Rexroth Inline terminal with 2 inputs for temperature sensors

R911170604
Edition 01

R-IB IL TEMP 2 RTD-PAC

2 analog input channels
Connection of temperature sensors
2, 3, and 4-wire technology

04/2008

1 Description

The terminal is designed for use within an Inline station. This terminal provides an two-channel input module for resistive temperature sensors. This terminal supports platinum and nickel sensors according to the DIN standard and the SAMA guideline. 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 application description for the Rexroth Inline system (see "Documentation" on page 3).

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

Table of contents

2 Ordering data

Products

Description	Type	MNR	Pcs./Pkt.
Rexroth Inline terminal with two resistive temperature sensor inputs, complete with accessories (connector and labeling field)	R-IB IL TEMP 2 RTD-PAC	R911170785	1

Documentation

Description	Type	MNR	Pcs./Pkt.
"Automation Terminals of the Rexroth Inline Product Range" application description	DOK-CONTRL-ILSYSINS***-AW..-EN-P	R911317021	1
"Configuring and Installing the Rexroth Inline Product Range for INTERBUS" application description	DOK-CONTRL-ILSYSPRO***-AW..-EN-P	R911317023	1

For additional ordering data (accessories), please refer to the product catalog at www.boschrexroth.com.

3 Technical data

General data	
Housing dimensions (width x height x depth)	12.2 mm x 136 mm x 72 mm (with connector)
Weight	67 g (with connector)
Operating mode	Process data mode with 2 words
Connection method for sensors	2, 3, and 4-wire technology
Ambient temperatures (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
Class of protection	III, IEC 61140
Connection data for Inline connectors	
Connection type	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	
R-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), 60 mA (maximum)
I/O supply voltage U_{ANA}	24 V DC
Current consumption at U_{ANA}	11 mA (typical), 18 mA (maximum)
Total power consumption	587 mW (typical), 882 mW (maximum)

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	Depends 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	
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	
Peripheral fault/user error	Yes (see page 13)

Approvals
For the latest approvals, please visit www.boschrexroth.com.

4 Local diagnostic indicators and terminal point assignment

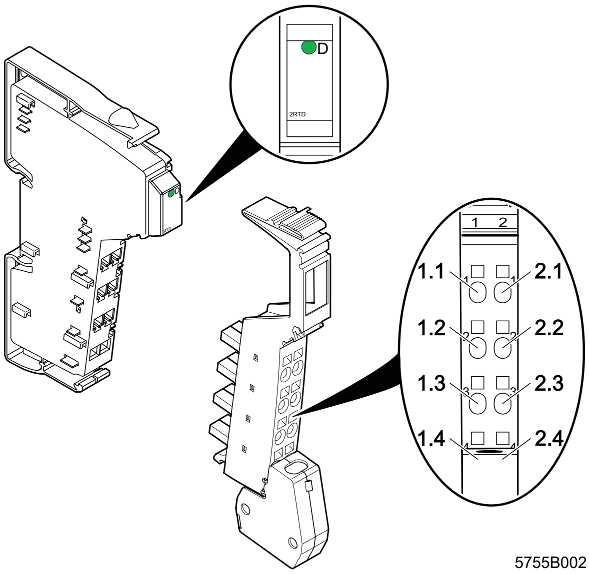


Fig. 1 Terminal with appropriate connector

4.1 Local diagnostic indicator

Des.	Color	Meaning
D	Green	Diagnostics

4.2 Function identification

Green

4.3 Terminal point assignment for 2/3-wire termination

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 termination on channel 1 and 2-wire termination 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)

A sensor can only be connected to channel 1 using 4-wire technology.

4.5 Safety note

CAUTION

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

5 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:

CAUTION

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 after all the other terminals at the end of the main circuit.

