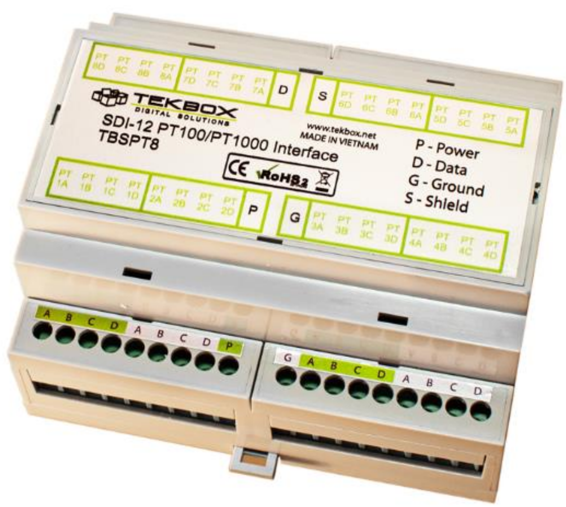
V1.0

TBSPT8-DR

SDI-12 8-Channel PT100/PT1000 INTERFACE

The TBSPT8-DR is a precision 8 – channel PT100/PT1000 interface. Measurement and configuration is controlled via SDI-12 commands. The interface is equipped with 4-wire inputs, matched noise filters, surge- and over voltage protection.
To achieve high precision, the TBSPT8-DR is calibrated to an absolute accuracy of ±0.02°C at 0°C, using a ±0.005%, ± 2ppm/°C resistance standard.
The device has a resolution of 0,001°C and a temperature drift less than ±0,01°C over the temperature range -40°C to + 80°C. Noise is ±0,0015°C when used with PT1000 sensors and ±0,01°C when used with PT100 sensors.
The device can output the measurement results in °Celsius or °Fahrenheit.



TBSPT8-DR 8 channel PT100/PT1000 interface

Features

- Precision, 4-wire PT100/PT1000 interface
- 8 measurement channels
- Resolution: 0.001°C
- Noise: ± 0.0015°C (PT1000)
- Absolute accuracy at 0°C: ± 0.02°C
- Measurement range: -80°C to +300°C
- Temperature drift: < ± 0.01°C
- Configurable measurement units: °C, °Fahrenheit
- Surge- and over voltage protection
- SDI - 12 standard V1.3
- Plug and play
- 6 - 16V supply voltage
- 115 mm x 90 mm x 57mm
- Din-rail housing
- Operating temperature range: - 40°C … + 85°C

Target Applications

- Environmental monitoring
- SDI-12 sensor networks

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Contents

Tables

Figures

1 Introduction

The TBSPT8-DR is a precision PT100/PT1000 4-wire interface for environmental monitoring applications. Measurement and configuration is controlled via SDI-12 commands.

1.1 Product features

- 8 PT100/PT1000 channels
- 4 – wire connectivity
- Input surge- and over voltage protection
- Input noise filter, 50Hz & 60Hz line rejection
- Measurement temperature range: - 80°C to + 300°C
- Operating temperature range: - 40 to + 80°C
- Resolution: 0.001°C (PT100/PT1000)
- Noise: ± 0.01°C (PT100); ± 0.001°C (PT1000)
- Compensated temperature drift of the measurement hardware: < ± 0.015°C
- Absolute accuracy at 0°C: better ± 0.02°C
- SDI-12 interface
- Supply voltage: 6V to 16V, nominal 12V
- Input protection
- DIN-rail housing
- Dimensions: 115mm x 90mm x 57mm
- Conformal coating

1.2 Calibration

The TBSPT8-DR is factory calibrated with respect to absolute accuracy at 0°C and temperature drift compensation.

The user can calibrate the absolute accuracy of the device using an extended SDI-12 command. Furthermore it requires 100 Ohm/1000 Ohm resistance standards with an accuracy of at least 0.005%, ± 2ppm/°C.

User calibration of the temperature drift compensation is not necessary. Nevertheless there is a corresponding extended SDI-12 command available. However it requires a thermal chamber to carry out the drift calibration process.

See chapter 3 for more details about calibration.

1.3 Sensor accuracy

The table below gives an overview on the accuracy classes of commercially available platinum sensors.

Class	**+/- limit deviations in ºC (K)**	area of validity of temperature class
DIN 60751, class B	0.30 + 0.005 x | t |	-200°C to 850°C
DIN 60751, class A	0.15 + 0.002 x | t |	-90°C to 300°C
⅓DIN 60751, class B	0.10 + 0.0017 x | t |	-50°C to 150°C
2DIN 60751, class B	0.60 + 0.01 x | t |	-200°C to 850°C
1/5 DIN 60751, class B	0.06 + 0.001 x | t |	manufacturer dependent
1/10 DIN 60751, class B	0.03 + 0.0005 x | t |	manufacturer dependent

Table 1 – Pt RTD classes

| t **|** is the numerical value of the temperature in °C without taking into account either negative or positive signs.

The performance of the TBSPT8 is optimized for PT1000 sensors. Use it instead of PT100 for maximum accuracy.

1.4 Installation

The TBSPT8-DR is compatible with any data logger or remote telemetry unit with SDI-12 interface. Refer to the data logger or RTU manual and to chapter 2 of this datasheet.

1.5 SDI-12

SDI-12 is a standard for interfacing data recorders with microprocessor-based sensors. SDI-12 stands for serial/digital interface at 1200 baud. It can connect multiple sensors with a single data recorder on one cable. It supports up to 60 meter cable between a sensor and a data logger.

The SDI-12 standard is prepared by

SDI-12 Support Group
(Technical Committee)
165 East 500 South
River Heights, Utah
435-752-4200
435-752-1691 (FAX)
http://www.sdi-12.org

The latest standard is version V1.3 which dates from July 18th, 2005. The standard is available on the website of the SDI-12 Support Group.

More information on SDI-12 is presented in chapter 3.

