

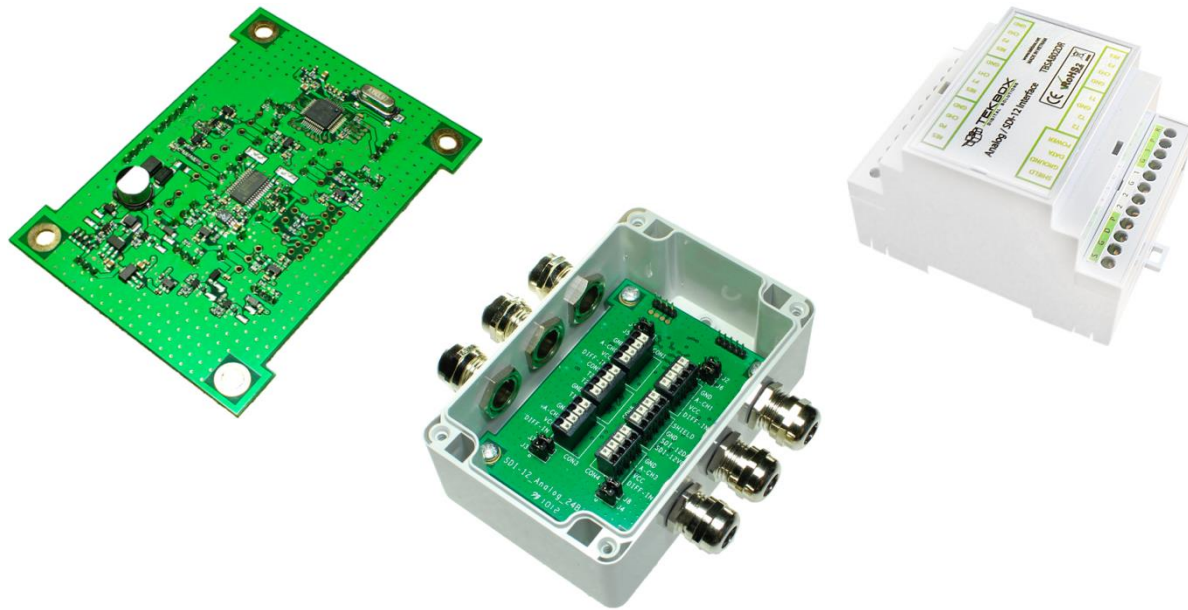
## 24 Bit Analogue to SDI-12 Interface

The TBSAB02/TBSAB02DR are 4+1 channel analogue to SDI-12 interfaces for 24 Bit A/D conversion of sensor signals. A/D conversion and configuration is controlled via SDI-12 commands. The interfaces are equipped with signal conditioning circuits which can be customized for various input voltage ranges. It offers low current consumption and is available in a Fibox PC081206 IP67 rated housing and in a DIN-rail housing.

Each channel can be independently scaled with a 3<sup>rd</sup> order polynomial to enable gain and offset calibration of the connected sensors.

A built in 3 wire interface for direct connection of PT100/PT1000 offers additional versatility.

The TBSAB02 / TBSAB02DR provide digital signals for the power management of the connected sensors. Four on-board, SDI-12 controlled high side FET- switches are provided to power on/off connected sensors.



TBSAB02(DR) 4+1 Channel Analog to SDI-12 Interface

### Features

- ANALOGUE to SDI-12 interface
- 4+1 24 Bit Sigma Delta ADC channels
- 4 analogue inputs; configurable as 4-20mA current loop or 0-2,5V voltage inputs; other voltage ranges upon order
- Input over-voltage protection
- 3-wire PT100/1000 interface
- Configurable sensor power management signal for each channel
- Configurable slope and offset for each channel
- $\pm 0,025\%$ , 2ppm/°C reference voltage
- Chopper stabilized buffer for low offset
- 50Hz & 60Hz line rejection filter
- SDI - 12 standard V1.3
- Plug and play
- 6 - 16V supply voltage
- 80 mm x 120 mm x 57mm
- IP67 housing – Fibox PC081206
- Alternatively available in Din-rail housing
- Operating temperature range: - 40°C ... + 85°C

### Target Applications

- SDI-12 Sensor Networks

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# 24 Bit Analogue to SDI-12 Interface manual

## 1 Introduction

The TBSAB02(DR)(DR) is a 24 Bit analogue to SDI-12 interface to connect sensors with voltage or current loop outputs to SDI-12 networks.

To extend its scope of application, the TBSAB02(DR) offers direct connectivity to PT100 or PT1000 temperature sensors via a 3-wire interface.

### 1.1 Measurement

The TBSAB02(DR) offers 5 input channels:

Channel 0	0V ... 2.5V
Channel 1	0V ... 2.5V
Channel 2	0V ... 2.5V
Channel 3	0V ... 2.5V
Channel 4	PT100/PT1000

On board temperature sensor

Reference voltage: 2.5V, 0.025%, 2ppm/°C  
ADC Resolution: 24 Bit, 19 Bit ENOB

### 1.2 Product Features

- Measurement of input channels with individual M-Commands
- Independent setting of the response time of each channel, configurable with Extended SDI-12 Commands
- Independent sensor power management control outputs for each channel, configurable with Extended SDI-12 Commands
- The measurement result of each channel can be independently scaled with a third order polynomial using Extended SDI-12 Commands
- On board temperature sensor
- Input protection
- 50Hz & 60Hz line rejection filter
- Dimensions: 80mm x 120mm x 57mm
- Mounted into IP67 housing of FIBOX, model PC081206
- Operating temperature range: -40 ... +85°C

### 1.3 Calibration

Any offset or gain error of the analogue system (sensor + TBSAB02(DR) analogue frontend) can be compensated using the scaling capability of the TBSAB02(DR).

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### 1.4 Installation

The TBSAB02(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 18<sup>th</sup>, 2005. The standard is available on the website of the SDI-12 Support Group.

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

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### 2 Application Examples

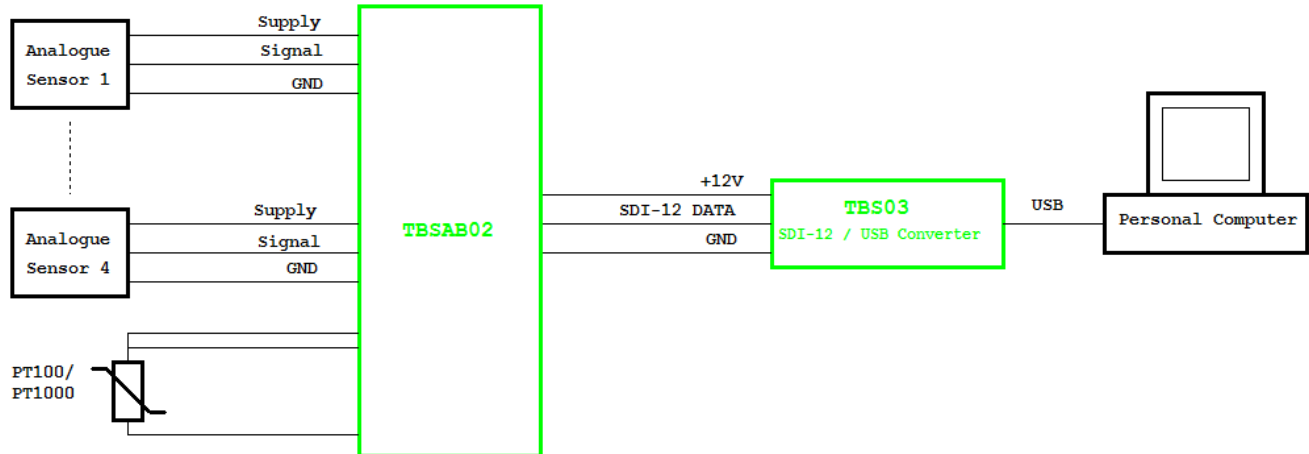


Figure 1 – Analogue sensors connected to TBSAB02(DR) and to TBS03 SDI-12 to USB converter; setup for controlling / testing sensors and for PC based data recording