6 Internal circuit diagram

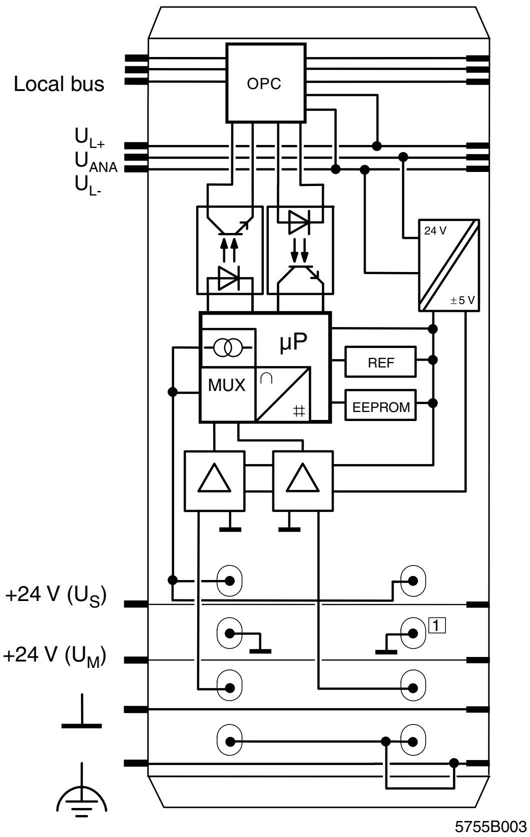
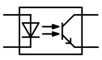
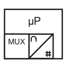


Fig. 2 Internal wiring of the terminal points

Key:

	Protocol chip
	Optocoupler
	DC/DC converter with electrical isolation
	Microprocessor with multiplexer, power source for the cold junction and analog/digital converter
	Reference voltage
	Electrically erasable programmable read-only memory
	Amplifier

Other symbols used are explained in the application descriptions for the Rexroth Inline system (see "Documentation" on page 3) or the application description for your bus system.

7 Electrical isolation

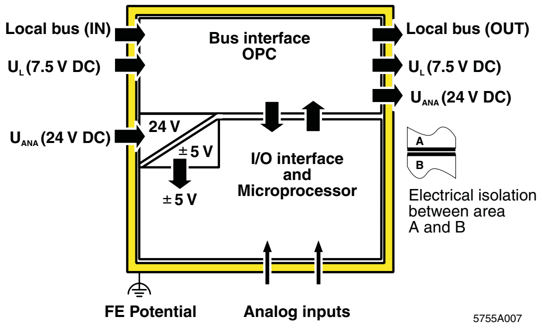


Fig. 3 Electrical isolation of the individual function areas

8 Connection notes

8.1 Thermocouple connection

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

8.2 Shield connection

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

Connect the shield to only one side of 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.

Insulate the shield at the sensor.

8.3 Sensor connection in 4-wire technology

A sensor can only be connected to channel 1 in 4-wire technology. In this case the sensor can only be connected to channel 2 using 2-wire technology.

9 Connection examples

When connecting the shield at the terminal you must insulate the shield on the sensor side (shown in gray in Fig. 4 and Fig. 5).
Use a connector with shield connection when installing the sensors. Fig. 4 shows the connection schematically (without shield connector).

