

SDI-12 SOIL TEMPERATURE SENSOR

The TBSST01 is a sensor for monitoring soil temperature values in precision farming and environmental monitoring applications.

The TBSST01 has been designed to work in any type of soil. It has a low current consumption and an SDI-12 interface. It is ideally suited for battery or solar powered remote applications. The TBSST01 has short measurement time and fast response to any changes in the soil temperature. It is easy to install and easy to calibrate. The TBSST01 is a rugged, hermetically sealed design, equipped with a polyurethane protected cable.



Features

- Accurate soil temperature measurement
- Fast response
- PT1000 DIN A accuracy
- 0.01°C resolution
- Suitable for any soil type
- SDI-12 Interface
- Low Power Consumption
- Simple installation
- Simple calibration
- Small size
- Rugged design
- Hermetically sealed
- Cable with PU jacket
- Operating Temperature Range:
-40°C - +85°C

Target Applications

- Agricultural monitoring
- Soil hydrology monitoring
- Erosion monitoring

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1 Introduction

The TBSST01 is a PT1000 based soil temperature sensor with SDI-12 interface. It offers a resolution of 0.01°C and PT1000 DIN A accuracy.

1.1 Product Features

- SDI-12 Measurement Commands for temperature measurement
- Averaging, configurable with Extended SDI-12 Commands
- PT1000 DIN A accuracy
- 0.1°C resolution
- Operating temperature range: -40 ... +85°C

1.2 Calibration

The TBSST01 comes factory calibrated, however it can be easily user calibrated, using an Extended SDI-12 command.

1.3 Installation

The TBSST01 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.

1.4 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.

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

2 Application Examples

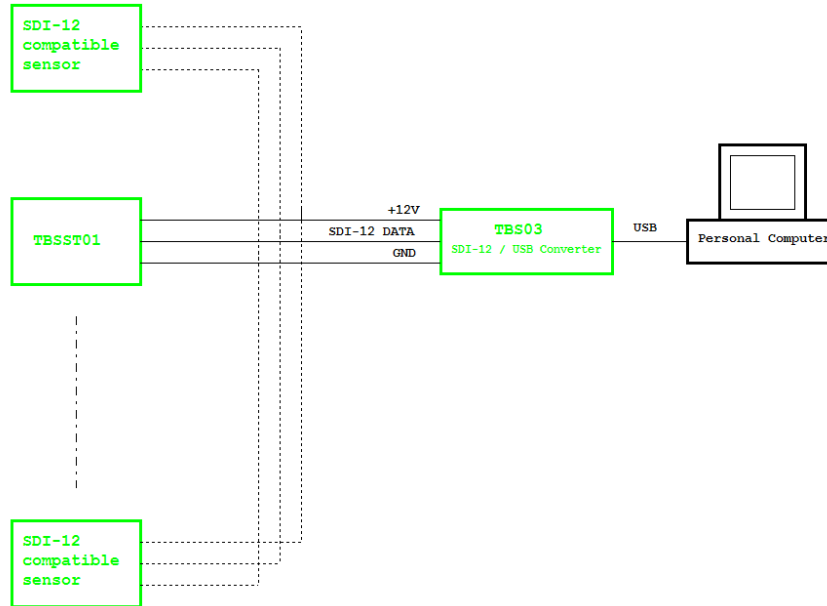


Figure 1 – TBSST01 sensor connected to TBS03 SDI-12 to USB converter; setup for controlling / testing sensors and for PC based data recording