2 Application examples

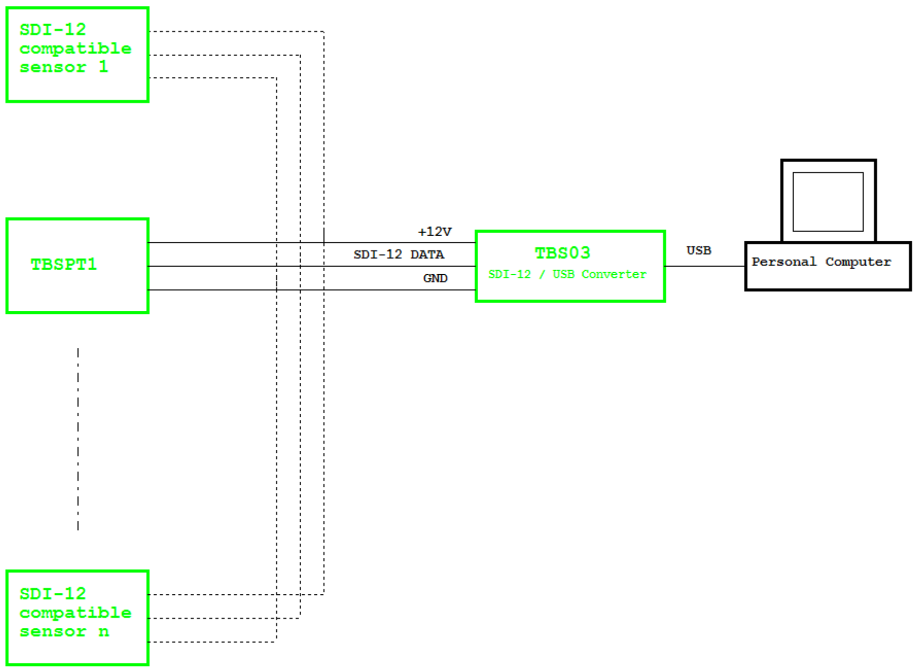

Figure 1 –TBSPT8 and other sensors with SDI-12 interface connected to TBS03 SDI-12 to USB converter; setup for controlling / testing sensors and for PC based data recording

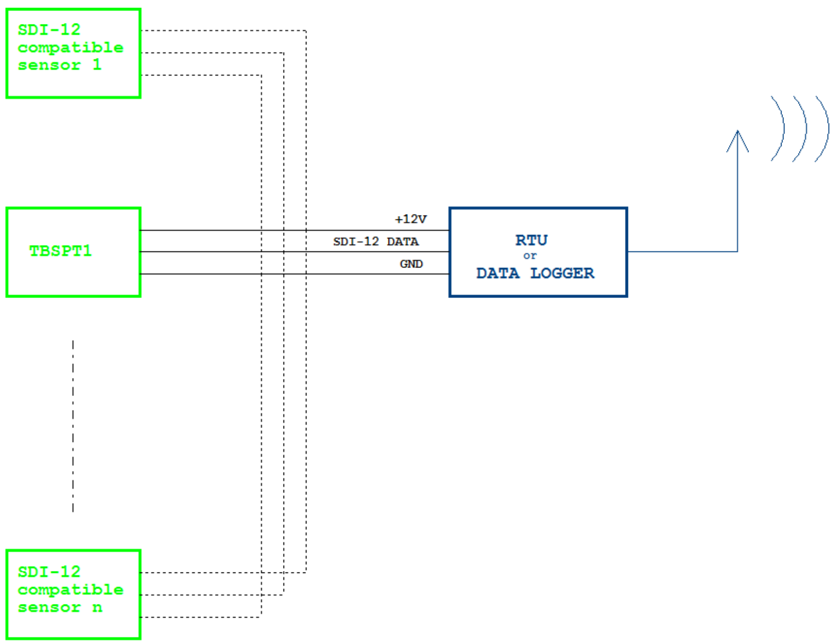

Figure 2 – TBSPT8 and other sensors with SDI-12 interface connected to Remote Telemetry Unit or Data Recorder

3 Hardware description

3.1 Connections

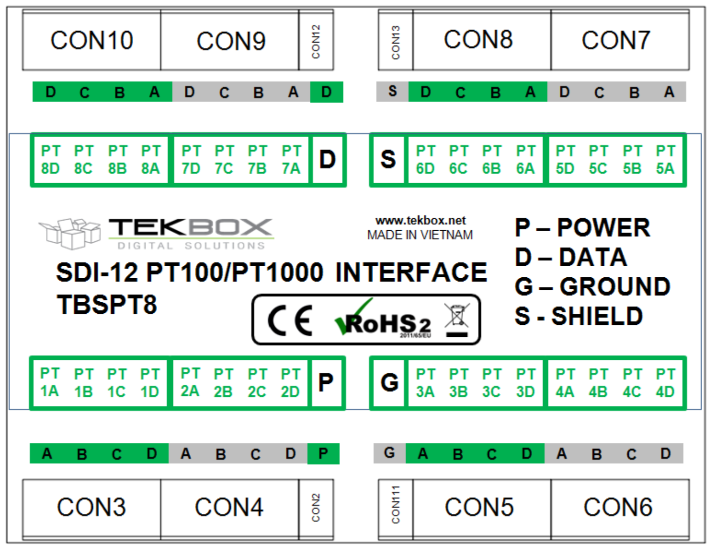

Figure 3 – TBSPT8 terminal block assignment

CON3 – PT100/PT1000 channel 1
CON4 – PT100/PT1000 channel 2
CON5 – PT100/PT1000 channel 3
CON6 – PT100/PT1000 channel 4

CON7 – PT100/PT1000 channel 5
CON8 – PT100/PT1000 channel 6
CON9 – PT100/PT1000 channel 7
CON10 – PT100/PT1000 channel 8

CON2 – SDI-12 POWER
CON12 – SDI-12 DATA

CON11 – SDI-12 GROUND
CON13 – SDI-12 SHIELD

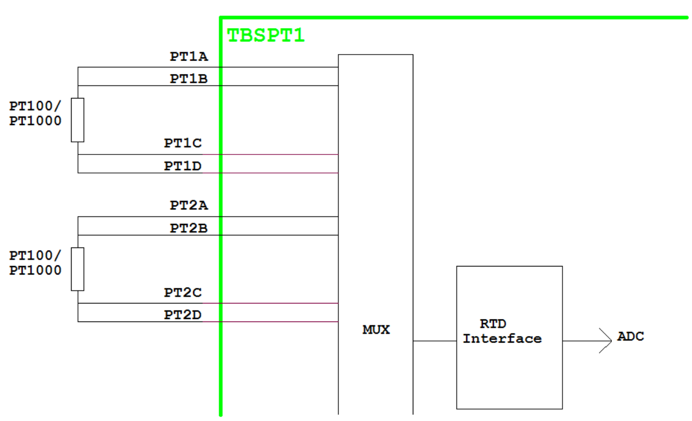

Figure 4 – TBSPT8 4-wire connectivity

3.2 Configuration

In order to set up a measurement, a few configuration commands may be required to be issued upfront. Configuration data is stored in non volatile memory, consequently the configuration commands only need to be issued once.