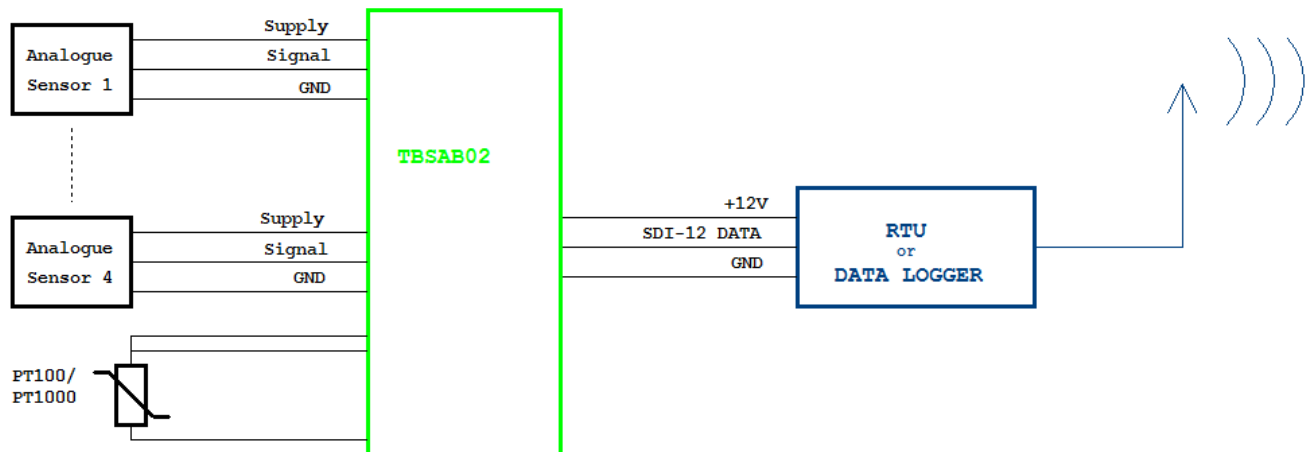


Figure 2 – Analogue sensors connected to TBSAB02(DR) and to Remote Telemetry Unit or Data Recorder

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### 3 Hardware Description

#### 3.1 Board overview

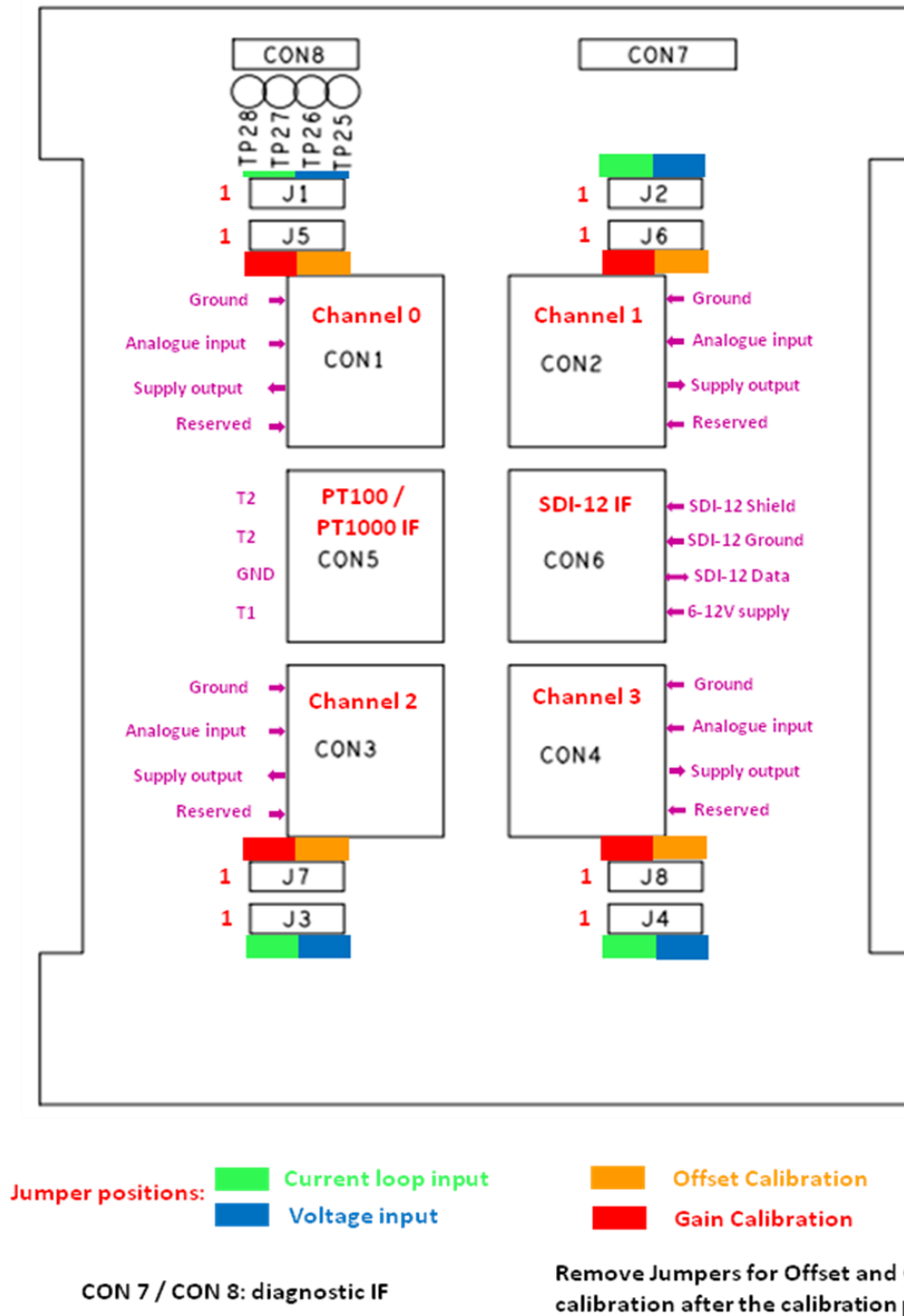


Figure 3 – TBSAB02 Board Connections, Jumper Settings; default: voltage measurement



