corresponding calculations. The results are almost as good in terms of quality as with 4-wire technology in Figure 8. However, 4-wire technology offers better results in environments with heavy noise.

2-Wire Technology

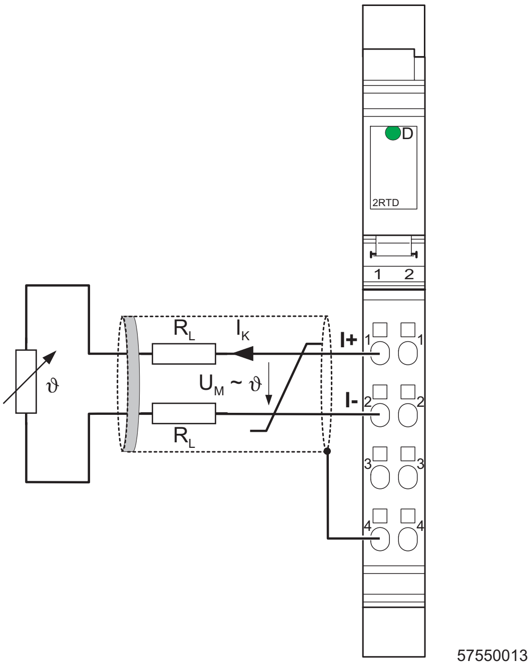


Figure 10 Connection of resistance thermometers in 2-wire technology

2-wire technology is a cost-effective connection method. The U+ and U- cables are no longer needed. The temperature-related voltage is not directly measured at the sensor and therefore not falsified by the two cable resistances R_L (see Figure 10).

The measuring errors that occur can make the entire measurement unusable (see diagrams in Figure 11 to Figure 13). However, these diagrams also show the positions in the measuring system where steps can be taken to minimize these errors.

15.2 Systematic Errors During Temperature Measurement Using 2-Wire Technology

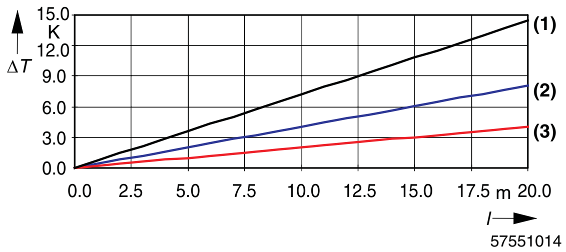


Figure 11 Systematic temperature measuring error ΔT depending on the cable length l

Curves depending on the cable diameter A

(1) Temperature measuring error for A = 0.14 mm^2

(2) Temperature measuring error for A = 0.25 mm^2

(3) Temperature measuring error for A = 0.50 mm^2

(Measuring error valid for:
copper cable χ = 57 m/Ωmm^2, T_A = 25°C and Pt100 sensor)

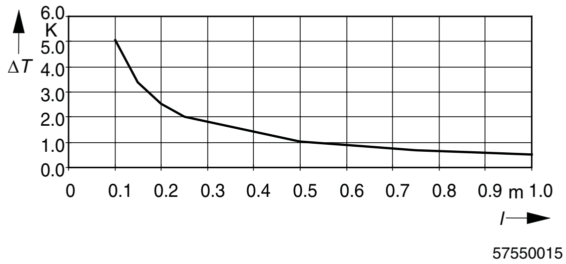


Figure 12 Systematic temperature measuring error ΔT depending on the cable diameter A

(Measuring error valid for:
Copper cable χ = 57 m/Ωmm^2, T_A = 25°C, l = 5 m and Pt100 sensor)

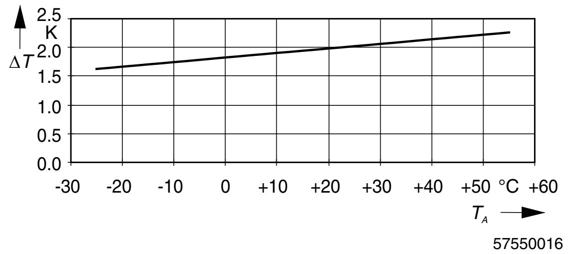


Figure 13 Systematic temperature measuring error ΔT depending on the cable temperature T_A

(Measuring error valid for:
Copper cable χ = 57 m/Ωmm^2, l = 5 m, A = 0.25 mm^2 and Pt100 sensor)

All diagrams show that the increase in cable resistance causes the measuring error.

A considerable improvement is made through the use of Pt1000 sensors. Due to the 10-fold higher temperature coefficient α (α = 0.385 Ω/K for Pt100 to α = 3.85 Ω/K for Pt1000) the effect of the cable resistance on the measurement is decreased by factor 10. All errors in the diagrams above would be reduced by factor 10.

Diagram 1 clearly shows the influence of the cable length on the cable resistance and therefore on the measuring error. The solution is to use the shortest possible sensor cables.

Diagram 2 shows the influence of the cable diameter on the cable resistance. It can be seen that cables with a diameter of less than 0.5 mm^2 cause errors to increase exponentially.

Diagram 3 shows the influence of the ambient temperature on the cable resistance. This parameter does not play a great role and can hardly be influenced but it is mentioned here for the sake of completeness.