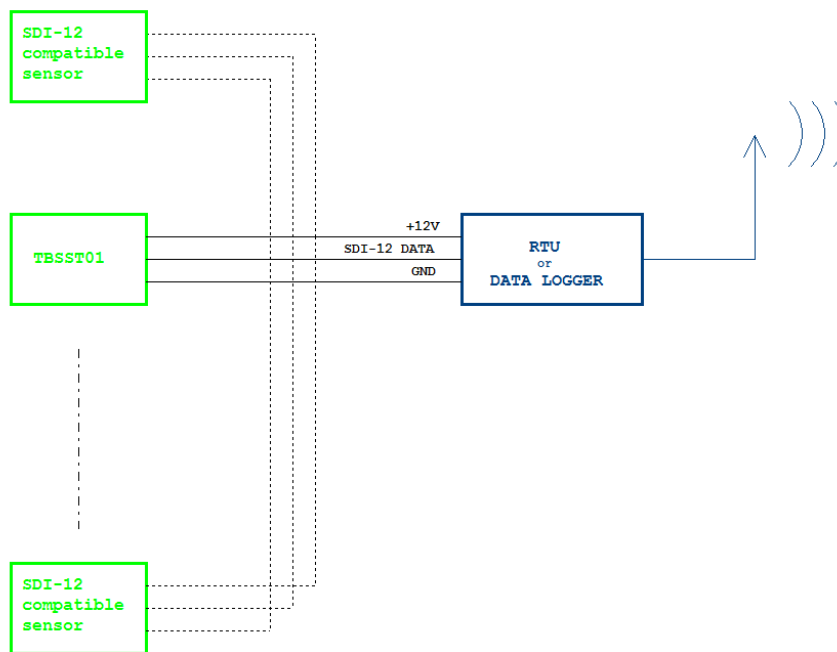


Figure 2 – TBSST01 sensors connected to Remote Telemetry Unit or Data Recorder

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3 Measurement Commands overview

SDI-12 Measurement Commands:

aM!	Read soil temperature [°C], [°F]
aMC!	Read soil temperature [°C], [°F] – measurement with cyclic redundancy check
aC!	Read soil temperature [°C], [°F]
aCC!	Read soil temperature [°C], [°F] – measurement with cyclic redundancy check

Extended SDI-12 Commands:

aXTUx!	set temperature unit to Celsius (C) or Fahrenheit (F) example: 0XTUF! set temperature unit to Fahrenheit
aXCTsoo.oo!	set temperature offset for external PT1000 example: 0XCT+00.03! -> add 0.03 degree offset;
aXSAn!	Set averaging n=1, 10 samples, 1 second response time n=2, 20 samples, 2 seconds response time n=3, 30 samples, 3 seconds response time n=4, 40 samples, 4 seconds response time
aXGD!	reset to default settings 1. Sensor address: 0 2. Temperature offset: 0 °C 3. Temperature unit: Celsius 4. number of samples for averaging: 10 samples

Refer to chapter 4 for a detailed description of the implemented SDI-12 commands.

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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 TBSST01 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 TBSST01, the TBS03 extracts the corresponding ASCII strings and sends them to the USB Virtual COM Port of the PC.

In remote applications, TBSST01 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 **0!**

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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 **0M!**

A TBSST01 with address 0 may respond **00011** which mean 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+29.37**. +29.37 is the measurement result which is corresponding to 29.37°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 TBSST01 will respond with following string upon sending the "Send Identification" command **a!**:

allccccccmmmmmmvvvxxxxxxxxxxxxx<CR><LF>

Example: 013TEKBOXVN_TBSST01_V0.10_000005 <CR><LF>

Where:	0	SDI-12 Sensor address
	13	SDI-12 version number, version 1.3
	TEKBOXVN	Company name
	TBSST01	Model Name
	0.10	Firmware version 0.10
	000005	Serial number of the device

4.4 Sensor Address

Each TBSST01 is delivered with a default address of "0"

The TBSST01 accepts SDI-12 addresses in the range "0" to "9", "A" to "Z" and "a" to "z". Setting the address of the TBSST01 can be done using the "Change Address Command" **aAb!**.

Note:

- If the new address is invalid, the current address will be kept.
- The TBSST01 sensor will remain unresponsive for approximately 1 second while the new address is saved in the EEPROM memory.
- The TBSST01 sensor interface supports "?" as an address only for "Acknowledge Active" Command **a!**.

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4.5 Measurement

The TBSST01 sensor interface accepts the “*Start Measurement*” Command **aM!** and “*Start Concurrent Measurement*” Command **aC!** for obtaining values from the probe. Furthermore it supports **aMC!** and **aCC!** Commands which add a CRC to the measurement response.

The TBSST01 sensor interface will not support the “*Continuous Measurement*” Command **aRn!** and “*Continuous Measurement and Request CRC*” Command **aRCn!**. The TBSST01 sensor will respond with its address followed by <CR><LF> in response to this command.

The response to “*Start Measurement*” **aM!** and “*Start Concurrent Measurement*” Command **aC!** reports the response time and how many sensor values - one Temperature Measurement Value in case of the TBSST01 - will be sent. In order to receive the desired sensor values, the recorder needs to issue the corresponding “*Send Data*” Command **aD0!**.