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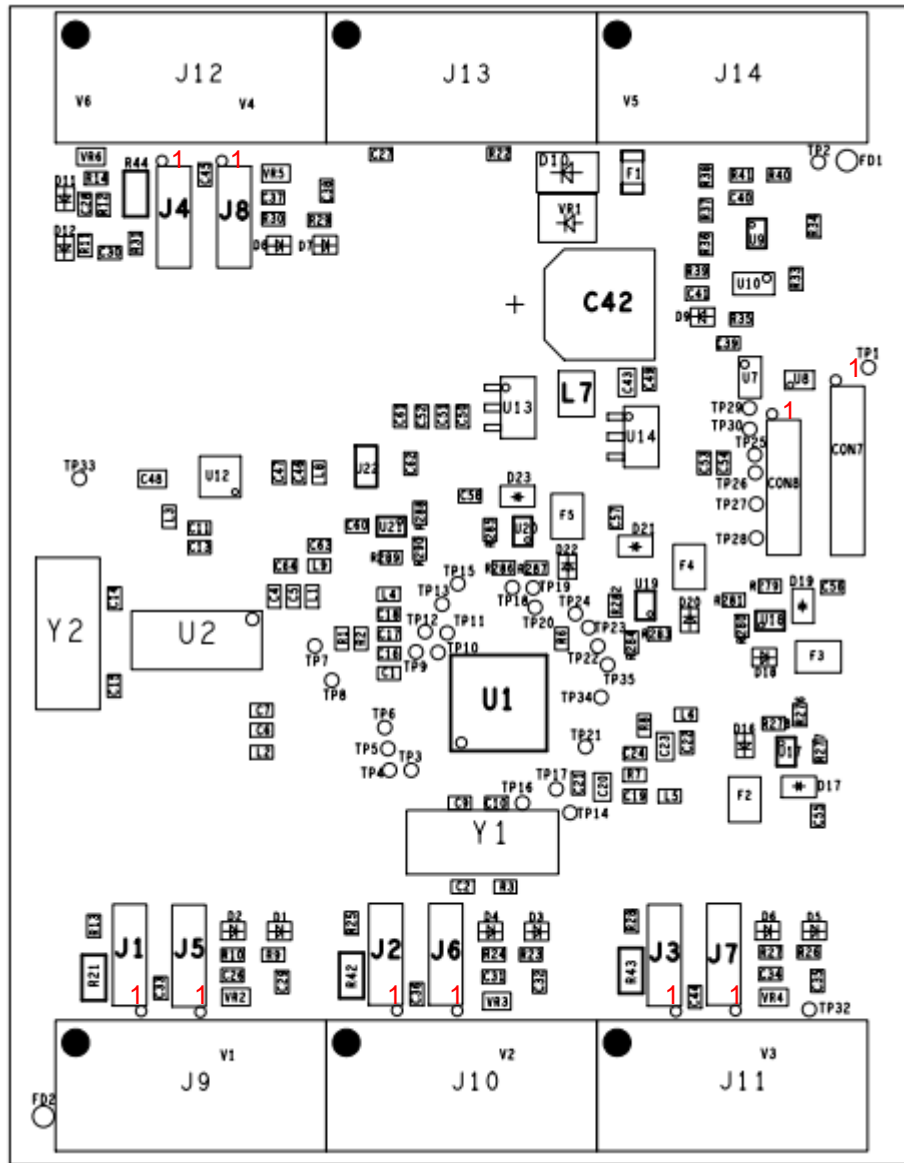


Figure 4 – TBSAB02DR Board Connections, Jumper Settings

Refer to Figure 3. Settings for J1 to J8 are identical with TBSAB02; default set to voltage measurement

The TBSAB02(DR) is based on a sensor front end with a 24 Bit ADC, low noise programmable gain amplifier and a precision voltage reference. A true continuous background calibration feature minimizes gain and offset errors across time and temperature. A microcontroller controls the analogue section, power management and the SDI-12 communication.



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### 3.2 TBSAB02 connections

#### **4 Pin terminal blocks:**

CON6 – SDI-12 Interface

*Shield:* connect to the shield of the SDI-12 cable or leave it unconnected

*Ground:* connect to the GND wire of the SDI-12 cable

*SDI-12 data:* connect to the data wire of the SDI-12 cable

*6-12V supply:* connect to the positive supply voltage wire of the SDI-12 cable

#### **4 Pin terminal blocks:**

CON1 – Analogue input channel 0 – voltage / current loop input; 6-12V sensor supply voltage output

CON2 – Analogue input channel 1 – voltage / current loop input; 6-12V sensor supply voltage output

CON3 – Analogue input channel 2 – voltage / current loop input; 6-12V sensor supply voltage output

CON4 – Analogue input channel 3 – voltage / current loop input; 6-12V sensor supply voltage output

*Ground:* connect to sensor GND

*Analogue input:* connect to the ratio metric voltage or current output of the sensor

*VCC:* connect to the sensor supply input. The output voltage is equivalent to the SDI-12 supply voltage and gets switched on during an SDI-12 measurement process concerning the respective channel.

*DIFF\_IN:* reserved for future use

CON5 – PT100/PT1000 3-wire interface. Connect the PTC according Figure 6. The PTC type and the unit (Celsius or Fahrenheit) can be selected with extended SDI-12 commands.

#### **Jumpers:**

J1 – Analogue input channel 0 – voltage input / current loop input selection

J2 – Analogue input channel 1 – voltage input / current loop input selection

J3 – Analogue input channel 2 – voltage input / current loop input selection

J4 – Analogue input channel 3 – voltage input / current loop input selection

Refer to Figure 3 for the jumper positions. “Blue” refers to the jumper position for voltage input mode; “green” refers to current loop mode.

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### 3.3 Voltage measurement mode

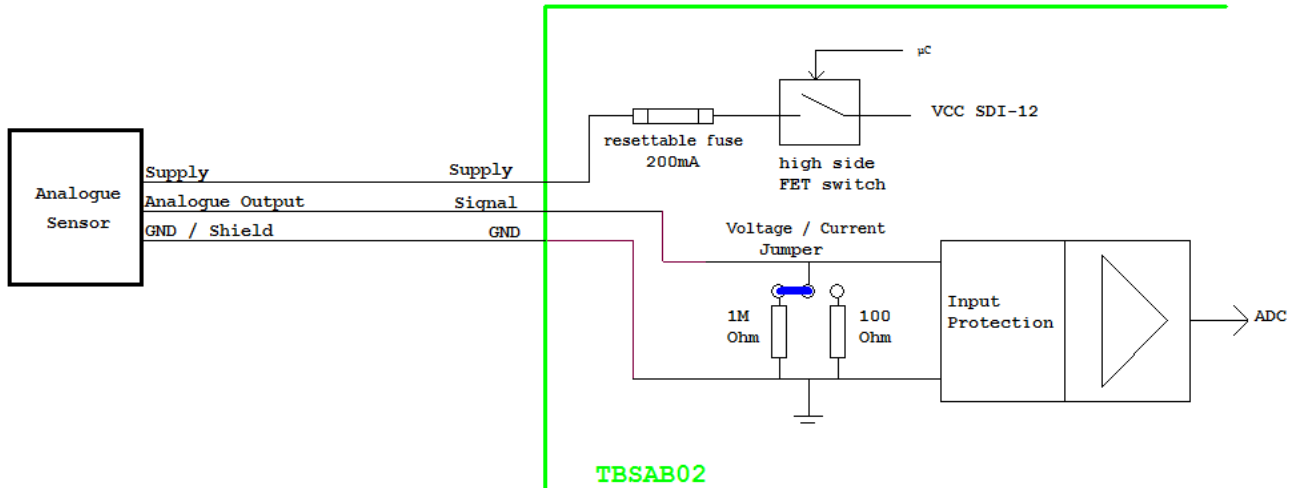


Figure 5 – Sensor with ratio metric voltage output connected to TBSAB02(DR)

Connect sensors with ratio metric voltage output to the TBSAB02(DR) according to figures 3/4.  
Input Voltage Range: 0...2,5V; other ranges available upon order