9.1 Connection of passive sensors

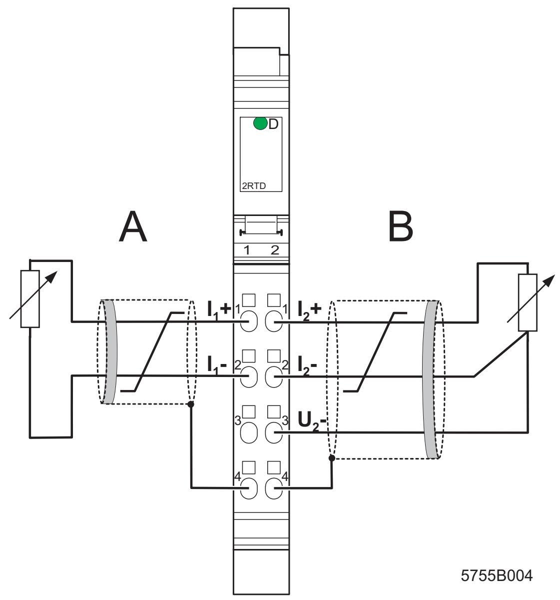


Fig. 4 Connection of sensors in 2 and 3-wire technology with shield connection

A	Channel 1; 2-wire technology
B	Channel 2; 3-wire technology

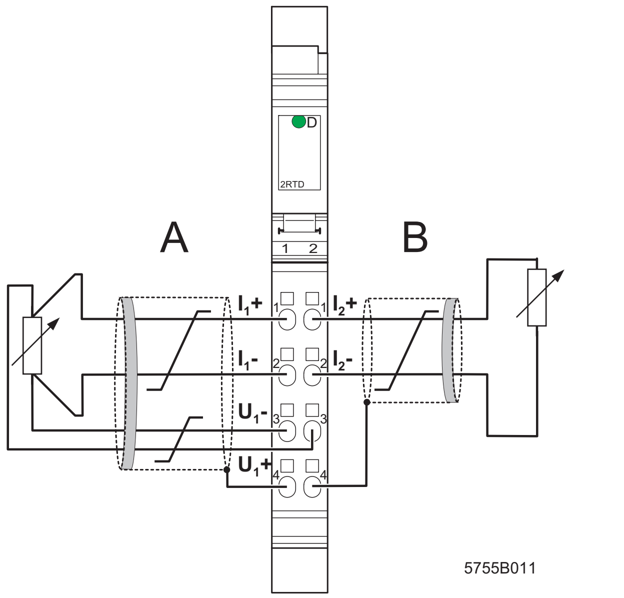


Fig. 5 Connection of sensors in 4 and 2-wire technology with shield connection

A	Channel 1; 4-wire technology
B	Channel 2; 2-wire technology

9.2 Connection of a potentiometer

1. **Connection and direct percent evaluation of a 2-kΩ potentiometer at channel 1 in 2-wire technology**

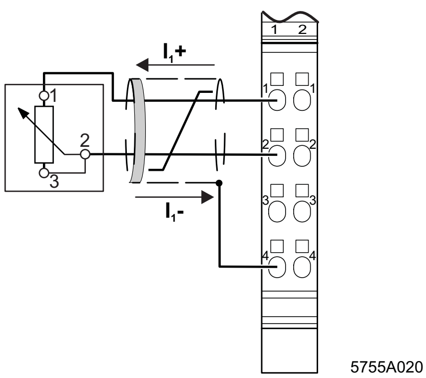


Fig. 6 Connection of a potentiometer at channel 1 in 2-wire technology with shield connection

2. **Connection and direct percent evaluation of a 2-kΩ potentiometer at channel 1 in 3-wire technology**

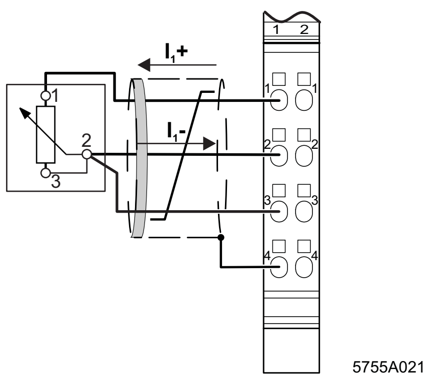


Fig. 7 Connection of a potentiometer at channel 1 in 3-wire technology with shield connection

Parameterization using the output process data (see "OUT process data" on page 10)

For example 1 (2-wire technology)

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Assignment	1	0	0	1	1	1	1	0	0	1	0	0	1	1	0	1
Meaning	Configur-ation		Connection type		R0				Resolution		Format		Sensor type			
Setting			2-wire		2 kΩ				0.1%		IB standard		Potentiometer ($D_{hex}/13_{dec}$)			

For example 2 (3-wire technology)

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Assignment	1	0	0	0	1	1	1	0	0	1	0	0	1	1	0	1
Meaning	Configura-tion		Connection type		R0				Resolution		Format		Sensor type			
Setting			3-wire		2 kΩ				0.1%		IB standard		Potentiometer ($D_{hex}/13_{dec}$)			