RTD configuration

aXPT100!	set connected RTD type to PT100
aXPT1000!	set connected RTD type to PT1000, default setting
aXGPT!	query RTD type setting

Following curve according to DIN EN 60751 standard describes the temperature dependence of the RTD resistance:

-200 bis 0°C $R(t) = R0(1 + A * t + B * t^2 + C * [t-100] * t^3)$

0 bis 850°C $R(t) = R0(1 + A * t + B * t^2)$

Platinum (3850 ppm/K):

$A = 3.9083 * 10^{-3}[°C^{-1}]; B = -5.775 * 10^{-7}[°C^{-2}]; C = -4.183 * 10^{-12}[°C^{-4}]$

Platinum (3750 ppm/K):

$A = 3.8102 * 10^{-3}[°C^{-1}]; B = -6.01888 * 10^{-7}[°C^{-2}]; C = -6 * 10^{-12}[°C^{-4}]$

Platinum (3770 ppm/K):

$A = 3.92 * 10^{-3}[°C^{-1}]; B = -6.03 * 10^{-7}[°C^{-2}];$

R0= Resistance value in Ω at 0°C; t = temperature in accordance with ITS 90

aXSABC,a.aaaaa,b.bbbbb,c.ccccc!	set RTD temperature coefficients A, B,C; a.aaaaa: coefficient A; default value: 3.9083 b.bbbbb: coefficient B; default value: -5.775 c.ccccc: coefficient C; default value: -4.183
aXGABC!	query RTD temperature coefficients A, B, C

Measurement Unit Configuration

The measurement result can be expressed in °Celsius or in °Fahrenheit. The TBSPT8 comes factory set to °C. Following extended SDI-12 command will switch from °Celsius to °Fahrenheit or vice versa:

aXTUx!	set temperature unit to Celsius [°C] or Fahrenheit [°F] example: 0XTUF! set temperature unit to Fahrenheit
aXGU!	query the configured measurement unit

Temperature compensation

The hardware temperature drift of the TBSPT8 causes an error of max. ± 0.05°C over the operating temperature range -40°C to + 80°C.

By activating temperature compensation, the measurement error caused by the hardware temperature drift can be reduced to less than ± 0.02°C over the complete operating temperature range

aXSTC,0!	disable temperature compensation
aXSTC,1!	enable temperature compensation; default setting
aXGTC!	query temperature compensation

The temperature compensation slightly increases noise. If the TBSPT8 is installed in a location with controlled temperature and if an extremely high resolution and low noise measurement is required, temperature compensation can be disabled.

3.3 Measurement

SDI-12 Measurement Commands:

aM!	measure RTD temperature at channel 1 [°C, °F]
aM1!	measure RTD temperature at channel 2 [°C, °F]
aM2!	measure RTD temperature at channel 3 [°C, °F]
aM3!	measure RTD temperature at channel 4 [°C, °F]
aM4!	measure RTD temperature at channel 5 [°C, °F]
aM5!	measure RTD temperature at channel 6 [°C, °F]
aM6!	measure RTD temperature at channel 7 [°C, °F]
aM7!	measure RTD temperature at channel 8 [°C, °F]
aM8!	measure RTD temperature at channels 1…4 [°C, °F]
aM9!	measure RTD temperature at channels 5…8 [°C, °F]

aMC!	measure RTD temperature at channel 1 [°C, °F]; measurement with cyclic redundancy check
aMC1!	measure RTD temperature at channel 2 [°C, °F]; measurement with cyclic redundancy check
aMC2!	measure RTD temperature at channel 3 [°C, °F]; measurement with cyclic redundancy check
aMC3!	measure RTD temperature at channel 4 [°C, °F]; measurement with cyclic redundancy check
aMC4!	measure RTD temperature at channel 5 [°C, °F]; measurement with cyclic redundancy check
aMC5!	measure RTD temperature at channel 6 [°C, °F]; measurement with cyclic redundancy check
aMC6!	measure RTD temperature at channel 7 [°C, °F]; measurement with cyclic redundancy check
aMC7!	measure RTD temperature at channel 8 [°C, °F]; measurement with cyclic redundancy check
aMC8!	measure RTD temperature at channels 1..4 [°C, °F]; measurement with cyclic redundancy check
aMC9!	measure RTD temperature at channel 5..8 [°C, °F]; measurement with cyclic redundancy check

aC!	concurrent measurement of temperature at channel 1 [°C, °F]
aC1!	concurrent measurement of temperature at channel 2 [°C, °F]

aC2!	concurrent measurement of temperature at channel 3 [°C, °F]
aC3!	concurrent measurement of temperature at channel 4 [°C, °F]
aC4!	concurrent measurement of temperature at channel 5 [°C, °F]
aC5!	concurrent measurement of temperature at channel 6 [°C, °F]
aC6!	concurrent measurement of temperature at channel 7 [°C, °F]
aC7!	concurrent measurement of temperature at channel 8 [°C, °F]
aC8!	concurrent measurement of temperature at channels 1...4 [°C, °F]
aC9!	concurrent measurement of temperature at channels 5…8 [°C, °F]
aCC!	concurrent temp. measurement at channel 1 [°C, °F] – with cyclic redundancy check
aCC1!	concurrent temp. measurement at channel 2 [°C, °F] – with cyclic redundancy check
aCC2!	concurrent temp. measurement at channel 3 [°C, °F] – with cyclic redundancy check
aCC3!	concurrent temp. measurement at channel 4 [°C, °F] – with cyclic redundancy check
aCC4!	concurrent temp. measurement at channel 5 [°C, °F] – with cyclic redundancy check
aCC5!	concurrent temp. measurement at channel 6 [°C, °F] – with cyclic redundancy check
aCC6!	concurrent temp. measurement at channel 7 [°C, °F] – with cyclic redundancy check
aCC7!	concurrent temp. measurement at channel 8 [°C, °F] – with cyclic redundancy check
aCC8!	concurrent temp. measurement at channels 1...4 [°C, °F] – with cyclic redundancy check
aCC9!	concurrent temp. measurement at channels 5…8 [°C, °F] – with cyclic redundancy check

3.4 Calibration

The TBSPT8 comes factory calibrated and does not require any user calibration.