### 3.4 Current loop mode

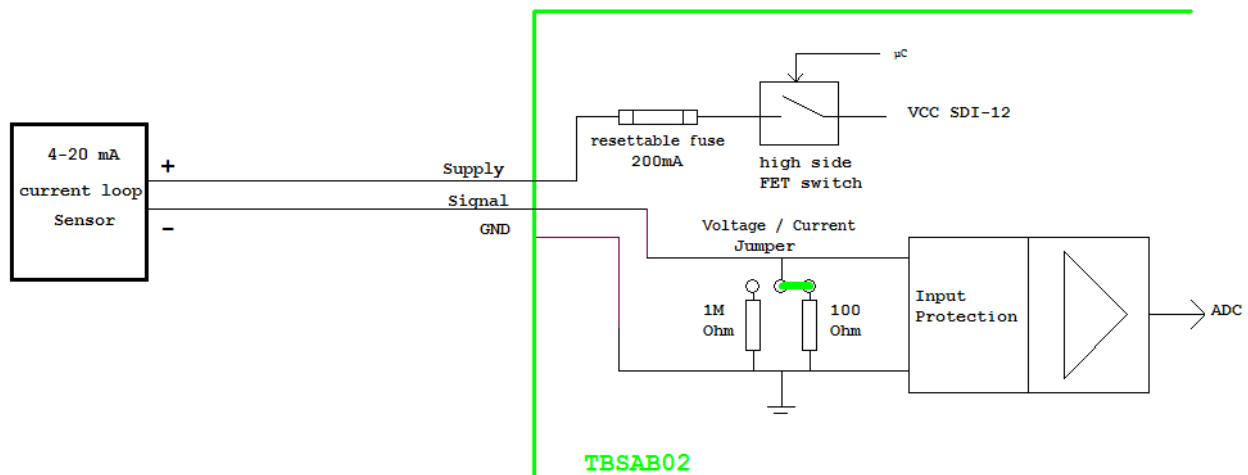


Figure 6 – Loop powered sensor connected to TBSAB02(DR)

Connect loop powered sensors to the TBSAB02(DR) according figures 3/5.  
A 4 - 20mA current loop translates into a 0,4V – 2V voltage drop across the 100 Ohm loop termination resistor.

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### 3.5 PT100/PT1000 interface

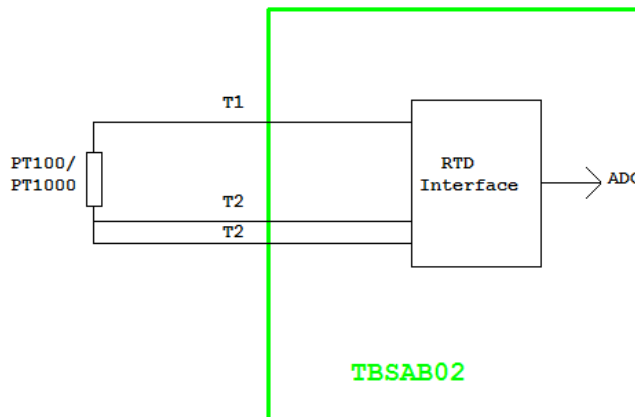


Figure 7 – PT100/PT1000 temperature sensor connected to TBSAB02(DR)

Connect PT100 or PT1000 sensors to the TBSAB02(DR) according figures 3/6.

The TBSAB02(DR) will directly output the temperature in Celsius or Fahrenheit. The unit can be set with an extended SDI-12 command.

### 3.6 Calibration

The TBSAB02(DR) is factory calibrated with respect to offset errors and gain errors of the analogue signal chain. The TBSAB02(DR) has excellent long term stability with respect to offset and gain errors:

Offset drift over time: 100nV/1000hrs

Gain drift over time: 1.6ppm/100hrs

In case that the user wants to re-calibrate the TBSAB02(DR), a two or three step calibration process has to be carried out. The current calibration can be skipped, if no current loop sensors are being connected.

#### Offset error calibration:

Short all 4 analogue inputs to ground by setting jumpers J5, J6, J7, J8 according figure 3. After grounding the inputs, issue the **aXOVL!** command. Remove the jumpers after calibration.

#### Gain error calibration:

Connect all analogue input pins to the onboard precision 2,5V reference voltage by setting jumpers J5, J6, J7, J8 according figure 3. Issue the **aXOVH!** command. Remove the jumpers after calibration.

#### Current calibration:

Connect a precision 10mA current source the same way as the current loop sensor in Figure 5. Issue the **aXOAn!** command.

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### 4 Measurement Commands overview

#### SDI-12 Measurement Commands:

aM!	Measure voltage at channel 0 [V]
aM1!	Measure voltage at channel 1 [V]
aM2!	Measure voltage at channel 2 [V]
aM3!	Measure voltage at channel 3 [V]
aM4!	Measure current at channel 0 [mA]
aM5!	Measure current at channel 1 [mA]
aM6!	Measure current at channel 2 [mA]
aM7!	Measure current at channel 3 [mA]
aMC!	Measure voltage/current at channel 0 [V] – measurement with cyclic redundancy check
aMC1!	Measure voltage/current at channel 1 [V] – measurement with cyclic redundancy check
aMC2!	Measure voltage/current at channel 2 [V] – measurement with cyclic redundancy check
aMC3!	Measure voltage/current at channel 3 [V] – measurement with cyclic redundancy check
aMC4!	Measure current at channel 0 [mA] – measurement with cyclic redundancy check
aMC5!	Measure current at channel 1 [mA] – measurement with cyclic redundancy check
aMC6!	Measure current at channel 2 [mA] – measurement with cyclic redundancy check
aMC7!	Measure current at channel 3 [mA] – measurement with cyclic redundancy check
aM8!	Measure temperature of connected PT100/PT1000 [°C], [°F]
aMC8!	Measure temperature of connected PT100/PT1000 – with cyclic redundancy check
aM9!	Measure temperature of internal temperature sensor [°C], [°F]
aMC9!	Measure temperature of internal temperature sensor – with cyclic redundancy check
aC!	Concurrent measurement of voltages at channel 0..3 [V]
aCC!	Concurrent measurement of voltages at channels 0..3 [V] – with cyclic redundancy check
aC1!	Concurrent measurement of currents at channel 0..3 [mA]
aCC1!	Concurrent measurement of currents at channels 0..3 [mA] – with cyclic redundancy check

#### Extended SDI-12 Commands:

aXRTMn,xxx!	set measurement response time example: 0XRTM0,002! - set measurement response time of channel 0 to 2 seconds (min. 1s)
aXDTn,xxx!	set sensor supply voltage turn OFF delay time example: 0XDT0,001! -> set turn OFF delay time for channel 0 to 1 second
aXSCn,saaa.aa,sbbb.bb,sccc.cc,sddd.dd!	set polynomial scaling coefficients

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( $y = a \cdot x^3 + b \cdot x^2 + c \cdot x + d$ ); 6 digits per coefficient; the decimal point may be at any position

example: 0XSC0,+0000.00,+0000.00,+0001.00,+0000.00! -> set coefficients for channel 0

example: 0XSC0,-0.00013,+0.00230,+0001.00,-0002.50! -> set coefficients for channel 0

aXOVL! offset voltage calibration, calibrate voltage offset for all channels

aXOVH! gain calibration, calibrate gain error for all channels

aXOAn! offset current calibration, calibrate current offset for channel n

aXTUx! set temperature unit to Celsius (C) or Fahrenheit (F)

example: 0XTUF! set temperature unit to Fahrenheit

aXTEsoo.oo! set temperature offset for external PT100/PT1000

example: 0XTE+00.03! -> add 0.03 degree;

aXTIsoo.oo! set temperature offset for internal temperature sensor

example: 0XTI-01.27! -> subtract 1.27 degree

aXIS! Set the TBS02A to indicate an input voltage range overflow by responding with 999999999

aXIR! Disable the indication of an input voltage range overflow

aXPT100! Set connected RTD type to PT100

aXPT1000! Set connected RTD type to PT1000

aXGD! reset to default settings

1. Sensor address: 0

2. Temperature offset for PT100/1000: 0 °C

3. Temperature offset for internal sensor: 0 °C

4. Temperature unit: Celsius

5. ADC polynomial scaling coefficients:  $a = 0$ ,  $b = 0$ ,  $c = 1$ ;  $d = 0$

6. Response Time

ADC channel (aM -> aM3): 1s

aC, concurrent measurement ADC[0...3]: 4s

7. Sensor supply voltage turn OFF delay: 0s

8. Input voltage range overflow indication: disabled

9. Default RTD: PT1000

10. Indication of input voltage overflow disabled

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

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### 5 Functional Description

#### 5.1 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 TBSAB02(DR) 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 TBSAB02(DR), the TBS03 extracts the corresponding ASCII strings and sends them to the USB Virtual COM Port of the PC.