Operation and evaluation of the input process data

No.	Position of the potentiometer slider tap	Potentiometer resistance at tap	Value in the input process data word	Percentage value
1	Open	2000 Ω	1000	100.0%
2	Center	1000 Ω	500	50.0%
3	Almost closed	22.0 Ω	11	1.1%
4	Closed	0 Ω	0	0.0%

10 Programming data/configuration data

Local bus

ID code	$7F_{hex}$ (127_{dec})
Length code	02_{hex}
Process data channel	32 bits
Input address area	2 words
Output address area	2 words
Parameter channel (PCP)	0 words
Register length (bus)	2 words

Other bus systems

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

11 Process data

11.1 Output data words for configuring the terminal (see page 10)

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

11.2 Assignment of terminal points to the input data word (see page 12)

(Word.bit) view	Word	Word 0															
	Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Terminal points channel 1	Signal	Terminal point 1.1: I1+ Sensor 1															
	Signal reference	Terminal point 1.2: I_1- Sensor 1								Terminal point 1.3 U_1- sensor 1							
	Shield (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
Terminal points channel 2	Signal	Terminal point 2.1: I2+ Sensor 2															
	Signal reference	Terminal point 2.2: I_2- Sensor 2								Terminal point 2.3 U_1+ sensor 2							
	Shield	Terminal point 2.4															

11.3 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
- Sensor type setting

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. 4-wire connection is only available for channel 1.

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

The configuration settings are stored in a volatile memory only. They must be transmitted in every 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:	3-wire technology
R_0:	100 Ω
Resolution:	0.1°C
Format:	Format 1 (IB standard)
Sensor type:	Pt100 (DIN)

If the configuration changes, the corresponding channel is re-initialized. The "Measured value invalid" message (error code 8004_{hex}) appears in the IN process data 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. As this format is preset on the terminal, it is available immediately after the voltage has been applied.

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

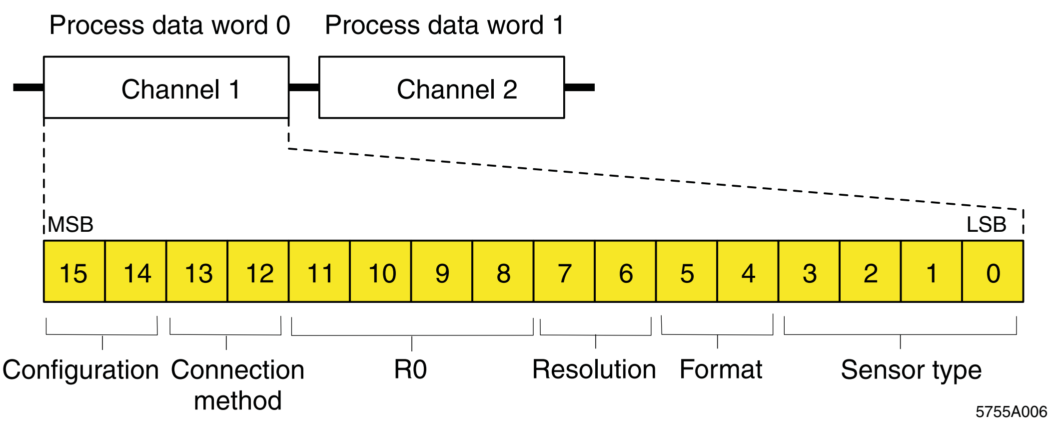


Fig. 8 OUT process data words

Bit 15 and bit 14:

In order to configure the terminal or a specific channel, set bit 15 of the corresponding output word to 1. If bit 15 = 0, the pre-set configuration is active. Bit 14 is currently not used, therefore set it to 0.

Bit 13 and bit 12:

Code		Connection type
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
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 the 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)
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

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.

Basically three formats are available for the representation of the input data, they are shown in Fig. 9. For more detailed information on the formats, please refer to Section "Formats for representing measured values" on page 14.