The formula for calculating the cable resistance is as follows:

$$R_L = R_{L20} \times (1 + 0.0043 \frac{1}{K} \times T_A)$$

$$R_L = \frac{l}{\chi \times A} \times (1 + 0.0043 \frac{1}{K} \times T_A)$$

Where:

R_L	Cable resistance in Ω
R_{L20}	Cable resistance at 20°C in Ω
l	Cable length in m
χ	Specific electrical resistance of copper in $\Omega mm^2/m$
A	Cable cross-section in mm^2
0.0043 1/K	Temperature coefficient for copper
T_A	Ambient temperature (cable temperature) in °C

Since there are two cable resistances in the measuring system (forward and return), the value must be doubled.

The absolute measuring error in Kelvin [K] is provided for platinum sensors according to DIN using the average temperature coefficient α (α = 0.385 Ω/K for Pt100; α = 3.85 Ω/K for Pt1000).

16 Tolerance and Temperature Response

Typical Measuring Tolerances at 25°C

	α at 100°C	2-Wire Technology		3-Wire Technology		4-Wire Technology	
		Relative [%]	Absolute	Relative [%]	Absolute	Relative [%]	Absolute
Temperature Sensors							
Pt00	0.385 Ω/K	±0.03 + x	±0.26 K + x	±0.03	±0.26 K	±0.02	±0.2 K
Pt1000	3.85 Ω/K	±0.04 + x	±0.31 K + x	±0.04	±0.31 K	±0.03	±0.26 K
Ni100	0.617 Ω/K	±0.09 + x	±0.16 K + x	±0.09	±0.16 K	±0.07	±0.12 K
Ni1000	6.17 Ω/K	±0.11 + x	±0.2 K + x	±0.11	±0.2 K	±0.09	±0.16 K
Cu50	0.213 Ω/K	±0.24 + x	±0.47 K + x	±0.24	±0.47 K	±0.18	±0.35 K
Ni1000 L&G	5.6 Ω/K	±0.13 + x	±0.21 K + x	±0.13	±0.21 K	±0.11	±0.18 K
Ni500 Viessmann	2.8 Ω/K	±0.17 + x	±0.43 K + x	±0.17	±0.43 K	±0.14	±0.36 K
KTY81-110	10.7 Ω/K	±0.07 + x	±0.11 K + x	±0.07	±0.11 K	±0.06	±0.09 K
KTY84	6.2 Ω/K	±0.06 + x	±0.19 K + x	±0.06	±0.19 K	±0.05	±0.16 K
Linear Resistance							
0 Ω to 400 Ω		±0.025 + x	±100 mΩ + x	±0.025	±100 mΩ	±0.019	±75 mΩ
0 Ω to 4 kΩ		±0.03 + x	±1.2 Ω + x	±0.03	±1.2 Ω	±0.025	±1 Ω

α: Average sensitivity for the calculation of tolerance values.

x: Additional error due to connection using 2-wire technology (see "Systematic Errors During Temperature Measurement Using 2-Wire Technology" on page 24).

Maximum Measuring Tolerances at 25°C

	α at 100°C	2-Wire Technology		3-Wire Technology		4-Wire Technology	
		Relative [%]	Absolute	Relative [%]	Absolute	Relative [%]	Absolute
Temperature Sensors							
Pt100	0.385 Ω/K	±0.12 + x	±1.04 K + x	±0.12%	±1.04 K	±0.10%	±0.83 K
Pt1000	3.85 Ω/K	±0.15 + x	±1.3 K + x	±0.15%	±1.3 K	±0.12%	±1.04 K
Ni100	0.617 Ω/K	±0.36 + x	±0.65 K + x	±0.36%	±0.65 K	±0.29%	±0.52 K
Ni1000	6.17 Ω/K	±0.45 + x	±0.81 K + x	±0.45%	±0.81 K	±0.36%	±0.65 K
Cu50	0.213 Ω/K	±0.47 + x	±0.94 K + x	±0.47%	±0.94 K	±0.38%	±0.75 K
Ni1000 L&G	5.6 Ω/K	±0.56 + x	±0.89 K + x	±0.56%	±0.89 K	±0.44%	±0.71 K
Ni500 Viessmann	2.8 Ω/K	±0.72 + x	±1.79 K + x	±0.72%	±1.79 K	±0.57%	±1.43 K
KTY81-110	10.7 Ω/K	±0.31 + x	±0.47 K + x	±0.31%	±0.47 K	±0.25%	±0.37 K
KTY84	6.2 Ω/K	±0.27 + x	±0.81 K + x	±0.27%	±0.81 K	±0.22%	±0.65 K
Linear Resistance							
0 Ω to 400 Ω		±0.10 + x	±400 mΩ + x	±0.10%	±400 mΩ	±0.08%	±320 mΩ
0 Ω to 4 kΩ		±0.13 + x	±5 Ω + x	±0.13%	±5 Ω	±0.10%	±4 Ω

α: Average sensitivity for the calculation of tolerance values.

x: Additional error due to connection using 2-wire technology (see "Systematic Errors During Temperature Measurement Using 2-Wire Technology" on page 24).

Temperature Response at -25°C to 55°C

	Typical	Maximum
2, 3, and 4-wire technology	±12 ppm/°C	±45 ppm/°C