Nevertheless there are extended SDI-12 commands available to enable re-calibration.

In order to understand the calibration procedure, it is necessary to understand a few details which will be explained in this chapter. It needs to be pointed out, that accuracy parameters mentioned in this manual refer to the accuracy of the TBSPT8 interface hardware. The overall accuracy of the measurement setup will be limited by the accuracy / tolerance of the connected RTD´s and the accuracy of the TBSPT8.

Calibration to absolute accuracy at 0°C

A PT100 (PT1000) has a nominal value of 100Ω (1000Ω) at 0°C. All channels are factory calibrated at room temperature with ± 0,005% / ± 2ppm/°C 100Ω (1000Ω) precision resistors. After calibration, a temperature measurement with this resistors connected to the 4-wire interface will show 0,000°C ± 0,001°C in uncompensated mode or 0,000°C ± 0,003°C in compensated mode.

An explanation of the difference between compensated mode and uncompensated mode will follow further down in this chapter.

A PT1000 has a temperature coefficient of 3,85Ω/°K. Consequently, a 0,005% 1000Ω resistor will have a value in the range of 1000 ± 0,05Ω.

±0,05Ω/3,85Ω = 0,013 translates into a calibration uncertainty of ± 0,013°C at 0°C.

Comparing this value with the tolerance classes of commercially available Pt RTDs (Table 1) shows that the typical error of a Pt RTD is approximately an order of magnitude higher than the corresponding measurement uncertainty introduced by the TBSPT8.

The TBSPT8 can be recalibrated with respect to its absolute accuracy at 0°C by issuing following extended SDI-12 commands:

aXCPT,a! PT100/PT1000 calibration; requires 4-wire connection of a precision 100Ω/1000Ω resistor*

a = 1, calibrate channel 1, 2, 3; connect RTD to channel 1

a = 2, calibrate channel 4, 5, 6; connect RTD to channel 4

a = 3, calibrate channel 7, 8; connect RTD to channel 7

*TBSPT8 needs to be set to PT100 measurement for calibration with a 100Ω resistor

*TBSPT8 needs to be set to PT1000 measurement for calibration with a 1000Ω resistor

The TBSPT8 comes factory calibrated for both PT100 and PT1000.

Temperature compensation

The measurement result of the TBSPT8 has a drift of 0,00075°C/°C with respect to its ambient temperature. The drift is measured by placing the TBSPT8 into a thermal chamber, while keeping a connected 1000 Ohm precision resistor at constant room temperature:

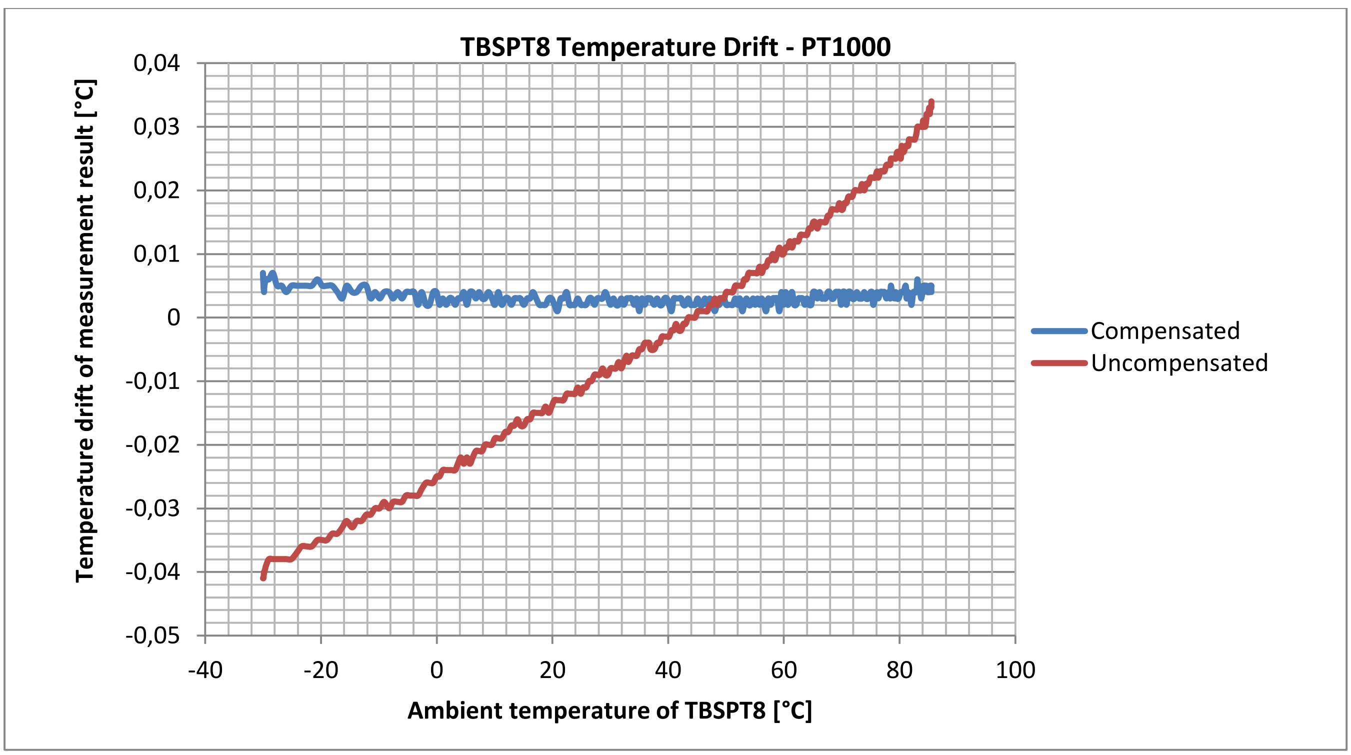

Figure 5 – TBSPT8, PT1000, temperature drift of the measurement result with respect to the ambient temperature of the TBSPT8. The connected RTD is replaced with a 1000 Ohm precision resistor kept at constant temperature.