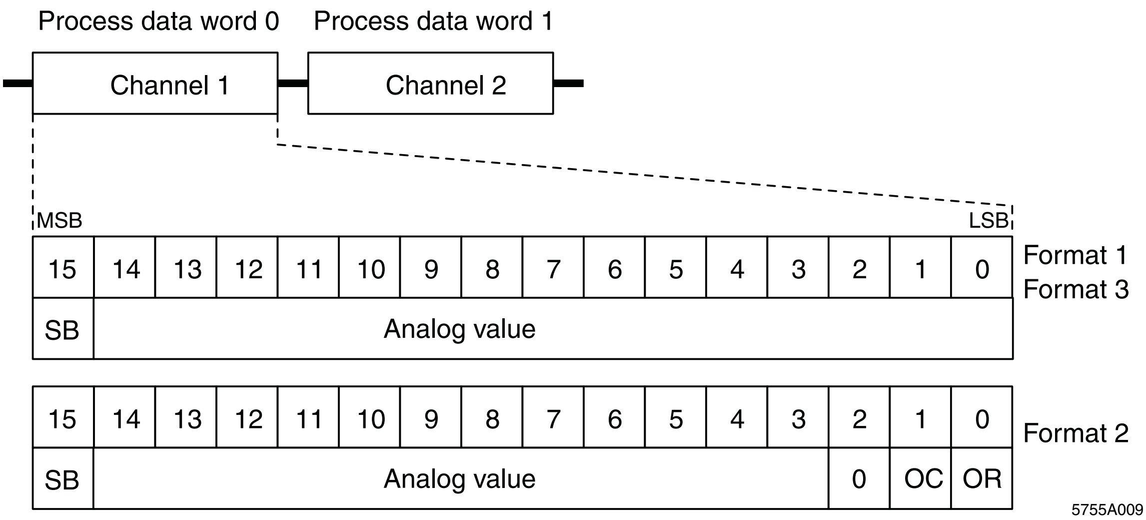


Fig. 9 Sequence of the IN process data words and representation of the bits of the first process data word in the different formats

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:

The following table shows how an open circuit is detected:

Defective 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.
–	For this connection method a cable is not connected.
No	Open circuit/short circuit is not detected because the value is a valid measured value.

12 Formats for representing measured values

12.1 Format 1: IB standard (default setting)

The measured value is represented in bits 14 to 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 page 13.

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 18)	–	> 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 (cf. Table page 18)	–	–	–
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	–	Overrange (see page 18)	–	> 325.12	> 3251.2
2710	10000	100.00	1000.0 (10 x R_0)	100.00	1000.0
03E8	1000	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 18)	–	–	–
8002		Short circuit	–	–	–

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

12.2 Format 2

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

The measured value is represented in bits 14 to 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 10)**	
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 18)	
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 18)	
xxxx xxxx xxxx $xx1x_{bin}$		Open circuit/short circuit (AV = negative final value from the table on page 18)	

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.

12.3 Format 3

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

The measured value is represented in bits 14 to 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	–

* For the limit values, please refer to page 18.

13 Measuring ranges

13.1 Measuring ranges depending on the resolution (IB standard format)

Resolution (Bits 7 and 6)	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 according to the following formula:

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

Where:

T [°F] Temperature in °F

T [°C] Temperature in °C

13.2 Input measuring ranges

No.	Input	Sensor type		Measuring range (software-supported)	
				Lower limit	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 OUT process data word.

14 Measuring errors

14.1 Systematic measuring errors during temperature measurement using resistance thermometers

When measuring temperatures using resistance thermometers, systematic measuring errors are often the cause for incorrect measuring results.

There are three possibilities of connecting sensors: 2, 3, and 4-wire technology.

4-wire technology

4-wire technology is the most precise way of measuring (see Fig. 10).