In remote applications, TBSAB02(DR) can be connected to a data logger, a data terminal or a Radio Telemetry Unit with a SDI-12 interface.

#### 5.2 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 **0!!**

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.

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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 TBSAB02(DR) 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+1.25639842**. +1.25639842 is the measurement result which is corresponding to 1.25639842 Volt.

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.

### 5.3 Sensor Identification

The TBSAB02(DR) will respond with following string upon sending the “*Send Identification*” command **al!**:

allccccccmmmmmmvvvxxxxxxxxxxxxx<CR><LF>

Example: 013TEKBOXVNTBSAB21.0000005<CR><LF>

Where:	0	SDI-12 Sensor address
	13	SDI-12 version number, version 1.3
	TEKBOXVN	Company name
	TBSAB2	Model Name
	1.0	Firmware version 1.0
	000005	Serial number of the device

### 5.4 Sensor Address

Each TBSAB02(DR) is delivered with a default address of “0”

The TBSAB02(DR) accepts SDI-12 addresses in the range “0” to “9”, “A” to “Z” and “a” to “z”. Setting the address of the TBSAB02(DR) can be done using the “*Change Address Command*” **aAb!**.

#### Note:

- If the new address is invalid, the current address will be kept.
- The TBSAB02(DR) sensor will remain unresponsive for approximately 1 second while the new address is saved in the EEPROM memory.
- The TBSAB02(DR) sensor interface supports “?” as an address only for “*Acknowledge Active*” Command **a!**.

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### 5.5 Measurement

The TBSAB02(DR) 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 TBSAB02(DR) sensor interface will not support the “Continuous Measurement” Command **aRn!** and “Continuous Measurement and Request CRC” Command **aRCn!**. The TBSAB02(DR) sensor 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 sensor values - Voltage Level and/or Temperature - 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 TBSAB02(DR) sensor interface uses a format of “sign” followed by n digits. Voltage measurement results have 9 digits. The position of the decimal point may differ, depending on scaling. Temperature measurement results have up to 6 digits.

### 5.6 Measurement Examples

#### aM! Measure voltage at channel0 [V]

Command	Response	Comment
aM!	a0011<CR><LF>	Means: 1 measurement value will be available after 1second
aD0!	a+1.25639842<CR><LF>	The voltage at the input of channel0 is 1.25639842V

[a] represents the SDI-12 bus address of the TBSAB02(DR)

The value 1.25639842 is the voltage measured at the input of channel1. The voltage is represented by 9 digits. The maximum measurable input voltage is +2.49999999V. If the input voltage exceeds the input range of 0 to 2.49999999V, an input voltage overflow can be indicated by delivering an output value of 999999999. To set the TBSAB02(DR) to indicate an input voltage overflow, it is required to issue the extended SDI-12 command **aXIS!**. The position of the decimal point may differ, depending on scaling.

#### aC! Measure Voltages at channels0, 1, 2, 3 [V]

Command	Response	Comment
aC!	a0044<CR><LF>	Means: 4 measurement values will be available after 4 seconds
aD0!	a+1.25639842+0.17685831+2.31893651+0.00009765<CR><LF>	The voltage levels measured at channel0, 1, 2, 3

[a] represents the SDI-12 bus address of the TBSAB02(DR)

#### aM8! Measure RTD Temperature [°C], [°F]

Command	Response	Comment
aM8!	a0011<CR><LF>	Means: 1 measurement value will be available after 1second
aD0!	a+23.175 <CR><LF>	The temperature of the connected PT1000 is 23.175 °C

[a] represents the SDI-12 bus address of the TBSAB02(DR)



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### 5.7 Supported SDI-12 Commands

Following commands are supported by the TBSAB02(DR):

Command	Description	Response
<b>a!</b>	Acknowledge Active	a<CR><LF>
<b>a!</b>	Send Identification	013TEKBOXVNTBSAB21.0000005xxxxx<CR><LF> With xxxxx representing the serial number
<b>aAb!</b>	Change Address	b<CR><LF> Changing the probe sensor address
<b>?!</b>	Address Query	a<CR><LF>
<b>aM!</b>	Start Measurement Measures voltage at analogue input channel 0	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aM1!</b>	Additional Measurement Measures voltage at analogue input channel 1	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aM2!</b>	Additional Measurement Measures voltage at analogue input channel 2	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aM3!</b>	Additional Measurement Measures voltage at analogue input channel 3	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aM4!</b>	Start Measurement Measures current at analogue input channel 0	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aM5!</b>	Additional Measurement Measures current at analogue input channel 1	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aM6!</b>	Additional Measurement Measures current at analogue input channel 2	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aM7!</b>	Additional Measurement Measures current at analogue input channel 3	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aM8!</b>	Additional Measurement PT100/PT1000 temperature measurement	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aM9!</b>	Additional Measurement Measures temperature using internal sensor	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aMC!</b>	Start Measurement and request CRC Measures voltage at analogue input channel 0 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aMC1!</b>	Additional Measurement and request CRC Measures voltage at analogue input channel 1 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aMC2!</b>	Additional Measurement and request CRC Measures voltage at analogue input channel 2 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (1)

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<b>aMC3!</b>	Additional Measurement and request CRC Measures voltage at analogue input channel 3 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aMC4!</b>	Additional Measurement and request CRC Measures current at analogue input channel 0 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aMC5!</b>	Additional Measurement and request CRC Measures current at analogue input channel 1 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aMC6!</b>	Additional Measurement and request CRC Measures current at analogue input channel 2 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aMC7!</b>	Additional Measurement and request CRC Measures current at analogue input channel 3 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aMC8!</b>	Additional Measurement and request CRC PT100/PT1000 temperature measurement and CRC calculation	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aMC9!</b>	Additional Measurement and request CRC Measures temperature using internal sensor calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
<b>aC!</b>	Start Concurrent Measurement Measures voltages at input channels 0 to 3 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (4)
<b>aC1!</b>	Start Concurrent Measurement Measures currents at input channels 0 to 3 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (4)
<b>aCC!</b>	Start Concurrent Measurement and request CRC Measures voltages at input channels 0 to 3 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (4)
<b>aCC1!</b>	Start Concurrent Measurement and request CRC Measures currents at input channels 0 to 3 and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (4)
<b>aD0!</b>	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.
<b>aV!</b>	Start Verification	a0000<CR><LF> Not supported
<b>aRn! aRCn!</b>	Continuous Measurement Continuous Measurement + CRC	a<CR><LF> Not supported

Table 1 – Standard SDI-12 commands

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### 5.8 Supported Extended Commands