Figure 5 shows the deviation with respect to a PT1000 kept at constant 0°C or a 1000K precision resistor and the TBSPT8 placed in a thermal chamber.

As the temperature drift shows good linearity and good repeatability, it can be easily compensated by firmware. An on board temperature sensor is used measure the ambient temperature of the TBSPT8. As it is a semiconductor temperature sensor, it got more noise than a RTD, however as it translates into a small factor of the compensation calculation, the effect on overall noise of the RTD measurement is not very significant. Figure 6 shows drift and noise in compensated mode.

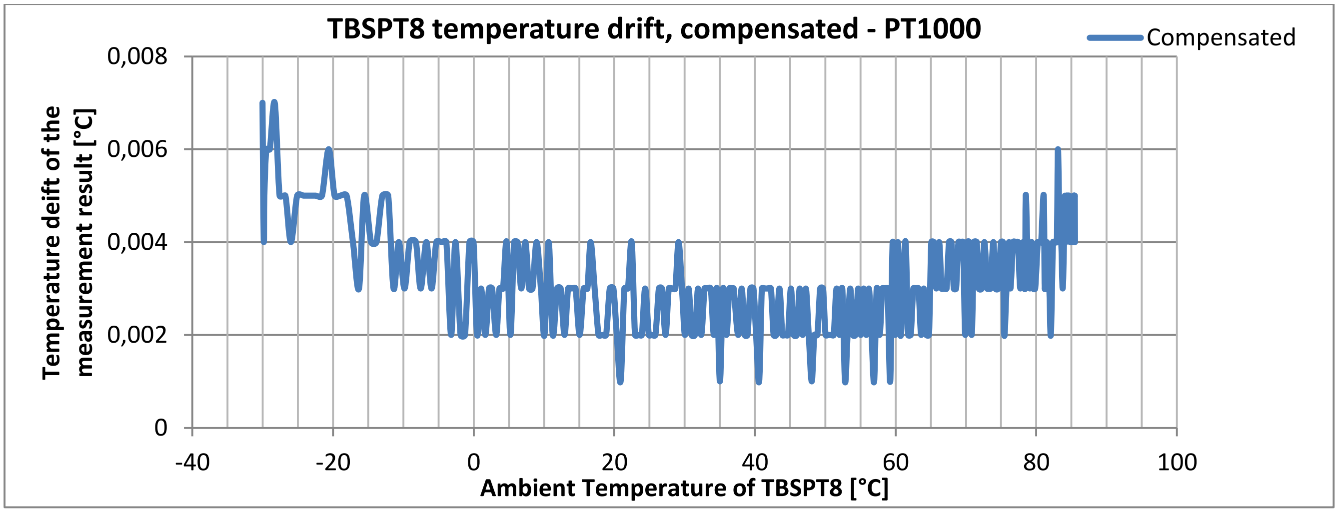

Figure 6 – TBSPT8, PT1000, temperature drift of the measurement result with respect to the ambient temperature of the TBSPT8. The connected RTD is replaced with a 1000 Ohm precision resistor kept at constant temperature. Noise is approximately ±0,0015 °C

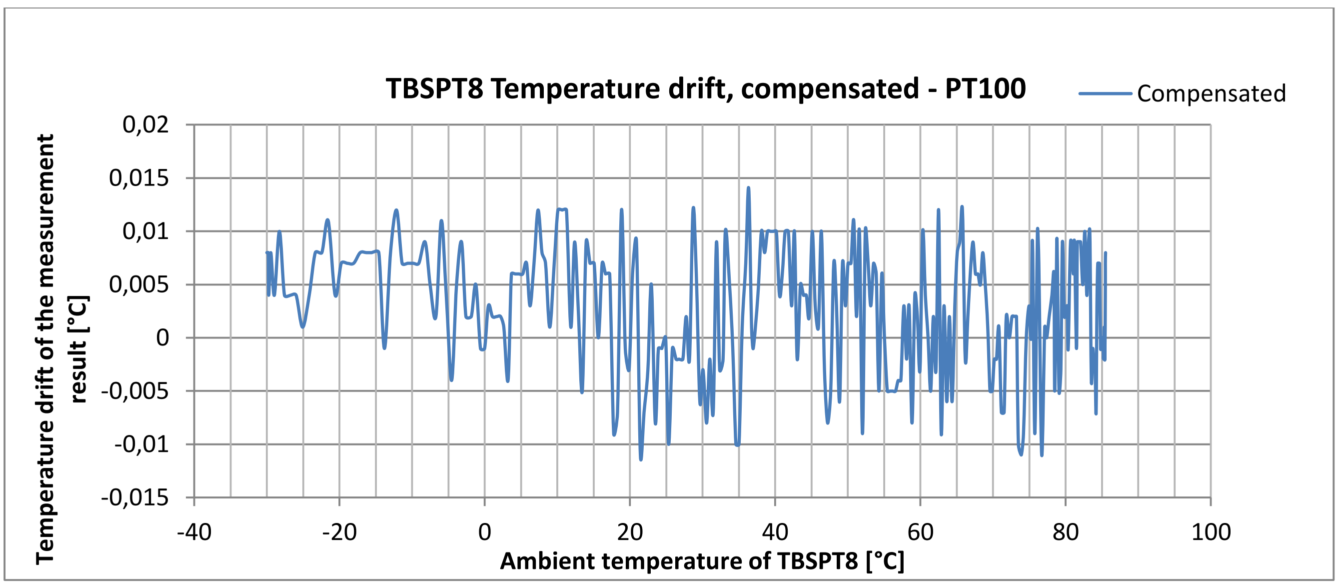

Figure 7 – TBSPT8, PT100, temperature drift of the measurement result with respect to the ambient temperature of the TBSPT8. The connected RTD is replaced with a 100 Ohm precision resistor kept at constant temperature. Noise is approximately ±0,01 °C

Following SDI-12 command is used for entering the temperature drift value:

aXDPT, sd.ddddd! TBSPT8 hardware temperature drift calibration
s: sign; d.ddddd: temperature drift [°C/°C]

*TBSPT8 needs to be set to PT100 measurement for HW temperature drift calibration in PT100 mode

*TBSPT8 needs to be set to PT1000 measurement for HW temperature drift calibration in PT1000 mode

default value for PT100: s**d.ddddd** = +0,00075

default value for PT1000: s**d.ddddd** = +0,00075

Offset calibration

An offset calibration can be applied to each of the 8 measurement channels. By default, all offsets are set to zero.

aXOTm,snnn.nnn! m: channel number s: sign; nnn.nnn: offset temperature to be added to the measurement result

Refer to chapters 5.7 and 5.8 for a detailed description of the implemented SDI-12 commands.