4.6 Measurement Examples

aM! Measure temperature

Command	Response	Comment
aM!	a0011<CR><LF>	Means: 1 measurement value will be available after 1second
aD0!	a+25.37<CR><LF>	The measured temperature is 25.37°C

[a] represents the SDI-12 bus address of the TBSST01

aC! Measure temperature

Command	Response	Comment
aC!	a0011<CR><LF>	Means: 1 measurement value will be available after 1second
aD0!	a+25.37<CR><LF>	The measured temperature is 25.37°C

[a] represents the SDI-12 bus address of the TBSST01

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4.7 Supported SDI-12 Commands

Following commands are supported by the TBSST01B:

Command	Description	Response
a!	Acknowledge Active	a<CR><LF>
al!	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	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
aMC!	Start Measurement and request CRC Measures temperature and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (1)
aC!	Start Concurrent Measurement Measures temperature and calculates CRC	att1<CR><LF> Delay (ttt) in seconds and number of values (4)
aCC!	Start Concurrent Measurement and request CRC Measures temperature and calculates CRC	att1<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 result.
aV!	Start Verification	a0000<CR><LF> Not supported
aRn! aRCn!	Continuous Measurement Continuous Measurement + CRC	a<CR><LF> Not supported

Table 1 – Standard SDI-12 commands

4.8 Supported Extended Commands

Command	Description	Response
aXTUx!	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>
aXCTsnnnnnn!	set temperature offset example: 0XTE,+00.32! -> add 0.32 degree;	aX_OK<CR><LF>

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aXCTsoo.oo!	set temperature offset for internal temperature sensor example: 0XTI,-01.27! -> subtract 1.27 degree	aX_OK<CR><LF>
aXSAn!	set number of samples for averaging n=1, 10 samples, 1 second response time n=2, 20 samples, 2 seconds response time n=3, 30 samples, 3 seconds response time n=4, 40 samples, 4 seconds response time	aX_OK<CR><LF>
aXGD!	reset to default settings 1. Sensor address: 0 2. Temperature offset: 0 °C 3. Temperature unit: Celsius 4. number of samples for averaging: 10 samples	aX_OK<CR><LF>

Table 2 – Extended SDI-12 Commands

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5 Application Example

This chapter is a practical guide on how to set up a TBSST01, interface it to a PC with a TBS03 SDI-12 to USB converter and carry out measurements.

5.1 Setting up TBSST01 together with TBS03

5.1.1 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)

5.1.2 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 is 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.

5.2 Hardware

- Connect the USB / SDI-12 Converter to the PC via USB port.
- Connect the TBS03 SDI-12 data interface to the TBSST01 Analogue to SDI-12 Interface.
- Connect a voltage source $0 < V < 2,5V$ to channel 0

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5.2.1 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”.

5.3 Operation

5.3.1 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>**

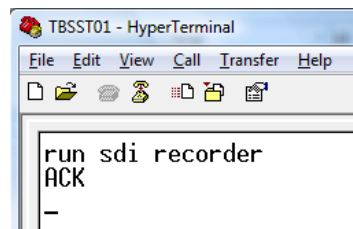


Figure 3 –TBS03 Transfer mode initialization using Windows Hyper Terminal

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 TBSST01.

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

TBSST01 response: 013TEKBOXVN_LCSMP1.0000005<CR><LF>

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

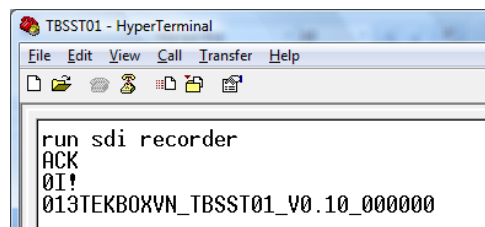


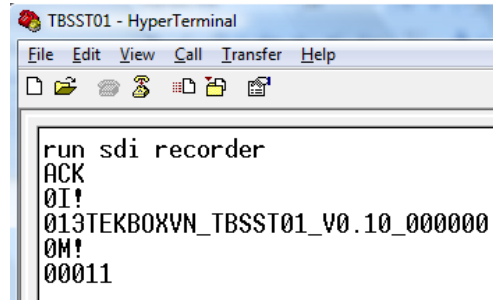
Figure 4 –TBSST01, sensor response to ID command 0!!