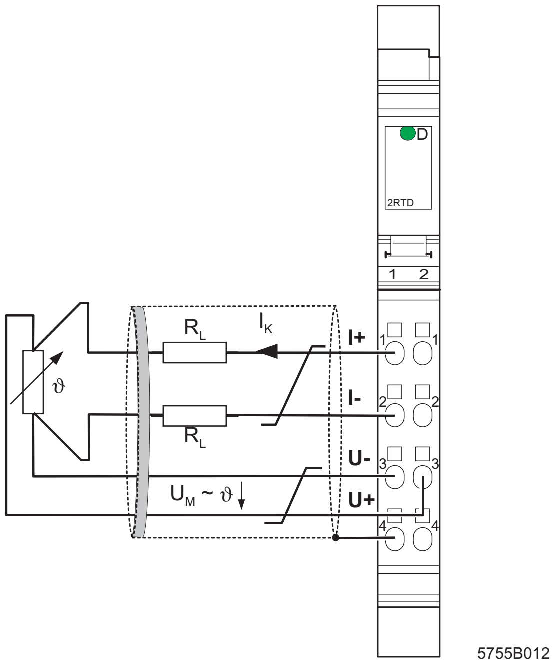


Fig. 10 Connection of resistance thermometers in 4-wire technology

When using the 4-wire technology, a constant current is sent through the sensor via conductors I+ and I-. With the other two conductors U+ and U-, the temperature-related voltage is tapped and measured at the sensor. The conductor resistances do not influence the measurement.

3-wire technology

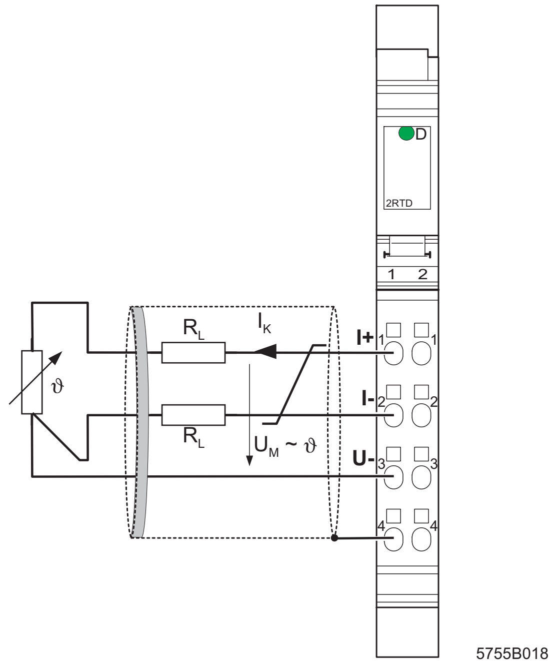


Fig. 11 Connection of resistance thermometers in 3-wire technology

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 Fig. 10. However, the 4-wire technology provides better results in environments subject to heavy noise.

2-wire technology

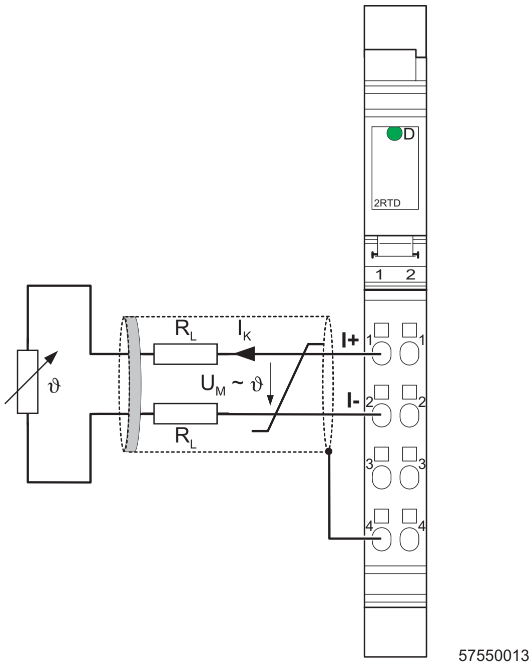


Fig. 12 Connection of resistance thermometers in 2-wire technology

2-wire technology is the most cost-effective connection method. The U+ and U- cables are no longer needed. Temperature-related voltage is not directly measured at the sensor and therefore falsified by the two cable resistances R_L (see Fig. 12).