4 Functional description

4.1 Overview

The SDI-12 standard defines a set of commands to configure sensors and to initiate measurements. Upon receiving specific commands, the sensor may carry out internal tasks, respond with information on conversion time or send measurement data.

SDI-12 commands are typically ASCII strings which are generated by the data recorder/controller firmware. The TBSPT8 can be connected to a TBS03 SDI-12 to USB converter and controlled by a PC application, such as hyper terminal software for example. TBS03 converts the command strings to the logic levels and baud rate specified by the SDI-12 standard. Furthermore, TBS03 handles breaks, marks and all other details of the SDI-12 protocol.

Upon receiving data or status information originated by TBSPT8, the TBS03 extracts the corresponding ASCII strings and sends them to the USB Virtual COM Port of the PC.

In remote applications, TBSPT8 can be connected to a data logger, a data terminal or a Radio Telemetry Unit with a SDI-12 interface.

4.2 SDI-12 basics

The SDI-12 is a serial data communication standard for interfacing multiple sensors with a data recorder. SDI-12 uses a shared bus with 3 wires: power (+12V), data, ground Data rate: 1200 baud. Each sensor at the bus gets a unique address which is in the range ASCII [0-9, a-z, A-Z]. The default address of every sensor is ASCII[0]. When setting up a SDI-12 sensor network, every sensor needs to be configured with a unique address. This can be done using the Change Address Command. A sensor can typically measure one or more parameters. Sensor manufacturers usually specify '*Extended Commands*' to configure or calibrate sensors. These commands are specified by the manufacturer, but they follow the command structure specified by SDI-12.

A typical recorder/sensor measurement sequence proceeds as follows:

1) The data recorder wakes all sensors on the SDI-12 bus with a break.
2) The recorder transmits a command to a specific, addressed sensor, instructing it to make a measurement.
3) The addressed sensor responds within 15.0 milliseconds, returning the maximum time until the measurement data will be ready and the number of data values it will return.
4) If the measurement is immediately available, the recorder transmits a command to the sensor instructing it to return the measurement result(s). If the measurement is not ready, the data recorder waits for the sensor to send a request to the recorder, which indicates that the data is ready. The recorder then transmits a command to get the data.
5) The sensor responds, returning one or more measurement results.

SDI-12 Command Structure:
Each SDI-12 command is an ASCII string with up to 5 characters, starting with the sensor address and terminated by a "**!**" character.

Example:
Send Identification Command **0I!**
0 is the sensor address (sensor zero). Upon receiving this command, the sensor will send an ASCII string containing sensor address, SDI-12 compatibility number, company name, sensor model number, sensor version number and sensor serial number.

The standard process to carry out a measurement is to send a measurement request upon which the sensor responds with the time that is required to carry out the measurement and the number of data items being returned. After waiting the time that the sensor requires to carry out the measurement, the data recorder sends a *"Read Command"* to get the measurement results.

Example:
Start Measurement Command **0M1!**
A TBSPT8 with address 0 may respond **00011** which means the measurement will take 1 second and deliver 1 value.
After min. 1 second, the data recorder can send the *"Read Data Command"* **0D0!** to which Sensor 0 might reply **0+22.256**. +**22.256** is the measurement result which is corresponding to **22.256** °C.

The response string of a sensor is always in ASCII format and may contain up to 40 or up to 80 characters, depending on the type of command. Out of 40 or 80 characters, the values part of the response string may contain up to 35 or 75 characters.

4.3 Sensor identification

The TBSPT8will respond with following string upon sending the *"Send Identification"* command **aI!**:

allccccccccmmmmmmvvvxxxxxxxxxxxxx<CR><LF>

Example: 013TEKBOXVNTBSPT81.0000005<CR><LF>

Where:	0	SDI-12 Sensor address
	13	SDI-12 version number, version 1.3
	TEKBOXVN	Company name
	TBSPT8	Model Name
	1.0	Firmware version 1.0
	000005	Serial number of the device

4.4 Sensor address

Each TBSPT8is delivered with a default address of "0"

The TBSPT8 accepts SDI-12 addresses in the range "0" to "9", "A" to "Z" and "a" to "z". Setting the address of the TBSPT8 can be done using the "*Change Address Command*" **aAb!**.

Note:

- If the new address is invalid, the current address will be kept.
- The TBSPT8 will remain unresponsive for approximately 1 second while the new address is saved in the EEPROM memory.
- The TBSPT8 supports "**?**" as an address only for *"Acknowledge Active"* Command **a!**.

4.5 Measurement

The TBSPT8 sensor interface accepts the "*Start Measurement"* Command **aM!**, *"Additional Measurement"* Commands **aMn!** and *"Start Concurrent Measurement"* Command **aC!**, "*Additional Concurrent Measurement"* Commands **aCn!** for obtaining calibrated values from the probe. Furthermore it supports **aMC!, aMCn!, aCC!, aCCn!** Commands which add a CRC to the measurement response.

The TBSPT8 sensor interface will not support the *"Continuous Measurement"* Command **aRn!** and *"Continuous Measurement and Request CRC"* Command **aRCn!**. The TBSPT8sensor will respond with its address followed by <CR><LF> in response to this command.

The response to *"Start Measurement"* **aM!**, *"Additional Measurement"* Commands **aMn!** and *"Start Concurrent Measurement"* Command **aC!**, the *"Additional Concurrent Measurement"* Command **aCn!** reports the response time and how many temperature values will be sent. In order to receive the desired sensor values, the recorder needs to issue the corresponding *"Send Data"* Command(s) **aDn!**.