Command	Description	Response
<b>aXRTMn,xxx!</b>	<p>set measurement response time</p> <p>[n] represents the channel number</p> <p>[xxx] represents the response time in seconds</p> <p>default value: 1s</p> <p>example: 0XRTM0,002! - set measurement response time of channel 0 to 2 seconds (minimum 1s)</p> <p>Application: Upon issuing a measurement command, the supply output for the concerned sensor will be switched on. As sensors require a certain time before a stable measurement signal can be obtained, sampling of the analogue input will be delayed. Default value is 1s. In case that the sensor takes more time to stabilize, the response time shall be changed accordingly.</p>	aX_OK<CR><LF>
<b>aXTDn,xxx!</b>	<p>set sensor supply voltage turn OFF delay time</p> <p>[n] represents the channel number</p> <p>[xxx] represents the response time in seconds</p> <p>default value: 0s</p> <p>example: 0XDT0,001! -&gt; set turn OFF delay time of the channel 0 supply output to 1 second</p> <p>Application: upon issuing a measurement command, the supply voltage output for the concerned sensor will be switched on. By default, the TBSAB02(DR) will turn off the sensor supply voltage after the specified measurement response time. If required, switching off the supply can be delayed by setting a turn OFF delay time.</p>	aX_OK<CR><LF>
<b>aXSCn,aaa.aa,bb.bb,ccc.cc,dd.d.dd!</b>	<p>set polynomial scaling coefficients</p> <p>[a], [b], [c], [d] represent the coefficients of the third order polynomial:</p> $y = a \cdot x^3 + b \cdot x^2 + c \cdot x + d$ <p>where [x] represents the sampled measurement value</p> <p>6 digits per coefficient; the decimal point may be at any position</p> <p>default value: a=0, b=0, c=1, d=0</p> <p>the output of the polynomial function is presented as measurement result.</p> <p>example: 0XSC0,+0000.00,+0000.00,+0001.00,+0000.00! -&gt; set coefficients for channel 0</p> <p>example: 0XSC1,+0.00013,+0.00230,+0001.00,+0002.50! -&gt; set coefficients for channel 1</p> <p>Application: scaling can be used to convert the measured voltage values into values which represent the physical parameter measured by the sensor. Scaling can also be applied to linearize or temperature compensate the sensor output.</p>	aX_OK<CR><LF>
<b>aXOVL!</b>	offset calibration, calibrate voltage offset for all channels	aX_OK<CR><LF>

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	voltage offset calibration is done at factory In order to calibrate the voltage offset, all analog input channels need to be connected to GND, before issuing the offset calibration command	
<b>aXOVH!</b>	gain calibration, calibrate gain error for all channels gain error calibration is done at factory In order to calibrate the gain error, all analog input channels need to be connected to the 2.5V reference voltage pin, before issuing the gain error calibration command	aX_OK<CR><LF>
<b>aXOAn!</b>	[n] represents the channel number current measurement calibration, calibrate channel n current measurement calibration is done at factory In order to calibrate the current measurement, a 10mA precision current source needs to be connected between VCC and analogue input of channel n	aX_OK<CR><LF>
<b>aXTUx!</b>	set temperature unit to Celsius (C) or Fahrenheit (F) example: 0XTUC! set temperature unit to Celsius example: 0XTUF! set temperature unit to Fahrenheit	aX_OK<CR><LF>
<b>aXTE,snnnnnn!</b>	set temperature offset for external PT100/PT1000 example: 0XTE,+00.032! -> add 0.032 degree;	aX_OK<CR><LF>
<b>aXTI,soo.oo!</b>	set temperature offset for internal temperature sensor example: 0XTI,-01.27! -> subtract 1.27 degree	aX_OK<CR><LF>
<b>aXIS!</b>	set the TBS02A to indicate an input voltage range overflow by responding with 999999999	aX_OK<CR><LF>
<b>aXIR!</b>	disable the indication of an input voltage range overflow	aX_OK<CR><LF>
<b>aXPT100!</b>	set connected RTD type to PT100	aX_OK<CR><LF>
<b>aXPT1000!</b>	set connected RTD type to PT1000	aX_OK<CR><LF>
<b>aXGD!</b>	reset to default settings 1. Sensor address: 0 2. Temperature offset for PT100/1000: 0 °C 3. Temperature offset for internal sensor: 0 °C 4. Temperature unit: Celsius 5. ADC polynomial scaling coefficients: a = 0, b = 0, c = 1; d = 0 6. Response Time ADC channel (aM -> aM3): 1s aC, concurrent measurement ADC[0...3]: 4s 7. Sensor supply voltage turn OFF delay: 0s 8. Input voltage range overflow indication: disabled 9. Default RTD: PT1000 10. Indication of input voltage overflow disabled	aX_OK<CR><LF>

Table 2 – Extended SDI-12 Commands

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### 6 Application Example

This chapter is a practical guide on how to set up a TBSAB02(DR), interface it to a PC with a TBS03 SDI-12 to USB converter and carry out measurements.

#### 6.1 Setting up TBSAB02(DR) together with TBS03

##### 6.1.1 Requirements

###### User Interface

Any hyper terminal (e.g.: Windows Hyper Terminal, Terminal V1.9B, RealTerm) or specific application software (e.g. LabVIEW VI)

###### Hardware Interface

PC or laptop with USB interface and mini USB-B cable (USB cable supplied with TBS03)

##### 6.1.2 Driver

Silicon Labs CP210x driver must be installed on PC (on CD supplied with TBS03 or download from Silicon Labs)

**Do not connect TBS03 to the PC, when starting the CP2102 driver installation process!**

- 1) Start the driver installation executable
- 2) Follow the installation instructions step by step until the driver installation process is finished
- 3) The system may need to restart
- 4) Upon restart after successful driver installation (**and not before**), connect the TBS03 to the USB interface of the PC
- 5) Wait until you get the notification that the new hardware has been installed and are ready to use.



Some terminal programs need manual COM port set up.

Open the hardware manager to check the COM port number assigned to the Silicon Labs USB bridge.

Every TBS03 device is serialized with an individual number. This enables the use of several TBS03's in parallel on a single PC or Laptop.

#### 6.2 Hardware

- Connect the USB / SDI-12 Converter to the PC via USB port.
- Connect the TBS03 SDI-12 data interface to the TBSAB02(DR) Analogue to SDI-12 Interface.
- Connect a voltage source  $0 < V < 2,5V$  to channel 0

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### 6.2.1 Setting up the HyperTerminal application

- Open the hardware manager to check the COM port number assigned to the Silicon Labs USB bridge.
- Start the Windows HyperTerminal application.
- Connect to the COM Port assigned to the SDI-12 USB converter.
- Set the COM speed to 19200, 8 Bits, No Parity, 1 Stop Bit, No Handshake.
- In Settings, click "ASCII Setup" and activate "Send line ends with line feed" and "Echo typed characters locally".

## 6.3 Operation

### 6.3.1 SDI-12 / USB converter transfer mode

Every mode of TBS03 needs to be initialized with an ASCII string. Upon reception, the TBS03 will switch into the initialized mode and remain in this mode until the device receives an initialization string for another mode or the device gets disconnected. At the start up time, "Transfer Mode" is the default mode.

Transfer Mode initialisation:

In Windows hyper terminal, enter **run sdi recorder** and press the enter key (or <CR><LF>)

The TBS03 will respond with **ACK<CR><LF>**

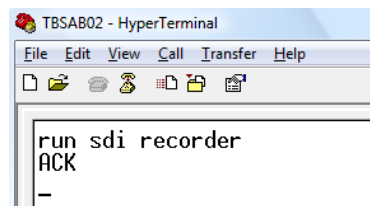


Figure 8 –TBS03 Transfer mode initialization using Windows Hyper Terminal

The TBS03 is now in transfer mode and ready to transfer commands to the sensor and respond data to the PC. The following screenshots show how to communicate with the TBSAB02(DR).