The measuring errors that occur may lead to the entire measurement to become useless (see diagrams in Fig. 13 to Fig. 15). However, these diagrams show at which points of the measurement system measures can be taken to minimize these errors.

14.2 Systematic errors during temperature measurement using 2-wire technology

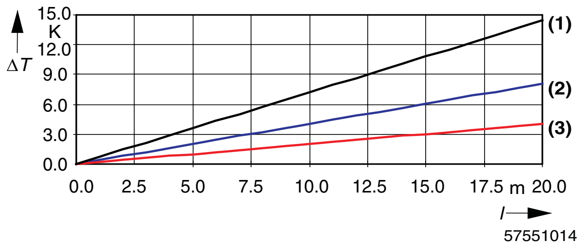


Fig. 13 *Systematic temperature measuring error ΔT depending on the cable length l*

Curves depending on the cable cross section 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)

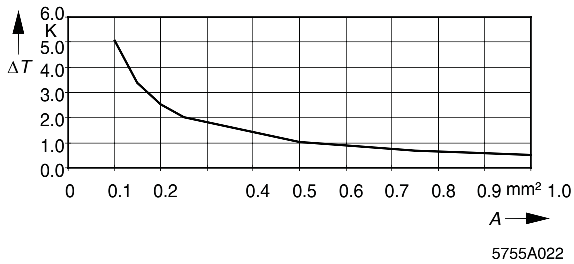


Fig. 14 *Systematic temperature measuring error ΔT depending on the cable cross section A*

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

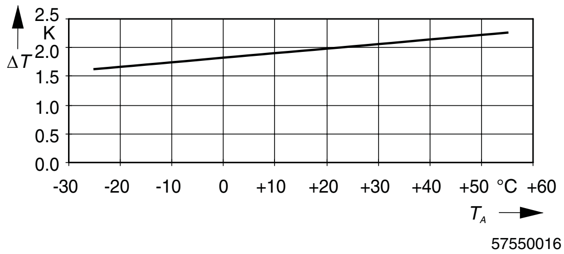


Fig. 15 *Systematic temperature measuring error ΔT depending on the cable temperature T_A*

(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 a factor 10.

Diagram 1 clearly shows the effect 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 cross section of less than 0.5 mm^2 cause errors to increase exponentially.

Diagram 3 shows the effect 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:

$$R_L = R_{L20} \text{ x } \left(1 + 0.0039 \frac{1}{K} \text{ x } (T_A - 20°C)\right)$$

$$R_L = \frac{l}{\chi \text{ x } A} \text{ x } \left(1 + 0.0039 \frac{1}{K} \text{ x } (T_A - 20°C)\right)$$

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 m/Ωmm^2
A	Cable cross-section in mm^2
0.0039 1/K	Temperature coefficient for copper (percentage purity of 99.9%)
T_A	Ambient temperature (cable temperature) in °C

Since there are two cable resistances in the measuring system (forward and return line), 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).

15 Tolerance and temperature response

α: Medium sensitivity to calculate the tolerance values.

x: Additional error when the connection is made using 2-wire technology (see "Systematic errors during temperature measurement using 2-wire technology" on page 21).

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							
Pt100	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 v

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

All errors indicated as a **percentage** are related to the positive measuring range final value.
The **maximum** tolerances contain the theoretical maximum possible tolerances. The data refers to nominal operation (installation on horizontal mounting rail, U_S = +24 V). Please also observe the values for temperature drift and the tolerances under EMI.

Temperature response at -25°C to 55°C

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

Additional tolerances influenced by electromagnetic fields

Type of electromagnetic interference	Typical deviation from the measuring range final value	Criterion
Electromagnetic fields; Field strength 10 V/m according to EN 61000-4-3/IEC 61000-4-3	< ±1.51%	A
Conducted interference Class 3 (test voltage 10 V) according to EN 61000-4-6/IEC 61000-4-6	< ±0.92%	A
Fast transients (burst) Class 3 according to EN 61000-4-4/IEC 61000-4-4	< ±0.24%	A

Notes:

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