Note: The TBSPT8 sensor interface uses a format of "sign" followed by n digits. Temperature measurement results have up to 6 digits.

4.6 Measurement examples

0M! Measure temperature at channel 1 [°C], sensor address 0

Command	Response	Comment
0M!	00011<CR><LF>	Means: 1 measurement value will be available after 1second
0D0!	0+22.256<CR><LF>	The temperature of the RTD connected to channel 1 is 22.256 °C

The value 22.256 is the temperature measured at channel1. The temperature is represented by up to 6 digits. The maximum measurable temperature is +300 °C, minimum is -80°C. If the temperature exceeds the range of -80°C to +300°C, if no RTD is connected or in case of a damaged RTD, the measurement indicates an invalid result by delivering an output value of 999999.

aM8! Measure temperatures at channels 1, 2, 3, 4 [°C], sensor address 0

Command	Response	Comment
0M8!	00044<CR><LF>	Means: 4 measurement values will be available after 4 seconds
0D0!	0+22.256+19.738+23.512+25.682<CR><LF>	The temperatures measured at channels 1, 2, 3, 4

5 Supported SDI-12 commands

Following commands are supported by the TBSPT8:

Command	Description	Response
a!	Acknowledge Active	a<CR><LF>

SDI-12 8-Channel PT100/PT1000 INTERFACE

aI!	Send Identification	013TEKBOXVNTBSAB21.0000005xxxxx<CR><LF> With xxxxx representing the serial number
aAb!	Change Address	b<CR><LF> Changing the probe sensor address
?!	Address Query	a<CR><LF>
aM!	Start Measurement Measures temperature at input channel 1	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aM1!	Additional Measurement Measures temperature at input channel 2	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aM2!	Additional Measurement Measures temperature at input channel 3	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aM3!	Additional Measurement Measures temperature at input channel 4	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aM4!	Start Measurement Measures temperature at input channel 5	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aM5!	Additional Measurement Measures temperature at input channel 6	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aM6!	Additional Measurement Measures temperature at input channel 7	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aM7!	Additional Measurement Measures temperature at input channel 8	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aM8!	Additional Measurement Measures temperature at input channels 1…4	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aM9!	Additional Measurement Measures temperature at input channels 5…8	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aMC!	Start Measurement and request CRC Measures temperature at input channel 1 and calculates CRC	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aMC1!	Additional Measurement and request CRC Measures temperature at input channel 2 and calculates CRC	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aMC2!	Additional Measurement and request CRC Measures temperature at input channel 3 and calculates CRC	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aMC3!	Additional Measurement and request CRC Measures temperature at input channel 4 and calculates CRC	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aMC4!	Additional Measurement and request CRC Measures temperature at input channel 5 and calculates CRC	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aMC5!	Additional Measurement and request	attt1<CR><LF>

	CRC Measures temperature at input channel 6 and calculates CRC	Delay (ttt) in seconds and number of values (1)
aMC6!	Additional Measurement and request CRC Measures temperature at input channel 7 and calculates CRC	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aMC7!	Additional Measurement and request CRC Measures temperature at input channel 8 and calculates CRC	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aMC8!	Additional Measurement and request CRC Measures temperature at input channel 1…4 and calculates CRC	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aMC9!	Additional Measurement and request CRC Measures temperature at input channel 5…8 and calculates CRC	attt1<CR><LF> Delay (ttt) in seconds and number of values (1)
aC!	Start Concurrent Measurement concurrent measurement of temperature at channel 1	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aC1!	Start Concurrent Measurement concurrent measurement of temperature at channel 2	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aC2!	Start Concurrent Measurement concurrent measurement of temperature at channel 3	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aC3!	Start Concurrent Measurement concurrent measurement of temperature at channel 4	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aC4!	Start Concurrent Measurement concurrent measurement of temperature at channel 5	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aC5!	Start Concurrent Measurement concurrent measurement of temperature at channel 6	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aC6!	Start Concurrent Measurement concurrent measurement of temperature at channel 7	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aC7!	Start Concurrent Measurement concurrent measurement of temperature at channel 8	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aC8!	Start Concurrent Measurement concurrent measurement of temperature at channels 1…4	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aC9!	Start Concurrent Measurement concurrent measurement of temperature at channels 5…8	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aCC!	Start Concurrent Measurement and	attt1<CR><LF>

	request CRC concurrent measurement of temperature at channel 1 and CRC calculation	Delay (ttt) in seconds and number of values (4)
aCC1!	Start Concurrent Measurement and request CRC concurrent measurement of temperature at channel 2 and CRC calculation	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aCC2!	Start Concurrent Measurement and request CRC concurrent measurement of temperature at channel 3 and CRC calculation	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aCC3!	Start Concurrent Measurement and request CRC concurrent measurement of temperature at channel 4 and CRC calculation	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aCC4!	Start Concurrent Measurement and request CRC concurrent measurement of temperature at channel 5 and CRC calculation	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aCC5!	Start Concurrent Measurement and request CRC concurrent measurement of temperature at channel 6 and CRC calculation	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aCC6!	Start Concurrent Measurement and request CRC concurrent measurement of temperature at channel 7 and CRC calculation	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aCC7!	Start Concurrent Measurement and request CRC concurrent measurement of temperature at channel 8 and CRC calculation	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aCC8!	Start Concurrent Measurement and request CRC concurrent measurement of temperature at channels 1…4 and CRC calculation	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aCC9!	Start Concurrent Measurement and request CRC concurrent measurement of temperature at channels 5…8 and CRC calculation	attt1<CR><LF> Delay (ttt) in seconds and number of values (4)
aD0!	Get Measurement Result(s)	Upon issuing the aD0! Command, the TBS02B will send the measurement results. The response format depends on the measurement command issued before.
aV!	Start Verification	a0000<CR><LF> Not supported
aRn! **aRCn!**	Continuous Measurement Continuous Measurement + CRC	a<CR><LF> Not supported