TBS03: Entering **0I!** <CR><LF> will respond with the sensor ID:

TBSAB02(DR) response: 013TEKBOXVN\_LCSMP1.0000005<CR><LF>

Upon sending the ID command **0I!**, the sensor responds with SDI-12 compatibility level, Manufacturer name, Model name, Firmware release number and Serial number

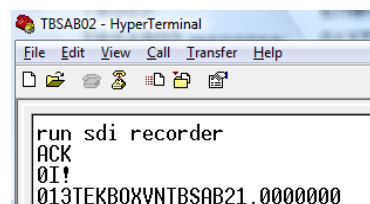


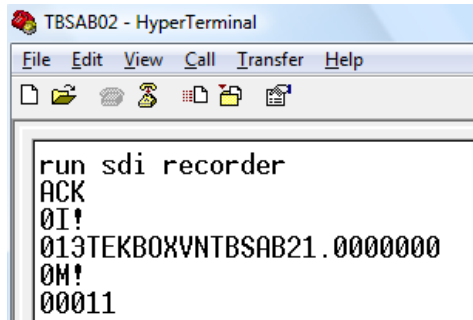
Figure 9 –TBSAB02(DR), sensor response to ID command **0I!**

TBS03: Entering **0M!** <CR><LF> will respond with:

TSMP01 response: 00011 <CR><LF>

which means that the sensor will be able to deliver 1 value after an acquisition time of 1 second

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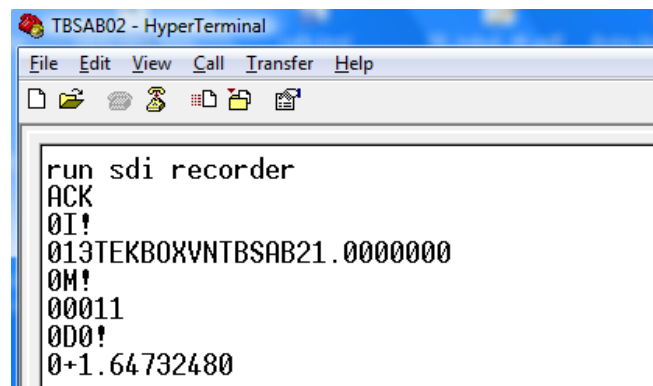


```

TBSAB02 - HyperTerminal
File Edit View Call Transfer Help
run sdi recorder
ACK
0I!
013TEKBOXVNTBSAB21.0000000
0M!
00011
  
```

Figure 10 – TBSAB02(DR) response to Start Measurement command **0M!**

TBS03:                    Entering **0D0!** <CR><LF> will respond with:  
 Sensor response:        0+1.64732480 <CR><LF>  
 where 1.64732480 is the voltage measured at channel 0



```

TBSAB02 - HyperTerminal
File Edit View Call Transfer Help
run sdi recorder
ACK
0I!
013TEKBOXVNTBSAB21.0000000
0M!
00011
0D0!
0+1.64732480
  
```

Figure 11 – TBSAB02(DR) response to Send Data command **0D0!**

Other SDI commands will work similarly.

### 6.3.2 Auto-measurement mode

Auto-measurement mode is only available on TBS03 with option OTBS03-1 or option OTBS03-2

Like SDI Transfer commands, this application sends measurement commands which are set up by the user, to the SDI-12 / USB interface. Then, it automatically collects measured data by sending aDn! commands and transfers the data via USB Interface. After that, the next measurement command is started with a user defined time interval in-between consecutive measurements. The maximum timer value is 4294967295ms. The maximum number of different SDI-12 measurement commands in an auto measurement string is 9. Auto-measurement mode is stopped by sending **stop** <CR><LF>

Syntax: run *auto* <measurement command 1> <timer value 1> ... <measurement command n> <timer value n>

Example of controlling a TBSAB02(DR) in auto measurement mode:

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TBS03: Entering **run auto OM! 200**<CR><LF> will respond with periodically measuring voltage values at channel 1. The time interval between two consecutive measurements is 200ms:

```
run auto OM! 200
ACK
OM!: 0+1.58313989
OM!: 0+1.58313694
OM!: 0+1.58313894
OM!: 0+1.58313035
OM!: 0+1.58313655
OM!: 0+1.58312501
OM!: 0+1.58312296
OM!: 0+1.58312978
OM!: 0+1.58313846
OM!: 0+1.58313393
OM!: 0+1.58313608
OM!: 0+1.58312559
OM!: 0+1.58313331
OM!: 0+1.58313751
OM!: 0+1.58313751
OM!: 0+1.58313274
.
.
.
.
.
OM!: 0+1.58312559
OM!: 0+1.58313347
OM!: 0+1.58312377
OM!: 0+1.58312702
OM!: 0+1.58313059
OM!: 0+1.58313298
OM!: 0+1.58312702
OM!: 0+1.58313217
OM!: 0+1.58313512
OM!: 0+1.58312106
stop
ACK
```

The results converted into an EXCEL graph:

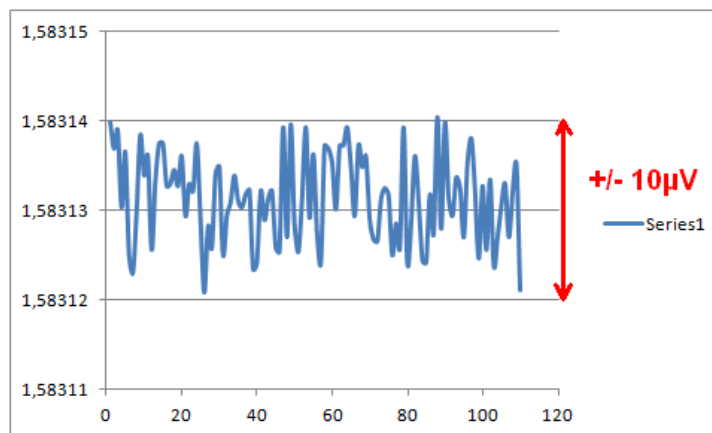


Figure 12 – TBSAB02(DR); Noise



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### 7 Tools for TBS03

The TBS03 can be controlled using hyper terminals or customized PC application software. National Instruments, for example, offers a LabView SDI-12 API which could be used for designing customized applications for TBS03.

When using Hyper Terminal programs, take care that the representation of <CR><LF> may be different for different programs.

Windows Hyper Terminal requires activation of "Send line ends with line feed" in ASCII setup and thereafter pressing the ENTER-key results in <CR><LF>

Many Hyper Terminal programs require \n at the end of each SDI-12 string – e.g. *0M!\n* or *run sdi recorder\n*

Terminal v1.9b – 20080315β – by Br@y ++ requires adding \$0D\$0A for <CR><LF>. This tool offers user defined macros for frequently used commands - a convenient feature when working with TBS03.

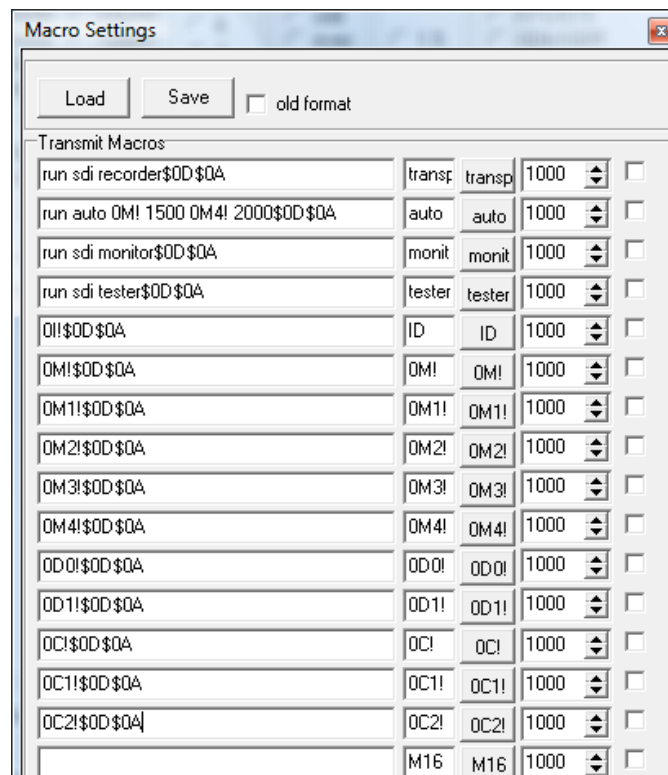


Figure 13 – Terminal v1.9b, defining Macros for mode initialization and SDI-12 commands

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When manually entering commands in Terminal v1.9b, tick the CR=CR+LF and +CR box.