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

TSMP01 response: 00011 <CR><LF>

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



```

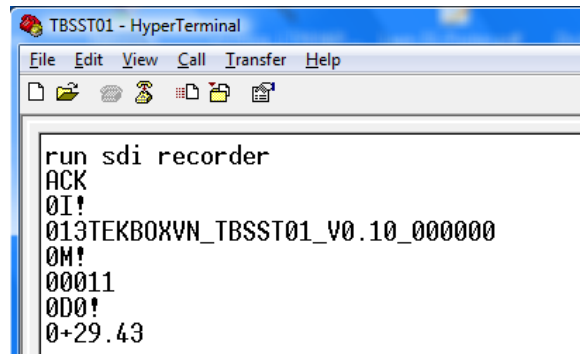
TBSST01 - HyperTerminal
File Edit View Call Transfer Help
run sdi recorder
ACK
OI!
013TEKBOXVN_TBSST01_V0.10_000000
OM!
00011
    
```

Figure 5 –TBSST01 response to Start Measurement command **OM!**

TBS03: Entering **OD0!** <CR><LF> will respond with:

Sensor response: 0+29.43 <CR><LF>

where 29.43 is the measured temperature



```

TBSST01 - HyperTerminal
File Edit View Call Transfer Help
run sdi recorder
ACK
OI!
013TEKBOXVN_TBSST01_V0.10_000000
OM!
00011
OD0!
0+29.43
    
```

Figure 6 –TBSST01 response to Send Data command **OD0!**

Other SDI commands will work similarly.

5.3.2 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

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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 TBSST01 in auto measurement mode:

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

```
run auto OM! 200
ACK
OM! : 0+29.71
OM! : 0+29.71
OM! : 0+29.74
OM! : 0+29.70
OM! : 0+29.71
OM! : 0+29.72
OM! : 0+29.71
OM! : 0+29.73
OM! : 0+29.70
OM! : 0+29.73
OM! : 0+29.73
OM! : 0+29.73
OM! : 0+29.74
OM! : 0+29.70
OM! : 0+29.75
OM! : 0+29.74
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OM! : 0+29.73
OM! : 0+29.72
OM! : 0+29.75
OM! : 0+29.73
OM! : 0+29.71
OM! : 0+29.71
OM! : 0+29.72
OM! : 0+29.72
OM! : 0+29.77
OM! : 0+29.73
OM! : 0+29.73
OM! : 0+29.73
OM! : 0+29.72
OM! : 0+29.74
OM! : 0+29.73
OM! : 0+29.73
OM! : 0+29.73
stop
ACK
```

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6 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. *OM!\n* or *run sdi recorder\n*

Terminal v1.9b – 20080315ß – 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.

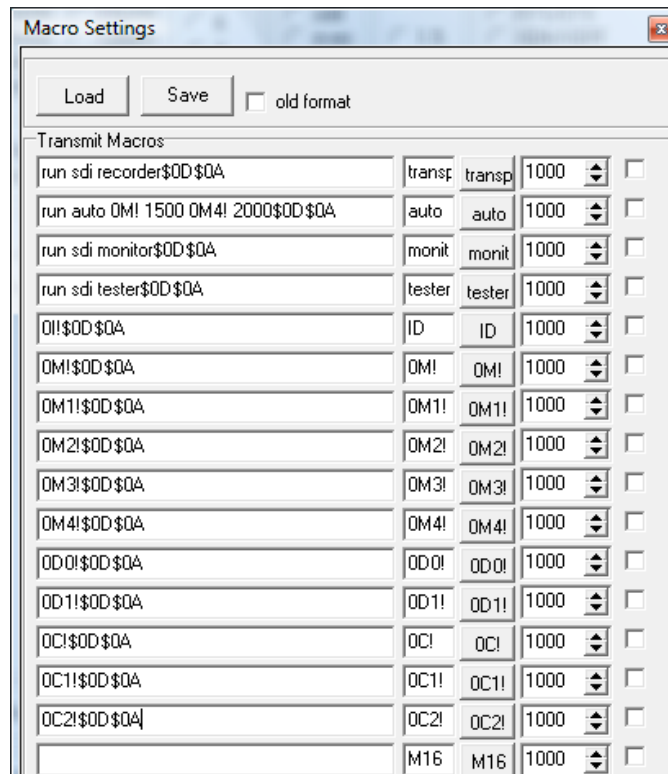


Figure 7 – Terminal v1.9b, defining Macros for mode initialization and SDI-12 commands