Table 2 – Standard SDI-12 commands

6 Supported extended SDI-12 commands

Command	Description	Response
aXPT100!	set connected RTD type to PT100 Application: Issue this configuration command, if you use the TBSPT8 in connection with PT100 RTDs. This command needs to be issued only once; the setting will remain stored in non volatile memory. The setting applies to all channels. The TBSPT8 can be used with either PT100 or PT1000. A mixed configuration, with different RTDs connected to the interface is not supported.	aX_OK<CR><LF>
aXPT1000!	set connected RTD type to PT1000 Application: Issue this configuration command, if you use the TBSPT8 in connection with PT1000 RTDs. This command needs to be issued only once; the setting will remain stored in non volatile memory. The setting applies to all channels. The TBSPT8 can be used with either PT100 or PT1000. A mixed configuration, with different RTDs connected to the interface is not supported. The TBSPT8 is by default configured to PT1000 sensors	aX_OK<CR><LF>
aXGPT!	query RTD type setting Application: Issue this command, if you are not sure about the settings of the device. The response will inform about which type of RTD is configured.	aX,PT100<CR><LF> or aX,PT1000<CR><LF>
aXSABC,a.aaaaa,b.bbbbb,c.ccccc!	set RTD temperature coefficients A, B,C; Application: Set the polynomial coefficients of the temperature curve according to DIN EN 60751 standard: -200 bis 0°C $R(t) = R0(1 + A * t + B * t^2 + C * [t-100] * t^3)$ 0 bis 850°C $R(t) = R0(1 + A * t + B * t^2)$ Default settings: Platinum (3850 ppm/K) $A = 3.9083 * 10^{-3}[°C^{-1}]$; $B = -5.775 * 10^{-7}[°C^{-2}]$; $C = -4.183 * 10^{-12}[°C^{-4}]$ a.aaaaa: coefficient A; default value: 3.9083 b.bbbbb: coefficient B; default value: -5.775 c.ccccc: coefficient C; default value: -4.183	aX_OK<CR><LF>
aXGABC!	query RTD temperature coefficients A, B, C	aX, **a.aaaaa,b.bbbbb,c.ccccc!**<CR><LF>
aXTUx!	set temperature unit to Celsius [°C] or Fahrenheit [°F] example: 0XTUC! set temperature unit to °Celsius example: 0XTUF! set temperature unit to °Fahrenheit The TBSPT8 is by default configured to [°C]	aX_OK<CR><LF>
aXGU!	query the configured measurement unit Response: C≡Celsius; F≡Fahrenheit	aX,C<CR><LF> or aX,F<CR><LF>
aXSTC,t!	Enable/disable temperature compensation T=0: disable temperature compensation; T=1: enable temperature compensation The temperature compensation is enabled by default	aX_OK<CR><LF>
aXGTC!	query temperature compensation Response: 0≡ disabled; 1≡enabled	aX,0<CR><LF> or aX,1<CR><LF>

aXCPT,a!	Calibration of absolute accuracy at 0°C PT100/PT1000 calibration; requires 4-wire connection of a precision 100Ω/1000Ω resistor* a = 1, calibrate channel 1, 2, 3; connect RTD to channel 1 a = 2, calibrate channel 4, 5, 6; connect RTD to channel 4 a = 3, calibrate channel 7, 8; connect RTD to channel 7 *TBSPT8 needs to be set to PT100 measurement for calibration with a 100Ω resistor *TBSPT8 needs to be set to PT1000 measurement for calibration with a 1000Ω resistor Factory calibrated!	aX_OK<CR><LF>
aXDPT, sd.ddddd!	TBSPT8 hardware temperature drift calibration*; s: sign; d.ddddd: temperature drift [°C/°C] *TBSPT8 needs to be set to PT100 measurement for HW temperature drift calibration in PT100 mode *TBSPT8 needs to be set to PT1000 measurement for HW temperature drift calibration in PT1000 mode default value for PT100: s**d.ddddd** = +0,00075 default value for PT1000: s**d.ddddd** = +0,00075 Factory calibrated!	aX_OK<CR><LF>
aXOTm,snnn.nnn!	Measurement offset calibration adds or subtracts an offset to the measurement result m: channel number s: sign nnn.nnn: offset temperature to be added to the measurement result default value for all channels: nnn.nn =0	aX_OK<CR><LF>
aXSD!	reset to default settings 1. Sensor address: 0 2. RTD type: PT1000 3. RTD coefficients: a.aaaaa: coefficient A; default value: 3.9083 b.bbbbb: coefficient B; default value: -5.775 c.ccccc: coefficient C; default value: -4.183 4. Temperature unit: Celsius 5. Temperature drift compensation: enabled 6. Temperature drift compensation coefficients PT100: s.ddddd = 0.00075 PT1000: s.dddd = 0.00075 7. Measurement offset calibration zero offset for all channels	aX_OK<CR><LF>

Table 3 – Extended SDI-12 Commands

7 Technical Specifications

Parameter	Conditions	Min	Typ	Max	Unit
Supply current	Active mode (during measurement)		9		mA
Supply current	Sleep mode		95		µA
Supply voltage		6	12	16	V
Measurement time, single channel measurement	Time in active mode upon receiving a measurement command	-	1	-	s
Measurement time, 4 channel measurement	Time in active mode upon receiving a measurement command	-	4	-	s
Operating temperature range		-40		+80	°C
Temperature measurement range		-80		+300	°C
Measurement resolution			0.001		°C
Measurement noise	PT1000 sensor, uncompensated		±0.001		°C
Measurement noise	PT1000 sensor, compensated		±0.0015		°C
Measurement noise	PT100 sensor, uncompensated		±0.01		°C
Measurement noise	PT100 sensor, compensated		±0.01		°C

Table 4 – Technical Specifications

8 Environmental Specifications

Symbol	Parameter	Conditions	Min	Max	Unit
T_A	Operating Ambient Temperature Range		-40	+85	°C
T_{STG}	Storage Temperature Range		-40	+85	°C
	Moisture level *)	No condensation	0	95	%

Table 5 - Environmental Specifications

*) The TBSPT8 PCB assembly is conformally coated with Peters Lack Elpeguard SL-1307FLZ/3

9 Ordering Information

Part Number	Description
TBSPT8-DR	TBSPT8, PT100/PT1000 Interface, DIN-RAIL housing

Table 6 – Ordering Information

10 History

Version	Date	Author	Changes
V1.0	04.12.2013	Mayerhofer	Creation of the document

Table 7 – History