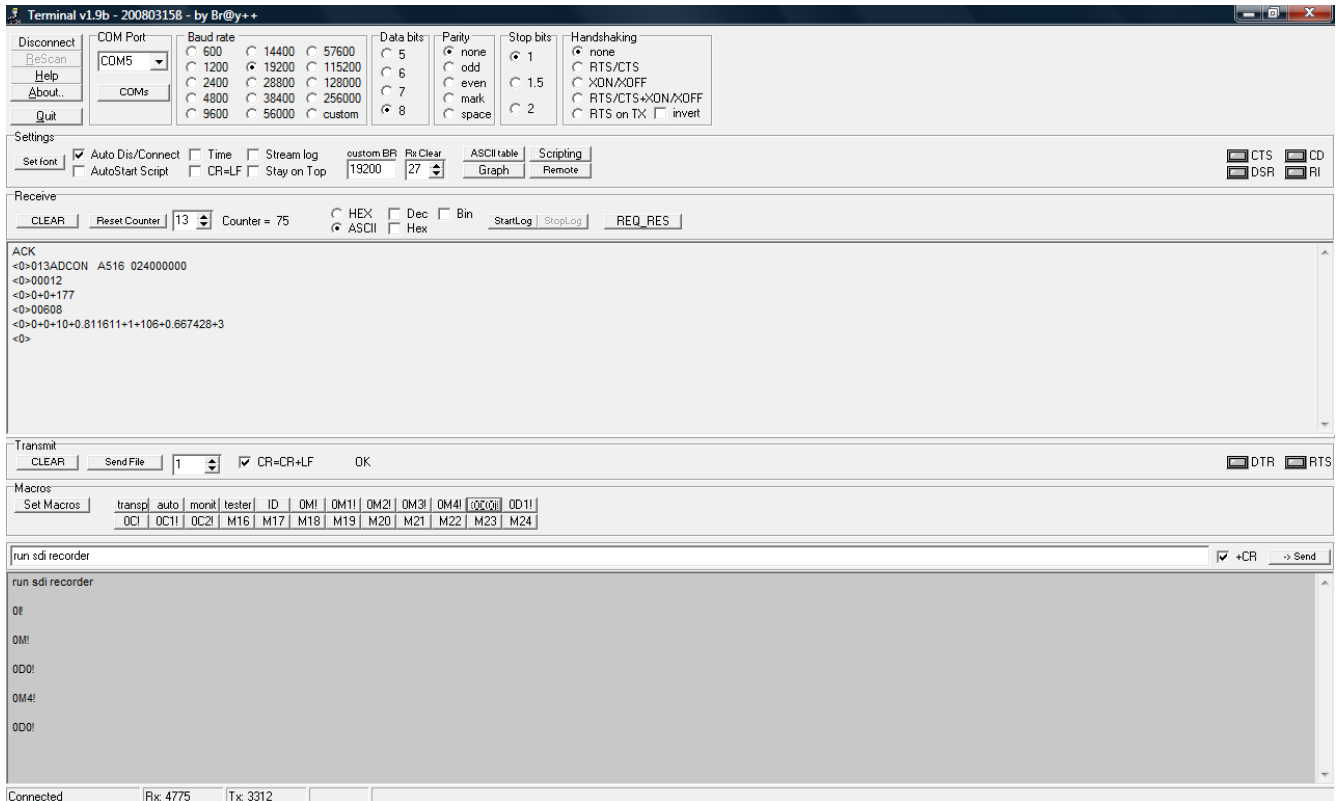


Figure 14 – Example set up of Terminal v1.9b

The above mentioned Hyper Terminal Programs are just examples to highlight that using such tools requires taking care of their way to handle <CR><LF>.

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### 8 Technical Specifications

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I <sub>s</sub>	Supply current	Active mode (during measurement)		7		mA
I <sub>s</sub>	Supply current	Sleep mode		95		μA
V <sub>s</sub>	Supply voltage		6	12	17	V
t <sub>m</sub>	Measurement Time	Time in active mode upon receiving a measurement command			1	s
V <sub>r</sub>	Voltage measurement range		0		2.5	V
R	Voltage measurement resolution			24		Bit
INL	Integral nonlinearity			±7	±15	ppm of FSR
ENOB	Noise free resolution			19		Bit
N	Noise			8.6		μV RMS
GE	Gain error			7		ppm
GET	Gain error over temperature			0.5		ppm/°C
GED	Gain error over time			1.6		ppm / 1000hrs
OE	Offset error			9.5		μV
OET	Offset drift over temperature			25		nV/°C
OED	Offset drift over time			100		nV / 1000hrs
ATT_50/60	50/60 Hz line rejection			>90		dB
V <sub>ref</sub>	2.5V reference voltage accuracy				0.025 2	% ppm/°C
TR_int	Internal sensor: Temperature measurement range		-40		+85	°C
TA_int	Internal sensor: Temperature calibration accuracy	@ 25°C		±0.5		°C
TL_int	Internal sensor: Temperature measurement linearity	from -40°C to +85°C		±1	±3	°C
TL_int	Internal sensor: Temperature measurement linearity	from -40°C to +85°C		±1	±3	°C
ZIN_v	Input Impedance	voltage measurement mode		1		MOhm
ZIN_i	Input Impedance	current measurement mode		100		Ohm
OV_V	Input overvoltage protection	voltage measurement mode		±75		V

Table 3 – Technical Specifications

## 24 Bit Analogue to SDI-12 Interface manual

### 9 Environmental Specifications

Symbol	Parameter	Conditions	Min	Max	Unit
T <sub>A</sub>	Operating Ambient Temperature Range		-40	+85	°C
T <sub>STG</sub>	Storage Temperature Range		-40	+85	°C
	Moisture level	closed housing	-	100	%

Table 4 - Environmental Specifications

### 10 Ordering Information

Part Number	Description
TBSAB02	Analogue to SDI-12 Interface, standard configuration, IP67 Fibox housing
TBSAB02DR	Analogue to SDI-12 Interface, standard configuration, DIN Rail housing
TBSAB02_1155	Analogue to SDI-12 Interface, customized voltage ranges, IP67 Fibox housing, see 12) Annex

Table 5 – Ordering Information

### 11 History

Version	Date	Author	Changes
V1.0	29.12.2011	Mayerhofer	Creation of the document
V1.1	19.01.2012	Mayerhofer	corrections
V1.2	18.04.2012	Mayerhofer	Update for PCB REV B
V1.3	07.03.2013	Mayerhofer	Correction (Example for aC! measurement command)
V1.4	07.08.2013	Mayerhofer	TBSAB02DR added
V1.5	27.08.2014	Mayerhofer	Annex added

Table 6 – History

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### 12 Annex

#### 12.1 Customized variant TBSAB02\_1155

The customized variant TBSAB02\_1155 differs with respect to the standard TBSAB02 in following parameters:

**Input voltage range:**

Channel 0	0V ... 1V
Channel 1	0V ... 1V
Channel 2	0V ... 5V
Channel 3	0V ... 5V