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

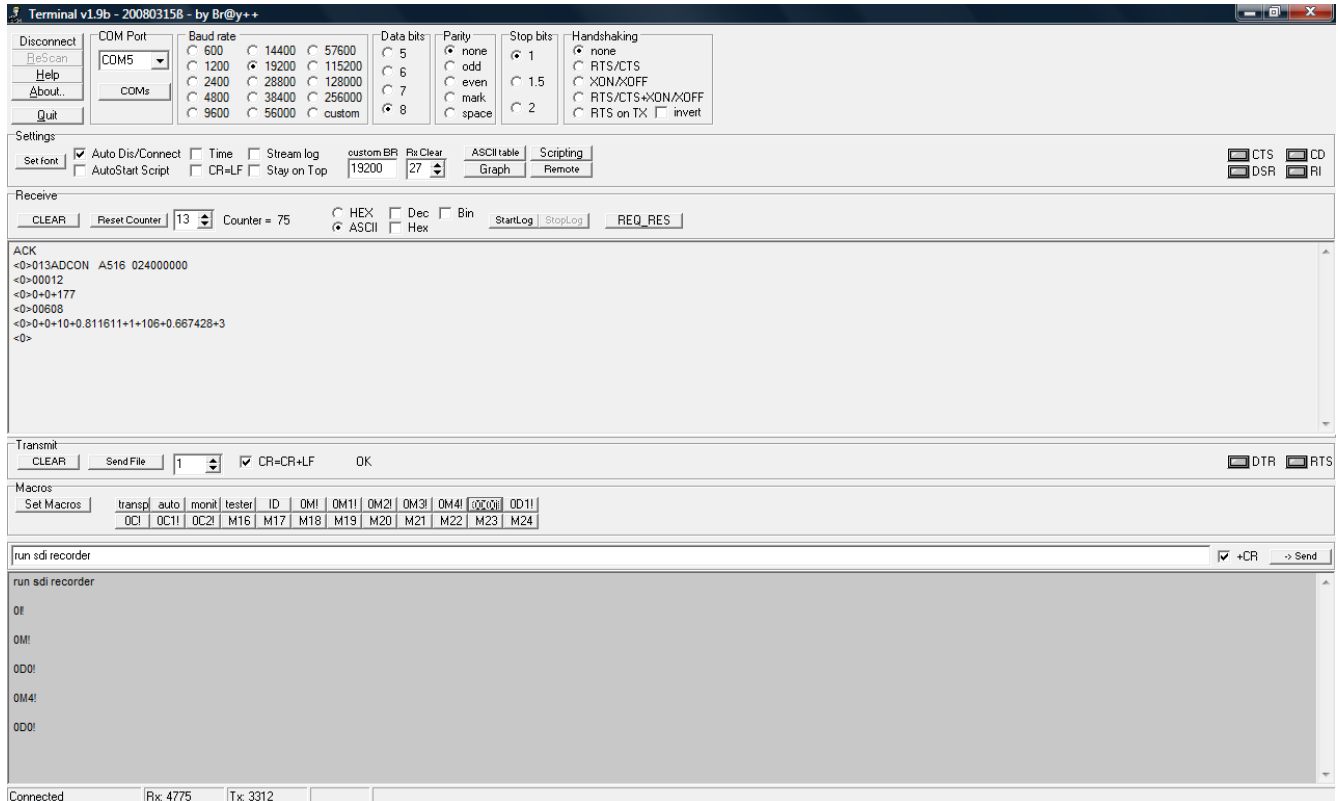


Figure 8 – Example set up of Terminal v1.9b

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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7 Technical Specifications

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Is	Supply current	Active mode (during measurement) For 1s...4s, depending on averaging settings		6		mA
Is	Supply current	Sleep mode		80		μA
Vs	Supply voltage		6	12	17	V
tm	Measurement Time	Time in active mode upon receiving a measurement command depending on averaging settings	1		4	s
TR	Temperature measurement range		-40		+85	°C

Table 3 – Technical Specifications

8 Cable Connection

Cable Colour	Signal Assignment
Green	SDI-12 Power
White	SDI-12 Data
Brown	GND
Black	Shield (GND)

Table 4 – Cable Connection

9 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	closed housing	-	100	%

Table 5 - Environmental Specifications

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10 Ordering Information

Part Number	Description
TBSST01	TBSST01, Analogue to SDI-12 Interface

Table 6 – Ordering Information

11 History

Version	Date	Author	Changes
V1.0	29.12.2011	Mayerhofer	Creation of the document
V1.1	18.02.2012	Mayerhofer	Chapter 8 added

Table 7 – History